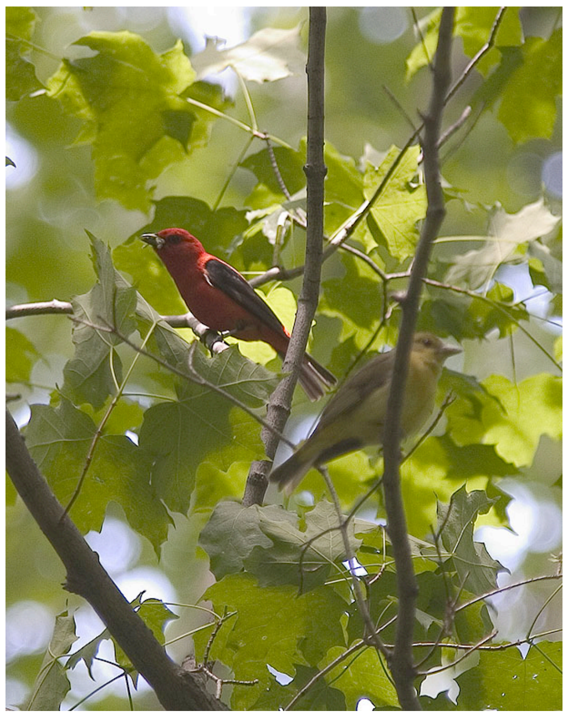
2002-2003 Cooperative Agreement

Pennsylvania Game Commission and the
Penn State Cooperative Wetlands Center

Sampling Design for Pennsylvania's 2nd Breeding Bird Atlas: 2004-2009



Final Report – March 2004

Report No. 2004-02

Penn State Cooperative Wetlands Center

PENNSTATE
Cooperative Wetlands Center

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Sampling design for Pennsylvania's 2nd Breeding Bird Atlas: 2004-2009

Final Report

Submitted to:
Pennsylvania Game Commission
Elmerton Avenue
Harrisburg, PA

Report No. 2004-02

Submitted by:

Timothy O'Connell, Joseph Bishop, Robert Mulvihill[1],
Michael Lanzone, Trish Miller, and Robert Brooks

Penn State Cooperative Wetlands Center
216 Walker Building
University Park, PA 16802

[1]Powdermill Nature Reserve
Field Station of the Carnegie Museum of Natural History
HC 64, Box 453
Rector, PA 15677-9605

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Cover photograph of Scarlet Tanagers by Mike Lanzone

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Executive Summary

In 2002, the Penn State Cooperative Wetlands Center (CWC) entered into a Cooperative Agreement with the Pennsylvania Game Commission to develop a sampling and design strategy for Pennsylvania's second Breeding Bird Atlas project, set to begin on January 1, 2004. Guided by the ultimate direction of the Atlas Steering Committee (a subset of the Pennsylvania Society for Ornithology), the CWC formed a core Design Team of five members: an ornithologist and a GIS specialist from the CWC, the Chair of the Atlas Steering Committee, and the Coordinator and Assistant Coordinator for the 2nd Atlas. The Design Team sought additional input from other participants, notably a biometrician from the Cooperative Fish and Wildlife Research Unit at Penn State University, veteran Pennsylvania birders, and representatives of past and concurrent atlas projects in the United States, Canada, and Great Britain.

In addition to providing a replication of Pennsylvania's 1st Atlas, the Design Team focused on new features for the 2nd Atlas. The Steering Committee identified greater attention to under-represented species and habitats as a priority for the 2nd Atlas, as well as a relative abundance sampling scheme. Both sampling rare habitats and abundance sampling as we have proposed using mini-routes in every Atlas block have required extensive GIS programming time and technical expertise. To facilitate these initiatives, the Design Team partnered with the Pennsylvania Spatial Data Access (PASDA) group. To create an interactive database for the Atlas on the Internet, the Design Team subcontracted to BirdSource, a joint organization of the National Audubon Society and Cornell Laboratory of Ornithology. The staff at BirdSource are leaders in the design of web-based applications for citizen science projects that rely on the participation of thousands of volunteers. Working through the Design Team, BirdSource and PASDA have developed a system through which online users can investigate GIS layers and enter data on BirdSource's Atlas site that correspond to point locations on PASDA's maps.

Significantly, and we think unique among all atlas projects thusfar, volunteers for Pennsylvania's 2nd Atlas will be able to view and print detailed maps of potential habitat for conservation priority species based on 187 predictive habitat models produced as part of Pennsylvania's Gap Analysis Project. The models are based on multiple GIS layers, and were reconfigured by the Design Team specifically for the 2nd Atlas using land cover data from Landsat 7 developed from satellite images captured from 1999 to 2002. This feature will allow Atlas volunteers to locate specific habitat patches for a given species that might not otherwise have been apparent from topographic maps alone. The ability to identify specific habitat patches for priority species will foster more efficient and objective general atlasing, as well as anchor specific abundance sampling efforts for wetland and nocturnal birds.

The 2nd Atlas will also include abundance sampling protocol for general breeding birds with randomly located, eight-stop mini-routes in 3,931 non-border Atlas blocks. We anticipate that this component will take 2-3 dozen select field observers three field seasons to complete. Because of the need for multiple observers, we will apply *post hoc* analyses using count removal models to correct for observer and species detection biases and facilitate direct abundance and density comparisons among observers for many species. Again, the scale at which we are proposing is unprecedented among atlas projects, and indeed, other large-scale monitoring programs.

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Background

At the 2001 annual meeting of the Pennsylvania Society for Ornithology (PSO) in State College, several members gathered for an exploratory discussion regarding planning for a second breeding bird atlas project for Pennsylvania. The original atlas (Brauning 1992) was based on data collected from 1983 to 1989; the primary goal for a second atlas in PA would be to provide comparative data on Pennsylvania's breeding birds approximately 20 years later. The British Trust for Ornithology, sponsors of the first breeding bird atlas in 1976 with data from 1968-1972 (Sharrock 1976), set the precedent for a 20-year gap between atlases with a renewed field effort from 1988-1991 (Gibbons, Reid, and Chapman 1993). In 2004, Pennsylvania will join Ontario, Maryland, and New York in second atlas attempts in North America; Massachusetts is the first U.S. state to have completed a second breeding bird atlas (Petersen and Meservey 2004).

The PSO members gathered in 2001 evolved into the Atlas Steering Committee and set themselves squarely behind a commitment to embark on a second atlas project for Pennsylvania. The Steering Committee set three conditions for their support, however. First, a new atlas had be directly comparable to the first breeding bird atlas. Second, the renewed effort had to include much more even coverage geographically, do a better job at providing information for undersampled species, and incorporate a measure of relative abundance that could be mapped at fairly small scales statewide. Lastly the committee recognized the novelty of the approach they were establishing, and decided to invest at least a year in project design and planning before the official start of field work.

In 2002, the Penn State Cooperative Wetlands Center (CWC) was selected to head up the design phase and entered into a Cooperative Agreement with the Pennsylvania Game Commission to develop the sampling and design strategy for Pennsylvania's 2nd Breeding Bird Atlas project, 2004-2009. This document is a Final Report of the progress made toward developing the second atlas from October 2002 to February 2004. We have structured this Final Report to respond to goals and objectives for the 2nd Atlas outlined in the Cooperative Agreement:

Goals:

- Determine geographic distribution of all breeding birds in the Commonwealth, allowing for direct comparison to the 1st Atlas.
- Improve coverage for 2-3 dozen species undersampled during the 1st Atlas
- Map geographic patterns of abundance for all species at a scale small enough to facilitate local conservation efforts.

Objectives:

Distribution

- compile a list of breeding birds from every atlas block in PA
- use a combination of land cover data and habitat modeling to reduce errors of omission relative to the 1st Atlas

Change

- compare species' distributions 1983-1989 to 2004-2009
- relate large scale changes in species' distributions to large scale changes in land cover over the same time period

Abundance

- determine and map the relative abundance of all breeding species in PA

With guidance from the Steering Committee, the CWC has designed the Atlas in partnership with several key individuals and contributing organizations. The Steering Committee Chair and Atlas Coordinator were given final approval over all decisions related to the Atlas, and have worked together with the CWC on all aspects of the design phase. Together with participating personnel from the CWC, the Steering Committee Chair and the Atlas Coordinator have functioned as a subcommittee of the Steering Committee, the “Design Team,” to propose, discuss, evaluate, and implement features of the Atlas. The Design Team has provided formal updates of its progress on several occasions over the past year:

- Atlas Steering Committee – State College, Apr. 2003
- PSO’s Annual Meeting – Indiana, May 2003
- Annual Report to the PGC – Harrisburg, Jul. 2003
- Atlas Advisory Committee – Harrisburg, Oct. 2003

The Design Team also gathered on several occasions in 2003 to solicit particular expertise from other significant contributors to the Atlas effort. Meetings with Dr. Duane Diefenbach (Pennsylvania Cooperative Fish and Wildlife Research Unit at Penn State), PSO President Doug Gross, and Robert Blye (PA Audubon Society) were especially fruitful in guiding the Design Team toward field sampling and analysis protocols.

The Design Team also held multiple meetings in 2003 with representatives of Pennsylvania Spatial Data Access (PASDA), the Commonwealth's GIS clearinghouse, to implement complex mapping features for atlas data. Also, we began collaboration in 2003 and continue to work closely with BirdSource, a joint effort of the National Audubon Society and the Cornell Laboratory of Ornithology based in Ithaca, NY, to develop a customized package for online data storage and display. BirdSource is a leader in citizen science projects using Internet resources; our project will be their first attempt to produce an application for breeding bird atlases. Finally and notably, our coalition of Atlas contributors has directly benefited from the Carnegie Museum of Natural History (CMNH) in Pittsburgh. In addition to providing the project with its Coordinator, the CMNH will sponsor a static website for the Atlas on its server space. This website will provide links to relevant GIS data from PASDA, and to the interactive database under development at BirdSource.

Distributions – General Atlasing

Sampling Grids. The basic sampling grid for the 2nd Atlas will be similar to the first, i.e., rectangular blocks covering approximately 24 sq km on the ground. These Atlas blocks occupy 1/6th of the land area in a USGS 7.5-minute quadrangle (Fig. 1). The decision to commit to atlasing every one of the nearly 5000 blocks in Pennsylvania was made early, and is crucial to facilitating direct comparisons to the 1st Atlas.

Figure 1 illustrates how Atlas blocks are subdivided into distinct categories. In this hypothetical example, the state border passes through this quadrangle, rendering blocks 2 and 4 as incomplete "border" blocks. Blocks 1, 3, 5, and 6 are "regular" blocks; block 6 is also the "priority" block for this quadrangle. Border blocks (eastern, southern, and western borders of the Commonwealth) encompass significantly less than 24 sq km, and data from these blocks are analyzed separately from regular blocks that are wholly contained within the state border (Brauning 1992). Except for Erie County, all blocks on Pennsylvania's northern border align with quadrangles bounded by the 42° latitude line and are approximately equivalent in area to the regular blocks. During the 1st Atlas, an attempt was made to standardize coverage in one of the six blocks in each quadrangle. Block 6 (the southeastern block) was designated as the priority block for field work, requiring a preferential minimum level of field effort preceding coverage in other blocks in the quadrangle. Only regular blocks at position 6 qualify as priority blocks (Brauning 1992). We will incorporate these same block designations for the 2nd Atlas.

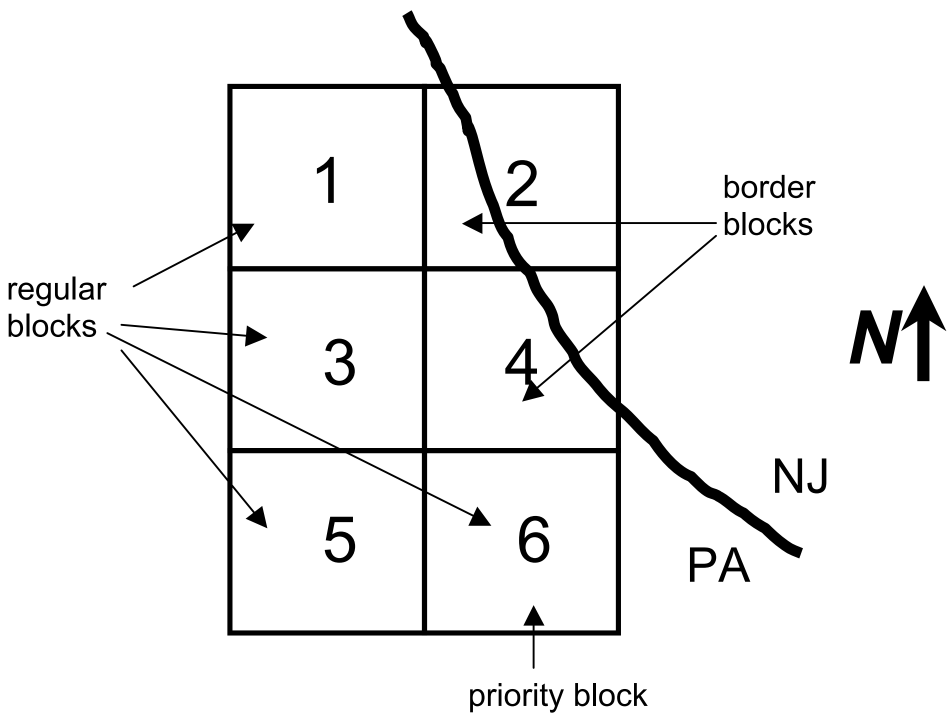

Figure 1. Schematic diagram of the six atlas blocks embedded within each USGS quadrangle.

There are 872 USGS quadrangles contained wholly or partially within Pennsylvania. Within these quadrangles are 4,928 Atlas blocks, of which 3,939 are regular blocks (787 priority blocks) and 202 are border blocks (Brauning 1992). Some blocks in this layer have been edited to accommodate the irregular USGS topographic map peculiar to the Erie, PA vicinity. We added three blocks to the initial layer bringing the total to 4931. The placement aligns the blocks as if they were part of a normal 7.5-minute grid. Fig. 2 illustrates the full density of Atlas blocks in Pennsylvania.

Atlas blocks are grouped within quadrangles, and quadrangles are grouped within regions. For the 1st Atlas, 43 regions were defined at the county level, with some regions containing as many as four counties (Brauning 1992). The discrepancy in region size meant that some Regional Coordinators (volunteer compilers and reviewers of data for each region) were responsible for many more Atlas blocks than others.

For the 2nd Atlas, we propose a new regional grid based on individual pages from the Pennsylvania Atlas and Gazetteer (DeLorme 2003). There are 57 regions, of which 46 will correspond exactly to a single page in the DeLorme Atlas; 11 will be comprised of 2-3 adjacent pages. Accordingly, regions can be named (numbered) for the associated single Delorme page (e.g., Region 30) or the multiple pages (e.g., Region 54/55). The eleven conjoined regions are (from top to bottom and left to right on the gridded DeLorme back cover): 26/28, 27/29, 54/55, 67/68, 82/83, 84/85, 86/87, 88/89, 90/91, 92/93, 94/95/96. The remaining regions will all be single page numbered. Each of these 57 regions contains approximately fourteen 7.5-minute USGS topographic map equivalents (12 full quads and 4 half quads), six breeding bird atlas blocks each, for a total of 84 atlas blocks per region. The regional grid will standardize sampling area within each region to a much greater extent, and result in a more equitable time investment among Regional Coordinators. Volunteer Regional coordinators identified to date are listed in Table 1.

Breeding bird atlas blocks can be identified by referencing the DeLorme Atlas page coordinates, A-D (rows) and 1-7 (columns), which refer precisely to the 7.5-minute topographic map boundaries. These can be located by the crosshairs on each DeLorme page marking the corners of each topographic map. For referencing a breeding bird atlas block, the first element in the block designation is the DeLorme Atlas *page* number followed by DeLorme page coordinates (e.g., A1, which is the topographic quad), followed by block number (1-6). In the first PA breeding bird atlas, Powdermill Nature Reserve was in block 6 of the Stahlstown quadrangle. In the new designation, it will be 73C46 (DeLorme page 73, quad C4, block 6). Importantly, most Atlasers will be working straight from the DeLorme publication, so it will be a simple matter for them to identify the block they are in, even if it is not "their" block. A likely benefit will be that this block designation system will greatly facilitate the entry of incidental records.

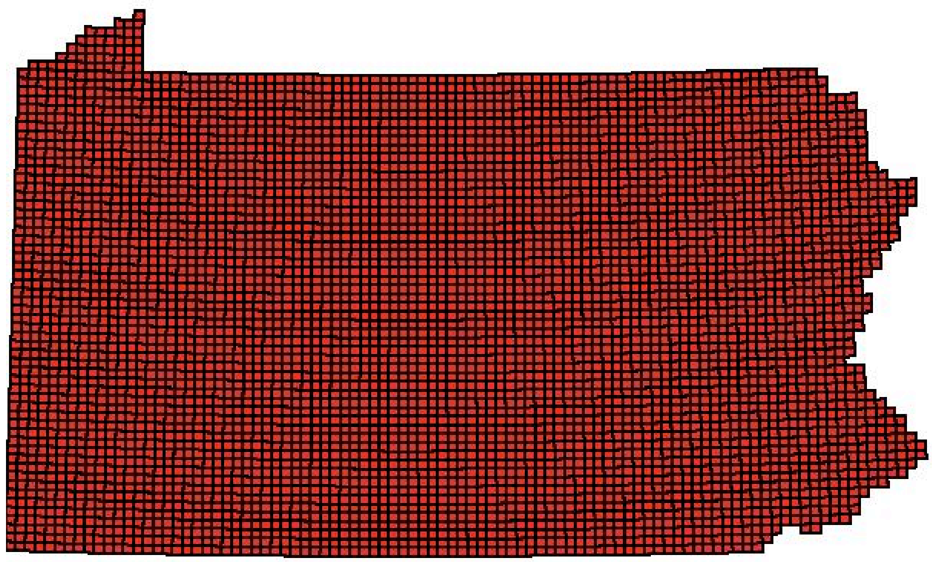

Figure 2. Breeding Bird Atlas blocks for Pennsylvania. All 4,928 blocks are delineated.

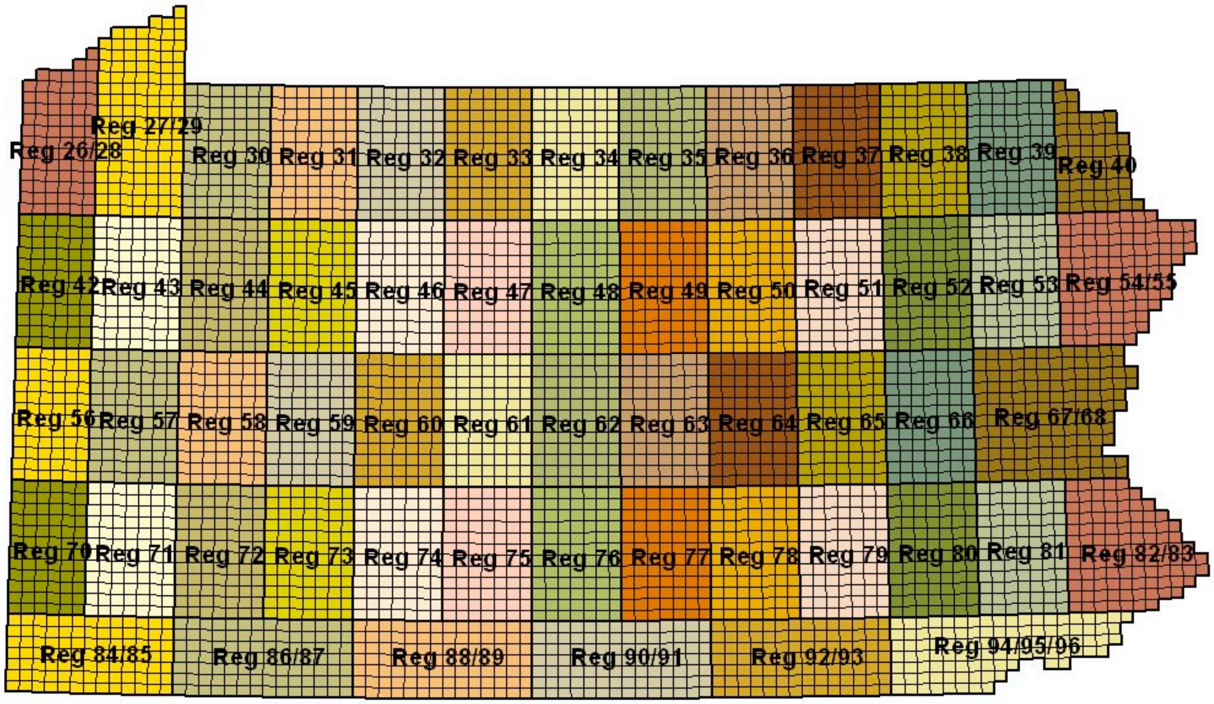

Figure 3. Breeding Bird Atlas regions for Pennsylvania. All 57 regions are delineated with their DeLorme-based numeric identifier.

Table 1. Volunteer Regional Coordinators identified as of February 2004.

Name	Region	Name	Region
John Tautin	Region 26/28	Margaret A. Higbee	Region 59
Chuck Gehringer	Region 27/29	unclaimed	Region 60
Flo McGuire	Region 30	unclaimed	Region 61
Don Watts	Region 31	Greg Grove	Region 62
John Fedak	Region 32	Roana Fuller	co-Region 62
David Hauber	Region 33	Mark Henry	Region 63
Mary Hirst	Region 34	Allen Schweinsberg	Region 64
Robert M. Ross	Region 35	Hoffman Deuane	Region 65
Jeff Holbrook	Region 36	Arlene Koch	Region 67/68
Bob Fowles	Region 37	Bernie Morris	co-Region 67/68
Bob Daniels	Region 38	Roy Ickes	Region 70
Jerry Skinner	Region 39	Mike Fialkovich	Region 71
Barbara Leo	Region 40	Dick Byers	Region 72
Randy Stringer	Region 42	Janet Kuehl	Region 73
Gary Edwards	Region 43	Dave Kyler	Region 75
Russ States	co-Region 43	unclaimed	Region 76
Mike Leahy	Region 44	Jane Earle	co-Region 77
unclaimed	Region 45	Ramsay Koury	Region 78
unclaimed	Region 46	Randy Miller	Region 79
Robert Martin	Region 47	Rosemary Spreha	co-Region 79
Nick Bolgiano	Region 48	Steven Fordyce	Region 80
Wayne Laubscher	Region 49	Susan K. Fordyce	Region 80
Dan Brauning	Region 50	F.Arthur McMorris	Region 81
Rick Koval	Region 52	Barb McGlaughlin	Region 82/83
Jim Hoyson	Region 53	Terry Dayton	Region 84/85
Mark Blauer	co-Region 53	Lauretta Payne	Region 86/87
Terry Master	Region 54/55	Mark Bowers	co-Region 86/87
JoAnn Albert	Region 57	Dan Snell	Region 88/89
Brian Shema	co-Region 57	unclaimed	Region 90/91
JoAnn Davis	co-Region 57	Karen Lippy	Region 92/93
Mark A. McConaughy	Region 58	Doris McGovern	Region 94/95/96

Field Protocol. In common with the 1st Atlas, volunteers will register with a Regional Coordinator to "own" an Atlas block. The volunteer then assumes primary responsibility for conducting field work in the block that will maximize the number of species documented as breeding within the block. Incidental records from other individuals may also be submitted for a given block, but block owners are expected to contribute the majority of records for their block.

General "atlasing" in the field will be almost identical to approaches used during the 1st PA Atlas (Brauning 1992) and other atlas projects (e.g., Laughlin, Carroll, and Sutcliffe 1990, Ontario Breeding Bird Atlas 2001, Maryland Ornithological Society 2002). Birds will be observed on multiple visits and their behaviors coded to provide evidence of breeding. We will recognize four hierarchical levels of breeding evidence: *observed, possible, probable*, and *confirmed* (Tab. 2).

Table 2. Breeding codes and associated behaviors for the 2nd Atlas.

OBserved	
O	detected within safe dates, but habitat unsuitable
POssible	
X	detected within safe dates in suitable habitat
PRobable	
T	territorial behavior
P	pair observed
C	courtship or copulation observed
U	used nest observed
A	agitated behavior/ anxiety calls
COnfirmed	
CN	carrying nest material
PE	physiological evidence of breeding condition
NB	nest building
DD	distraction display
FL	fledged young observed
CF	adult carrying food or fecal sac
FY	adult feeding fledged young
NE	nest with eggs (cowbird egg = confirmation of host + cowbird)
ON	occupied nest
NY	nest with young (cowbird nestling = confirmation of host + cowbird)

While the ostensible purpose of every breeding bird atlas is to maximize the number of species confirmed to be breeding in every block, *ex*tensive coverage better serves the goals of the Atlas than does *in*tensive coverage. That is, it is better to sample more blocks at some minimal level of coverage than for there to be great variability in the effort expended among blocks. While the Atlas will certainly incorporate information on breeding status, we do not recommend undue effort to *confirm* breeding of common species in a particular block when the volunteer field time could be better-spent compiling lists of *possible* or *probable* breeders from multiple blocks.

Review of species distributions and species accounts in the 1st Atlas (Brauning 1992) reveals that many species were likely undersampled relative to other more common or widespread species. Moreover, due simply to the unequal distribution of atlasers in the state, major habitats may have been subjected to biased sampling in the 1st Atlas. For example, large sections of Pennsylvania's Northern Tier received substantially less atlas effort than southern and eastern regions of the Commonwealth. Thus, the northern hardwoods forests of north-central and northwestern Pennsylvania were underrepresented relative to the oak forests of the Pennsylvania Piedmont in the southeast. Such challenges are not unique to Pennsylvania, but the Design Team was charged by the Steering Committee to develop means to ensure relatively equal sampling effort of habitats, geographic regions, and species in the 2nd Atlas. An important psychological tool to encourage atlas volunteers to spend some time in many blocks (rather than all their time in one or two) is the de-emphasis on breeding confirmations for common species. For the 2nd Atlas, we will prefer five probable records for Red-eyed Vireo (in five different Atlas blocks) to a single confirmed record, given equal field effort.

Of course some species will be much higher priorities for confirmation of breeding. Examples include state listed and special concern species (Brauning et al. 1994), regional conservation priorities identified by Partners in Flight (Beissenger et al. 2000, Pashley et al. 2000), and species that may be documented as breeders in Pennsylvania for the first time, e.g., Eurasian Collared Dove. For records of these species, we will stress the importance of confirming breeding and require additional verification on a specific form and point location data at a scale more specific than the Atlas block. Appendix C lists the species for which additional field verification will apply.

One way to encourage more equitable coverage in Atlas blocks from Atlas volunteers is to provide guidance on a recommended level of field effort. A standardized amount of time surveying the block, number of trips, or percentage of the estimated total number of species in the block provides some indication that a given block has received some minimum level of coverage and may be included in analysis of breeding bird distributions. Standardized effort recommendations do not, however, account for differences in observer abilities in the field or differences in habitat among blocks, so they can create a false sense of standardization in practice.

For the 1st Atlas, a block was deemed completed when 20 hours of field time had been devoted to atlasing the block, or 70 species documented in the block regardless of field time. These figures are intended to sufficiently reveal 75% of the species breeding in the block (Robbins and Geissler 1990, Brauning 1992). Atlases vary in the recommended field effort per block, largely as a function of the number of observers and/or the projected number of breeding species in each block. Oklahoma requested a minimum of ten hours spaced across at least two visits per block for its first atlas (Reinking 2000); New Mexico's first atlas requested 20 hours spread over 6-8 visits (Fettig 2001). The San Diego County (CA) Atlas recommends 25 hours per block (San Diego Natural History Museum 2001). Ontario's second atlas recommends 20 hours per block over the total five-year span for the project (Ontario Breeding Bird Atlas 2001).

Other atlases have stressed numeric rather than timed coverage goals. Ohio capped coverage at 75% of the species likely to occur in a block, but set a 90% goal for its priority blocks (Peterjohn and Rice 1991). New York's second atlas set a numeric block goal of 76 species (Corwin 2000); volunteers for Maryland's second atlas are asked to "equal or exceed" the number of breeding species documented in each block during the first atlas (Maryland Ornithological Society 2002).

For Pennsylvania's 2nd Atlas, a strict numeric goal based on results of the 1st Atlas is untenable, because large areas of the state did not meet the 20 hour/block recommendation (Brauning 1992). Hence the species totals from the undersampled blocks could fall well below the actual number of breeding species in the block. We could, however, predict the species that occur in each block using habitat models for breeding birds written for the Pennsylvania Gap Analysis project (Myers et al. 2000). The models were originally prepared with Landsat land cover data from 1992; we have re-configured all the models for the 2nd Atlas with 2000 Landsat data.

We recommend a timed approach with a goal of 20 hours/block. In addition, we recommend an analysis of current coverage following the third year of data collection. We will determine a potential number of breeding species for each block based on predicted occurrence from Gap habitat models. We recommend coverage goals of 75% of the species modeled for a regular block and 90% for priority blocks.

Mapping Block Status. Various forms of block status could be mapped for volunteers to provide at a glance information on block ownership or coverage goals. The interactive Atlas pages developed by BirdSource and PASDA will allow for real-time status of updates on the Atlas website. Figures 5-7 illustrate how status could be represented at different scales.

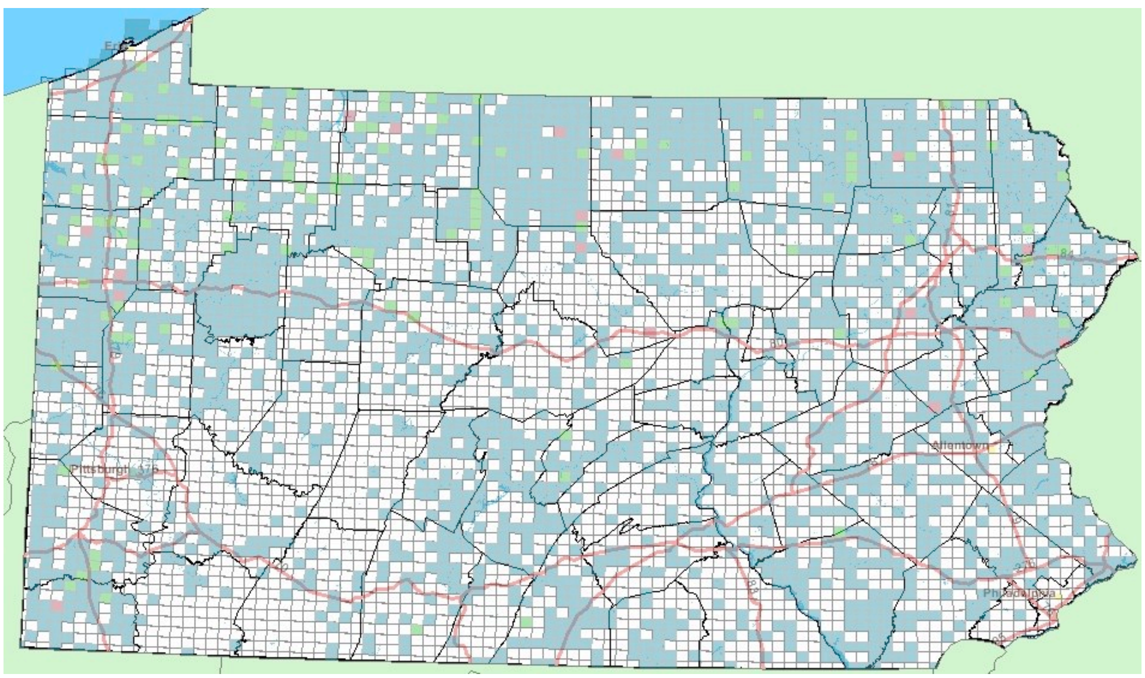

Figure 5. Statewide scale of coverage goals for atlasing. Colored blocks could indicate block status in terms of registered block owners or degrees of coverage goal completion.

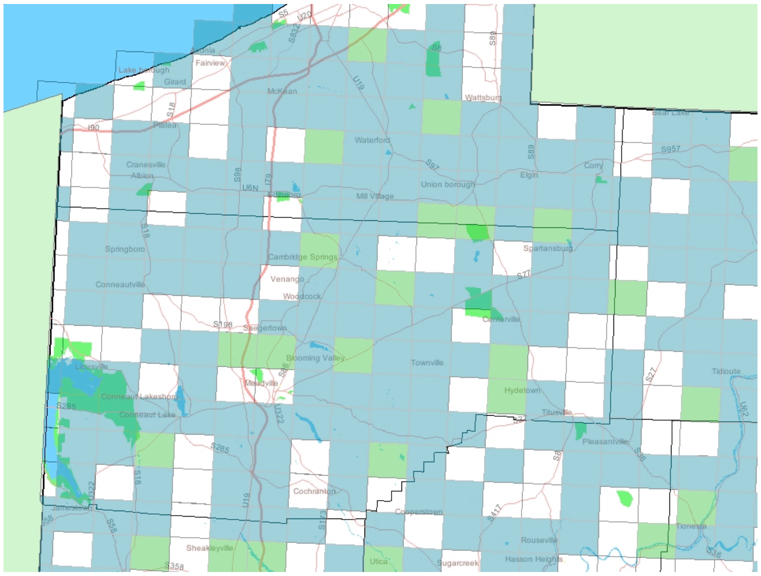

Figure 6. Regional view of block status.

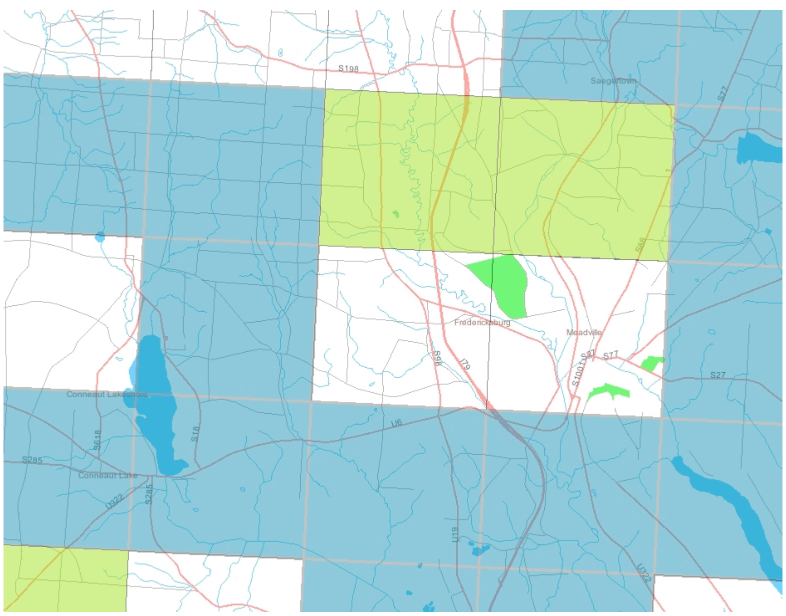

Figure 7. Local view of block status.

We anticipate that Atlas volunteers will base their decisions on where to invest their energies according to status maps as illustrated in Figs. 5-7. Those decisions will also be based, at least in part, on habitat features in a block that might make a particular block especially attractive to a given atlaser. At a regional scale, the Pennsylvania Atlas and Gazetteer (DeLorme 2003) is familiar to many birders, and the regions we have identified in Fig. 3 will make intuitive sense to most volunteers. At finer scales, however, volunteers will require more specific mapping information that clearly indicates roads, houses, fencelines and other landmarks, as well as major habitat features.

We will provide additional mapping features on line through the PASDA link on the interactive Atlas website under development by BirdSource. Figures 8-11 illustrate the level of detail we will be able to provide to guide volunteers to where they intend to conduct Atlas field work.

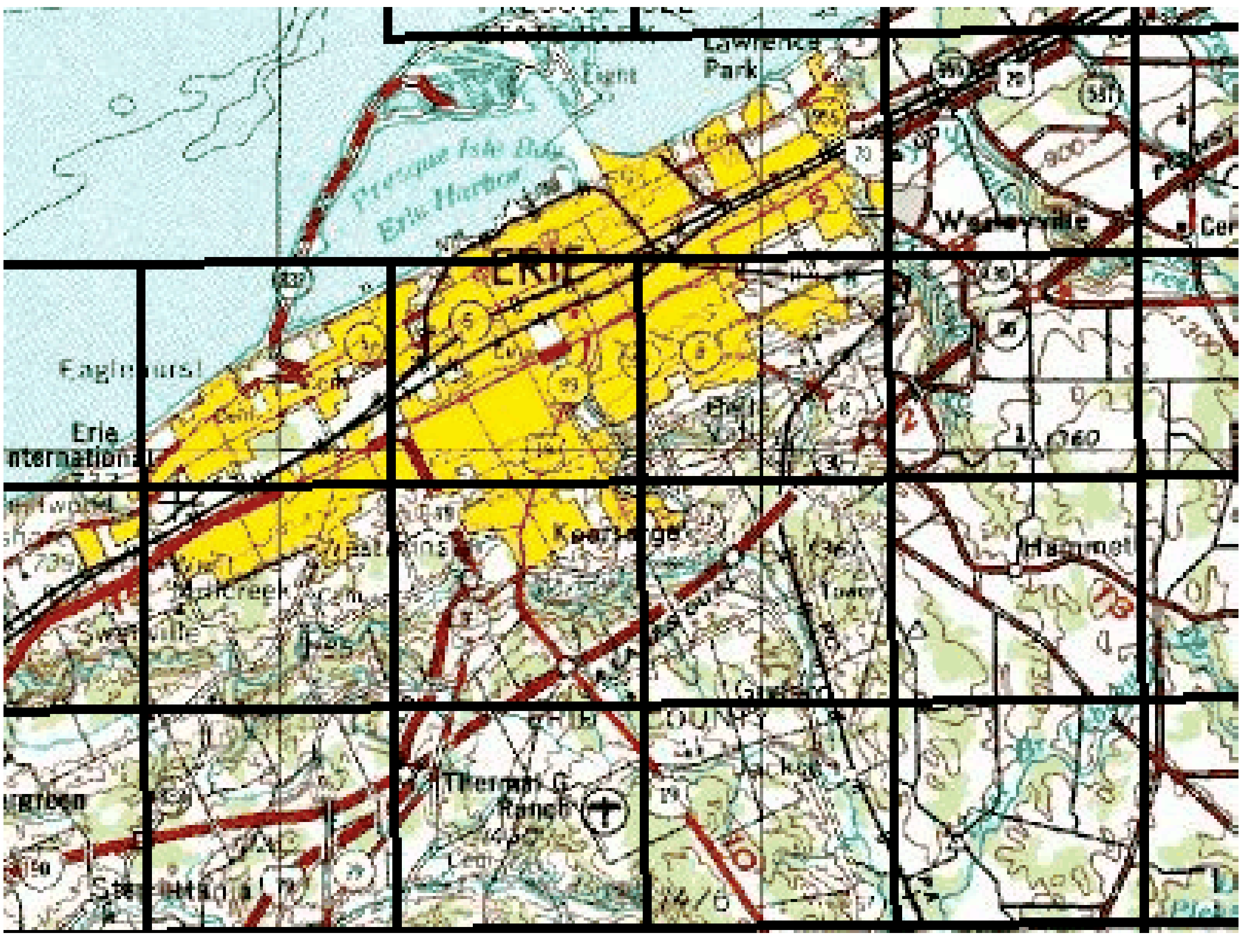

Figure 8. USGS topographic map of a local area of blocks.

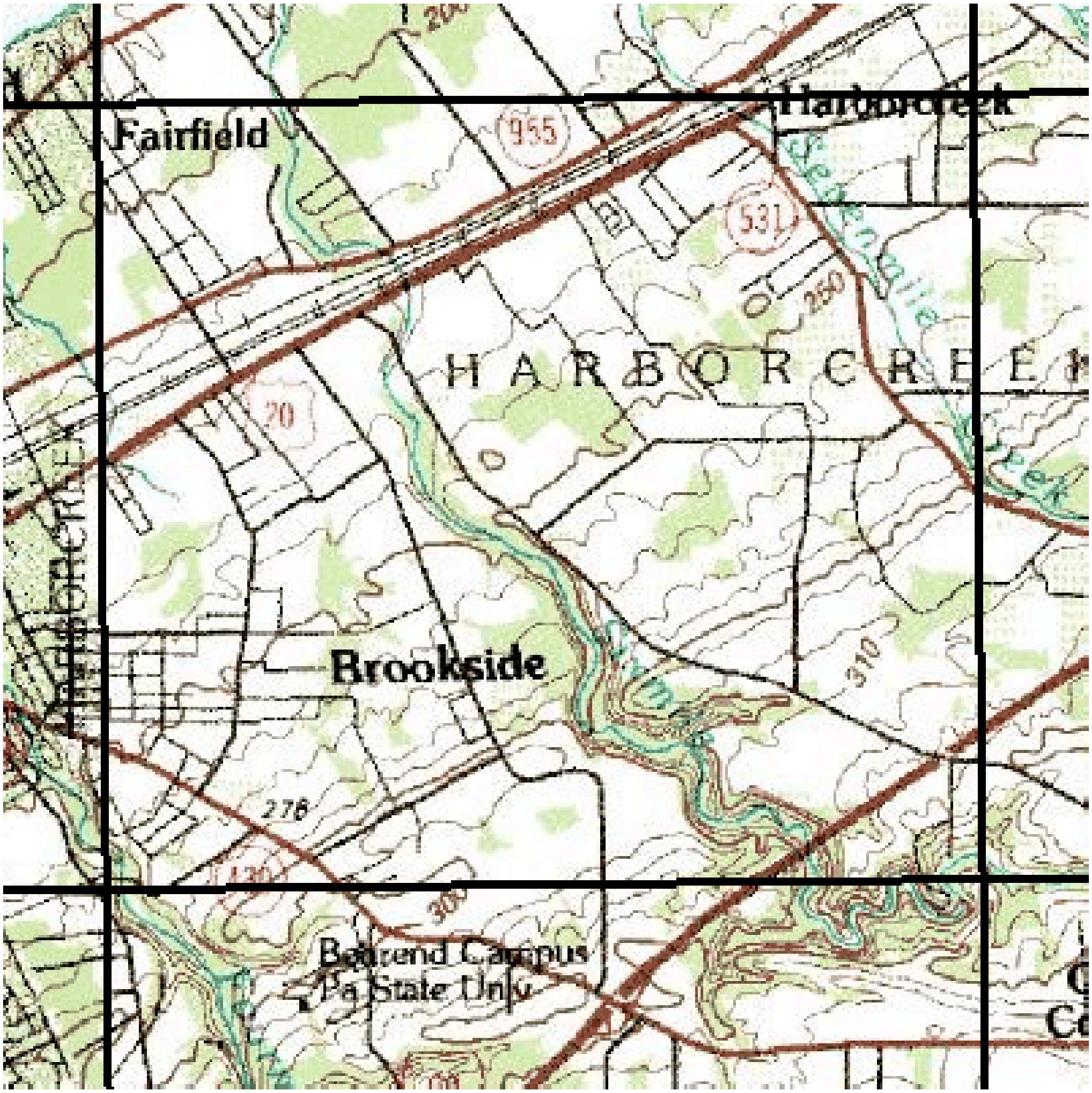

Figure 9. USGS topographic map at the block scale.

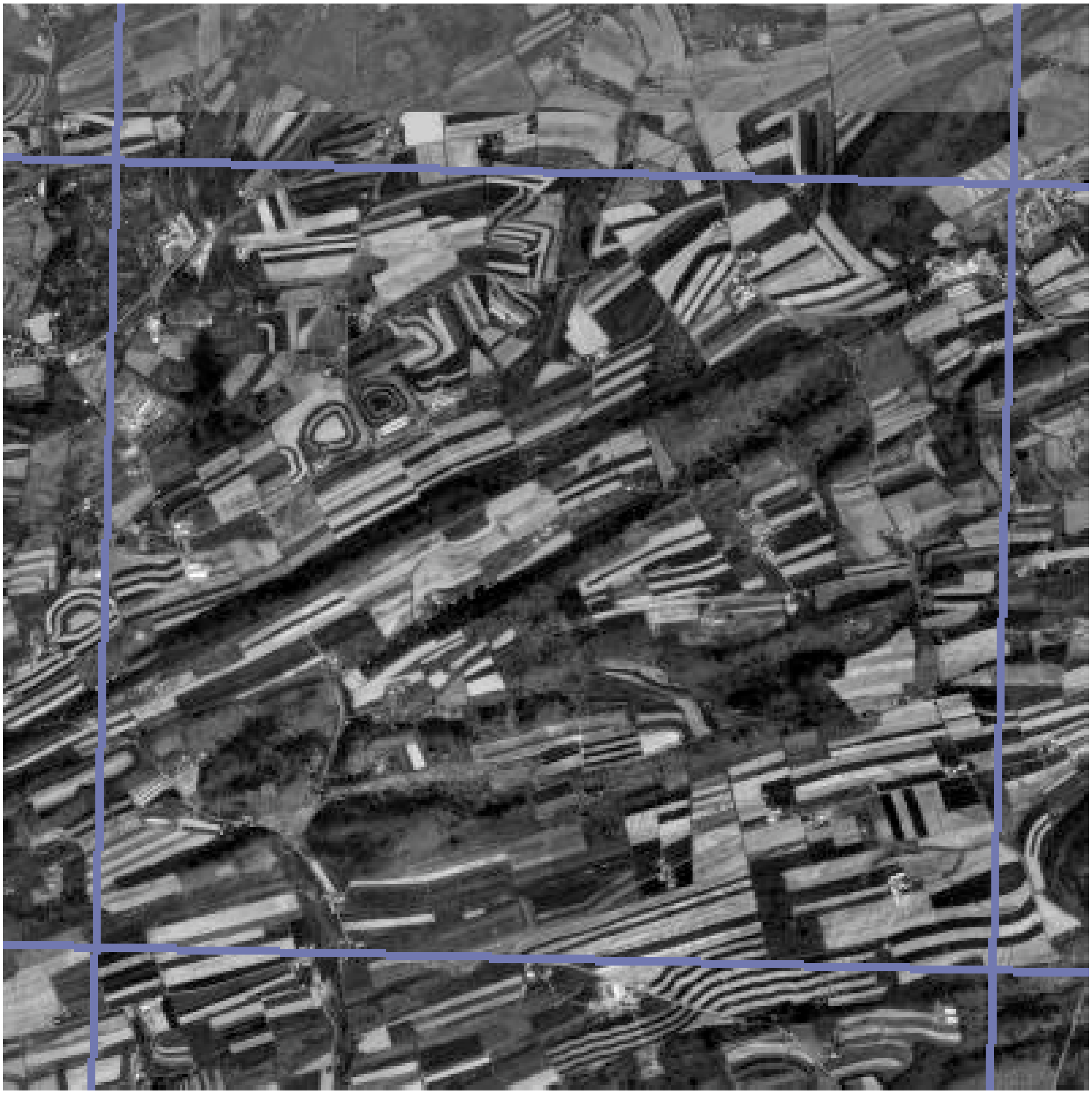

Figure 10. Block view of aerial photograph.

Figure 11. Aerial photograph at partial block scale.

Predicting Species by Habitat. The 2nd Atlas will feature several advances in mapping technologies to guide volunteers to specific areas to conduct field work. In addition to providing detailed maps and aerial photographs for this purpose, we will provide map images that specifically point to modeled habitat for particular species of concern. The Oregon atlas project (Adamus et al. 2002) produced habitat maps as a product of their atlas field work, and similar maps were prepared by the Washington Gap Analysis Project based on atlas data from that state (Washington Gap Analysis Project 1997). The Gap Analysis Project for Pennsylvania (Myers et al. 2000) also produced maps of predicted species distributions using, among many sources, data from Pennsylvania's 1st Breeding Bird Atlas. The 2nd Pennsylvania Breeding Bird Atlas will be the first attempt by any large-scale atlas project to use such predictive models to systematically point out individual habitat patches likely to support individual species.

During Pennsylvania's 1st Atlas, some species may have been undersampled regardless of their location in the Commonwealth or the atlas effort expended in a particular block. Species that occur in rare, patchily distributed, or ephemeral habitats were likely under-represented in the 1st Atlas relative to species that occur in more widespread and abundant habitats, e.g., forest and farmland. Habitat types that do not fall neatly into the forest/farmland categorization can be difficult to identify on USGS topographic maps, even for seasoned map interpreters. Because topographic maps were the primary source of information used by 1st Atlas volunteers, it is likely that many important habitat patches for various priority species were unknown to atlasers, and never visited.

With predictive models of species occurrence developed from 1st Atlas data, we now have the ability to highlight rare or unusual habitat types within a block that might not have been known to the first atlasers. For the 2nd Atlas, we will institutionalize sampling methods and share information *a priori* that will help ensure that differences among species distributions are genuine differences rather than sampling bias artifacts. A description of how these models were developed and modified for Atlas use appears in Appendix D.

For example, various wetland types from boreal bogs to sedgey wet meadows warrant greater investment for the 2nd Atlas than they received during the 1st Atlas, but these habitats are difficult to identify from topographic maps. We propose to use predictive models of bird distributions from the Gap Analysis project (Myers et al. 2000) to highlight patchily distributed habitat types and areas where particular rare species could be reasonably expected to occur. Specific habitat and bird model predictions will be available to atlasers synoptically on the Atlas website. Thus, an atlaser would know prior to commencing field work if, for example, an isolated bog occurred within his or her block and plan accordingly to sample that particular habitat.

Predictive models of bird distributions for the Gap analysis Project were produced using Landsat land cover imagery from 1991. For application to the 2nd Breeding Bird Atlas, we reconfigured and re-ran all 187 models with updated Landsat data from 1999-2002. The Design Team concluded that the newer data were essential for an application to the 2nd Atlas due to the rapid pace of land cover conversion in Pennsylvania, particularly in the Piedmont physiographic province. We had little confidence in the ability of 1991 data to reveal complex bird/habitat associations from 2004-2009; our confidence was significantly higher with the prospect of 1999-2002 land cover imagery (Fig. 12).

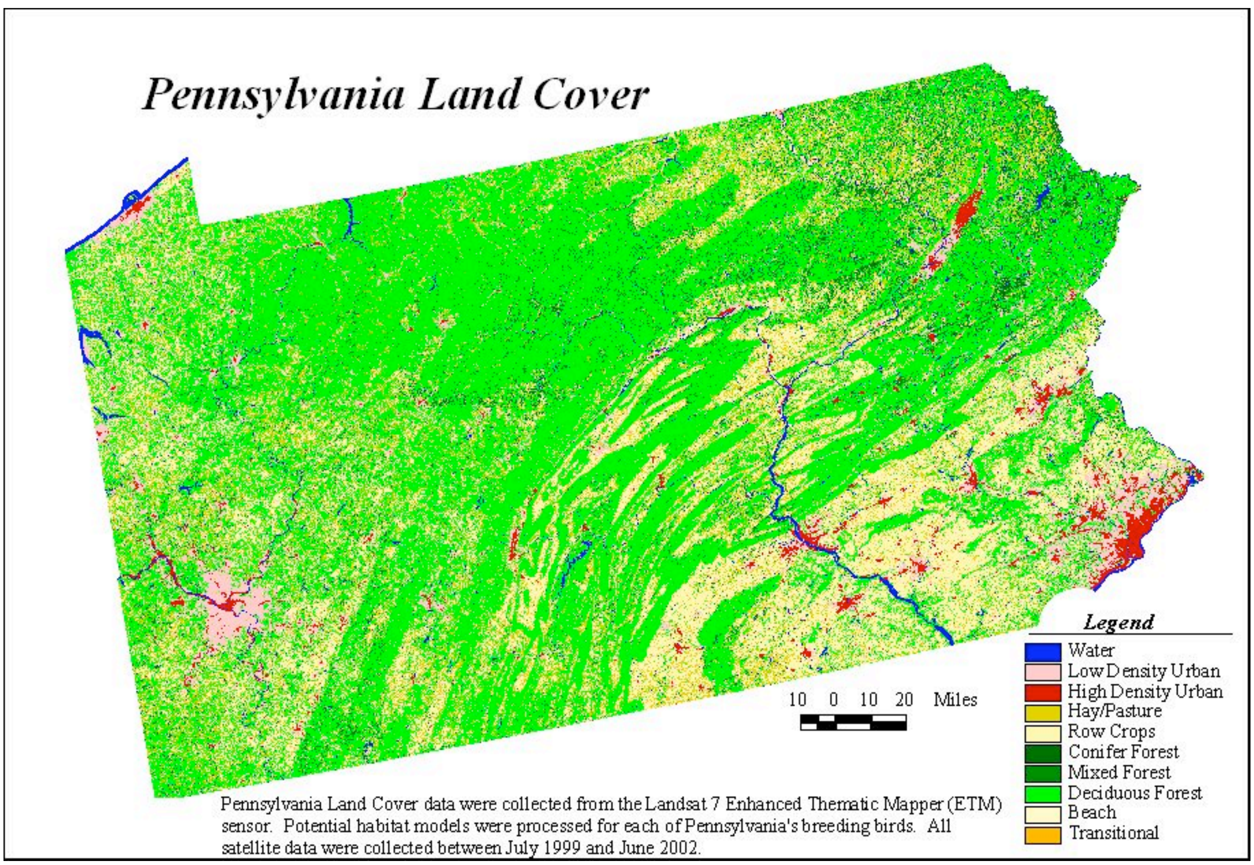

Figure 12. Land cover data for Pennsylvania based on Landsat 7.

The raw Landsat imagery for Pennsylvania was scheduled to have been reclassified for practical applicability in 2002, but was not made available until the summer of 2003. This delay significantly slowed our efforts to proceed with some key Atlas features, including field testing of predictive model utility. Thus the models will appear on the Atlas website having been subjected to the scrutiny of expert peer review, but not field verification.

For the purposes of the Pennsylvania Gap Analysis Project (Myers et al. 2000) we produced models of primary and secondary habitat for breeding birds. The secondary habitat layer produces a liberal prediction of species occurrences, and would produce many errors of commission (predicting the species to occur where it does not) for most species in practice. For this reason, we did not apply secondary habitat models in Gap Analysis. Primary habitat models present a small risk of committing errors of omission (not predicting a species to occur where it does), but still present a more likely risk of commission errors by highlighting potential habitat in an area that may simply lie outside a given species' range. For example, apparent habitat for Blue Grosbeak extends north in Pennsylvania toward the New York border, but the species was found to be confined to the Piedmont during the 1st Atlas. Because of many examples like this, and the importance of reducing commission errors for Gap Analysis, we filtered primary habitat models on the known range of species in Pennsylvania. Thus, for Blue Grosbeak, our model for Gap Analysis only included suitable habitat in the Piedmont.

For the purposes of guiding Atlas volunteers to habitat patches that might harbor a particular species of interest, we are still interested in reducing errors of commission and omission in predictions of species occurrence. In this case, an error of commission is less a problem than it was for Gap Analysis: Even if volunteers fail to locate a given species in a rare or unusual habitat they will likely gain insights into the natural history of their block from investigating a habitat they might not have otherwise. Errors of omission, however, are more problematic. The primary reason for using a predictive habitat model is to help ensure that Atlas volunteers do not systematically overlook habitats capable of supporting a priority species. If the model fails to indicate areas that could support a priority species then it has not served its purpose for the Atlas.

With the recognition, therefore, that our predictive habitat models will produce many errors of commission, we have produced models of primary habitat but removed all range filters. For example, our Blue Grosbeak model for the Atlas will highlight potential habitat anywhere it occurs in the Commonwealth, even as far north as the New York border. We will encourage consultation of predictive models for most of the species listed in Appendix C, however, models will be available for 187 species likely to be documented in the Commonwealth during the Atlas period. The Atlas field card (Appendix B) will include a space for volunteers to indicate how the predictive models might have influenced their ability to find particular species in the field.

To illustrate the type of information provided in a predictive model image, Figures 13-21 present modeled habitat for Worm-eating Warbler, Golden-winged Warbler, and Henslow's Sparrow at three different scales. The three scales of presentation are intended to give a volunteer working in a single block some sense of context for the habitat that appears in the block. Is it part of a larger habitat complex in adjacent blocks, or does it occur as isolated habitat? At the Atlas block scale, the modeled habitat appears on a background that includes a road layer to help volunteers better orient to a particular habitat patch in the field.

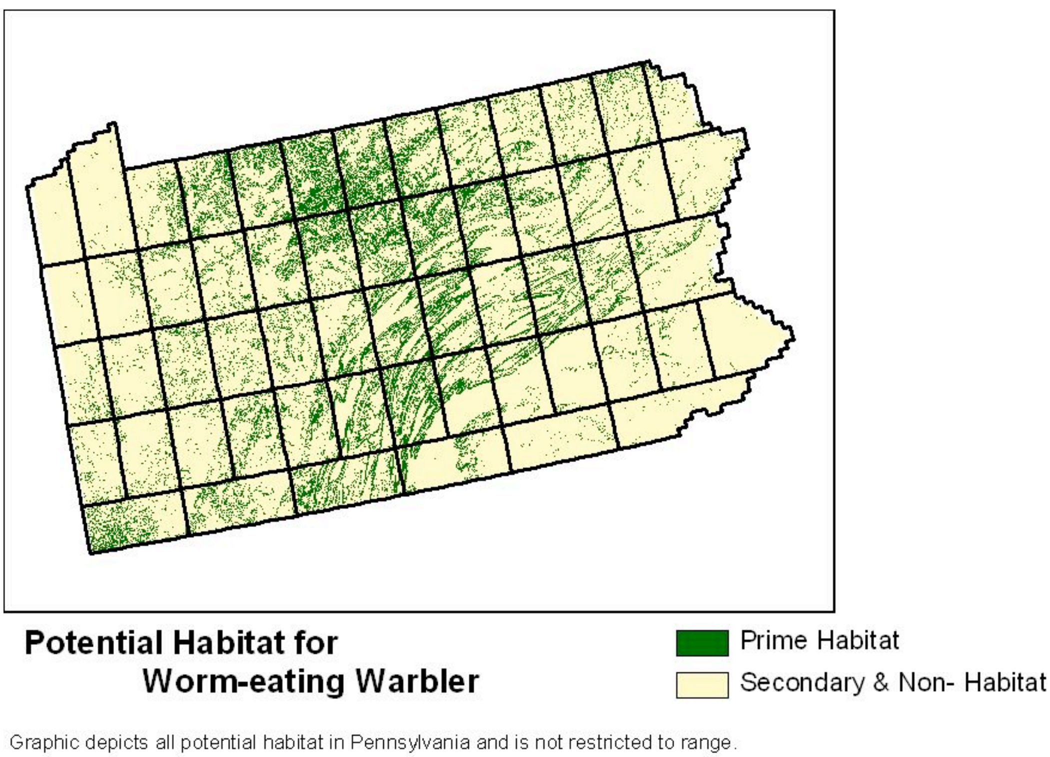

Figure 13. Predictive model map for Worm-eating Warbler at the state level.

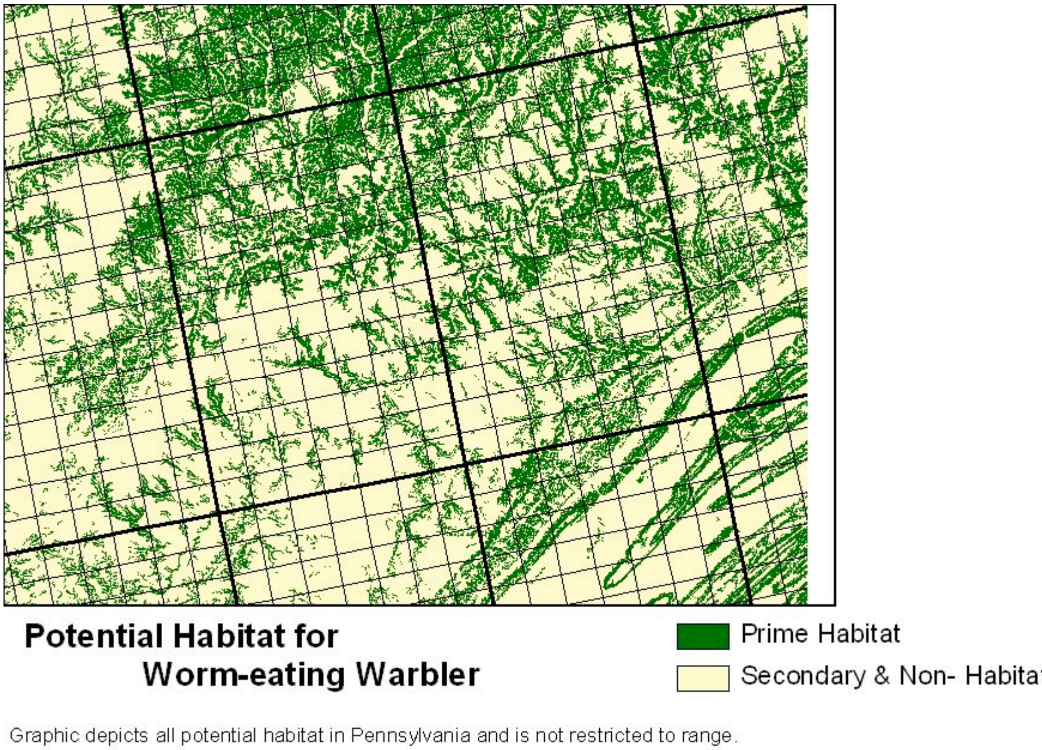

Figure 14. Predictive model map for Worm-eating Warbler at the regional level.

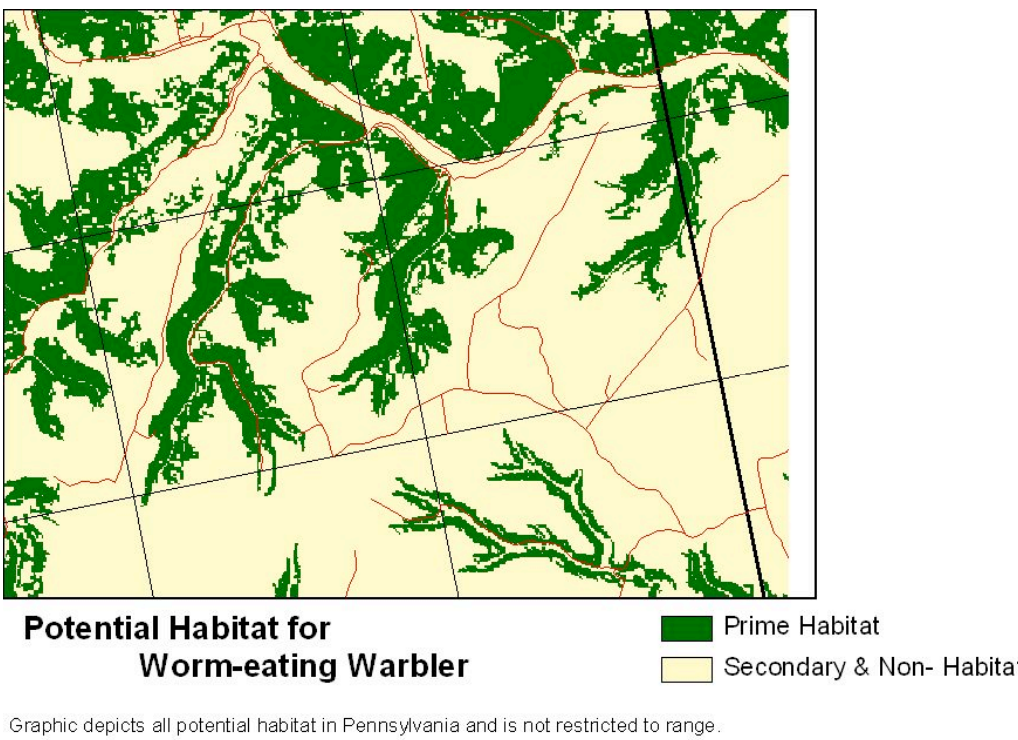

Figure 15. Predictive model map for Worm-eating Warbler at the block level.

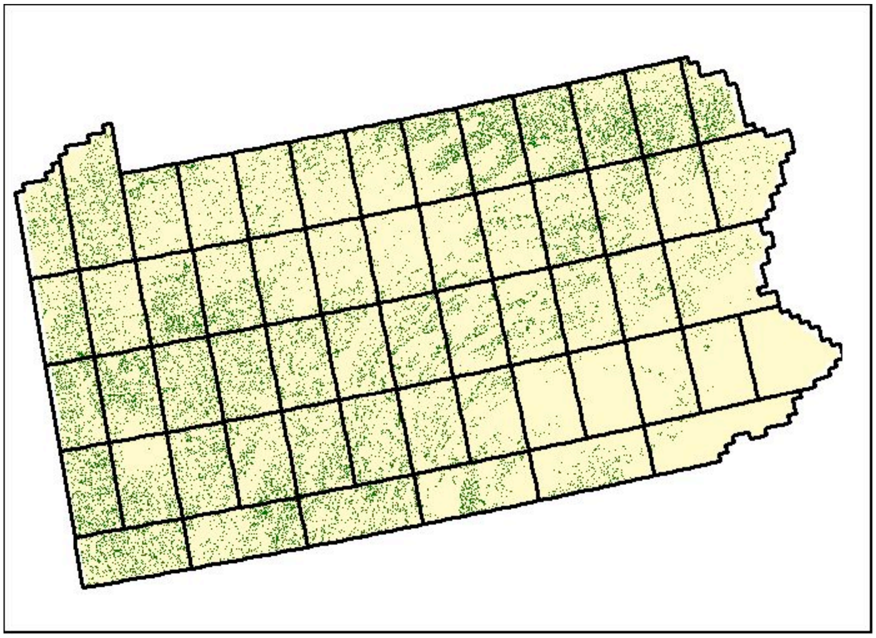

Figure 16. Predictive model map for Golden-winged Warbler at the state level.

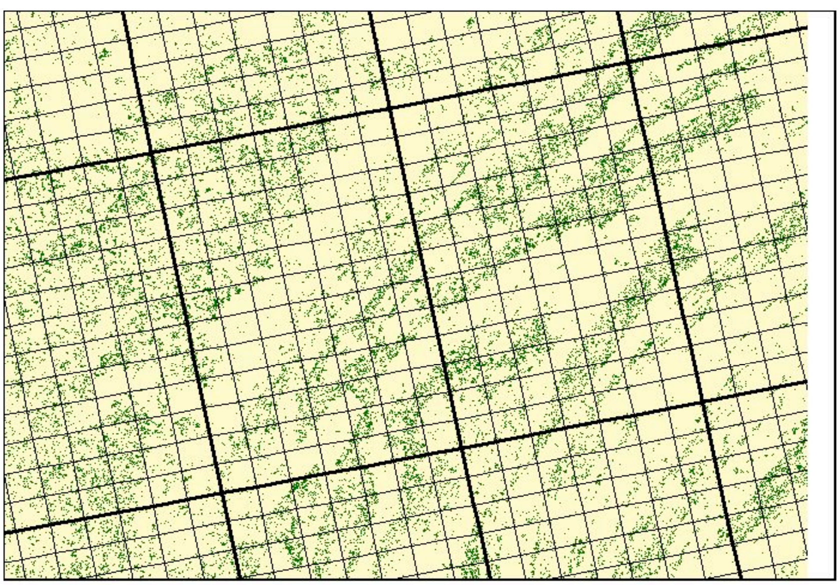

Figure 17. Predictive model map for Golden-winged Warbler at the regional level.

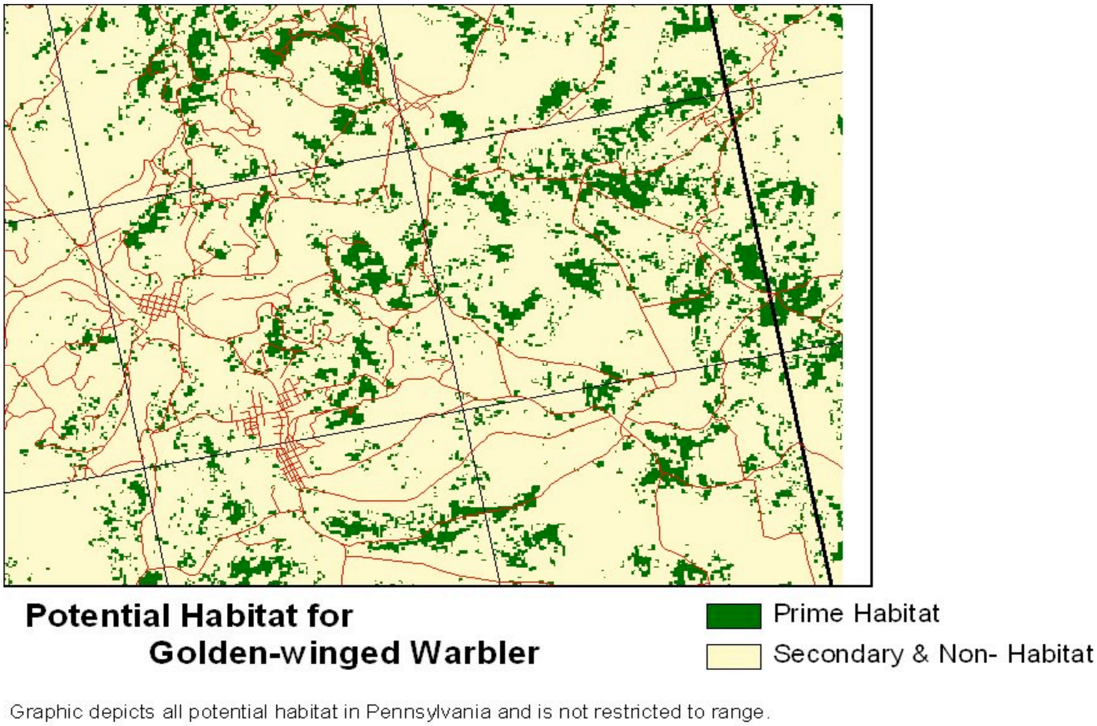

Figure 18. Predictive model map for Golden-winged Warbler at the block level.

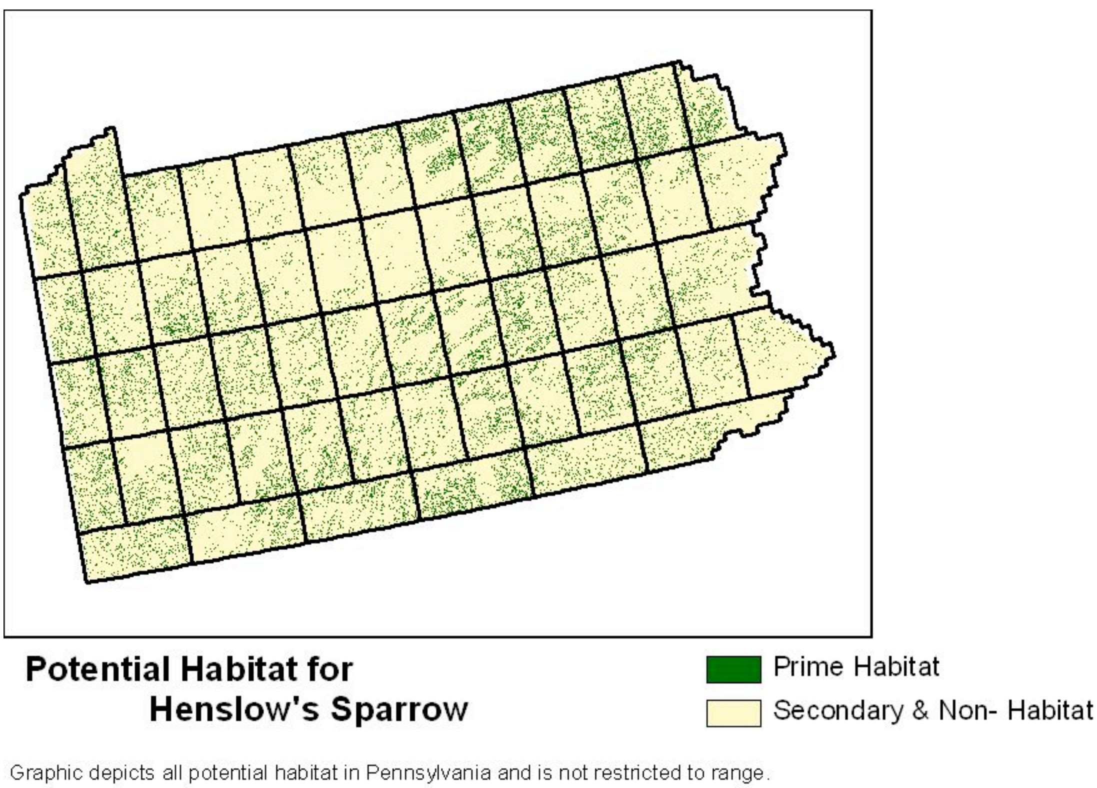

Figure 19. Predictive model map for Henslow's Sparrow at the state level.

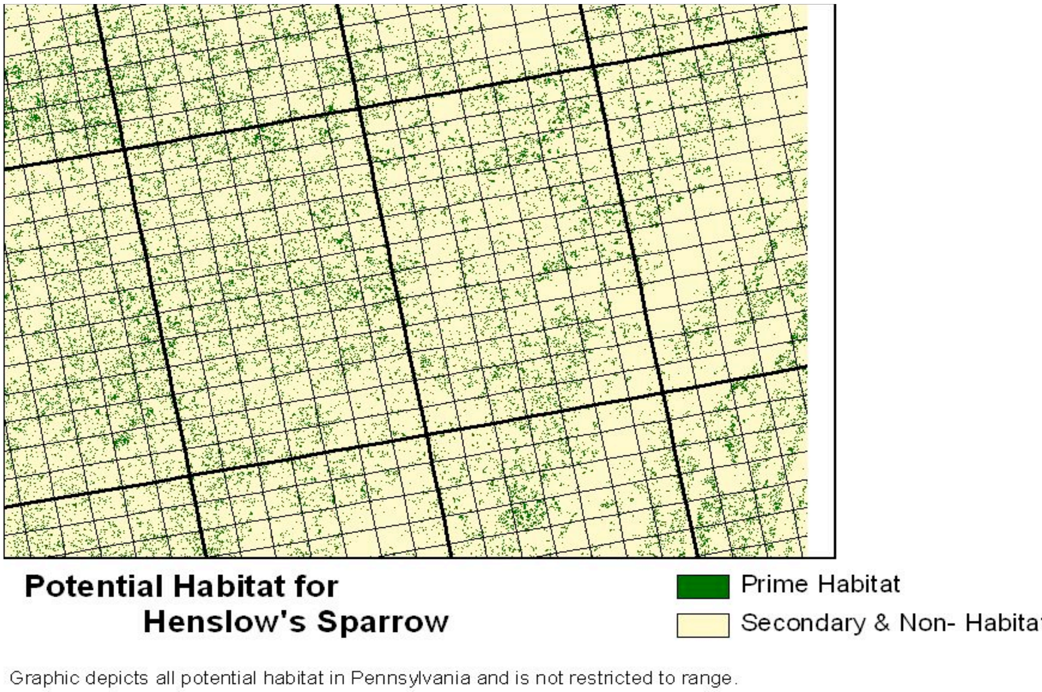

Figure 20. Predictive model map for Henslow's Sparrow at the regional level.

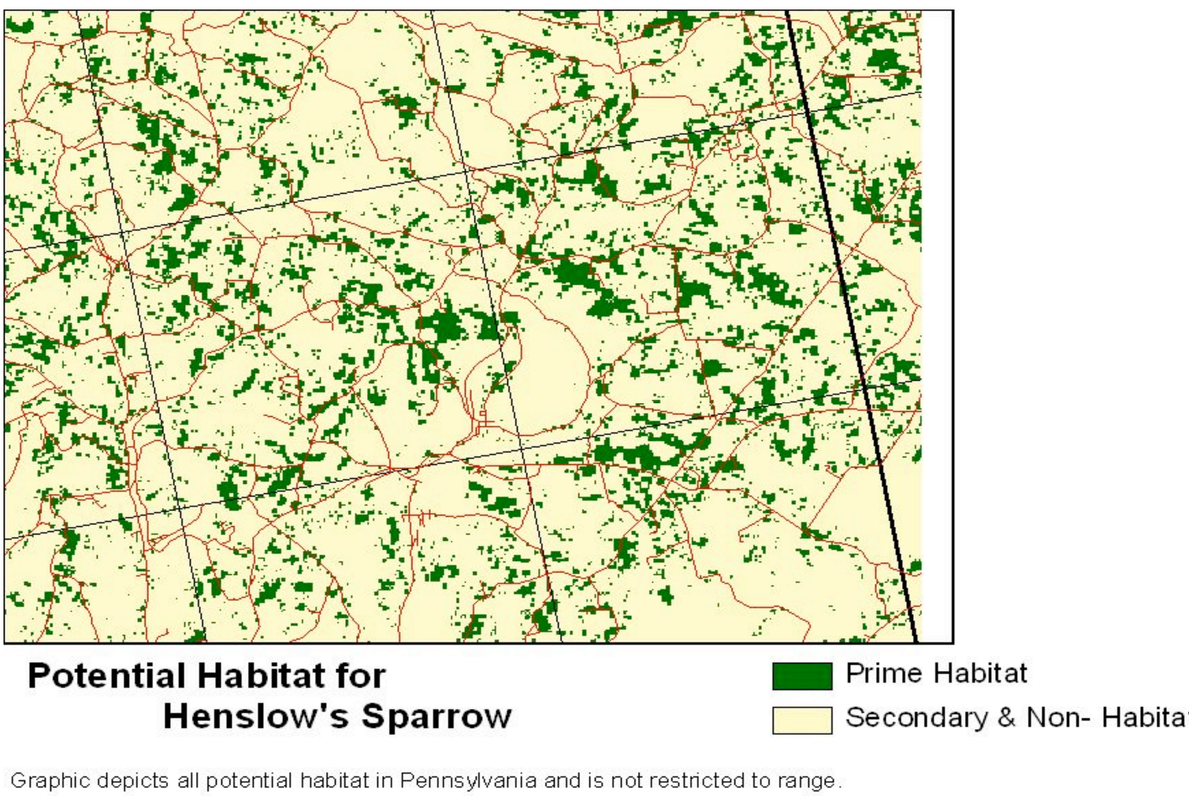

Figure 21. Predictive model map for Henslow's Sparrow at the block level.

Relative Abundance Sampling

From the first organized discussion of the 2nd Atlas with the group that would evolve into the Steering Committee, Pennsylvania birders indicated their desire to set a new standard with their new Breeding Bird Atlas. While the desire to make legitimate comparisons to the 1st Atlas, and hence, to conduct field work in every Atlas block, was immediately apparent, so was the emphatic charge that the 2nd Atlas should go further. Specifically, the need to address those species undersampled in the 1st Atlas became an obvious priority. In addition, Pennsylvania birders indicated that a new Atlas effort would not be worth the investment unless it incorporated some measure of relative abundance for all breeding species in Pennsylvania. Abundance estimates are included in the second atlas attempts of Britain and Ireland (Gibbons, Reid, and Chapman 1993), Maryland (Maryland Ornithological Society 2002), and Ontario (Ontario Breeding Bird Atlas 2001), as well as the first attempts for Vermont (Laughlin and Kibbe 1985) and San Diego County, CA (San Diego Natural History Museum 2001), among others. Table 3 summarizes the abundance sampling methods for a number of atlas projects.

To address the matter of abundance sampling, we considered several options. There are, for example, dozens of Breeding Bird Survey (BBS) routes run every June in Pennsylvania, but their spatial distribution was judged to be too coarse to map contours of abundance on a useful scale (McWilliams and Brauning [2000] provide examples). We considered starting with BBS data as a baseline, and filling in coverage with other established programs, such as monitoring that occurs in Important Bird Areas. The scale difference between samples, however, made integration problematic. We encountered similar obstacles to every established program under discussion: the sampling scales of multiple programs could not be rectified and no single existing program provided the extent of coverage needed to meet our goals for statewide abundance estimation. We became increasingly convinced that the best option was to extract abundance information from our own original data.

Table 3. Abundance sampling methods for some breeding bird atlas projects.

Project	Abundance Sampling Method
Florida (1st)	None
Illinois	None
Texas	None
Virginia	None
Nevada	None
Washington	None
Oklahoma	None
Iowa	None
Arkansas	None
New Mexico	None
Oregon	None
New Jersey	None
Colorado	None
Georgia	None
Ohio	None
South Carolina	None
West Virginia	None
Humboldt Co., CA	None
Contra Costa Co., CA	None
Australia	None
Quebec	None
Vermont	Adjacent block frequency
New York (2nd)	Adjacent block frequency
Britain and Ireland (2nd)	Frequency of occurrence in adjacent blocks with timed surveys
Wisconsin	Counts within atlas blocks reported by orders of magnitude
Alberta	Atlasers report estimate of numbers for each species in block
North Dakota	Atlasers report estimate of numbers for each species in block
San Diego Co., CA	Atlasers report estimate of numbers for each species in block
South Dakota	Atlasers report estimate of numbers for each species in block
Isle of Man	Atlasers report estimate of numbers for each species in block
Missouri	Supplement BBS routes with point counts
Ontario (2nd)	Road and off-road point counts
Maryland/DC (2nd)	Point counts organized as mini-routes

Key elements of the decision on an abundance sampling approach are the sampling density and the personnel. We discussed sampling from a relatively small number of randomly located sites as in the probability sampling outlined in O'Connell et al. (2000), but decided that a sample along roads would be easier to implement than one which required a large investment in landowner contact, and, for most common songbirds, would not introduce a significant "road" bias (e.g., Keller and Fuller 1995). By confining the sample to roads, the amount of field time required to do each survey is greatly reduced relative to an off-road survey, and opens up the possibility of sampling from many more sites. We discussed sampling, then, from priority blocks, which would involve field work at 787 sites evenly distributed across the Commonwealth. Responding to input on this topic from the Steering Committee, we began to seriously consider road-based sampling for breeding Passerines (primarily), implemented at a significantly smaller scale than BBS routes. So-called "mini-routes" had been used effectively in Maryland's 1st Atlas (Bystrak 1980) and are recommended as an efficient means to collect abundance information quickly over a large geographic area (Robbins and Geissler 1990).

Mini-routes are designed to provide abundance data from a series of point counts along a roaded transect. In practice, they also are valuable in "block-busting" efforts, because they provide a rapid accumulation of possible breeding species from a large area within an Atlas block. Several volunteers ran mini-routes for precisely this purpose during the 1st Atlas.

We considered, therefore, that if mini-routes can be implemented so easily and if volunteers will run them anyway as a means to gain a quick snap-shot of the species in their block, that we might officially expand the mini-route coverage to all non-border Atlas blocks. The ambitious goal of abundance sampling from 3,931 Atlas blocks for total coverage within the Commonwealth then became dependent on the projected number of observers necessary to complete the task. The number of observers could not, in turn, be determined until the specific field methods for point counts were worked out.

Mini-routes in Every Block – How Many Stops? To determine the length (i.e., number of mini-route stops or count stations), we had to first demonstrate that a sufficient road density exist in each block to ensure that the selected number of points can be fit within the block on suitable roads and with enough distance between stops to minimize the possibility of double-counting individuals. We began with a distance between stops of 0.40 mi/ 0.64 km, which is slightly less than the distance between stops on BBS routes. Next, we analyzed the Pennsylvania Department of Transportation's state road layer to determine the number of stops that could be fit within an Atlas block. We omitted interstate and primary state highways from the analysis to address field safety concerns and because persistent road noise from major thoroughfares is incompatible with point count sampling. As a somewhat arbitrary starting point, we chose 10 stops, which would necessitate 3.6 mi /5.9 km of suitable roads in each Atlas block. Because many blocks failed to provide enough right-of-way to accommodate 10 stops, we tried again with a shorter, 8-stop route. An 8-stop route requires 2.8 mi/4.5 km. Nearly 100% of regular atlas blocks provided suitable roadside survey conditions for at least 2.8 miles within the block. Thus we decided to survey for Passerine relative abundance from 8-stop mini-routes in every one of the 3,931 regular Atlas blocks.

While most Atlas blocks will provide 2.8 mi. of roads suitable for mini-routes, few provide that mileage in a single linear feature. Rather, most of the road length occurs as disconnected fragments at the scale of an individual block. Thus, we needed to provide some way for eight survey points to be identified in a block even if the eight points are *not* configured in a line. To identify eight potential survey points in each block, we developed a unique geographic information system (GIS) application. For each atlas block the GIS randomly places 16 potential survey points. Fields teams will conduct counts at eight of those points proceeding from points 1 through 8 as numbered by the random placement software. Points that are deemed in the field to be unsuitable for a count location (e.g., on a dangerous curve or in plain view of a loudly barking dog) may be skipped, and the next point in the sequence selected. When a point is skipped the team must proceed to point 9, then 10 etc., depending on how many of the first 8 points need to be skipped. Routes will not necessarily be completed within each block before proceeding to the next but likely will incorporate the points of several adjacent blocks as long as point selection within any specific block is limited to the first eight points for that block.

Conceptually, with the assistance of a GIS, the points will be placed as follows:

- A Pennsylvania Roads GIS layer is identified along with the atlas block layer (Fig. 22).
- Using software that places points randomly within a polygon 16 points will be placed within each atlas block while maintaining a 0.4-mile minimum distance between each point (Fig. 23). The random point placement software numbers the points in the order that they are located.
- Each point is moved to the nearest road (line) while maintaining the 0.4-mile minimum distance (Fig. 24).
- Any point that cannot be moved while maintaining the minimum distance is eliminated and replaced (Fig. 25).

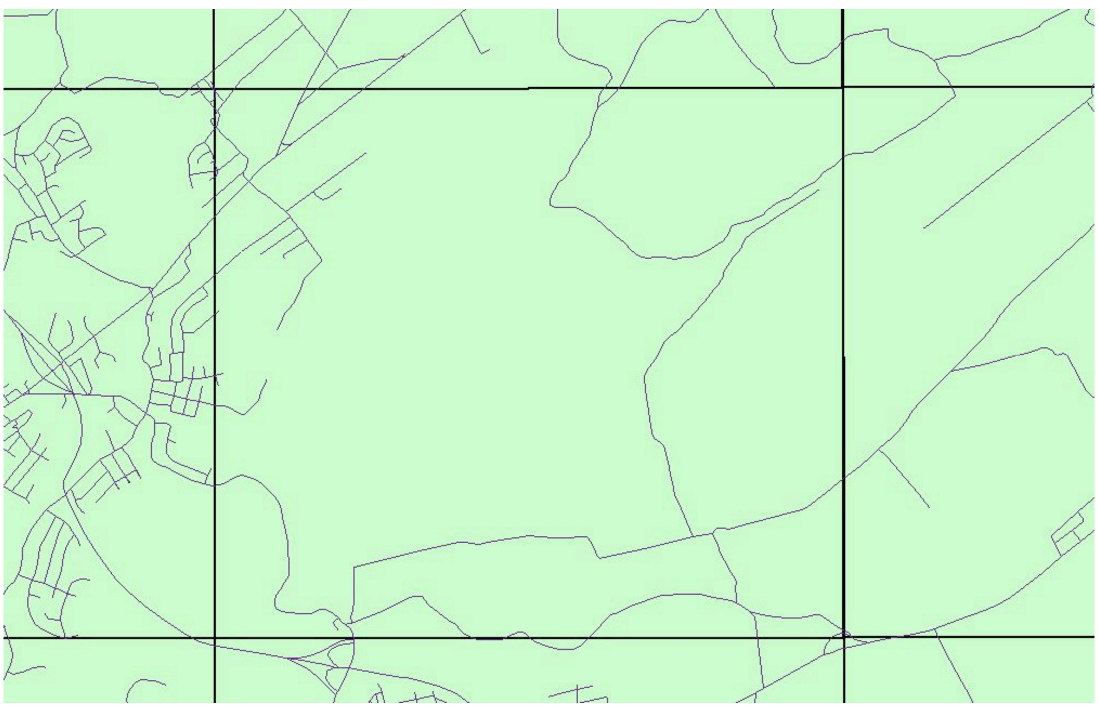

Figure. 22. Pennsylvania road layer at the Atlas block scale.

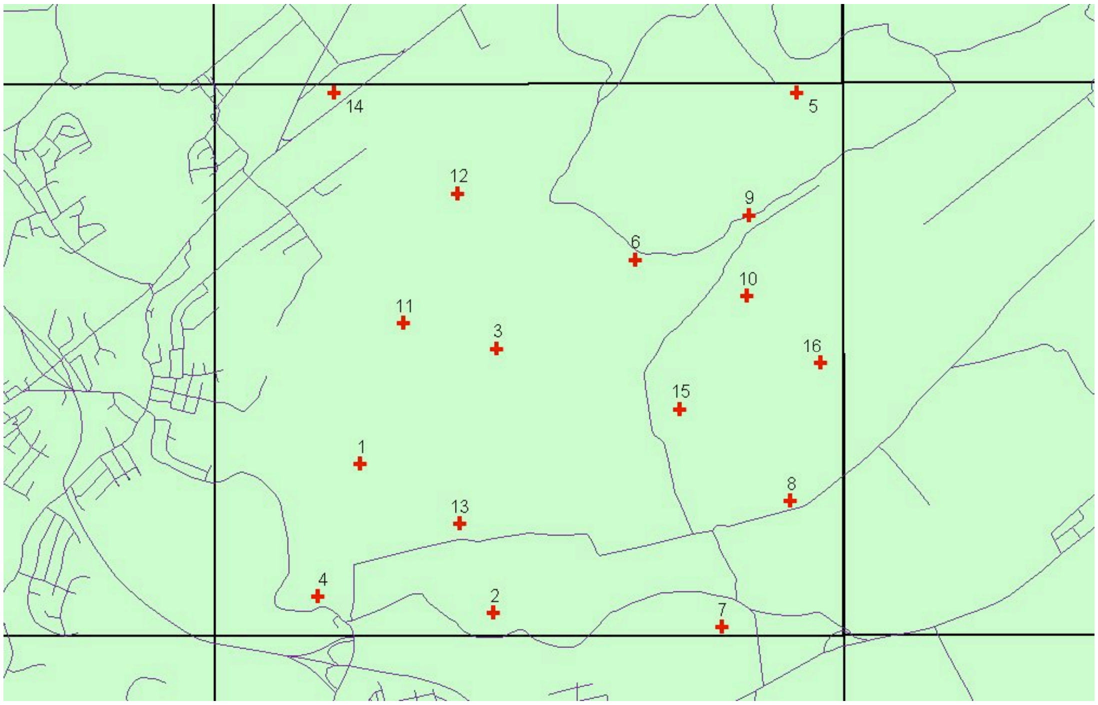

Figure 23. Sixteen random points generated by the point-placement software.

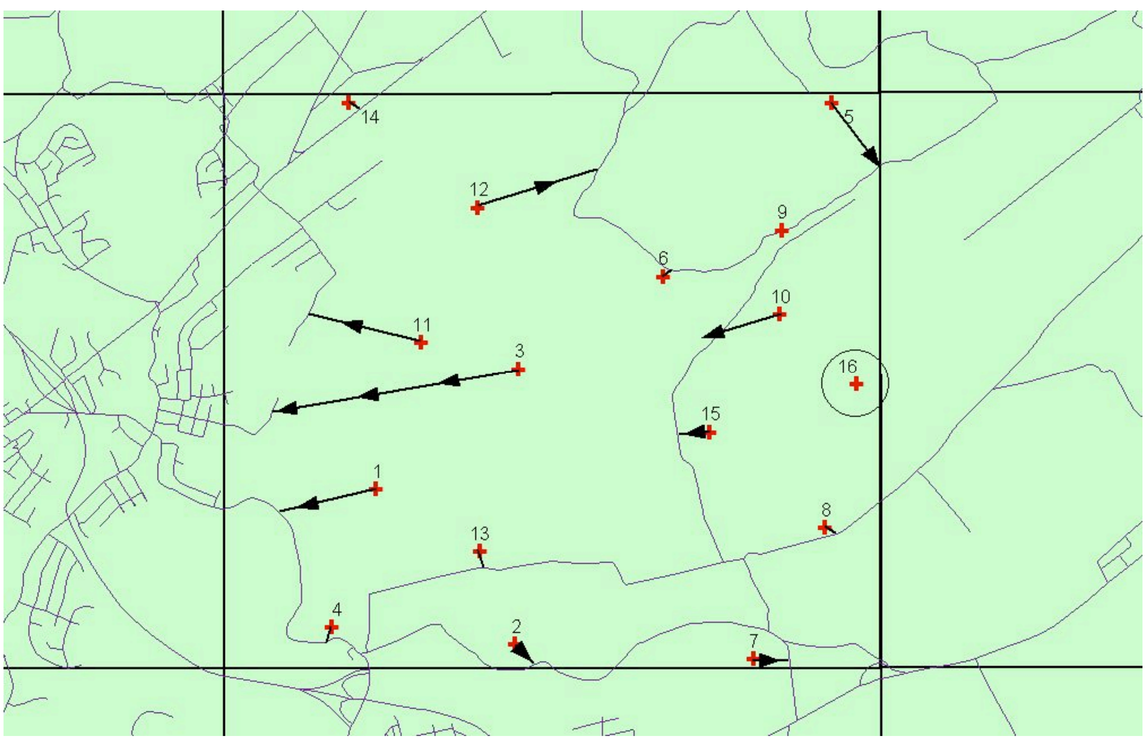

Figure 24. Points are moved to the nearest road (line) while maintaining the 0.4 mile minimum distance between them.

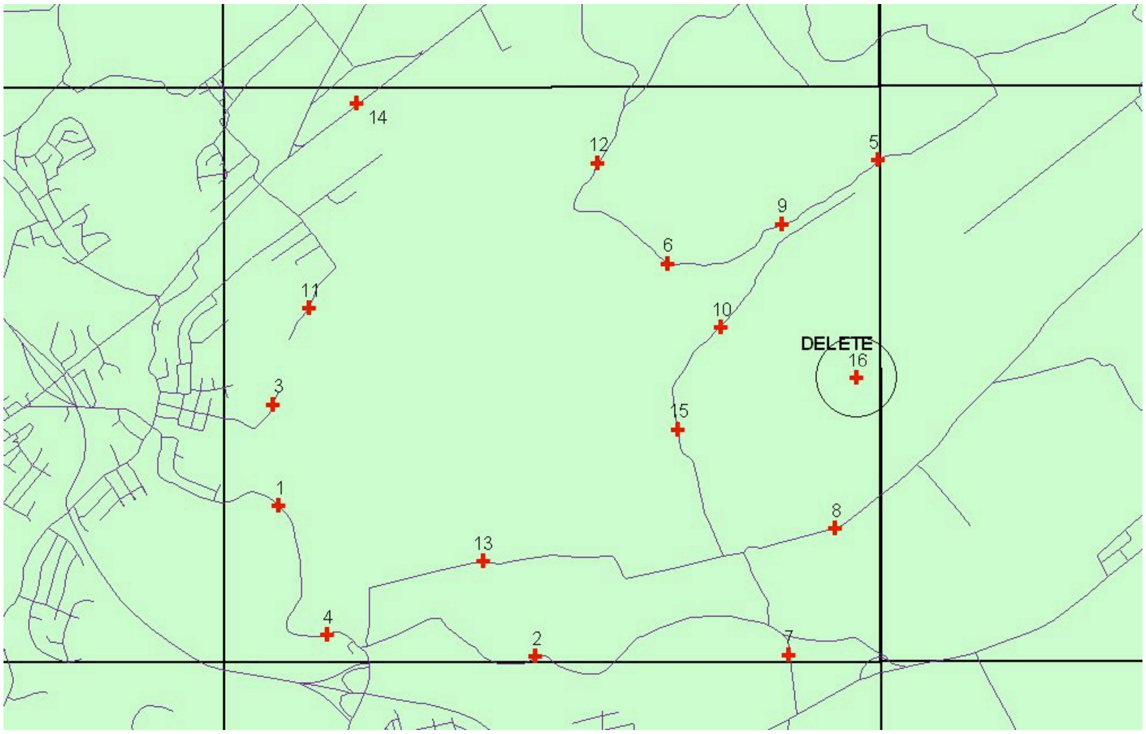

Figure 25. Any point (e.g., 16) that cannot be moved while maintaining the minimum distance is eliminated and replaced.

The data collection and preprocessing of road and block data is complete. Road files have been edited to exclude any easily identified heavily traveled road (i.e., Interstates). Road files have been clipped and processed for each atlas block. Individual software tools have been identified for random point placement and point movement to nearest roadline. The specific points in each block that are ultimately sampled will be archived through recording waypoints with a hand-held GPS unit.

Mini-routes – Field Protocol. For basic abundance sampling of the greatest number of species, we recommend that mini-routes be surveyed on rain- and wind-free mornings from approximately 25 May to 5 July and from roughly 0530-1000 hrs EDT. We will conduct point counts of singing territorial males using standard point-count methods (Ralph et al. 1993, 1995, Howe et al. 1997). Each count will last for five minutes, consisting of an initial three-minute sample followed by two, one-minute samples. It will be essential for *post hoc* analysis that individual birds are counted only within a single time band. For example, if a species is detected in the first listening period (3 minutes) and also in the second and third periods, it must only be recorded in the first period. Only newly detected individuals of a species may be recorded in subsequent time periods of the count.

Regardless of habitat type, count circles will be a fixed 75-m radius; individuals will be recorded as within or beyond 75m. Mini-routes will feature actual counts of singing males detected within 75m of the observer. Counts will not include those birds detected outside 75m; these distant birds will be recorded merely as "present" in a separate running species list for the route, i.e., a "1" in the database no matter how many individuals are spotted. If two singing males are detected outside 75 m when the count begins but later move into the 75 m circle, they may then be counted as two individuals (instead of as "1" beyond 75 m).

Because our sampling design will attempt to focus on sampling breeding birds with the least potential bias in detectability, we will restrict actual counts of individuals to singing males. The point is males and females typically differ greatly in their probability of detection because breeding males sing while females are less conspicuous. If we allow numbers of females to be included in population estimates, and the probability of including females varies by species, then we are biasing population estimates toward higher counts of species with conspicuous females. Therefore, multiple individuals of the same species that are seen only (not singing) or heard calling (but not singing) will be recorded as one individual. For example, two clearly audible calling Pileated Woodpeckers will be recorded as one. Four calling Eastern Towhees would be recorded as a single individual; if two of them begin to sing at any point, they then can be recorded as two individuals. Other specific cases include:

- Within 75m, all calling birds within a species are recorded as single individuals no matter how many are visible at one time or audibly discernible. This includes woodpeckers, nuthatches, titmice, etc.
- Gregarious species and flocking birds like waxwings, House Sparrows, starlings, and pigeons will be recorded on the tally sheet with an order of magnitude estimate of numbers at the point, i.e., 1-10, 11-100, 101-1000, 1000+. The same approach applies to swallows, swifts, and flyover vultures, raptors, and waterfowl.

In addition to recording data on birds from every mini-route stop, we will ask field workers to complete a "10-second" habitat assessment check off modeled after Crick (1992) and the information provided to atlas volunteers in San Diego County, CA (San Diego Natural History Museum 2001). We decided to include questions in our assessment that will reveal details of habitat composition and structure that are not available from Landsat imagery, but could very much affect distribution and abundance of breeding birds. The questions we have prepared will provide information on each sampling point roughly equivalent to level IV in the Anderson (et al. 1976) Land Use Classification System. Figure 26 is a sample field form for mini-routes, including the habitat assessment.

Analysis of Abundance Data. We endeavored to develop a generalized sampling scheme for songbirds incorporating the latest advances in estimation of detection probabilities. This is because, despite large scale monitoring programs aimed at determining bird abundance, important sampling biases remain in point count methodology. For example, the probability of detecting a species on a plot varies by season, by species, by time of day, and by observer, to name just a few. Recently, Link and Sauer (1998) have suggested accounting for sampling biases by incorporating a method that estimates detection probabilities (Thompson 2002). Options for accounting for bias in abundance estimates include distance sampling (Rosenstock et al. 2002, Diefenbach et al. 2003), double sampling (Nichols et al. 2000, Bart and Earnst 2002, Pollock et al. 2002), and the *post hoc* application of count removal models (Farnsworth et al. 2002). We invested a great deal of discussion time toward the resolution of which method would likely be the most advantageous for our purposes in the 2nd Atlas. We ultimately decided to pursue the count removal model approach outlined by Farnsworth using the computer program SURVIV available as a free download from the website of the Patuxent Wildlife Research Center (White et al. 1982).

The program SURVIV allows for the calculation of detection probabilities that can address the aforementioned biases among observers, species, habitats, etc. We are particularly concerned about accounting for observer sampling bias because the scope of our field effort will require many observers to complete. We have molded our proposed field protocols around the requirements of SURVIV, namely the three time bands and fixed radius count circle (Farnsworth et al. 2002). With a numeric estimate of individuals for a species along a route, SURVIV allows for the calculation of the probability of detection. Dividing the raw total number of individuals by the detection probability for that species yields a population estimate in the area sampled, which can readily be converted to an informed density estimate.

2nd Pennsylvania Breeding Bird Atlas – Mini-Route Field Data Form

Instructions: Record all individual singing males within 75m. Each individual may only be recorded once per stop # – The numbers you list for each species in the time band columns must refer to different individuals. All flyovers, flocking species, and species detected beyond 75m must be entered in the Running Tally column. Please indicate your estimate of abundance for Running Tally species: 1, 1-10, 11-100, 101-1000, 1000+. The order of magnitude abundance estimate applies to raptors, vultures, and waterfowl, swallows and swifts, and birds that form flocks during the breeding season: grackles, starlings, pigeons, and waxwings. All other species detected as flyovers or otherwise outside the 75m count circle should be listed under the Running Tally with an abundance estimate of 1.

observer	Block ID	date	time	Stop #	spp	1st 3 min	min. 4	min. 5	Running tally

10-second Habitat Assessment

Please circle the answer to these questions relative to your count area (75m radius):

- **Is hemlock present? Y N**
- **Do more of the trees appear alive/healthy or dead/dying? alive dead**
- **Are there any mature spruce trees within the plot? Y N**
- **Do these appear mostly natural or ornamental? natural ornamental**
- **Do Mountain Laurel and/or Rhododendron appear to contribute roughly 33% or more to the surrounding understory? Y N**
- **Are there livestock and/or a working (actively housing livestock or grain) barn on your plot? Y N**
- **Do you see bluebird-style nest box(es) in the plot? Y N** **GPS Waypoint_________**

Figure 26. Sample field form for mini-route sampling.

Effort Needed. We estimate that each mini-route will take 80 total minutes to complete, including sampling and travel between sample points. We recommend that each route be sampled only once. With a 240 minute window of sampling time each morning a single observer could conduct 24 point counts or 3 total mini-routes. We estimate a seasonal window of 30 potential field days between 25 May and 5 July, or 90 mini-routes potentially completed by a single observer in each field season. At this rate, every regular block could be sampled with a mini-route in three years (2004-2006) with the equivalent of 15 field staff contributing 30 days over those three years. We strongly recommend that all mini-routes be completed by the end of the 2006 field season to allow ample time for analysis before other data would need to be compiled after the 2008 season.

Sampling for abundance with mini-routes will require an elite corps of highly-skilled field observers. Some level of minimum, standardized hearing proficiency should be demonstrated among observers, but different hearing abilities will be largely accounted for with the *post hoc* application of count removal models to determine detectability. Perhaps the more important issue is that field staff need to be able to immediately recognize the songs and calls of any species that might be detected on a standardized point counts, no matter what the specific field protocol. No amount of statistical analyses applied after the data have been collected can correct for mis-identified individuals.

Because of the high skill level required to conduct mini-routes, we expect that most block owners will not be able to run "official" mini-routes in their own blocks. (All block owners are, however, encouraged to implement their own mini-routes as a quick and efficient means to generate a list of possible breeding species in their block.) We recommend some combination of paid, seasonal field staff and highly-skilled volunteers to conduct mini-routes. All field staff collecting mini-route data for abundance estimation will be required to attend a training session before they are approved for participation by the Project Coordinator.

Abundance Analysis – An Option. In addition to a recommendation from the Steering Committee to pursue mini-routes for abundance sampling, we were also presented with a method to assess abundance in each block that requires no additional field work. As indicated in Table 3, Vermont's atlas and the 2nd atlas efforts of Great Britain and Ireland and New York State opted to represent abundance for all species as an indirect estimate based on the frequency of adjacent blocks in which each species was detected. The British atlas based the frequencies on standardized, timed surveys in every block (Gibbons et al. 1993). The New York and Vermont atlases base the frequencies on the sum total of atlasing efforts in each block, at the conclusion of the project (e.g., Laughlin and Kibbe 1985).

As a comparison to estimates of relative abundance obtained from mini-routes, we recommend calculation of a frequency of occurrence index based solely on the presence of a species as a breeder in the blocks surrounding a particular block. For example, each regular block borders eight additional blocks: four in the cardinal directions and one at each corner. For each species documented as a breeder in a block, its prevalence in the region could be coded as a proportion of the adjacent blocks in which it also occurs. If a species was recorded as at least a *possible* breeder in 5 out of the 8 adjacent blocks, then the block in question could be coded as “0.63” for that species. Each block receives a frequency index value for each species ranging from 0-1, with nine different categories of index values that could be represented as different colors or shades. With 3,931 regular Atlas blocks, the state-level composite map would provide a fairly detailed image of distribution and an indirect index of abundance that, in practice, will likely yield similar results to the mini-route samples.

While the frequency index obtained from adjacent block analysis is artificial, the approach offers several advantages. Assuming only that all blocks have received their recommended minimum level of field work coverage:

- No additional field-work is required to calculate the Adjacent Block Index
- Adjacent Block Index scores are directly comparable among all species, regardless of habitat affiliation, rarity, nocturnal behavior, etc.
- Adjacent Block Indices are summarized at the same scale as mini-route estimates, i.e., the individual atlas block
- Adjacent Block Indices could be calculated for the 1st Atlas as well and provide a direct comparison of change in relative abundance for all species

Additional Surveys

Although we quickly abandoned the idea of relying on BBS routes to provide the desired abundance data, the discussion of BBS as a viable option was fruitful in terms of identifying additional items to be addressed in an abundance sampling protocol. For example, if we allow that point counts are appropriate for estimating abundance and monitoring trends of common territorial songbirds in June, then what of nocturnal birds, or wetland birds, or raptors, or species that breed earlier that the typical BBS sampling period in June? To address these questions, we invested deliberation among the Design Team members on the pros and cons of including multiple "special" surveys for birds that would not be effectively sampled with a BBS-type field effort, i.e., roadside point counts in June. We considered nocturnal sampling for owls in March and May (Takats 2001), early breeding season counts when woodpeckers, titmice, and nuthatches are most vocal (Badzinski 2003), diurnal raptor surveys (Yahner et al. 2001), and sampling of herbaceous wetlands in search of rails and other secretive marsh birds (Timmermans and Craigie 2002).

Few other atlases involve targeted surveys for species or groups of species. South Dakota purposefully added survey blocks in rare or unusual habitat types to supplement their random sample. In Maryland, wetland mini-routes along tidal creeks were accessed by canoe (Bystrak 1980). North Dakota included specific surveys for marsh birds and waterfowl. Both Alberta and Ontario employ the owl sampling procedures outlined by Bird Studies Canada (Takats 2001); Ontario also encourages field workers to establish off-road abundance sampling points for wetlands.

Because Pennsylvania's 2nd Atlas will incorporate the predictive Gap Analysis models precisely as a means to better identify rare or undersampled habitat types, we anticipate much greater confidence in the distributions of species that rely on those habitats relative to the 1st Atlas. Thus the need to target surveys for priority species in Pennsylvania may be lower than that for other atlases, none of which apply predictive models. Ultimately, the Design Team concluded that the species most in need of targeted surveys are wetland birds and the lesser-known nocturnal species. We, therefore, recommend:

- Early Breeders – no specific coordinated effort to survey for early-breeders

- Diurnal Raptors - no specific coordinated effort to survey for diurnal raptors. Instead, we recommend that Atlas volunteers submit directly to their Regional Coordinator an annual estimate of the *total number of breeding pairs* in their block of all Falconiformes that are at least *possible* breeders in the block. These data are separate from any incidental records for raptors that appear on the tally lists for mini-route samples.

- Owls and nightjars – no general nocturnal sampling protocol to target Great Horned, Barred, or Eastern Screech owls. These species were readily discovered in suitable habitat during the 1st Atlas, and we recommend that estimates of their numbers be reported annually to Regional Coordinators, just as for diurnal raptors. Again, this number should be an estimate of the total number of *breeding pairs*, not individuals, within each Atlas block. Specific targeted surveys for nocturnal birds are described in a subsequent section.

- Wetland birds – a habitat-based sampling protocol that attempts to standardize abundance sampling for wetland-dependent species.

Wetland Sampling Protocol

At least 33 of the "priority" species listed in Appendix C are associated with wetland habitats, and would likely be undersampled by mini-routes. Because these species make our priority list, all Atlas volunteers will be encouraged to consult specific Gap models for them to help focus general atlasing. Thus, we fully expect a much better informed picture of wetland bird distributions to result from the 2nd Atlas without any further sampling protocol. To develop abundance estimates for many of these species, however, we recommend a standardized procedure for sampling herbaceous wetlands (Fike 1999) i.e., marshes and wet meadows.

Identifying on a map where the appropriate wetlands are is the first step in designing a sampling strategy for wetland birds. Figures 27-29 illustrate how atlasers will be able to pinpoint wetland locations in their block using GIS layers of National Wetlands Inventory (NWI) maps.

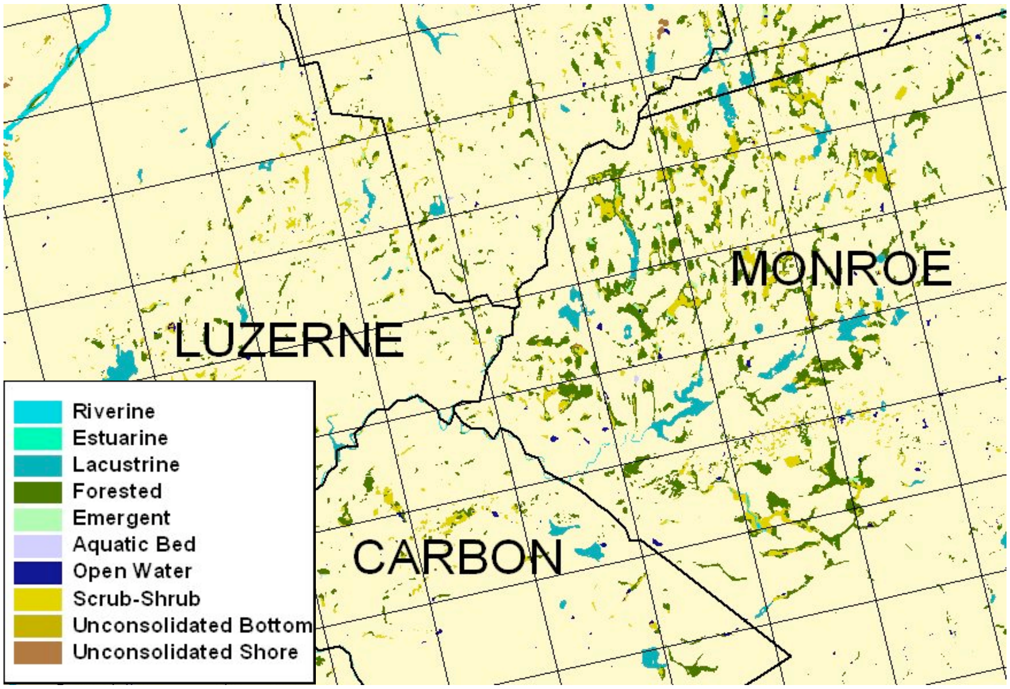

Figure 27. Multi-county view of mapped wetlands in Pennsylvania.

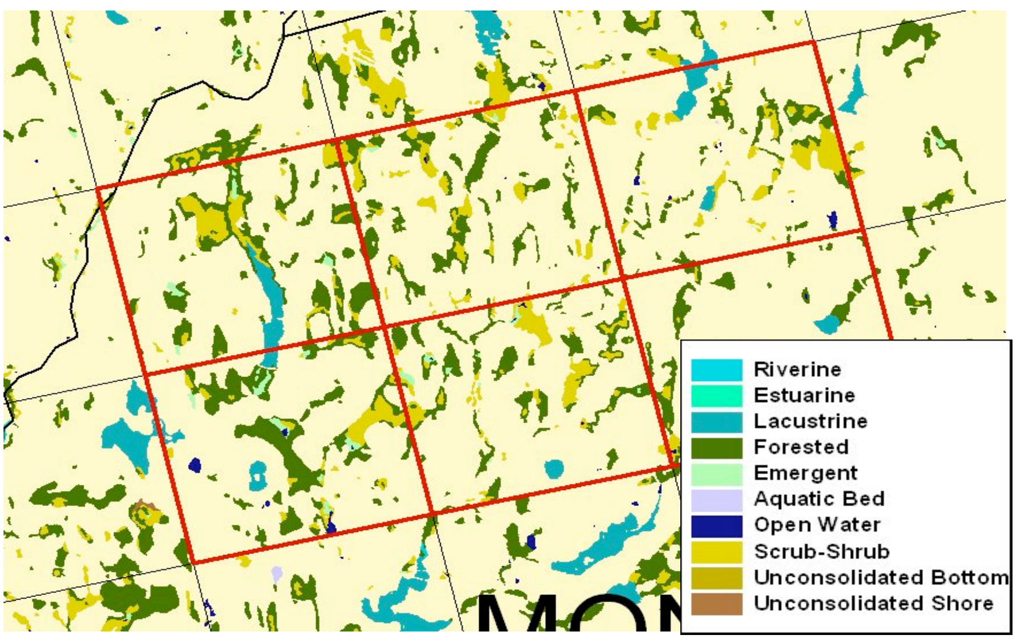

Figure 28. Six-block view of mapped wetlands in Pennsylvania.

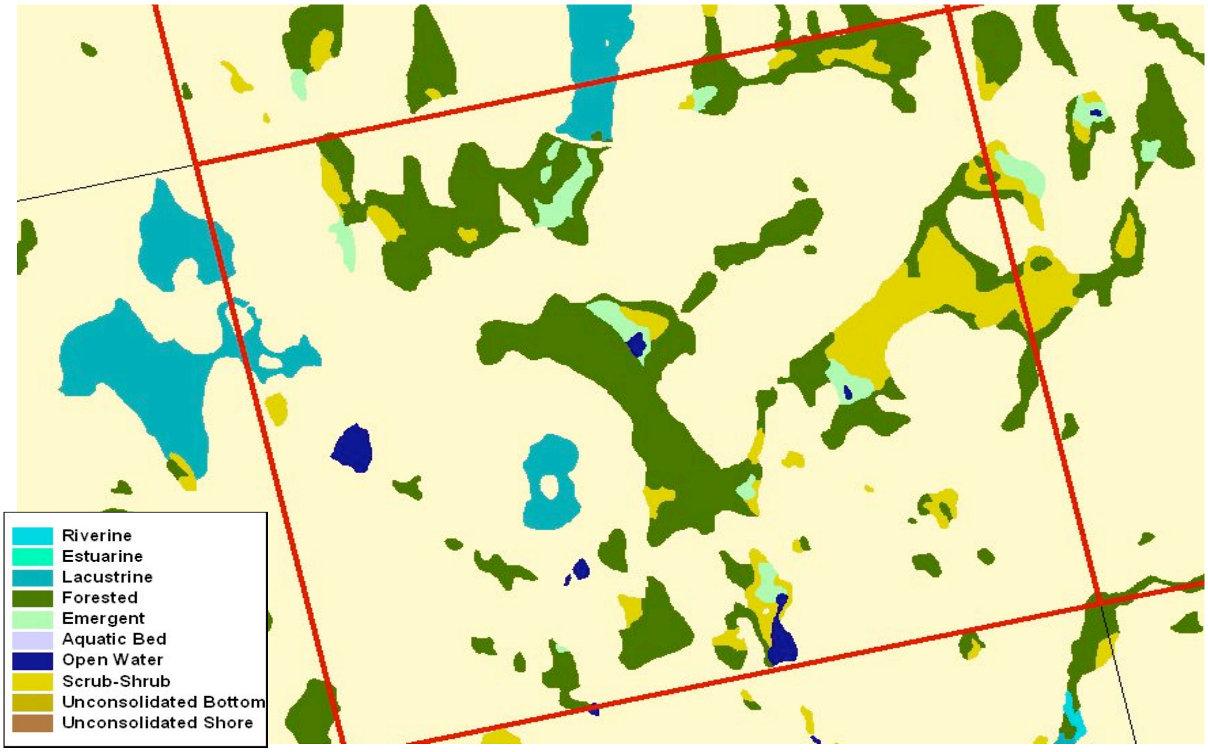

Figure 29. Wetlands mapped at the scale of an individual Atlas block.

For an abundance estimate of obligate wetland birds in Pennsylvania, our target species are Sedge Wren, Marsh Wren, and Swamp Sparrow among the Passerines, plus Least Bitten, American Bittern, Pied-billed Grebe, Common Moorhen, American Coot, King Rail, Virginia Rail, Sora, and Black Rail. All except Swamp Sparrow are conservation priorities for the Atlas; we have included Swamp Sparrow in this survey because it is likely to be under-represented by the road-based mini-route surveys. All of these species are associated with herbaceous wetlands, typically with a conspicuous cattail (*Typha*) component and a mix of emergent vegetation and shallow open water (McWilliams and Brauning 2000, Kirk et al. 2001, Timmermans and Craigie 2002). Wetland types potentially providing these habitats in the NWI layer are “emergent” and “lacustrine.”

To determine where specifically to establish survey points within a given Atlas block, field staff will identify suitable habitat patches and then filter these by size. Wetland area is frequently identified as the single most important factor contributing to species richness of wetland birds, especially rare species (Watts 1992, Kirk et al. 2001, Timmermans and Craigie 2002). We will, therefore, focus our efforts for this survey on relatively large wetlands, i.e., those with the greatest likelihood of harboring the species the methods are designed to detect. We recommend that this protocol be limited to sites greater than 4 ha in area. In Pennsylvania, most marshes will be smaller than 4 ha, and many of these will provide suitable habitat for some of the priority wetland species. The smaller wetlands, however, should be viewed as the responsibility of the block owners to survey for breeding evidence to the best of their abilities. For this survey that attempts to standardize sampling for an estimate of relative abundance, we recommend that the special field effort required be spent in the potentially most productive sites statewide.

Regarding spatial extent of the survey, we recommend that wetland surveys be implemented in each priority block. Field observers involved in this effort will use the GIS information provided on NWI wetlands to identify all patches of emergent and lacustrine wetland in the priority Atlas block. Pending ground-truthing to confirm the accuracy of the NWI information, field observers will select the largest wetland patch in the block as the preferential study location for that block. If the priority block does not contain a wetland patch of at least 4 ha, field observers will identify and select the nearest patch (straight line distance in any direction) that meets the > 4 ha criterion, regardless of the block in which the patch is located. We recognize, however, that many of Pennsylvania's largest and most productive wetlands occur near the Commonwealth's borders. We therefore recommend that, in addition to the priority blocks, the wetland bird sampling protocol be implemented in any wetland patch > 50 ha in a border block. Thus, we expect to generate wetland bird abundance estimates from a sample of over 800 wetlands, which would potentially make this feature of the 2nd Pennsylvania Breeding Bird Atlas the largest systematic survey of marsh birds yet attempted in North America. For comparison, the Marsh Monitoring Program administered by Bird Studies Canada reported on 425 routes surveyed between 1995 and 1997 (Weeber et al. 1999).

Within a surveyed wetland, field observers will establish two sample plots, regardless of absolute wetland patch size. Center points of sample plots should be at least 250m from each other; the center points will anchor a 100 m fixed radius count circle. In larger wetlands, in which both plots can be located more than 100 m into the interior of the marsh, we recommend that both plots be full, 360° interior plots. For smaller wetlands or those with a more narrow, linear shape, the center points may be placed on the wetland edge to anchor a 180° sampling arc (Ribic et al. 1999, Weeber et al. 1999, Timmermans and Craigie 2002). All center point UTM coordinates will be recorded with portable GPS receivers.

Wetland surveys should be run in the early morning, from one hour before local sunrise to three hours after. We recommend that each wetland be surveyed twice (early and late season) in the same year (Francis et al. 1999, Ribic et al. 1999) but each wetland should only be sampled in one year of the Atlas. Early season surveys should be run between 15 May and 15 June, on warm mornings with light winds and no rain (Ralph et al. 1993, 1995). Late season surveys should be run between 16 June and 15 July. There should be at least a 10-day difference between early and late season samples for any one site.

During surveys, observers will record and count every priority wetland species (listed on the datasheet) detected within 100 m; species detected beyond 100 m will count as one individual. Any species detected that is not listed as a wetland priority on the datasheet may be listed on a separate species tally for the wetland.

At each sample point, observers will record birds in specific time bands, using a combination of passive listening and response to call broadcast from portable CD or cassette players. The specific device used is up to the discretion of the observer, but it must be able to broadcast a Black Rail call, for example, audible to human ears without distortion at least 100 m from the observer. To determine the sequence of sampling with broadcast calls, we specifically consulted Gibbs et al. (1999), Ribic et al. (1999), Therres et al. (1999), Timmermans and Craigie (2002) and the “Marsh-Wetland Bird Survey Protocol” developed by Pennsylvania Audubon for surveys of marsh birds in Pennsylvania Important Bird Areas (R. Blye, *unpublished*):

- 3 minute passive listening
- 1 minute Sedge Wren (1 min. passive listening)
- 1 minute Least Bittern (1 min. passive listening)
- 1 minute Black Rail (1 min. passive listening)
- 2 minute mix of Sora, Virginia Rail, and King Rail (1 min. passive listening)
- 1 minute mix of Pied-billed Grebe, Common Moorhen, and American Coot (1 min. passive listening)

- 1 minute of American Bittern (1 min. passive listening)
- Total sampling time: 16 minutes/point, 32 min./wetland

If any of the target species are detected while moving through the marsh between counts, they should be listed on the running tally for the wetland. A sample field data sheet for wetland surveys is illustrated in Fig. 30.

We estimate that wetland surveys will take approximately an hour from start to finish, so that a single individual could do three in a day. If we take a more conservative approach and assume two per day, with effectively 20 suitable field days each season (40 total, but visiting each wetland twice), a full time crew of 10 field observers could finish 400 surveys in one year, or 800 over two years which would provide the total priority block coverage desired. Like the mini-routes, the field effort will probably result from a combination of paid staff and enthusiastic volunteers. Also like the mini-routes, all observers will need to take part in mandatory training of field method before participating in this survey. All data generated from the wetland surveys will go directly to the Regional Coordinator listed for the block from which the data were collected; these data will not be entered directly into the Atlas database online.

2nd Pennsylvania Breeding Bird Atlas – Wetland Survey Field Data Form

Instructions: Record the number of new individuals heard or seen in each time band (corresponding to a broadcast call and its associated passive listening period). Do not record the same individual more than once in any of the time band columns. Begin the 16-minute count as soon as arrive at the center point. Any species detected other than those listed should be added to the "Additional Species" column. You may record as "present" species outside 100m, but please limit actual counts to individuals detected within 100 m.

Name______________________ Date ________________ Start Time______________

Block Identifier_______________ Sample Station (circle one): 1 2 GPS Waypoint_________

Species	Number of new individuals detected in each time band							Additional Species
	Initial passive	Sedge Wren	Least Bittern	Black Rail	Rail mix	Grebe mix	American Bittern	
Sedge Wren								
Marsh Wren								
Swamp Sparrow								
Least Bittern								
American Bittern								
Pied-billed Grebe								
Common Moorhen								
American Coot								
Black Rail								
Sora								
Virginia Rail								
King Rail								

10-second Habitat Assessment

Please circle the answer to these questions relative to your count area (100m radius):

- **Is there evidence of beaver activity? Y N**
- **Is there any purple loosestrife in this wetland? Y N**
- **Are there any waterfowl nest boxes at this site? Y N**

Use the diagram at right to help keep track of individual birds and their distance to the observer

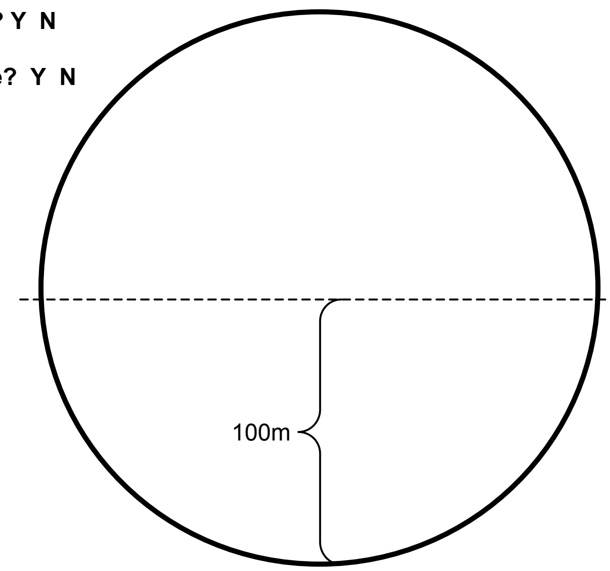

Figure 30. Sample wetland survey sheet.

Nocturnal Survey Protocol

Regardless of habitat affinity, nocturnal species tend to be under-represented in breeding bird atlases and other large-scale surveys and monitoring programs. Some of these species are abundant and well distributed in appropriate habitat. Others are much less well known, either because their rarity makes them less often encountered by birders, because they do inhabit rare or unusual habitats, or both.

In recent years, there have been some notable attempts to develop standardized survey protocols for owls. For example, Takats (2001) has assembled a comprehensive document for Bird Studies Canada that addresses major issues related to developing a monitoring program for owls at the provincial/state level. Recommendations from that document have helped to shape the owl survey protocols for current breeding bird atlas projects in Alberta and Ontario. In Pennsylvania, "Toot-Routes" (mini-routes using broadcast owl calls) have been instrumental in better delineating the distribution of Northern Saw-whet Owls since the inception of this program in 2000.

After much debate, the Design Team decided not to adopt any one owl survey protocol that would provide information equally on all breeding owls in Pennsylvania. Instead, we turned our attention to the real information gap regarding the rare and lesser-known owls. Thus, while we certainly encourage all atlas volunteers to spend significant time owling in their blocks, we recommend no specific survey protocol for Eastern Screech-Owl, Barred Owl, or Great Horned Owl. For these species, atlasers should conduct their own owl searches in their block and report an estimate of the total number of breeding pairs of each species in the block to their Regional Coordinator.

Four other species are considerably more difficult to locate in Pennsylvania than Eastern Screech, Barred, and Great Horned Owls. Despite the success of toot-routes, there is still plenty to learn about distribution and abundance of Northern Saw-whet Owl. We are correspondingly less confident in our assessments of distribution and abundance for Common Barn Owl, Short-eared Owl, and Long-eared Owl. We recommend four specific survey protocols for these species, as outlined below:

Northern Saw-whet Owl - We recommend that the existing toot-route program be supplemented with new sample locations from the 2nd Atlas. Specifically, we propose that toot-routes be run in every priority block, at the same eight stop locations that are identified for mini-routes. Where toot-routes are currently implemented, we will identify the Atlas block in which the route is run and consider that block the "toot-route block" in that USGS quadrangle, rather than the priority block. Thus, each quadrangle will have only one toot-route. We recognize that most of these new route locations will not occur in appropriate habitat or even within the range of saw-whets, however, toot routes have demonstrated a fairly impressive list of "non-target" species that respond to the broadcast calls, e.g., Barred Owl and Whip-poor-will (D. Gross, *pers comm*), and we are confident that an expanded toot route program will prove a worthwhile investment for the 2nd Atlas. A complete version of toot-route methods and a sample datasheet appear in Appendix E.

Because the expanded toot-route sampling locations will be shared with the mini-route sample points, data form the toot-routes can be readily folded into the interactive database developed for the 2nd Atlas by BirdSource. We have proposed fields for the database indicated by Table 4, summarized from the field data sheet in Appendix E.

Table 4. Basic field structure for online data entry and archival for the expanded toot-routes.

observer	Block ID	date	time	Stop #	spp	Listen #1 1 min	Broadcast & Listen 9 min	Final listen 5 min

Common Barn Owl - The distribution of barn owl is enigmatic in Pennsylvania, and is probably influenced by a host of factors including availability of nesting sites, proximity of those sites to grassland foraging habitat (McWilliams and Brauning 2000), and climatic factors such as winter snow depth. The Design Team concluded when considering this species that owl surveys of grasslands would probably not provide any insights into distribution and abundance. Fortunately, the Pennsylvania Game Commission administers a program that places nest boxes in farm buildings and monitors use of these nest boxes. We recommend that data from this program be incorporated into the 2nd Atlas, as well as an effort to revisit known breeding locations identified during the 1st Atlas (Brauning 1992).

Short-eared Owl and Long-eared Owl (separate surveys, same approach) – We recommend targeting areas in every priority block to survey for these species based on predicted habitat from the Gap models. The few known historical locations should also be revisited.

While known locations for both of these species are extremely local (Brauning et al. 1994), potential habitat is patchy but widespread (Figs. 31 and 32). Roadside surveys should be conducted in the largest habitat complexes identifiable at the Atlas block scale. Because so little is known about the distributions of these two species, field observers should investigate potential habitat for them wherever it occurs in the Commonwealth, with no pre-conceived notions as to what their statewide range might be. If there is no habitat for one or the other species in a priority block, then the survey should be done at the nearest available habitat patch for the species in adjacent blocks.

We recommend roadside survey routes with sample stations at least 1.6 km apart. The only stipulations on survey locations are that they be located in modeled habitat for the target species in the Atlas block, maintain the minimum distance, and that the coordinates be recorded in the field with a GPS receiver. There should be four stations for Long-eared Owl and four stations for Short-eared Owl; again, if enough suitable habitat does not occur in the priority block observers should establish stations in the next closest habitat patch, regardless of block.

Because distributions of these two species are poorly known, any amount of detection provided by surveys of Gap-modeled habitat potentially contributes greatly to the Atlas. We recommend a 10-minute survey for each species at each sampling point. Surveys should take place no earlier than 1/2 hour after sunset and no later than midnight. We recommend broadcast calls interspersed with periods of passive listening (Takats 2001). The sampling protocol will be the same for these species, but divided by habitat: Long-eared Owl in forested sites with grassland nearby; Short-eared Owl in expansive grasslands. We recommend a 10-minute sample at each station. Sampling should begin with a 2-minute passive listening period followed by four alternating 1-minute call broadcasts and 1-minute listening periods. The survey window for this protocol will be 20 March to 20 May. Figure 33 presents a potential field data sheet for effort.

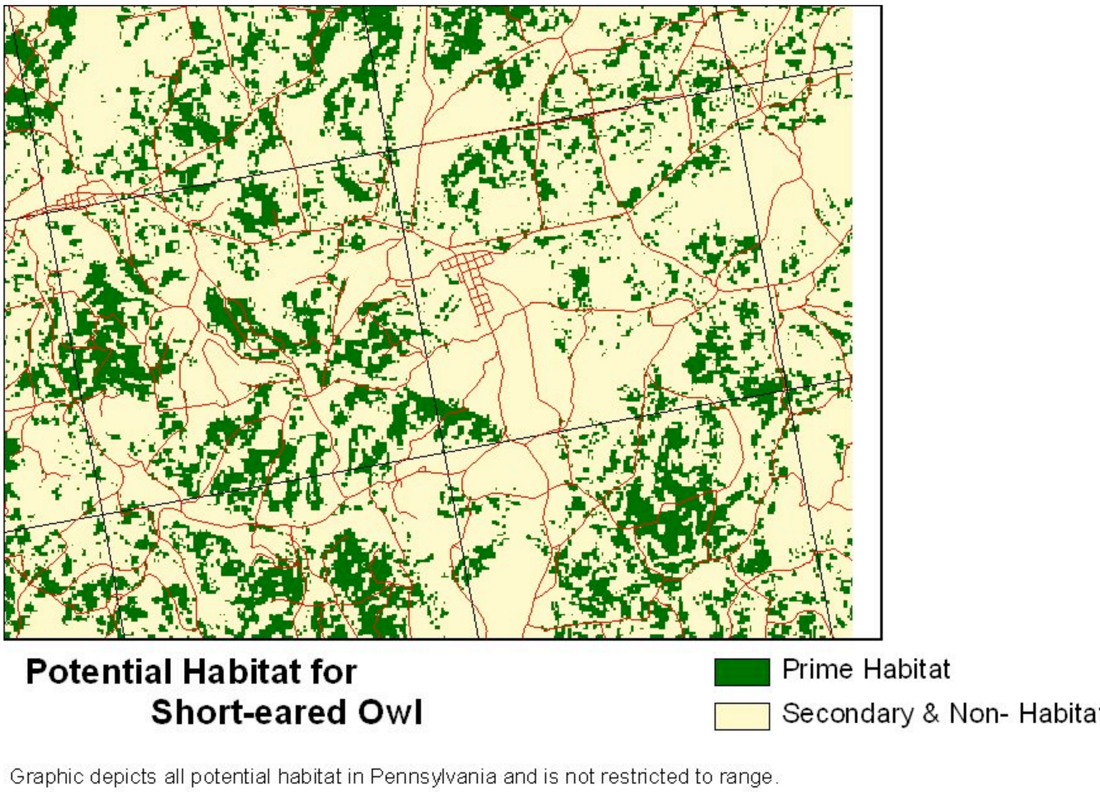

Figure 31. Predicted habitat for Short-eared Owl approaching block scale.

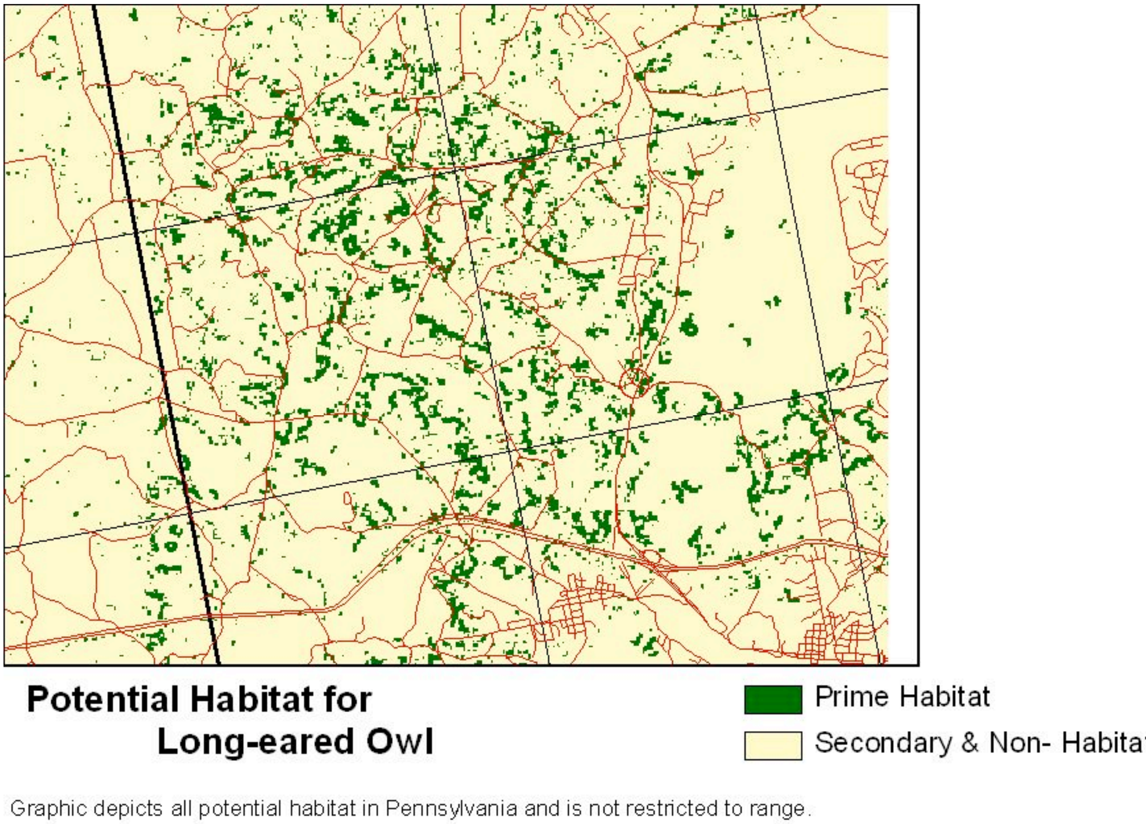

Figure 32. Predicted habitat for Long-eared Owl approaching block scale.

2^{nd} Pennsylvania Breeding Bird Atlas – Eared Owls Survey Form

Instructions: Record the number of new individuals heard in each time band. Do not record the same individual more than once in any of the time band columns. The count begins with 2-minute passive listening, followed by three periods of alternating 1-minute broadcast and 1-minute listening periods. Begin the 8-minute count as soon as you arrive at the center point. Any species detected other than those listed should be added to the "Additional Species" column. These are unlimited radius counts.

LONG-EARED OWL

Name______________________ Date ________________ Start Time______________

Block Identifier_______________ Sample Station (circle one): 1 2 3 4 GPS Waypoint_________

Species	Number of new individuals detected in each time band							Additional Species
	Initial passive	Call 1	Listen 1	Call 2	Listen 2	Call 3	Listen 3	
Long-eared Owl								
Short-eared Owl								
Barred Owl								
Great Horned Owl								
Eastern Screech Owl								
N. Saw-whet Owl								
Whip-poor-will								
Chuck-wills-widow								
Common Nighthawk								

SHORT-EARED OWL

Name______________________ Date ________________ Start Time______________

Block Identifier_______________ Sample Station (circle one): 1 2 3 4 GPS Waypoint_________

Species	Number of new individuals detected in each time band							Additional Species
	Initial passive	Call 1	Listen 1	Call 2	Listen 2	Call 3	Listen 3	
Long-eared Owl								
Short-eared Owl								
Barred Owl								
Great Horned Owl								
Eastern Screech Owl								
N. Saw-whet Owl								
Whip-poor-will								
Chuck-wills-widow								
Common Nighthawk								

Figure 33. Field data sheet for owl surveys.

Data Quality Control

More than 2000 volunteers contributed over 300,000 total records to Pennsylvania's 1st Atlas (Brauning 1992). The abundance of data from many observers was at once a blessing (the 1st Atlas was an unqualified success in terms of data generated from every block) and a curse (Regional Coordinators had to be constantly vigilant to maintain data quality). The most basic data quality issue that must be addressed in a large-scale atlas project poses the question "Are species identified correctly?" Mis-identified species can enter the database by accident, such as a transcription error from field notes. For example, many birders use four-letter "alpha codes" for species names as a form of field note shorthand, and it can be easy to confuse codes such as "BWWA" (Blue-winged Warbler) and "BAWW" (Black-and-White Warbler). Errors like this become more prevalent when the observer has many records to submit, and especially when someone other than the observer enters data from field notes.

In a dataset with over 300,000 records, there are undoubtedly mis-identifications in the field. Even experienced birders can catch a glimpse of a Sharp-shinned Hawk darting through a forest and mistake it for a Cooper's Hawk. Also, one of the main strengths of atlas projects as forces for conservation is that beginners are very much encouraged to participate. The benefit of getting new people involved in birding offsets the cost of a relatively higher rate of mis-identifications.

For the 2nd Atlas, we are confident that more volunteers will take part than the 1st Atlas, and the Project Coordinator is personally committed to increasing the ranks of beginning birders among the block owners. Between the larger number of beginning birders potentially contributing to the Atlas and the fact that data will potentially be available as instant updates on the BirdSource Internet database application, the Design Team weighed several options for data review.

We exchanged proposals for data quality and display with BirdSource several times during the design phase for the 2nd Atlas. These discussions are largely incorporated into the BirdSource Work Plan (Appendix F). Records submitted to BirdSource will be immediately updated and viewable to the registered user who has entered the data, i.e., the block owner, but those records will not be viewable to the general public until end of season review by Regional Coordinators and/or the Project Coordinator.

In addition, we have developed a system to notify the database user immediately if a record that has been entered is potentially cause for scrutiny, and the user will be prompted with instructions to respond. A record will immediately prompt the user for additional action under the following conditions:

- *it is listed as a species of special concern in Appendix C.* Action: Supplemental information (e.g., habitat, estimate of numbers, point location) is requested before record can be fully accepted.

- *it is being recorded outside its normal range in Pennsylvania (Appendix H).* Action: User is informed that the record is extralimital in Pennsylvania and asked to confirm that the location entered was accurate.

- *the breeding evidence supplied is outside the known safe dates for the species in question.* Action: User is informed of the unusual date entered for the species behavior reported, and asked to confirm that the date was accurate.

- *it is not on the list of accepted AOU species for PA.* Action: User is prevented from entering any species name that does not currently occur on the list of expected species (Appendix A). The record must first be reported to the Regional Coordinator and extensive documentation provided to the Pennsylvania Ornithological Records Committee (PORC). If PORC accepts the record, the Project Coordinator will request that BirdSource add the species to the official list so that the user will ultimately experience the satisfaction of personally entering the record into the Atlas database.

Change Since the 1st Atlas

An ostensible purpose for conducting periodic breeding bird atlases is to compare results through time and assess broad changes in distribution and abundance that may correspond to changes in land use. The challenge for atlas administrators is to correctly identify changes in distribution and/or abundance over time that represent biologically significant differences. If we were merely replicating the 1st Atlas in terms of effort and coverage, we could set some arbitrary bounds based on a proportion of the total number of blocks in which a given species occurs to decide if distribution is greater than, less then, or roughly equal to that obtained during the 1st Atlas. Unfortunately, the degree to which we will be able to do a better job at reducing errors of omission in the 2nd Atlas complicates our ability to determine if an apparent expansion of occurrence is due to better atlasing or an actual change in a species' distribution. Some species that appear to have the same distribution as the 1st Atlas despite more accurate atlasing for the 2nd Atlas may actually have experienced a decline in Pennsylvania. Species that exhibit a smaller distribution within the Commonwealth during the 2nd vs. the 1st Atlas may indeed be cause for grave conservation concern.

To assess the degree of state-level change in bird distributions, we recommend a *post hoc* analysis of the correlation between key species' distributions and land cover between 1st and 2nd Atlas attempts in Pennsylvania. Large-scale analyses such as these could answer specific questions relevant to the conservation and management of birds in the Commonwealth. For example, the simple (hypothetical) demonstration that Northern Bobwhite has disappeared from areas of (1992) farmland to 2002 (residential development) would point to land use change as an obvious pressure on this rapidly declining species. Conversely, if Cerulean Warbler was found to be much reduced in distribution while overall forest patch sizes had increased, we might have produced some compelling evidence to suggest that events on the breeding grounds are not the primary concern for this declining species.

Future atlases in Pennsylvania will be able to compare relative abundance estimates for most species directly to the results we will obtain in the 2nd Atlas. We will not be able to compare direct abundance estimates between the 1st and 2nd atlases. The adjacent block analysis, however, could be used to develop and indirect index of abundance for both the 1st and 2nd atlases. We recommend that this analysis be conducted at the conclusion of the 2nd Atlas.

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Appendix A: Master list of species likely to be determined as breeding in Pennsylvania during field work for the 2nd Atlas. Taxonomy follows American Ornithologists' Union (1998).

No.	Species Common Name	Scientific Name
1	Canada Goose	*Branta canadensis*
2	Trumpeter Swan	*Cygnus buccinator*
3	Mute Swan	*Cygnus olor*
4	Wood Duck	*Aix sponsa*
5	Green-winged Teal	*Anas crecca*
6	American Black Duck	*Anas rubripes*
7	Mallard	*Anas platyrhynchos*
8	Blue-winged Teal	*Anas discors*
9	Northern Shoveler	*Anas clypeata*
10	American Wigeon	*Anas americana*
11	Northern Pintail	*Anas acuta*
12	Gadwall	*Anas strepera*
13	Hooded Merganser	*Lophodytes cucullatus*
14	Common Merganser	*Mergus merganser*
15	Red-breasted Merganser	*Mergus serrator*
16	Redhead	*Aythya americana*
17	Ring-necked Duck	*Aythya collaris*
18	Ruddy Duck	*Oxyura jamaicensis*
19	Ring-necked Pheasant	*Phasianus colchicus*
20	Ruffed Grouse	*Bonasa umbellus*
21	Wild Turkey	*Meleagris gallopavo*
22	Northern Bobwhite	*Colinus virginianus*
23	Common Loon	*Gavia immer*
24	Pied-billed Grebe	*Podilymbus podiceps*
25	Double-crested Cormorant	*Phalacrocorax auritus*
26	American Bittern	*Botaurus lentiginosus*
27	Least Bittern	*Ixobrychus exilis*
28	Great Blue Heron	*Ardea herodias*
29	Great Egret	*Ardea alba*
30	Snowy Egret	*Egretta thula*
31	Cattle Egret	*Bulbulcus ibis*
32	Green Heron	*Butorides striatus*
33	Black-crowned Night-Heron	*Nycticorax nycticorax*
34	Yellow-crowned Night-Heron	*Nycticorax violaceus*
35	Glossy Ibis	*Plegadis falcinellus*
36	Black Vulture	*Coragyps atratus*
37	Turkey Vulture	*Cathartes aura*
38	Osprey	*Pandion haliaetus*
39	Bald Eagle	*Haliaeetus leucocephalus*
40	Sharp-shinned Hawk	*Accipiter striatus*
41	Cooper's Hawk	*Accipiter cooperii*
42	Northern Goshawk	*Accipiter gentilis*

No.	Species Common Name	Scientific Name
42	Northern Goshawk	*Accipiter gentilis*
43	Northern Harrier	*Circus cyaneus*
44	Red-shouldered Hawk	*Buteo lineatus*
45	Broad-winged Hawk	*Buteo platypterus*
46	Red-tailed Hawk	*Buteo jamaicensis*
47	American Kestrel	*Falco sparverius*
48	Peregrine Falcon	*Falco peregrinus*
49	Sandhill Crane	*Grus canadensis*
50	Yellow Rail	*Coturnicops noveboracensis*
51	Black Rail	*Laterallus jamaicensis*
52	King Rail	*Rallus elegans*
53	Virginia Rail	*Rallus limicola*
54	Sora	*Porzana caroliniana*
55	Common Moorhen	*Gallinula chloropus*
56	American Coot	*Fulica americana*
57	Killdeer	*Charadrius vociferus*
58	Piping Plover	*Charadrius melodus*
59	Black-necked Stilt	*Himantopus mexicanus*
60	Spotted Sandpiper	*Actitis macularia*
61	Upland Sandpiper	*Bartramia longicauda*
62	Wilson's Snipe	*Gallinago delecta*
63	American Woodcock	*Scolopax minor*
64	Ring-billed Gull	*Larus delawarensis*
65	Herring Gull	*Larus argentatus*
66	Black Tern	*Chlidonias niger*
67	Common Tern	*Sterna hirundo*
68	Least Tern	*Sterna antillarum*
69	Rock Pigeon	*Columba livia*
70	Mourning Dove	*Zenaida macroura*
71	Eurasian Collared Dove	*Streptopelia decaocto*
72	Yellow-billed Cuckoo	*Coccyzus americanus*
73	Black-billed Cuckoo	*Coccyzus erythrophthalmus*
74	Barn Owl	*Tyto alba*
75	Eastern Screech-Owl	*Megascops asio*
76	Great Horned Owl	*Bubo virginianus*
77	Barred Owl	*Strix varia*
78	Long-eared Owl	*Asio otus*
79	Short-eared Owl	*Asio flammeus*
80	Northern Saw-Whet Owl	*Aegolius acadicus*
81	Common Nighthawk	*Chordeiles minor*
82	Chuck Will's Widow	*Caprimulgus carolinensis*
83	Whip-Poor-Will	*Caprimulgus vociferus*

Appendix A *(continued)*

No.	Species Common Name	Scientific Name	No.	Species Common Name	Scientific Name
84	Chimney Swift	*Chaetura pelagica*	128	Carolina Wren	*Thryothorus ludovicianus*
85	Ruby-throated Hummingbird	*Archilochus colubris*	129	Bewick's Wren	*Thryomanes bewickii*
86	Belted Kingfisher	*Ceryle alcyon*	130	House Wren	*Troglodytes aedon*
87	Red-headed Woodpecker	*Melanerpes erythrocephalus*	131	Winter Wren	*Troglodytes troglodytes*
88	Red-bellied Woodpecker	*Melanerpes carolinus*	132	Sedge Wren	*Cistothorus platensis*
89	Yellow-bellied Sapsucker	*Sphyrapicus varius*	133	Marsh Wren	*Cistothorus palustris*
90	Downy Woodpecker	*Picoides pubescens*	134	Golden-crowned Kinglet	*Regulus satrapa*
91	Hairy Woodpecker	*Picoides villosus*	135	Blue-Gray Gnatcatcher	*Polioptila caerulea*
92	Northern Flicker	*Colaptes auratus*	136	Eastern Bluebird	*Sialia sialis*
93	Pileated Woodpecker	*Dryocopus pileatus*	137	Veery	*Catharus fuscescens*
94	Olive-sided Flycatcher	*Contopus borealis*	138	Swainson's Thrush	*Catharus ustulatus*
95	Eastern Wood-Pewee	*Contopus virens*	139	Hermit Thrush	*Catharus guttatus*
96	Yellow-bellied Flycatcher	*Empidonax flaviventris*	140	Wood Thrush	*Hylocichla mustelina*
97	Acadian Flycatcher	*Empidonax virescens*	141	American Robin	*Turdus migratorius*
98	Alder Flycatcher	*Empidonax alnorum*	142	Gray Catbird	*Dumetella carolinensis*
99	Willow Flycatcher	*Empidonax traillii*	143	Northern Mockingbird	*Mimus polyglottos*
100	Least Flycatcher	*Empidonax minimus*	144	Brown Thrasher	*Toxostoma rufum*
101	Eastern Phoebe	*Sayornis phoebe*	145	European Starling	*Sturnus vulgaris*
102	Great Crested Flycatcher	*Myiarchus crinitus*	146	Cedar Waxwing	*Bombycilla cedrorum*
103	Eastern Kingbird	*Tyrannus tyrannus*	147	Blue-winged Warbler	*Vermivora pinus*
104	Loggerhead Shrike	*Lanius ludovicianus*	148	Golden-winged Warbler	*Vermivora chrysoptera*
105	White-eyed Vireo	*Vireo griseus*	149	Brewster's Warbler	*V. pinus x chrysoptera*
106	Blue-headed Vireo	*Vireo solitarius*	150	Lawrence's Warbler	*V. pinus x chrysoptera*
107	Yellow-throated Vireo	*Vireo flavifrons*	151	Nashville Warbler	*Vermivora ruficapilla*
108	Warbling Vireo	*Vireo gilvus*	152	Northern Parula	*Parula americana*
109	Red-eyed Vireo	*Vireo olivaceus*	153	Yellow Warbler	*Dendroica petechia*
110	Blue Jay	*Cyanocitta cristata*	154	Chestnut-sided Warbler	*Dendroica pensylvanica*
111	Eurasian Jackdaw	*Corvus monedula*	155	Magnolia Warbler	*Dendroica magnolia*
112	American Crow	*Corvus brachyrhynchos*	156	Black-throated Blue Warbler	*Dendroica caerulescens*
113	Fish Crow	*Corvus ossifragus*	157	Yellow-rumped Warbler	*Dendroica coronata*
114	Common Raven	*Corvus corax*	158	Black-throated Green Warbler	*Dendroica virens*
115	Horned Lark	*Eremophila alpestris*	159	Blackburnian Warbler	*Dendroica fusca*
116	Purple Martin	*Progne subis*	160	Yellow-throated Warbler	*Dendroica dominica*
117	Tree Swallow	*Tachycineta bicolor*	161	Pine Warbler	*Dendroica pinus*
118	Northern Rough-winged Swallow	*Stelgidopteryx serripennis*	162	Prairie Warbler	*Dendroica discolor*
119	Bank Swallow	*Riparia riparia*	163	Cerulean Warbler	*Dendroica cerulea*
120	Cliff Swallow	*Hirundo pyrrhonota*	164	Blackpoll Warbler	*Dendroica striata*
121	Barn Swallow	*Hirundo rustica*	165	Black-and-white Warbler	*Mniotilta varia*
122	Black-capped Chickadee	*Poecile atricapillus*	166	American Redstart	*Setophaga ruticilla*
123	Carolina Chickadee	*Poecile carolinensis*	167	Prothonotary Warbler	*Protonotaria citrea*
124	Tufted Titmouse	*Baeolophus bicolor*	168	Worm-eating Warbler	*Helmitheros vermivorus*
125	Red-breasted Nuthatch	*Sitta canadensis*	169	Swainson's Warbler	*Limnothlypis swainsonii*
126	White-breasted Nuthatch	*Sitta carolinensis*	170	Ovenbird	*Seiurus aurocapilla*
127	Brown Creeper	*Certhia americana*	171	Northern Waterthrush	*Seiurus noveboracensis*

No.	Species Common Name	Scientific Name
172	Louisiana Waterthrush	*Seirus motacilla*
173	Kentucky Warbler	*Oporornis formosus*
174	Mourning Warbler	*Oporornis philadelphia*
175	Common Yellowthroat	*Geothlypis trichas*
176	Hooded Warbler	*Wilsonia citrina*
177	Canada Warbler	*Wilsonia canadensis*
178	Yellow-breasted Chat	*Icteria virens*
179	Summer Tanager	*Piranga rubra*
180	Scarlet Tanager	*Piranga olivacea*
181	Northern Cardinal	*Cardinalis cardinalis*
182	Rose-breasted Grosbeak	*Pheucticus ludovicianus*
183	Blue Grosbeak	*Guiraca caerulea*
184	Indigo Bunting	*Passerina cyanea*
185	Dickcissel	*Spiza americana*
186	Eastern Towhee	*Pipilo erythrophthalmus*
187	Bachman's Sparrow	*Aimophila aestivalis*
188	Chipping Sparrow	*Spizella passerina*
189	Clay-colored Sparrow	*Spizella pallida*
190	Field Sparrow	*Spizella pusilla*
191	Vesper Sparrow	*Pooecetes gramineus*
192	Savannah Sparrow	*Passerculus sandwichensis*
193	Grasshopper Sparrow	*Ammodramus savannarum*
194	Henslow's Sparrow	*Ammodramus henslowii*
195	Song Sparrow	*Melospiza melodia*
196	Swamp Sparrow	*Melospiza georgiana*
197	White-throated Sparrow	*Zonotrichia albicollis*
198	Dark-eyed Junco	*Junco hyemalis*
199	Lark Sparrow	*Chondestes grammacus*
200	Bobolink	*Dolichonyx orizyvorus*
201	Red-winged Blackbird	*Agelaius phoeniceus*
202	Eastern Meadowlark	*Sturnella magna*
203	Western Meadowlark	*Sturnella neglecta*
204	Common Grackle	*Quiscalus quiscula*
205	Brown-headed Cowbird	*Molothrus ater*
206	Orchard Oriole	*Icterus spurius*
207	Baltimore Oriole	*Icterus galbula*
208	Red Crossbill	*Loxia curvirostra*
209	Purple Finch	*Carpodacus purpureus*
210	House Finch	*Carpodacus mexicanus*
211	Pine Siskin	*Carduelis pinus*
212	American Goldfinch	*Carduelis tristis*
213	Evening Grosbeak	*Coccothraustes vespertinus*
214	House Sparrow	*Passer domesticus*

Appendix C – Information priority species for the 2nd Breeding Bird Atlas of Pennsylvania.

Species	OTC Status	Atlas Status	Special Atlas Survey Type	Atlas Volunteer Actions (**bold** = required)
Pied-billed Grebe	CR	SSC	Wetland	**Verify, Point Locate**
American Bittern	E	SSC	Wetland	**Verify, Point Locate**
Least Bittern	E	SSC	Wetland	**Verify, Point Locate**
Great Blue Heron (nesting colonies)	None	Conservation Interest	None	Point Locate, Count Nests
Great Egret	E	SSC	None	**Verify, Point Locate, Count Nests**
Snowy Egret	CA	SSC	None	**Verify, Point Locate, Count Nests**
Black-crowned Night Heron	E	SSC	None	**Verify, Point Locate, Count Nests**
Yellow-crowned Night Heron	E	SSC	None	**Verify, Point Locate, Count Nests**
Green-winged Teal	CR	SSC	None	**Verify, Point Locate**
Northern Shoveler	None	Rare	None	**Verify, Point Locate**
American Wigeon	None	Rare	None	**Verify, Point Locate**
Hooded Merganser	None	Rare	None	Point Locate
Osprey	T	SSC	None	**Verify, Point Locate**
Bald Eagle	T	SSC	None	**Verify, Point Locate**
Northern Harrier	CA	SSC	GAP	**Verify, Point Locate**
Sharp-shinned Hawk	None	Conservation Interest	GAP-Habitat (Conifer)	Point Locate
Northern Goshawk	CR	SSC	GAP-Habitat (Conifer)	**Verify, Point Locate**
Red-shouldered Hawk	None	Conservation Interest	None	Point Locate
Peregrine Falcon	E	SSC	None	**Verify, Point Locate**
Northern Bobwhite	CR	SSC	None	**Verify, Point Locate**
Sandhill Crane	None	Rare	None	**Verify, Point Locate**
Black Rail	None	Rare (Unconfirmed Breeder)	None	**Verify, Point Locate**
King Rail	E	SSC	Wetland	**Verify, Point Locate**
Virginia Rail	None	Conservation Interest	Wetland	Point Locate
Sora	CR	SSC	Wetland	**Verify, Point Locate**
Common Moorhen	CA	SSC	Wetland	**Verify, Point Locate**
American Coot	CR	SSC	Wetland	**Verify, Point Locate**
Killdeer	None	Education Focus	Schools	Point Locate, Nesting Dates, Nest Success
Upland Sandpiper	T	SSC	GAP-Species Model	**Verify, Point Locate**
Wilson's Snipe	T	SSC	GAP-Species	**Verify, Point Locate**
American Woodcock	None	Conservation Interest	GAP-Species Model	Point Locate
Common Tern	E	SSC	None	**Verify, Point Locate**
Black Tern	E	SSC	None	**Verify, Point Locate**
Barn Owl	CA	SSC	GAP-Species Model, Farmer Surveys	**Verify, Point Locate**
Long-eared Owl	CU	SSC	GAP-Species Model	**Verify, Point Locate**
Short-eared Owl	E	SSC	GAP-Habitat	**Verify, Point Locate**
Northern Saw-whet owl	recently delisted	Conservation Interest	Nocturnal	Point Locate
Common Nighthawk	None	Education Focus	Schools	Point Locate, Count Birds
Chuck-wills-widow	None	Rare	Nocturnal	**Verify, Point Locate**
Whip-poor-will	None	Conservation Interest	Nocturnal	Point Locate

Chimney Swift	None	Education Focus	Schools	Point Locate, Count Birds
Red-headed Woodpecker	None	Conservation Interest	None	Point Locate
Yellow-bellied Sapsucker	None	Conservation Interest	None	Point Locate
Olive-sided Flycatcher	X	Extirpated	GAP?	**Verify, Point Locate**
Yellow-bellied Flycatcher	E	SSC	GAP-Species Model	**Verify, Point Locate**
Alder Flycatcher	None	Conservation Interest	GAP-Species	Point Locate
Loggerhead Shrike	E	SSC	None	**Verify, Point Locate**
Bewick's Wren	X	Extirpated	None	**Verify, Point Locate**
Sedge Wren	E	SSC	Wetland, GAP-Species	**Verify, Point Locate**
Marsh Wren	CR	SSC	Wetland	**Verify, Point Locate**
Golden-crowned Kinglet	None	Conservation Interest	GAP-Habitat (Conifer)	Point Locate
Swainson's Thrush	CR	SSC	GAP-Species Model	**Verify, Point Locate**
American Robin	None	Education Focus	Schools	Point Locate, Nesting Dates, Nest Success
Golden-winged Warbler	None	Conservation Interest	GAP-Habitat (Transitional)	Point Locate
Black-throated Green Warbler	None	Conservation Interest	None	Point Locate
Blackburnian Warbler	None	Conservation Interest	None	Point Locate
Blackpoll Warbler	E	SSC	None	**Verify, Point Locate**
Yellow-throated Warbler	None	Conservation Interest	None	Point Locate
Prairie Warbler	None	Conservation Interest	GAP-Habitat (Transitional)	Point Locate
Cerulean Warbler	None	Conservation Interest	GAP-Species Model	Point Locate
Prothonotary Warbler	CR	SSC	GAP-Species Model	**Verify, Point Locate**
Swainson's Warbler	None	Rare (Unconfirmed Breeder)	GAP-Species Model	**Verify, Point Locate**
Northern Waterthrush	None	Conservation Interest	None	Point Locate
Louisiana Waterthrush	None	Conservation Interest	Priority Block Headwater Surveys?	Point Locate, Count Birds?
Kentucky Warbler	None	Conservation Interest	None	Point Locate
Summer Tanager	CR	SSC	None	**Verify, Point Locate**
Dickcissel	T	SSC	GAP-Habitat	**Verify, Point Locate**
Clay-colored Sparrow	None	Rare	None	**Verify, Point Locate**
Bachman's Sparrow	X	Extirpated	None	**Verify, Point Locate**
Lark Sparrow	X	Extirpated	None	**Verify, Point Locate**
Henslow's Sparrow	None	Conservation Interest	GAP-Habitat	Point Locate
Red Crossbill	CU	SSC	GAP-Habitat (Conifer)	**Verify, Point Locate**
Pine Siskin	CU	SSC	GAP-Habitat (Conifer)	**Verify, Point Locate**
Evening Grosbeak	None	Conservation Interest	GAP-Habitat (Conifer)	**Verify, Point Locate**

Appendix D. Development and refinement of predicted occurrence models for Gap Analysis

Potential habitat mapping, originally completed under the Pennsylvania Gap Analysis Project (Myers et al. 2000), will be used to assist with BBA survey planning. These habitat models will be used to help focus survey efforts to address both specific habitats that were underrepresented in the initial survey as well as guiding teams to the habitats of specific species that are not representative of their probable occurrence. The base layer for PA Gap was land cover data that was based on Landsat TM data collected between 1993 and 1996 (Myers and Bishop 1999; Myers et al. 2000). To reflect current habitat conditions this layer was replaced with current land cover information and the models were reprocessed. The following introduction is taken from Myers et al. (2000) and is intended to provide some background into the process of habitat modeling.

All species range maps are predictions about the occurrence of those species within a particular area (Csuti 1994). Traditionally, the predicted occurrences of most species begin with samples from collections made at individual point locations. Most species range maps are small-scale (e.g., >1:10,000,000) and derived primarily from point data to construct field guides. The purpose of the GAP vertebrate species maps is to provide more precise information about the current predicted distribution of individual native species within their general ranges. With this information, better estimates can be made about the actual amounts of habitat area and the nature of its configuration.

GAP maps are produced at a nominal scale of 1:100,000 or better, and are intended for applications at the landscape or “gamma” scale (homogeneous areas generally covering 1,000 to 1,000,000 hectares and made up of more than one kind of natural community). Applications of these data to site- or stand-level analyses (site – a microhabitat, generally 10 to 100 square meters; stand – a single habitat type, generally 0.1 to 1,000 ha; Whittaker 1977, see also Stoms and Estes 1993) are likely to be compromised by the finer-grained patterns of environmental heterogeneity that are resolved at those levels.

Gap analysis uses the predicted distributions of animal species to evaluate their conservation status relative to existing land management (Scott et al. 1993). However, the maps of species distributions may be used to answer a wide variety of management, planning, and research questions relating to individual species or groups of species. In addition to the maps, great utility may be found in the consolidated specimen collection records and literature that are assembled into databases used to produce the maps.

Previous to this effort there were no maps available, digital or otherwise, showing the likely present-day distribution of species by habitat type across their ranges. Because of this, ordinary species (i.e., those not threatened with extinction or not managed as game animals) are generally not given sufficient consideration in land-use decisions in the context of large geographic regions or in relation to their actual habitats. Their decline because of incremental habitat loss can, and does, result in one threatened or endangered species “surprise” after another. Frequently, the records that do exist for an ordinary species are truncated by state boundaries. Simply creating a consistent spatial framework for storing, retrieving, manipulating, analyzing, and updating the totality of our knowledge about the status of each animal species is one of the most necessary and basic elements for preventing further erosion of biological resources.

Methods for the 2nd Atlas

The habitat models originally developed for the PA-GAP project were reviewed for the BBA effort. All but a few models, listed here, were unchanged and simply reprocessed using current land cover data. The models that, based on current knowledge, were updated include Upland Sandpiper, Long-eared Owl, Peregrine Falcon, Golden-winged Warbler, and Canada Warbler.

The development of each model began as a matrix with columns representing habitat variables and rows representing species. Each species row includes the scientific name, common name, and the 'element occurrence code' (ELCODE) provided by The Nature Conservancy. The model for each species was then implemented as a sequence of conditional GIS operations designed to identify habitat and eliminate non-habitat areas.

Habitat variables in the matrix models for the birds are coded with numbers that range from 1 to 4 which rate the variable as to its relevance for the particular species. The code designations are: 1 = habitat type required by the species (primary use); 2 = habitat type may be used by the species (secondary use); 3 = habitat type avoided by the species; 4 = not relevant to the species. Habitat maps for these groups were produced as (raster) grids having 30-meter resolution.

<u>Wildlife Habitat Relationships:</u>

Our habitat models are based primarily on species affinity for seven available land cover categories that were identified with relative consistency from satellite imagery. These seven categories were supplemented with modifications for aquatic ecosystems (riverine, palustrine, and open water), landscape position regarding elevation, urban density (high and low), and stream order (first through eighth).

The Pennsylvania GAP Project elected to use a matrix approach where habitat factors were characterized by simple categorical variables in a spreadsheet format. These factors had to be compatible with either existing or derived statewide GIS databases (e.g., cover type, topographic orientation, proximity to water, spatial landscape pattern). Factors that were both positively associated and negatively associated with probable occurrence of a species were considered. This allowed us to highlight areas of suitable habitat and mask out unsuitable areas within the general range of a species.

We used local and regional literature, best professional judgment, and peer reviewers to develop and check the habitat models. The latter group of experts also provided suggestions for changes in nomenclature or range distribution. Pertinent references for birds are American Ornithologist's Union (1983, 1995, 1997); Andrle & Carroll (1988); Boone & Krohn (1996); Brauning (1992); Brooks & Croonquist (1990); Buckelew & Hall (1994); Clark & Wheeler (1987); Curson, Quinn, & Beadle (1994); DeGraff & Rudis (1986); Dunn & Garrett (1997); Ehrlich, Dobkin & Wheye (1988); Freemark & Collins (1992); Harrison (1983); Isler & Isler (1987); Madge & Burn (1988); O'Connell (1999); and Rising & Beadle (1996).

<u>Updated Land Cover Data</u>:

The base layer for PA GAP was land cover data that was based on Landsat TM data collected between 1993 and 1996 (Myers and Bishop 1999; Myers et al. 2000). To reflect current habitat conditions this layer was replaced with current land cover information. A team from the Penn

State Institutes for the Environment, under contract from the Department of Conservation of Natural Resources of Pennsylvania, created a new land cover interpretation for Pennsylvania. Using PA-GAP classification methodologies the new land cover layer was based on Landsat 7 ETM (Enhanced Thematic Mapper) data. Dates for the images selected for this effort ranged from 1999 to 2002.

Distribution Modeling:

Habitat relations for each bird species were determined by a series of conditional operations that identified specific categories in GIS thematic layers as to their habitat suitability for each species. All final mapping procedures and most preliminary procedures for these taxa were completed using the *Spatial Analyst Extension*™ of the ArcView™ geographic information system (GIS) software. This software is created and distributed by the Environmental Systems Research Institute (ESRI) of Redlands, CA.

A suite of compatible cellular (raster) GIS layers having 30-meter resolution was used to accomplish mapping of potential habitat. The codes used as column headings in the matrices of habitat relations appear with the ensuing synopses of these GIS layers.

Vegetative Land Cover is the result of our classification of Enhanced Thematic Mapper (ETM) satellite imagery for Pennsylvania. Nine types of vegetative land cover were identified:

1 = Water [OPEWAT]
2 = Low intensity (suburban) development – [URBLO]
3 = High intensity (urban) development – [URBHI]
4 = Hay/Pasture [PERHER]
5 = Row crops [ANNHER]
6 = Coniferous forest [CONFOR]
7 = Mixed forest [MIXFOR]
8 = Deciduous forest [BLFFOR]
9 = Woody transitional [WOODSUC]

A *Digital Elevation Model (DEM)* prepared by the United States Geological Survey (USGS) has a 30-meter resolution (cell size). This grid layer classifies each raster cell as a distance above sea level in meters. Several avian models identified specific elevations above or below which an animal occurred, with this being specified by the [ELEVAT] column in the bird habitat matrix. The models for Worm-eating Warbler and White-throated Sparrow include slope as an important component.

Wetlands data were converted to a raster format from National Wetlands Inventory (NWI) data. Two wetland types along with open water were identified and grouped to form this layer, palustrine herbaceous wetlands and palustrine woody wetlands. To facilitate the process each of these wetland types was isolated into separate layers. In addition to the isolated wetlands, most models requiring wetlands data also needed to include a buffer zone around the wetlands as well. Using the *Spatial Analyst Extension*™ of ArcView™ a distance command was used to calculate distances away from each wetland. This preliminary layer was classified to delineate buffer zones of 100 meters. Animals that are sensitive to the presence of wetlands were modeled with the assistance of these data. Generally, for wetland sensitive birds the 100-m buffers were used. The column headings [PALWOO] and [PALHER] represented these layers in the habitat matrices.

Pennsylvania Streams were originally digitized in a vector format by the Pennsylvania Department of Transportation, and later edited and verified by the Environmental Resources Research Institute (ERRI) at Penn State Univ. These data were converted into a raster format, and using the same procedure as described above for the wetlands layers, processed to create a layer that delineates 100-m riparian buffers. Stream sensitivity was listed as [RIVERI] in the habitat matrices.

A *Shedorder* (small watersheds) data layer was based on information originally digitized in vector format by the Water Resources Division of USGS and subsequently refined by the ERRI at Penn State University. As part of aquatic gap analysis for Pennsylvania, each watershed was interpretively assigned a classification according to stream order. For modeling of wetland-associated animals, the *Shedorder* layer was usually paired with a streams layer to help identify stream size. For avian models, stream use was identified as either being larger or smaller than a specific stream order, and was listed in the matrix as [STMORD]. The mapping process for mammals, amphibians, reptiles, and birds proceeded as a series of conditional GIS operations for each species formulated to identify habitat and eliminate non-habitat areas. The aforementioned data layers were manipulated with the *Spatial Analyst Extension* of ArcView GIS software to process the models within a raster GIS environment on the basis of 30-m cells.

Models fit into two general modeling approaches depending upon the habitat preferences. The first approach dealt with all areas based first on vegetative land cover. As each additional layer was incorporated into the model, changes were made based on the matrix specifications. The final step(s) removed larger areas such as urban areas, often coded as avoided habitat, to complete the model. The second general approach was used for species associated with water and wetland conditions. Under this second approach, models were constrained by the 100-m buffers from the wetland layers. The sequence of conditional statements proceeded like the first approach, but the last step used the appropriate buffer like a 'cookie cutter' to restrict the scope. The result was a map having habitat possibilities only within the buffer zone and all areas outside the buffer being coded as non-habitat.

With few exceptions, the modeling sequence and decision rules went according to the following scenario:

1 – The vegetative land cover was reclassified based on the matrix specifications. Non-habitat (3's) for any model variables was noted immediately. Any area of non-habitat was excluded from subsequent alteration.

2 – Variables coded as "4 = not applicable" were noted in order to control interaction of variables. If an urban variable had a code of 4, for example, then the vegetative land cover took precedence over those areas that would otherwise have been treated as urban.

3 – Wetlands, including streams, were typically addressed next. The coincidence of a wetland coded 2 (secondary habitat) and vegetation coded 1 (primary habitat) would return a code of 2. Coincidence of a wetland coded 1 (primary habitat) and vegetation coded 2 (secondary habitat) would return a code of 1. A wetland coded 3 (non-habitat) would return a code of three regardless of vegetation.

4 – Stream modifying conditions were then addressed. This step either selected streams outside the proper size class for removal or degraded the classification

within the stream buffer according to degree of disturbance. This was always a degrading process. Streams initially classed as primary or secondary would be reduced to secondary or non-habitat, respectively.

5 – Due to their restrictive influence, urban areas were always treated as a degrading layer. If urban areas had been classed as secondary, then all coincident areas previously designated as primary habitat would be returned as secondary. Also, urban areas classed as non-habitat always received a value of 3.

6 – The minimum area and elevation variables were considered in the final stage. Whereas steps 3-5 can be considered as modifiers, minimum area and/or elevation are more extractive. Any area too small, too large, or not within specifications for elevation would become non-habitat.

7 – For a few species it was necessary to consider exceptions and/or special cases. Thereafter, the hexagon-based mask for range limits was applied unless the species is considered to be ubiquitous for Pennsylvania.

List of species for which Gap models were produced from filtered and unfiltered land cover.

Pied-billed Grebe
American Bittern
Least Bittern
Great Blue Heron
Great Egret
Snowy Egret
Cattle Egret
Green Heron
Black-crowned Night-Heron
Yellow-crowned Night-Heron
Mute Swan
Canada Goose
Wood Duck
Green-winged Teal
American Black Duck
Mallard
Blue-winged Teal
Northern Shoveler
American Wigeon
Hooded Merganser
Common Merganser
Black Vulture
Turkey Vulture
Osprey
Bald Eagle
Sharp-shinned Hawk
Cooper's Hawk
Northern Goshawk
Northern Harrier
Red-shouldered Hawk
Broad-winged Hawk
Red-tailed Hawk
American Kestrel
Peregrine Falcon
Ring-necked Pheasant
Ruffed Grouse
Wild Turkey
Northern Bobwhite
King Rail
Virginia Rail
Sora
Common Moorhen
American Coot
Killdeer
Black-necked Stilt
Spotted Sandpiper
Upland Sandpiper
Wilson's Snipe
American Woodcock
Black Tern
Rock Dove
Mourning Dove
Yellow-billed Cuckoo
Black-billed Cuckoo
Barn Owl
Eastern Screech Owl
Great Horned Owl
Barred Owl
Long-eared Owl
Short-eared Owl
Northern Saw-Whet Owl
Common Nighthawk
Chuck Will's Widow
Whip-Poor-Will
Chimney Swift
Ruby-throated Hummingbird
Belted Kingfisher
Red-headed Woodpecker
Red-bellied Woodpecker
Yellow-bellied Sapsucker
Downy Woodpecker
Hairy Woodpecker
Northern Flicker
Pileated Woodpecker
Olive-sided Flycatcher
Eastern Wood-Pewee
Yellow-bellied Flycatcher
Acadian Flycatcher
Alder Flycatcher
Willow Flycatcher
Least Flycatcher
Eastern Phoebe
Great Crested Flycatcher
Eastern Kingbird
Horned Lark
Purple Martin
Tree Swallow
Northern Rough-winged Swallow
Bank Swallow
Cliff Swallow
Barn Swallow
Blue Jay
American Crow
Fish Crow
Common Raven
Black-capped Chickadee
Carolina Chickadee
Tufted Titmouse
Red-breasted Nuthatch
White-breasted Nuthatch
Brown Creeper

Carolina Wren
House Wren
Winter Wren
Sedge Wren
Marsh Wren
Golden-crowned Kinglet
Blue-Gray Gnatcatcher
Eastern Bluebird
Veery
Swainson's Thrush
Hermit Thrush
Wood Thrush
American Robin
Gray Catbird
Northern Mockingbird
Brown Thrasher
Cedar Waxwing
Loggerhead Shrike
European Starling
White-eyed Vireo
Blue-headed Vireo
Yellow-throated Vireo
Warbling Vireo
Red-eyed Vireo
Blue-winged Warbler
Golden-winged Warbler
Nashville Warbler
Northern Parula
Yellow Warbler
Chestnut-sided Warbler
Magnolia Warbler
Black-throated Blue Warbler
Yellow-rumped Warbler
Black-throated Green Warbler
Blackburnian Warbler
Yellow-throated Warbler
Pine Warbler
Prairie Warbler
Blackpoll Warbler
Cerulean Warbler
Black-and-white Warbler
American Redstart
Prothonotary Warbler
Worm-eating Warbler
Swainson's Warbler
Ovenbird
Northern Waterthrush
Louisiana Waterthrush
Kentucky Warbler
Mourning Warbler
Common Yellowthroat
Hooded Warbler
Canada Warbler
Yellow-breasted Chat
Summer Tanager
Scarlet Tanager
Northern Cardinal
Rose-breasted Grosbeak
Blue Grosbeak
Indigo Bunting
Dickcissel
Eastern Towhee
Chipping Sparrow
Clay-colored Sparrow
Field Sparrow
Vesper Sparrow
Savannah Sparrow
Grasshopper Sparrow
Henslow's Sparrow
Song Sparrow
Swamp Sparrow
White-throated Sparrow
Dark-eyed Junco
Bobolink
Red-winged Blackbird
Eastern Meadowlark
Western Meadowlark
Common Grackle
Brown-headed Cowbird
Orchard Oriole
Baltimore Oriole
Purple Finch
House Finch
Pine Siskin
American Goldfinch
House Sparrow

List of species for which atlasers will use unfiltered models to locate primary habitat.

Upland Sandpiper
American Woodcock
Barn Owl
Long-eared Owl
Yellow-bellied Flycatcher
Alder Flycatcher
Sedge Wren
Marsh Wren
Swainson's Thrush
Golden-winged Warbler
Cerulean Warbler
Prothonotary Warbler
Swainson's Warbler
Henslow's Sparrow