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PENNSYLVANIA BREEDING BIRDS OF SPECIAL CONCERN: A LISTING RATIONALE AND STATUS UPDATE[1]

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ABSTRACT

The list of birds of special concern in Pennsylvania has been revised substantially since it was established in 1979 (Gill 1985). Forty-seven past or present breeding birds are now listed as "special concern," including seven endangered, eight threatened, six extirpated, one extinct, and 25 candidate species. Status designations were determined by the Ornithological Technical Committee (OTC) of the Pennsylvania Biological Survey, drawing on *Atlas of Breeding Birds in Pennsylvania* (Brauning 1992a), the U.S. Fish and Wildlife Service Breeding Bird Survey (BBS), a species ranking system (Kirkland and Krim 1990), the literature, and combined personal experience of OTC members. Species associated with wetland, grassland, and forest interior habitats are disproportionately represented (in that order) as special concern birds. Thirty-four of these species (75%) are also listed in conservation categories by neighboring states. *Endangered* species are Osprey, Bald Eagle, Peregrine Falcon, King Rail, Black Tern, Short-eared Owl, and Loggerhead Shrike. *Threatened* species are American Bittern, Least Bittern, Great Egret, Yellow-crowned Night-Heron, Common Snipe, Upland Sandpiper, Yellow-bellied Flycatcher, and Sedge Wren. *Extirpated-Extinct* species are Piping Plover, Common Tern, Greater Prairie-Chicken, Passenger Pigeon, Olive-sided Flycatcher, Bewick's Wren, and Bachman's Sparrow. *Candidate-At-Risk* species are Snowy Egret, Northern Harrier, Barn Owl, and Prothonotary Warbler. *Candidate-Rare* species are Pied-billed Grebe, Green-winged Teal, Northern Goshawk, American Coot, Marsh Wren, Swainson's Thrush, Summer Tanager, and Blue Grosbeak. *Candidate-Undetermined* species are Cattle Egret, Northern Pintail, Northern Shoveler, Gadwall, American Wigeon, Ruddy Duck, Northern Bobwhite, Long-eared Owl, Northern Saw-whet Owl, Common Nighthawk, Whip-poor-will, Dickcissel, Henslow's Sparrow and Red Crossbill. The Pennsylvania Game Commission formally adopted the Endangered and Threatened species list established here, except for Common Snipe.
[J PA Acad Sci 68(1):3-28, 1994]

INTRODUCTION

The lists of Endangered and Threatened birds and mammals, as adopted by the Pennsylvania Game Commission, have been published in the *Pennsylvania Bulletin* and the *Pennsylvania Game News* (Volume 62, page 24). The complete list, as of 1991, was published in *Pennsylvania Birds* (Brauning 1991). This paper summarizes the criteria used to determine species' status as of May, 1993, reviews the current status and habitat requirements of listed species, and supplements the periodic revision of more comprehensive publications by the Pennsylvania Biological Survey (PABS) (e.g., Genoways and Brenner 1985). This paper is PABS publication number 5.

The PABS was founded in 1979 by a group of private organizations and public agencies concerned with protecting the natural resources of Pennsylvania. PABS is a nonprofit scientific organization incorporated to "increase the knowledge of and to foster the perpetuation of the

[1]Received for publication 30 July 1993; accepted 3 January 1994.

natural biological diversity of the Commonwealth of Pennsylvania (PABS Constitution and Bylaws). Government agencies responsible for Pennsylvania's natural resources and experts on a broad range of taxonomic groups are represented on the organization's steering committee. Since the PABS serves as an independent, non-governmental organization, it has no legal authority. The Ornithological Technical Committee (OTC) is one of eight taxonomically based technical committees that comprise the PABS.

Species of Special Concern categories adopted by the PABS include Extinct, Extirpated, Endangered, Threatened, and Candidate. The categories are hierarchical, reflecting the relative risk of a taxon disappearing (or having disappeared) from the state. Candidates are divided into sub-categories: At-Risk, Rare, and Undetermined. Extirpated species rediscovered in Pennsylvania are automatically regarded as Endangered. Federally Endangered or Threatened species nesting in the state are automatically listed as Endangered. PABS category definitions published by Kirkland and Krim (1990) are employed here (Table 1).

For legal protection to be extended to Special Concern species, the state agency responsible for that taxonomic group must designate official protective status. For birds and mammals, that agency is the Pennsylvania Game Commission. Endangered, Threatened and Extirpated bird and mammal lists, developed by the respective technical committees, are recommended to the Commission for official

TABLE 1. Abbreviated definitions of special concern categories.[1]

EXTIRPATED	Species that disappeared from Pennsylvania since 1600 but still is extant elsewhere. The OTC constrains Extirpated to having bred in Pennsylvania for at least 10 years and to having been gone from the state for 10 years.
ENDANGERED	Species in imminent danger of extinction or extirpation throughout their range in Pennsylvania, if the deleterious factors affecting them continue to operate. Species listed as Extirpated and rediscovered nesting are automatically reclassified as Endangered.
THREATENED	Species that may become endangered within the foreseeable future throughout their range in Pennsylvania, unless the factors affecting them are abated.
CANDIDATE	Species that are real or potential candidates for Endangered or Threatened status; this includes species for which the listing of Endangered or Threatened status may be appropriate but for which conclusive data on biological vulnerability or threats are not currently available.
AT-RISK	Although relatively abundant, species that are particularly vulnerable to certain types of exploitation or environmental modification.
RARE	Species existing in one or a few restricted geographic areas or habitats, or in low numbers over relatively broad areas of Pennsylvania.
UNDETERMINED	Species for which there is insufficient data available to provide adequate assessment, but for which populations are considered at some risk.

[1]Complete definitions of special concern species as compiled by the Pennsylvania Biological Survey were published in Kirkland and Krim (1990).

regulatory purposes. The candidate category is not currently adopted by the Commission in its regulations. In 1990, the Commission adopted the lists of Endangered and Threatened birds and mammals as revised by the OTC, with the exception of Common Snipe.

Because birds can expand and contract their ranges rapidly, the OTC has adopted criteria for inclusion of birds on the list of special concern species that are not required by PABS status definitions for other taxa. Only native birds that nested in the state for a period of at least ten consecutive years may be assigned to one of these categories. This ensures that the list targets established species and does not include "accidentals" appearing for short time periods. Similarly, Extirpated species are required to have bred over at least ten consecutive years but not during the most recent ten years. These constraints effectively eliminate from these categories irregularly occurring, peripheral species that have no local breeding history and focuses protection on established nesting species naturally occurring in the state.

METHODS

The decision to list a species and the choice of status category were based largely on its abundance, distribution, and population trend in Pennsylvania. As a result, some species selected, even as Endangered or Threatened, are relatively common elsewhere in their range. In most cases, the species appears to be in decline range-wide, where such data are available.

The Pennsylvania Breeding Bird Atlas Project (hereafter, the Atlas) provided current distribution data for the state's nesting birds (Brauning 1992a). U.S. Fish and Wildlife Service Breeding Bird Surveys (BBS), conducted annually since 1966 (Robbins et al. 1986), provided the best data on relative abundance and population trends for many species. These data, the habitat requirements in Pennsylvania, and biological characteristics of each species were incorporated into a systematic ranking procedure designed to provide an objective index of a species' status (Kirkland and Krim 1990). The Atlas, BBS, and rank values (presented here as the percent of the maximum possible value), evaluated in relation to historic sources, served as the primary data sets for assigning species' status. Population declines alone were not sufficient to place species on the list; such declines must threaten a species with extirpation. Assessments were obtained through open discussion using both historic and more recent data. Members participating in this process are listed in Appendix 1.

RESULTS

Changes From Past List

A total of 47 of the state's 203 nesting birds was assigned to special concern categories. Seven species were regarded as Extirpated-Extinct, seven Endangered, eight Threatened, and twenty-five fell into Candidate categories; four At-Risk, eight Rare, and thirteen Undetermined.

Sixteen (76%) of the Endangered, Threatened and Extirpated birds were previously listed in one of those categories (Table 2). Except for the Black Tern, which was revised from Threatened, three species that had been listed previously as Extirpated (Osprey, Peregrine Falcon, and Loggerhead Shrike) were the only additions to the Endangered Species list. Four species not listed previously (Great Egret, Yellow-crowned Night-Heron, Yellow-bellied Flycatcher, and Common Snipe) were added to the Threatened list. Each was considered during the 1981 listing process but not included either because of insufficient evidence to justify any specific status or the species was thought to be at the edge of its range.

The Extirpated list remained relatively stable, partly because of the ten-year requirement. Species were removed from this list because they recovered or were added because the population had disappeared. In this revision, the Lark Sparrow (*Chondestes grammacus*) was dropped from the Extirpated list because an extended breeding history could not be established. The Dickcissel was moved from Extirpated to Candidate-Undetermined rather than Endangered, an exception to the rule, primarily because of sporadic occurrence at recent nesting locations. Two species not found nesting in the past ten years were added to the Extirpated list (Bewick's Wren and Olive-sided Flycatcher). The Bewick's Wren had previously been listed as Endangered.

The most dramatic revisions came in the category now known as Candidate. The Candidate sub-categories, At-Risk and Rare, correspond in definition to the "vulnerable" category used previously. Status Undetermined was continued as a sub-category of Candidate. Only eight of the current 26 Candidates were previously listed and only five of those were in the same category. This list revision was primarily a result of the data collected by Atlas volunteers. The Atlas showed that many species previously listed as Vulnerable or Status Undetermined, like Least Flycatcher (*Empidonax minimus*) and Eastern Bluebird (*Sialia sialis*), are not in danger of extirpation. Table 3 itemizes birds previously listed as special concern that do not appear on the current list and the number of Atlas blocks in which each species was observed. All species previously listed were found in many more blocks than currently listed birds, and most were ranked at lower levels.

Although considerable overlap occurs, there is a strong increasing trend in the ranking scores and a decreasing trend of occurrence in the number of Atlas blocks across the three primary status designations (Table 4). These trends are not apparent within the Candidate categories because these are not as strongly hierarchical as are Endangered, Threatened, and Candidate.

Characteristics of Listed Species

The special concern list includes a disproportionate

TABLE 2. Ranking scores and number of Atlas blocks reported "probable" or "confirmed" breeding evidence for special concern birds.

Species	Ranking # Score	Atlas Blocks[1]	Previous Status
ENDANGERED			
Osprey[2]	50	9	Extirpated
Bald Eagle[2]	47	11	Endangered
Peregrine Falcon	53	3	Extirpated
King Rail	55	3	Endangered
Black Tern	60	7	Threatened
Short-eared Owl	56	4	Endangered
Loggerhead Shrike	52	2	Extirpated
Average	**53**	**6**	
THREATENED			
American Bittern	50	13	Threatened
Least Bittern	46	16	Threatened
Great Egret	43	7	—
Yellow-crowned Night-Heron	40	9	—
Upland Sandpiper	56	38	Threatened
Common Snipe	47	14	—
Yellow-bellied Flycatcher	64	8	—
Sedge Wren	57	9	Threatened
Average	**51**	**14**	
EXTIRPATED-EXTINCT			
Greater Prairie-Chicken	—	—	Extirpated
Piping Plover	74	—	Extirpated
Common Tern	70	—	Extirpated
Passenger Pigeon	—	—	Extinct
Olive-sided Flycatcher	66	4	—
Bewick's Wren	46	—	Endangered
Bachman's Sparrow	48	—	—
Average	**61**	**—**	
CANDIDATE-AT RISK			
Snowy Egret	50	2	—
Northern Harrier	39	98	Vulnerable
Barn Owl	35	150	Vulnerable
Prothonotary Warbler	44	22	—
Average	**42**	**68**	
CANDIDATE-RARE			
Pied-billed Grebe	46	38	—
Green-winged Teal	40	9	—
Northern Goshawk	42	55	Undetermined
American Coot	48	15	—
Marsh Wren	54	44	Vulnerable
Swainson's Thrush	54	21	—
Summer Tanager	38	40	—
Blue Grosbeak	24	70	—
Average	**43**	**37**	
CANDIDATE-UNDETERMINED			
Cattle Egret[2]	39	1	—
Northern Shoveler	48	4	—
Gadwall	46	0	—
American Wigeon	44	1	—
Ruddy Duck	55	0	—
Northern Bobwhite	22	308	Vulnerable
Long-eared Owl	50	7	Undetermined
Northern Saw-whet Owl	38	39	—
Common Nighthawk	36	276	—
Whip-poor-will	20	398	Undetermined
Dickcissel	57	29	Extirpated
Henslow's Sparrow	35	230	Threatened
Red Crossbill	65	3	—
Average	**43**	**100**	

[1]Out of a total 4,928 Atlas blocks.
[2]Species for which only "confirmed" blocks are included in Atlas totals.

TABLE 3. Ranking scores and number of Atlas blocks of previously listed special concern birds.

VULNERABLE	RANK SCORE	ATLAS BLOCKS[1]
Great Blue Heron	25	2279
Cooper's Hawk	32	1048
Red-shouldered Hawk	34	750
Red-headed Woodpecker	21	698
Purple Martin	19	935
Eastern Bluebird	19	3866
Vesper Sparrow	18	1087
Grasshopper Sparrow	15	1629
Average	**23**	**1537**
STATUS UNDETERMINED		
Sharp-shinned Hawk	31	1051
Yellow-bellied Sapsucker	17	733
Least Flycatcher	13	1816
Bobolink	21	1527
Average	**21**	**1282**

[1]Out of a total 4,928 Atlas blocks.

TABLE 4. Range and average rank value by status category.

	Range	Mean
Extirpated	48 - 74	61
Endangered	47 - 60	53
Threatened	43 - 64	51
Candidates	20 - 65	43
C-At Risk	39 - 50	42
C-Rare	24 - 54	43
C-Undetermined	20 - 65	43

TABLE 5. Habitat of special concern birds.[1]

GRASSLAND/AGRICULTURE	WETLAND
Northern Harrier	Pied-billed Grebe
Greater Prairie-Chicken	American Bittern
Northern Bobwhite	Least Bittern
Upland Sandpiper	Great Egret
Barn Owl	Cattle Egret
Short-eared Owl	Yellow-crowned Night-Heron
Loggerhead Shrike	Green-winged Teal
Blue Grosbeak	Northern Shoveler
Dickcissel	Gadwall
Bachman's Sparrow	American Wigeon
Henslow's Sparrow	Ruddy Duck
	Osprey
FOREST	Bald Eagle
Northern Goshawk	King Rail
Long-eared Owl	American Coot
Northern Saw-whet Owl	Common Snipe
Whip-poor-will	Common Tern
Olive-sided Flycatcher	Black Tern
Yellow-bellied Flycatcher	Sedge Wren
Swainson's Thrush	Marsh Wren
Summer Tanager	Prothonotary Warbler
Red Crossbill	

[1]Species not placed into one of the three categories above include the Common Nighthawk and Peregrine Falcon, which currently nest exclusively in urban environments, and the Bewick's Wren which formerly was found in brushy edges.

number of non-passerines, compared with the state's total breeding bird fauna (Brauning 1992a). This is particularly true of Endangered and Threatened birds, only two of which are passerines, and probably reflects the higher percentage of wetland-dependent birds that are non-passerines. Twenty-six (55%) of all special concern birds and 79% of Endangered and Threatened birds are wetland obligates (Brooks and Croonquist 1990), whereas just 39% of all nesting birds in Pennsylvania fall into this category (Table 5). A disproportionate number of birds at higher trophic levels are listed as Endangered, Threatened, At-risk, and Rare, including the diurnal and nocturnal birds of prey (hawks and owls) and fish-eating birds (like herons and egrets).

Two categories of birds have shown significant population declines on Breeding Bird Surveys across the nation: grassland species (Droege, pers. comm.) and neotropical migrants that nest and over winter in forests (Askins et al. 1990; but also see Martin 1992). Both categories of birds are well represented in Pennsylvania and declines have been noted here as well. Eight (17%) of the special concern birds are associated with grasslands or other agricultural habitats, and six (13%) are neotropical migrants that breed and winter in forests (Table 5). In addition to those listed species, a number of warblers, thrushes and flycatchers that use forests, and grassland-associated species such as the Eastern Meadowlark, have shown a significant decline on BBS routes (Droege and Sauer 1990). However, current populations of most of these species are too high to be considered in danger of extirpation and achieve special concern status.

Uncertainty remains about the status of several species, notably nocturnal birds and waterfowl. Several were listed as Candidate-Undetermined because it was unclear whether or not they nested regularly in the state. Several of the ducks are probably casual breeders in Pennsylvania, but little documentation exists. Fifty percent of the waterfowl species that have nested in Pennsylvania are listed as either Candidate-Rare or Undetermined. Several other waterfowl are not listed (e.g. Ring-necked Duck [*Aythya collaris*] and Redhead [*Aythya americana*]) because nesting activities were documented in just a few years following the creation of Pymatuning Lake. Some waterfowl currently listed as Undetermined (e.g., Ruddy Duck and American Wigeon) may be eliminated from the list in future reviews because their irregular nesting occurrence fails to meet the ten-year breeding requirement for special concern birds.

Comparison With Neighboring States

Pennsylvania's special concern lists are intended to reflect the status of populations within the state's boundaries. A comparison of status listing from neighboring states provides an indication of the degree of conservation concern for the species across wider geographic areas (Table 6).

All but three of Pennsylvania's Threatened or Endangered birds (Great Egret, Common Snipe, and Yellow-

bellied Flycatcher) are listed by at least one neighboring state at the same or higher level. Neither the Great Egret or Yellow-bellied Flycatcher is listed by any neighboring state. Common Snipe is listed as of "Scientific Interest" in Ohio. Only 44% of Candidate species are listed in a special concern category in any adjacent state. A majority (66%) of Candidate-Undetermined species are not listed in neighboring states. Table 6 summarizes the status of Pennsylvania's special concern birds in the six bordering states. Over 100 species are listed in some Special Concern category by the bordering six states and Pennsylvania, nearly half of which are not listed in Pennsylvania in any category.

CONCLUSION

Status designation is an ongoing process. Comprehensive reviews of the list of special concern birds are scheduled for five-year intervals. Species may be removed from or added to the list between these periods by petitioning the Committee chairman for consideration, and by submission of the status review update form found in Appendix 2. Changes in status from Extirpated to Endangered will follow established rules, discussed above.

In the past decade, successes in the conservation of some natural resources have occurred. Bald Eagle, Peregrine Falcon, and Osprey have recovered in the state as a result of reintroduction efforts. The Osprey populations in Pennsylvania are probably higher now than ever before. Other less prominent species, which nonetheless contribute to Pennsylvania biodiversity, have not fared as well. Black Tern populations are only marginally viable and Olive-sided Flycatcher and Bewick's Wren have disappeared within the past three decades. The list of birds of Special Concern will continue to identify species for which focused conservation efforts are necessary.

The accounts that follow identify the status of each special concern bird and reasons for their listing. Species are listed in taxonomic order (AOU 1983) within each status category. Initials following each account identify its author.

SPECIES ACCOUNTS

ENDANGERED

Osprey (Pandion halieatus)

Historical records of Osprey breeding in Pennsylvania are few. Records from the 1800s indicate nesting along the Delaware, Susquehanna, and Schuylkill rivers, and the Brandywine Creek in the eastern part of the state (Warren 1890), and Beaver County and along the Allegheny River in Clarion County (Todd 1940; Wood 1979) in the western counties. There are few reliable nesting records from the 1900s (Wood 1979). Ospreys breed in a range of aquatic habitats including salt marshes and large inland rivers and

TABLE 6. Status of Pennsylvania's birds of special concern in adjacent states.

	PA	NY[1]	NJ[2]	DE[3]	MD[4]	WV[5]	OH[6]
Pied-billed Grebe	CR	—	E	s2	—	—	—
American Bittern	T	—	T	—	nc	si	E
Least Bittern	T	sc	·	—	nc	si	E
Great Egret	T	—	—	s2	—	—	—
Snowy Egret	AR	—	—	S1	—	—	SI
Cattle Egret	CU	—	—	s2	—	—	SI
Yellow-crowned Night-Heron	T	—	T	s1	—	—	E
Green-winged Teal	CR	—	—	·	—	·	—
Northern Pintail	SU	—	—	—	—	·	—
Northern Shoveler	SU	—	—	—	—	·	—
Gadwall	SU	—	—	—	—	·	—
American Wigeon	SU	—	—	—	—	·	—
Ruddy Duck	SU	—	—	—	—	—·	—
Bald Eagle	E	E	E	E	E	E	E
Osprey	E	t	t	—	—	si	·
Northern Harrier	AR	T	E	S1	—	si	E
Northern Goshawk	CR	—	T	·	E	SI	·
Peregrine Falcon	E	E	E	E	E	E	E
Greater Prairie-Chicken	X	·	·	·	·	·	X
Northern Bobwhite	SU	—	—	—	—	—	—
American Coot	CR	—	—	S2	·	·	—
King Rail	E	·	—	—	—	—	E
Piping Plover	X	e	e	t	e	·	e
Common Snipe	T	—	—	·	—	·	SI
Upland Sandpiper	T	sc	E	s1	E	si	T
Common Tern	X	t	—	s1	—	·	e
Black Tern	E	sc	·	·	·	·	E
Passenger Pigeon	X	X	X	X	X	X	X
Barn Owl	AR	SC	—	—	—	SC	E
Long-eared Owl	SU	—	—	·	—	SU	SI
Short-eared Owl	E	sc	E	s2	nc	·	sc
Northern Saw-whet Owl	SU	—	—	·	—	—	SI
Common Nighthawk	SU	SC	—	—	—	—	—
Whip-poor-will	SU	—	—	—	—	—	—
Olive-sided Flycatcher	X	—	·	·	E	sc	·
Yellow-bellied Flycatcher	T	—	·	·	·	—	·
Bewick's Wren	X	·	·	·	e	sc	e
Sedge Wren	T	sc	E	s1	nc	si	E
Marsh Wren	CR	—	—	—	—	—	SC
Swainson's Thrush	CR	—	·	·	—	—	·
Loggerhead Shrike	E	E	E	s1	E	sc	E
Prothonotary Warbler	AR	—	—	—	—	—	—
Summer Tanager	CR	·	—	—	—	—	—
Blue Grosbeak	CR	—	—	—	—	—	—
Dickcissel	SU	—	—	—	—	SI	—
Bachman's Sparrow	X	·	·	·	X	sc	X
Henslow's Sparrow	SU	SC	E	S1	NC	SC	SI
Red Crossbill	SU	—	—	·	—	—	—

Notes: Capital letters indicate status categories higher or equal than that in Pennsylvania, small case status indicates a lower status to Pennsylvania. A " — " indicates the species occurs, but was not listed for that state. A " · " indicates species does not occur, or nest, regularly enough to be considered for listing.

Status codes: X, Extirpated; E, Endangered; T, Threatened; SI, State Concern, AR, Candidate At-Risk; CR, Candidate-Rare; S2, State Interest; SC, Special Concern; SI, Scientific Interest; NC, in Need of Conservation; SU, Status Undetermined.

X > E > T > SI, AR, NC, CR, S2, SC, SI, NC > SU

[1]New York: Robert Miller, Department of Environmental Conservation, Delmar.
[2]New Jersey: Lawrence Niles, Division of Fish, Game and Wildlife, Hampton.
[3]Delaware: Lisa Gelvin-Innvear, Division of Wildlife, Dover.
[4]Maryland: Glenn Therres, Department of Natural Resources, Wye Mills.
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[6]Ohio: Dan Rice, Department of Natural Resources, Columbus.

lakes. Nesting requirements include an abundant and dependable supply of fish, and appropriate snags or other structures as nest sites (Rymon 1992).

The Osprey is classified as Endangered in Pennsylvania because it is highly localized and vulnerable to habitat degradation, declines in fish populations, and human disturbance. Loss of wetlands to development, especially along the shorelines of major rivers and lakes, was probably the initial reason for the species' decline in Pennsylvania. The use of DDT, and various other forms of human disturbance, probably kept the population from recovering or expanding into new areas, until the advent of the hacking program begun by biologists at East Stroudsburg University in 1980 (Spitzer 1989). An extensive hacking program reestablished the Osprey in the Poconos and along the middle Delaware River (Rymon 1989). A five-year hacking program began at Hammond Reservoir, Tioga County in 1990 and hacking began at Moraine State Park in 1993. Nesting pairs are found annually along the Susquehanna River in Lancaster County and one pair nested successfully in Somerset County in 1991 and 1992 (Sager and Sager 1991; Smith, pers. comm.). TLM

*Bald Eagle (**Haliaeetus leucocephalus**)*

Prior to 1950, the Bald Eagle nested in at least eight counties, most commonly along the shore of Lake Erie (Todd 1904, 1940) and the Susquehanna River in Lancaster County (Harlow 1918; Beck 1924). Although it has the lowest rank value and highest number of confirmed Atlas locations of any state endangered bird, it will remain so classified at least until it is removed from the federal Endangered species list.

A small population of eagles remained in Crawford County wetlands through the middle of this century (Poole 1964). However, until the early 1980s, rarely were more than two or three young produced per year. A Pennsylvania Game Commission hacking program released 12 to 16 birds each year between 1983 and 1989. The nesting population began to expand when the adults from the two hack sites, and hacked birds from neighboring states, reached the breeding age of five years. The population has grown from three nesting pairs in 1987, which produced one young, to 13 active pairs that produced 19 young in 1992. The current population status surpasses the recovery goal for Pennsylvania, set by the Northern States Bald Eagle Recovery Plan (Grier et al. 1983).

Prospects for this species are now excellent (Brauning and Peebles 1992), although nesting birds remain susceptible to disturbance and eagles still are occasionally shot illegally. DWB

*Peregrine Falcon (**Falco peregrinus**)*

Historically, the Peregrine Falcon occupied at least 34 eyries in eastern Pennsylvania before its decline in the 1950s (Hickey 1969). Most eyries in the state were on cliffs overlooking the Susquehanna and Delaware rivers or their major tributaries (Poole 1964).

The decline of this and several other raptors due to pesticide contamination is well known and documented (e.g., Pendleton 1989). Peregrines last nested in Pennsylvania in the late 1950s or early 1960s, and were extirpated from the eastern United States by 1964 (Hickey 1969). The species was included on the federal Endangered species list in 1972 and designated Extirpated from Pennsylvania in 1980 (Gill 1985). It now retains the state status of Endangered.

The banning of DDT use in the United States provided an opportunity for the restoration of the Peregrine Falcon, as well as Osprey, Bald Eagle, and several other birds of prey. The Peregrine Fund began releasing, captive-raised young peregrines in 1975 (Cade 1988) at sites around the eastern United States, including three counties in Pennsylvania. The species first was documented as reestablished in Pennsylvania in 1987 when a Peregrine Fund team discovered nest sites on the Girard Point and Walt Whitman bridges in Philadelphia. Intensified monitoring beginning in 1991 documented nesting activity on five Delaware River bridges and in downtown Philadelphia and Pittsburgh (Brauning and Dooley 1991). A total of six pairs nested in Pennsylvania in 1992, successfully raising seven young. Two young were successfully hacked from a building site in Harrisburg that year and a total of five were introduced into Harrisburg, Reading, and Williamsport in 1993. No historic eyries were known to have been reoccupied as of 1993.

In Pennsylvania the Peregrine Falcon is listed as Endangered to reflect its federal status. There are good prospects for continued recovery, since most historic sites are available for occupancy and the species has expanded its potential array of sites with the use of buildings and bridges. However, recent reproductive success rates have been low. The eastern U.S. population reached 96 pairs by 1993, including 66 that raised young (Cade and Burnham 1993). DWB

*King Rail (**Rallus elegans**)*

A rare species at the northern periphery of its range in Pennsylvania, King Rail breeding records are known from nine counties (Wood 1979). It was most frequently reported in the freshwater tidal marshes adjacent to the lower Delaware River and in the Pymatuning region of Crawford County.

The loss of emergent wetlands is described as the single most critical threat to populations of this specis (Meanley 1992). Nesting has not been confirmed in Crawford County since flooding of the historic marshes to create Pymatuning Lake. Confirmed breeding was restricted to two locations in the state during the 1980s, in Tioga and Butler Counties, where historic nesting had not been reported (Brauning 1992a). Recent sightings in southern Philadelphia County suggest that one or two pairs may remain near the John Heinz National Wildlife Refuge at Tinicum (formerly known as Tinicum National Wildlife Refuge) (Fingerhood 1990; J. Miller, pers. comm. 1992).

The King Rail continues to be listed Endangered because of its small, disjunct populations. Although it is easily overlooked because of its secretive nature, no more than two or three pairs are believed to nest in the state in any given year. Further surveys are needed to determine the status of populations at known sites and its presence in other areas of appropriate habitat. DWB

*Black Tern (**Chlidonias niger**)*

The Black Tern was never a common or widespread nesting bird in Pennsylvania. It was first confirmed nesting here in 1910 (Sutton 1928b), although earlier nestings were suggested (Warren 1890). Nests were confined to large emergent wetlands in the northwest, including Conneaut Lake, Pymatuning Reservoir, Hartstown Marsh, Smith's Marsh, Conneaut Lake Outlet in western Crawford County, and at Presque Isle, Erie. As many as 50 pairs once were recorded in a single colony on Pymatuning Lake (Trimble 1940).

During the Atlas, nesting pairs were observed at many of the historic sites, but with only a few birds present at any location. It is unlikely that any single site was occupied throughout the 1980's (Leberman 1992a). The Hartstown Marsh supported three nests in 1988, then the largest remaining colony in the state (Bush 1989). This site was reduced to one pair in 1991 and 1992 (R.C. Leberman, pers. comm.).

Breeding Bird Survey routes nationwide show an average annual decrease of 8.1 percent, among the highest of any species monitored (Droege and Sauer 1990). The Black Tern received the second highest rank value of any bird currently nesting in the state, because of declining populations and limited habitat. Its state status was changed from Threatened to Endangered in 1990 to reflect its current condition.

Careful monitoring, research on wetland management practices, and strict control of human activities in breeding areas are necessary to preserve this species. DWB

*Short-eared Owl (**Asio flammeus**)*

The Short-eared Owl was never a common nesting species in Pennsylvania. Historically, nesting probably occurred in large marshes and bogs that were the only major expanses of open habitat present in the state before settlement. Reliable nesting reports begin with Audubon, who located a nest in "The Great Pine Forest" on 17 June 1840, in what is now Carbon County (Audubon and Chevalier 1840-44). Nesting also occurred in Berks, Lehigh, and Crawford counties (Todd 1940; Poole 1964).

The Short-eared Owl is listed as endangered in Pennsylvania. Habitat disturbance as a result of modern agricultural techniques, pesticide and herbicide use, and urban development probably played a role in its decline (Fimreite et al. 1970). One of the major discoveries of the Atlas was a new nesting area for the species on reclaimed surface mine land in Clarion County (Buckwalter 1988). This nesting area has had intermittent use as recently as 1992 (W. Fye pers. comm.). Previously, the only known regular nesting site was at the Philadelphia International Airport (Master 1992), which appears to have been abandoned in 1989 (J. Miller, pers. comm.). TLM

*Loggerhead Shrike (**Lanius ludovicianus**)*

The Loggerhead Shrike previously was listed as Extirpated by the Biological Survey (Gill 1985) because nesting had not been confirmed in the state since 1937 (Todd 1940). It is currently listed as a Category 2 Candidate species by the U.S. Fish and Wildlife Service (Department of Interior 1991).

The shrike's historic range includes most of the United States, but it has largely disappeared from much of the northeast, and it is declining across its entire range (Robbins et al. 1986). It is now listed as Endangered or Extirpated in most northeastern states, including those bordering Pennsylvania (Table 6). Pennsylvania's shrike population was always small and localized. Nesting records were restricted to western counties; most were in the northwestern counties of Crawford, Erie, and Mercer, where it was considered locally common (Warren 1890; Todd 1904). Habitat used by this spcies includes open pasture bordered by and sparsely scattered with shrubs, particularly hawthorns (Novak 1989).

Nesting was documented for the first time in over 50 years with the observation of several juvenile shrikes in 1991 and discovery of two successful nests in 1992 (Kennell 1992; Hunter et al. in press). Confirmed nesting prompted a change in legal status from Extirpated to Endangered in 1992. The cause of the shrike's decline is not fully understood. The greatest mortality appears to occur during the winter months and has been attributed to predation and automobile strikes (Blumpton 1989). The discovery of nesting pairs in 1992 and again in 1993 provides encouraging news. However, nesting habitat used by the species is under a variety of threats. Close monitoring will be necessary to promote the recovery of this species. DWB

THREATENED SPECIES

*American Bittern (**Botaurus lentiginosus**)*

American Bitterns breed primarily in large, shallow, freshwater marshes with tall, emergent vegetation such as cattails and thick growths of spatterdock, bulrush and sedges interspersed with areas of open water (Gibbs and Melvin 1992a). American Bitterns are "area sensitive," with breeding occurring primarily in large (> 4 hectares) marshes (Gibbs and Melvin 1992a). Bitterns are found occasionally in small marshy areas along rivers or streams, and in bogs or wet meadows (Leberman 1992b).

American Bitterns are secretive birds that are difficult to observe and monitor. Historically, they were probably never widespread or abundant within Pennsylvania, but were reported as occasional to uncommon in the northwestern counties and were scattered throughout the state in low numbers (Warren 1890; Sutton 1928a; Poole 1964). American Bitterns were recorded in a total of 53 Atlas blocks, with over one-third of all records and 65% of probable and confirmed nestings coming from glaciated sections of northwestern Pennsylvania (Leberman 1992b).

Populations have declined and the species is considered less abundant today than in the past. Declines, both nationwide and within Pennsylvania, are attributed primarily to loss of wetlands (Gibbs and Melvin 1992a). Due to low abundance, patchy distribution, and dependence on vulnerable wetland habitats, American Bitterns are classified as Threatened in Pennsylvania. The bittern is currently listed by the U.S. Fish and Wildlife Service as a migratory bird of management concern (U.S. Fish and Wildlife Service 1987) and has been "blue-listed" by the National Audubon Society since 1976 (Tate 1986).

Protecting large wetlands, monitoring specifically for bitterns, and determining the effects of wetland management on bittern populations are needed to reverse population declines. MCB

*Least Bittern (**Ixobrychus exilis**)*

Least Bitterns breed in large freshwater or brackish marshes, swamps, or bogs and prefer more dense vegetation and deeper water habitat than American Bitterns (Gibbs and Melvin 1992b; Leberman 1992c). Nesting usually occurs where dense, tall emergents, such as cattail or bulrush are interspersed with woody vegetation and open water. In Pennsylvania, large deep-water cattail marshes, with trees and shrubs scattered in and around them, are preferred breeding habitat (Leberman 1992c). Examples include Conneaut Marsh in Crawford County and John Heinz National Wildlife Refuge near Philadelphia.

The Least, like the American Bittern, is a shy secretive bird that is generally not detected by traditional survey methods. Because of its dependence on wetland habitats, it was never abundant in Pennsylvania (Warren 1890; Sutton 1928a). The Atlas reported Least Bitterns in 31 blocks scattered across the state, with concentrations of confirmed breeding in the northwest and southeast (Leberman 1992c).

Because Least Bitterns are easily overlooked, it is difficult to determine the extent of population decline within Pennsylvania. Nearly one-half of the wetlands that bitterns depend on have been destroyed (Tiner and Finn 1986). The Least Bittern is listed as Threatened because of its low abundance, patchy distribution, and dependence on diminishing wetlands. It is currently listed by the U.S. Fish and Wildlife Service as a migratory bird of management concern (U.S. Fish and Wildlife Service 1987) and is on the National Audubon Society's "blue list" (Tate 1986).

Protection of large, deep-water emergent wetlands will be necessary to maintain Least Bittern populations in Pennsylvania. A monitoring program specifically for bitterns has been established at a few sites and should be expanded. MCB.

*Great Egret (**Casmerodius albus**)*

The Great Egret was a post-breeding wanderer from the south in Pennsylvania during the 1800s. Only one record was obtained for this species in western Pennsylvania during the 35-year period from 1890-1925 (Todd 1940). Observations of wanderers increased thereafter, as southern populations recovered from the effects of plume hunters (Schutsky 1992a).

The first documented nesting occurred in 1957, in fresh water tidal marshes along the Delaware River in Tinicum Township (Miller and Price 1959). Subsequent nests were found in the same area in 1956 and 1959 (Miller 1979) and again in 1978. By 1989, 18 nests were active on nearby Mud Island, at the confluence of the Schuylkill and Delaware rivers (Dunn 1989). During the Atlas, additional nesting sites were located on Wade Island, near Harrisburg, and Rookery Island, near Washington Boro, Lancaster County on the Susquehanna River (Schutsky 1992a). Wade Island still contains the largest colony in the state; 90 nests were counted in 1986 (Dunn 1989) and 161 in 1992.

The species is currently listed as Threatened in Pennsylvania because of its regular, but localized, nesting status. As with other colonial nesting species, listing is based on the vulnerability of the relatively few nesting sites known in the state. For example, the colony at Rookery Island was not reoccupied, and Mud Island appears to have been abandoned in 1991 as a result of dredge spoil dumping and development pressures (J. Miller, pers. comm.). TLM

*Yellow-crowned Night-Heron (**Nycticorax violaceus**)*

Few historical nesting records exist for the Yellow-crowned Night-Heron in Pennsylvania. During this century, nests were found in several southeastern counties (Poole 1964). One or two nests have been consistently reported along the Conestoga, Little Conestoga, and similar sycamore-lined streams in Lancaster County throughout the 1970s and 1980s (Amico et al. 1984).

Yellow-crowned Night-Herons typically nest in two specific habitat types, vegetated islands in the Susquehanna River and sycamore-lined streams south and east of the Allegheny Mountains (Schutsky 1992b). The birds are fairly tolerant of human populations; nests are often within 91 m (100 yds) of houses and roads.

The species is currently listed as Threatened because of its local distribution and small population size. About half of the nests in the state found in 1991 were in one location, an island adjacent to the Governor's residence on the Susquehanna River (Schutsky 1992b). TLM

*Common Snipe (**Gallinago gallinago**)*

Information on the local history of the Common Snipe is scanty. The first known account of breeding in Pennsylvania is of a nest found at Conneaut Marsh, Crawford County, and published in *Forest and Stream* in 1877 (Todd 1940). Warren (1980) and Stone (1894) reported birds from a few other scattered localities within the northwestern and northeastern sections of the state. Sutton (1923) considered the snipe a fairly common breeding bird at Pymatuning Swamp during his field work there in 1922-1923. The most extensive information on recent distribution was gathered during the Atlas. The species was reported as a "probable" or "confirmed" nester in 14 blocks (Leberman 1992d), most of which were scattered across the northern half of the state and south along the mountains of the high plateau into Somerset and Bedford counties.

A variety of wetland habitats may be suitable for snipe during the breeding season, including marshlands, bogs, swamps, and wet grasslands (Harrison 1978). In much of Pennsylvania the species prefers wet, irregularly grazed pastures with grassy hummocks in which to nest (Leberman 1992d). The Threatened status proposed by the PABS, is warranted not only by the small size of the breeding population, but also from the vulnerability of its wetland habitat. As with the snipe on its European breeding grounds (Marchant et al. 1990), the effects of drainage and pasture improvements that result in the loss of rough, damp grazing land with numerous hummocks may be an important factor in the decline of the species in our area.

The size and extent of the current breeding population of Common Snipe in Pennsylvania are poorly understood and in need of long-term, systematic study. The impact of hunting on our breeding population is unknown. The Pennsylvania Game Commission recently shortened the hunting season to minimize the impact of hunting on breeding populations. RCL

*Upland Sandpiper (**Bartramia longicauda**)*

The natural habitat of the Upland Sandpiper is prairie. In Pennsylvania, it rapidly adopted agricultural land and fallow fields as suitable habitat during the 1800s. Audubon (Audubon and Chevalier 1840-44) reported breeding at his plantation in Mill Grove, Montgomery County, in 1805 and 1806. Subsequent 19th century authors considered the species to be common to abundant (Baird 1845; Turnbull 1869).

Following drastic reductions in Passenger Pigeons, market hunters turned toward this and other palatable shorebird species with devastating effects in the early 1900s (Todd 1940). Beck (1924) considered it easy to find 300-400 individuals within a square mile of prime Lancaster County habitat in 1900. Twenty-four years later he stated that "not 10 percent of that abundance remains today" (Beck 1924). Further declines have occurred throughout this century because of natural succession in abandoned agricultural lands, intensive farming practices, and reduced pasture acreage.

Although the Atlas documented more nesting sites than were previously thought to exist, its current status as Threatened reflects a continued decline of 8% per year according to Breeding Bird Survey data nationwide (Droege and Sauer 1990). Currently, the Upland Sandpiper is a scattered breeder in Pennsylvania that is dependent on ephemeral habitats subject to intensive cultivation and development. TLM.

*Yellow-bellied Flycatcher (**Empidonax flaviventris**)*

The Yellow-bellied Flycatcher is one of the state's rarest and most poorly known breeding birds. Its unobtrusiveness and the remoteness of its breeding grounds obscured its status before the Atlas. Historically, it was considered an extremely rare breeding species limited to a very few high elevation locations in several northern counties (Todd 1940; Poole 1964). Nesting was documented only in the Poconos (Bailey 1916), but implied in northwestern counties (Todd 1940).

The species reaches the southern edge of its continuous breeding range in Pennsylvania where, as far as is known, it is found exclusively on the plateaus (AOU 1983; Gross 1992a). Pairs usually nest in mossy, poorly drained forested wetlands that contain a dense understory of shrubs and an open canopy of trees (Gross 1991). Its habitat can be conifer swamps, streamside thickets, grown-in beaver ponds, or small bogs. It was found in 13 Atlas blocks with confirmed nesting in two (Gross 1992a). Four additional breeding locations and eight nests have been found during the 1989 through 1993 seasons. Five of these nests were successful.

The Yellow-bellied Flycatcher's extreme rarity and the vulnerability of its habitat justify its Threatened status. It received the highest ranking of any species still nesting in the state. The few known breeding grounds support very small, isolated populations that could be jeopardized by habitat degradation and catastrophic events. Small, forested wetlands are affected by droughts and subject to flooding and destruction by beavers, as well as people (Mellon 1990). Protection of these wetlands and the surrounding forests is vital to the viability of this species and the preservation of the boreal component of the state's biodiversity. DAG

*Sedge Wren (**Cistothorus platensis**)*

Sedge Wrens nest in moist upland sedge meadows with little or no standing water (Leberman 1992e), as well as in low moist pastures, hayfields, and grassy margins around ponds and marshes (Leberman 1992e; Gibbs and Melvin 1992c). The habitat type preferred by Sedge Wrens is extremely unstable, becoming unsuitable with drought, heavy rains, and natural succession. As a result, Sedge Wrens exhibit low site tenacity and quickly abandon areas that become unsuitable (Gibbs and Melvin 1992c).

Prior to European settlement, Sedge Wrens were probably extremely rare. As forests were cut and land was converted to agricultural uses, available habitat for Sedge Wrens increased. Warren (1890) and Sutton (1928a) described the Sedge Wren as a regular but rare summer resident, with breeding populations primarily in the southeastern counties. In the 1930s, as marginal farms were abandoned, Sedge Wren habitat was probably at a peak. Todd (1940) reported increasing populations of Sedge Wrens in the northwestern corner of the state and others were reported at scattered locations throughout the state (Gill 1985). Since that time, the quantity of Sedge Wren habitat has declined as a result of urbanization. Currently, the Sedge Wren is extemely rare in Pennsylvania. Evidence of breeding was reported primarily from the poorly drained Glaciated Section of northwestern Pennsylvania, but not from the southeastern counties where they nested historically (Leberman 1992e).

Sedge Wrens are listed as a Pennsylvania Threatened species because of their extremely rare and patchy distribution. Evidence of continuing population decline across their range (Robbins et al. 1986), their reliance on a rare and unstable habitat type currently being lost due to changing agricultural practices, urbanization, wetland loss, and natural succession also justify the Threatened status. The species received the third highest ranking score of any regularly nesting species in the state but was not listed as endangered primarily because of a perception that it is easily overlooked and somewhat more widespread than the Atlas suggests. MCB

EXTIRPATED AND EXTINCT SPECIES

*Piping Plover (**Charadrias melodus**)*

The sole nesting location of the Piping Plover was Presque Isle, Erie County, now the most heavily visited state park in Pennsylvania. Nesting was first documented in 1900 (Todd 1904) and last reported in the mid-to late 1950s (Stull et al. 1985). Early reports suggest a long history of nesting at Presque Isle. At its peak, approximately 15 pairs were said to "nest annually" (Todd 1940).

Nesting only on sandy beaches, this species predictably came into dramatic conflict with human pressures. The mid-Atlantic population is now federally listed as Endangered. The Great Lakes population has apparently been reduced to fewer than 17 pairs, all of which now occur in Michigan (U.S. Fish and Wildlife Service 1988). Only one site was confirmed on Lake Ontario in New York and none were found on Lake Erie (Cadman et al. 1987; Andrle and Carroll 1988). Two spring observations of Piping Plover were made at Presque Isle during the 1980s (Fingerhood 1992a) and a single male was present and territorial through most of May, 1992.

The occurrence of this single male in 1992 provides the only recent suggestion that the Piping Plover could once again nest in Pennsylvania, but the prospects for recovery are dismal. Restricted human access to a portion of Gull Point is required and predator control necessary to protect any nests. Vegetation on previously pristine beaches, as a result of the use of upland fill material, now makes them less suitable for beach-nesting birds such as the Piping Plover and reduces the chances of recovery. DWB

*Common Tern (**Sterna hirundo**)*

The Common Tern was known to nest at only one locality in Pennsylvania: Presque Isle in Erie County. Although the early history of this species nesting is ambiguous (Fingerhood 1992b), Common Terns were known to nest at Presque Isle from 1926 to 1966 (Stull et al. 1985). Increased recreational use of the beaches and subsequent modifications of the peninsula resulted in abandonment of the area by both this species and the Piping Plover. Although Common Terns are regularly seen each spring, no nesting attempts have been documented for 25 years.

In recognition of a general decline of Common Tern, the Great Lakes' population of Common Terns was listed as a Category 2 Candidate by the U.S. Fish and Wildlife Service (Department of Interior 1991). Heavy use by recreational boaters and bathers during the nesting season, deposition of upland fill on beach areas with the subsequent vegetation of beach-front habitat, and declining regional populations may deter the recovery of this species as a nesting bird in Pennsylvania. DWB

*Greater Prairie-Chicken (**Tympanuchus cupido**)*

The Greater Prairie-Chicken was once a locally common species in eastern Pennsylvania, where it occurred in pine and oak scrub (Gross 1932). It was the first species documented to be extirpated from the state (Warren 1890). The prairie-chicken disappeared during an era in which wildlife was noted primarily for its value as food for early settlers (Fingerhood 1992c). Its disappearance is directly attributed to over-hunting.

The species was represented here by the race known as the Heath Hen (*T. c. pinnatus*) (AOU 1957; Parkes, pers. comm.). That race subsequently became extinct; the last Heath Hens were found on Martha's Vineyard, Massachusetts in 1932 (Poole 1949). Attempts to introduce other races of prairie-chickens into Pennsylvania were unsuccessful (Warren 1890) and no plans are being made to restore this species. DWB

*Passenger Pigeon (**Ectopistes migratorius**)*

The Passenger Pigeon was the most abundant bird on the North American continent prior to European settlement. Original population estimates range from 3-5 billion (Schorger 1973). It was reported by many authors to breed across much of Pennsylvania (Fingerhood 1992d). This is the only extinct species of bird that was known to have nested in Pennsylvania.

The most outstanding characteristic of the Passenger Pigeon was its gregarious social structure and nomadic nature. The first documented report of nesting colonies in Pennsylvania came in 1810 when Lyman observed 20 colonies, containing perhaps 20 million individuals, extending along the Allegheny River from Coudersport to Warren (French 1919). The last major nesting occurred in 1898 in Potter County, but was abandoned due to disturbance by

hunters (French 1919). The birds preferred extensive forested areas dominated by American beech which supplied their favorite food (Todd 1940).

Extinction of this species was ultimately caused by market hunters using various methods including shooting, whipping with long poles, suffocation with sulfur fumes and felling of nesting trees to collect birds. The most recent, reliable documentation occurred in 1906 when William Hazen observed five individuals at Roulette, Potter County (Todd 1940). The species was extinct by 1914 (AOU 1983). The disappearance of this species robbed many raptors of an important food source. TLM

*Olive-sided Flycatcher (**Contopus borealis**)*

The Olive-sided Flycatcher is classified as Extirpated because it has not been confirmed nesting in Pennsylvania in over 60 years (Poole 1964; Gross 1992b). Before the 1930s, this flycatcher was a widespread, but thinly distributed breeder in northern forests and swamps from the Poconos as far west as Pymatuning Swamp, and in the highlands perhaps as far south as Maryland (Todd 1940; Poole 1964). In the late 19th century, its loud whistled call was a common summer sound in some mature forests, especially near water. It persisted into this century in cutover or burned areas with large snags (Todd 1940). At the time of the Atlas, no nesting pairs were found and only six reports of singing birds were accepted (Gross 1992b).

The Olive-sided Flycatcher's extirpation is part of the decline of Pennsylvania's boreal habitats. The cutting of mature conifers and destruction of boreal wetlands depleted this flycatcher's nesting grounds. Fire suppression, eradication of beavers, and urban development have also contributed to habitat loss (Peterson and Fitchel 1992). The loss of neotropical highland rainforests, its winter home, may also contribute to this species' decrease. (Terborgh 1980; Marshall 1988).

The Olive-sided Flycatcher may be declining throughout northeastern United States (Robbins et al. 1986). On BBS routes, from 1966 through 1990, a statistically significant annual decline of 4% was found in this region (Peterson and Fitchel 1992). Declines in several parts of its range led to its inclusion on the federal list of Migratory Nongame Birds of Management Concern (U.S. Fish and Wildlife Service 1987). DAG

*Bewick's Wren (**Thryomanes bewickii**)*

The known history of occurrence of the Bewick's Wren as a breeding bird in Pennsylvania began in Cumberland County in 1845 and ended with the last reported nesting attempts of the species in Greene and Lycoming counties in the late 1970s (Fingerhood 1992e). The Bewick's Wren once nested over much of the western and southern two-thirds of Pennsylvania. It was found locally from Greene County east to Adams County and north to Mercer, Clinton and Lycoming counties. It was probably common only in Greene County in the extreme southwestern corner of the state, where it was formerly a characteristic bird in and around brushy hilltop farmlands (Christy 1924a). The species began to decline generally and disappear locally as a breeding bird after about 1950. This trend was also observed in adjacent Ohio (Peterjohn and Rice 1991) and West Virginia (Hall 1983). Eastern regional declines after 1965 are also evident from Breeding Bird Survey data (Robbins et al. 1986). These declines followed in the wake of a rapid southward expansion of the House Wren's (*Troglodytes aedon*) range after 1920 (Odum and Johnston 1951). Aggressive displacement of the Bewick's Wren by House Wrens has frequently been suggested as their underlying cause (e.g., Christy 1924a; Smith 1980; but see Todd 1940).

The often reported mutual intolerance of these two species for each other may be a consequence of their comparatively recent contact in this region (Brooks 1947; Whitmore 1977). In the West, where they have occurred sympatrically for a much longer period of time, Breeding Bird Survey data show no decrease in Bewick's Wren numbers through 1979 (Robbins et al. 1986) and there is little or no evidence of interspecific territoriality (Kroodsma 1973; Whitmore 1977; but see Root 1969). In that region, however, separation of the two species by habitat, with the Bewick's occurring in the less open, more densely vegetated areas, has been documented (Kroodsma 1973; Whitmore 1977). An important contributing factor to Bewick's Wren declines in the East may be loss of habitat (Mengel 1956; Smith 1980); specifically, a reduction in the number of brushy, unkempt farms that the species prefers. By contrast, the dramatic increase in suburban habitats and nest boxes, both of which are used infrequently by Bewick's Wrens, has doubtless benefited the House Wren.

Although the real cause or causes of the Bewick's Wren's decline may never be known, it seems unlikely that the species will ever regain its former status as a widespread, locally common breeding bird in Pennsylvania. RSM

*Bachman's Sparrow (**Aimophila aestivalis**)*

Around the turn of the century, the Bachman's Sparrow began to extend its range northward from open pine woods and scrub palmetto habitats in the southeastern United States. It eventually reached as far north as southern Ohio and extreme southwestern Pennsylvania, where it occupied sterile fields, steep, brushy hillsides and open oak groves (Brooks 1938). The first nesting attempt in the state may have been in 1909 in Greene County, where a deserted nest with one egg was tentatively identified as belonging to this species. Nesting was not confirmed until 10 May 1916, when S. Dickey found an active nest near Waynesburg (Todd 1940). Until 1922, the species was an uncommon but regular breeder in various parts of Greene County. Stray singing males were observed for a period of one to several days in Beaver and Allegheny counties in 1924 and 1928 (Christy 1924b, 1929). In 1937, Sutton found a brood of young and their parents in central Washington County

(Todd 1940). The last Pennsylvania record of the species was on 29 July 1940, when a singing male was observed on Chestnut Ridge in Fayette County (Brooks 1941).

The Bachman's Sparrow had a very restricted range and period of occurrence in Pennsylvania. It was observed in just four southwestern counties and confirmed nesting in only two of those. The only evidence of regular breeding was for the period 1916-1922 in Greene County, with proven or suspected isolated breeding attempts in 1909, 1937 and 1940. Because of its brief and sporadic occurrences as a Pennsylvania breeding bird, the Bachman's Sparrow barely met the criteria for an Extirpated species. Pennsylvania is clearly at the limit of the species' range. In fact, it has not been confirmed breeding in any of the states bordering Pennsylvania since the 1970s (Fingerhood 1992f). It is unlikely that the species will ever become reestablished here. RSM

CANDIDATE-AT RISK

Snowy Egret ***(Egretta thula)***

The first documented breeding record of the Snowy Egret in Pennsylvania was in 1975, when two pairs nested on Rookery Island in the Susquehanna River near Washington Boro, Lancaster County (Schutsky 1976). At the time of the Atlas period, three pairs nested on the same island in 1987. The birds may have nested on the island in the intervening years when serious searches were not conducted (Schutsky 1992d).

The species is currently listed as "At Risk" in Pennsylvania due to the small, isolated nesting populations that are vulnerable to disturbance. A higher level of classification is not justified because of its sporadic presence in the state. No evidence exists that the Snowy Egret has nested anywhere in the state since 1988. TLM

Northern Harrier ***(Circus cyaneus)***

The Northern Harrier's former name, Marsh Hawk, provides a better indication of its habitat and reasons for its decline. The Northern Harrier generally nests on the ground in densely vegetated wetlands and grasslands, including agricultural fields and abandoned strip mines (Hamerstrom and Kopeny 1981; Goodrich 1992). Harriers seem more successful where there are a variety of such habitats in one area, providing a plentiful prey base of small mammals and birds (Serrantino 1992).

Historically, Northern Harriers nested most frequently in northern and western counties, but were also concentrated in marshes along major rivers, including the Delaware (Stone 1894; Todd 1940; Poole 1964). A steady decline in its nesting population has been noted for decades (Poole 1964), including a gradual decrease from 1966 to 1989 indicated by BBS data (Robbins et al. 1986; Droege and Sauer 1990). The Atlas further revealed the degree of the Harrier's decline and rarity; although it was found in 334 blocks (7% of the total), it probably nested in only a fraction of that total, as indicated by its low confirmation rate (6%). It was absent from several former strongholds. Its decline led to its listing as Candidate-At Risk in Pennsylvania and as a federal Migratory Nongame Bird of Management Concern (U.S. Fish and Wildlife Service 1987).

Agricultural fields may act as population sinks for the Northern Harrier because early mowing and harrowing, pesticide use, and lack of dense vegetation decrease its nesting productivity (Serrantino 1992). This raptor can survive in the state only if suitable portions of its breeding habitat are protected. DAG

Barn Owl ***(Tyto alba)***

The Barn Owl is one of only five Candidate species that are maintained at the same position as their previous listing. The classification At-Risk (formerly Vulnerable) reflects the precipitous decline this species has experienced across its range. It has become rare even at the heart of its historic range in the Midwest (Hands et al. 1989).

Population data are lacking. Because of its nocturnal habits, population studies such as the Breeding Bird Survey do not adequately monitor Barn Owl population trends. The species has disappeared, or become scarce, in parts of its range in Pennsylvania, notably the southwestern counties (Sutton 1928a; Santner 1992a).

Habitat requirements include open foraging areas and large cavities or buildings for nesting (Santner 1992a). Pasture and grassland provide ideal hunting conditions, and high vole populations are related to increased nesting success (Wallace 1948). Population declines are largely attributed to changing agricultural land-use patterns, although Barn Owls may survive in a wide range of habitats, from agricultural to highly urbanized areas. The loss of farm buildings and silos suitable for nest sites has eliminated Barn Owls from areas where they might otherwise occur. Removal of large trees from agricultural areas also depletes potential nesting areas and perhaps prey populations. The species benefits from placement of nest box structures. DWB

Prothonotary Warbler ***(Protonotaria citrea)***

The Prothonotary Warbler nests in wooded swamps or wetlands with standing dead trees and snags, wet woods bordering lakes, and flooded bottomland forests (Leberman 1992f). Pennsylvania is at the northern edge of the Prothonotary Warbler's breeding range. This species differs from many birds of special concern in that it is probably more abundant in Pennsylvania today than at any time in the past (Leberman 1992f). Warren (1890) described the Prothonotary Warbler as rare. By 1940, the number of reports of Prothonotary Warblers and the number of confirmed nest records had increased, including a nest in Erie County (Todd 1940). Poole (1964) described the Prothonotary

Warbler as a summer resident that appeared to be extending its range northward. At the time of the Atlas, Prothonotary Warblers were reported in 43 blocks with confirmed breeding in eight, most of which were from the northwestern counties.

Although probably increasing in number in some areas of the state, the Prothonotary Warbler is listed as At-Risk because of its low abundance and dependence on a relatively rare, vulnerable habitat. MCB

CANDIDATE-RARE

Pied-billed Grebe ***(Podilymbus podiceps)***

The Pied-billed Grebe was not well known to Pennsylvania's earlier ornithologists as a breeding bird. Todd (1940) recorded only five scattered breeding records from the western part of the state through 1931, after which the birds became common nesters at the newly created Pymatuning Reservoir and at a few nearby marshes in western Crawford County. In the eastern part of the state, Stone (1894) reported just one nesting. By the 1920s and 1930s, the Pied-billed Grebe had become a frequent breeding bird along the Delaware River near Philadelphia and nested at John Heinz National Wildlife Refuge at Tinicum into the 1950s (Ickes 1992a).

Pied-billed Grebe breeding sites include ponds or marshes with plenty of emergent vegetation, heavy cover along the shoreline, with some open water. Although Pied-billed Grebes often associate closely with other marsh birds, like coots and moorhens, they are usually solitary nesters. Generally only one pair inhabits a pond of up to 10 acres (Palmer 1962). The lack of large areas of suitable breeding habitat across most of the state, and the fact that it was confirmed in just 26 scattered Atlas blocks, resulted in listing this grebe as a species of special concern (Candidate-Rare) in Pennsylvania. The species is rather shy and secretive during the breeding season and not very tolerant of human disturbance.

Although the Pied-billed Grebe may correctly be classified as Rare statewide, it can be fairly common locally. Where game propagation areas at Conneaut Marsh in Crawford County have been managed at high water levels during the breeding season, pied-bills have become among the more typical marsh birds nesting there (pers. obs.). A stable population has also become established a few kilometers to the west, at Hartstown Marsh where Harrison and Harrison (1965) documented nesting.

Although Ickes (1992a) concluded that there has been a recent downward population trend for this grebe in Pennsylvania, Atlas results show that the species is still widely, but sparsely, distributed across much of the state, with the exception of the southeast corner. Opportunistic nesters, Pied-billed Grebes were found in a variety of aquatic situations away from their traditional marshes in northwestern Pennsylvania, including beaver dams, fishing lakes, flooded quarries and old sediment ponds. RCL

Green-winged Teal ***(Anas crecca)***

The first breeding Green-winged Teal confirmation in Pennsylvania came in 1931 when a female with her brood was seen at the Tinicum marshes, near Philadelphia (Miller 1933). Additional evidence of breeding was established there from 1953 through 1958 (Miller and Price 1959). In western Pennsylvania, Green-winged Teal were first found nesting at Pymatuning Reservoir, Crawford County on 25 May 1936 (Trimble 1940). Breeding was inferred at Pymatuning for a few years thereafter, but Grimm (1952) knew of no subsequent records. Elsewhere in Pennsylvania, there was a scattering of summer records of paired birds over the years prior to the Atlas, most without breeding confirmation.

The Green-winged Teal usually nests on dry ground within dense stands of grasses or weeds, in the vicinity of a large marsh or lake (Kortright 1942; Harrison 1975). The scarcity of such habitats, combined with the rarity of nesting teal, make the green-wing a species of special concern in Pennsylvania. The Atlas, however, indicated that the green-wing was more common and widespread as a breeding species than was previously realized, with confirmations in five counties. Atlas results indicated that this was a difficult species to confirm (Hartman 1992a), and future field work might prove that it has an even broader breeding distribution within Pennsylvania. RCL

Northern Goshawk ***(Accipiter gentilis)***

The Northern Goshawk was always associated with less settled parts of the state, where observations were scarce. This species generally inhabits extensive mature forests at high elevations (Bednarz and Kimmel 1992). Anecdotal accounts suggest that its decline probably was caused by lumbering, human persecution, and loss of the Passenger Pigeon, probably an important prey item (Todd 1940). As the state's forests recovered and matured, this species became more widespread. Legislative protection of raptors also helped.

At the time of the Atlas, it was found in 120 blocks, predominately on the extensively forested plateaus, but also in the Valley and Ridge Province (Bednarz and Kimmel 1992). Goshawk home ranges are quite large (Reynolds 1983), limiting the numbers of this large raptor, even where extensive appropriate habitat exists. This secretive species is probably somewhat more widespread than records indicate, but it is nowhere common.

The Northern Goshawk is still vulnerable to human interference, including direct persecution and habitat destruction. It is listed as Candidate-Rare to reflect its low numbers and vulnerability. DAG

*American Coot (**Fulica americana**)*

Both Warren (1890) and Stone (1894) hinted that the American Coot might be a rare summer resident in Pennsylvania, but Harlow (1918) found no evidence of nesting in the state during the early part of this century. Sutton (1928b), however, found hatchlings at Hartstown, Crawford County in 1923, and breeding was first confirmed at the Tinicum Township marshes, Delaware County in June of 1933 (Debes 1934). The coot is well known as an opportunistic nester, so it is not surprising that for several years following the flooding of Pymatuning Swamp (starting in 1932), the newly created reservoir became a haven for nesting coots (Trimble 1937 and 1940; Todd 1940). Similarly, with the construction of the Shenango Reservoir in Mercer County in 1968, coots were reported by Ross as the most common waterbird nesting there (Leberman 1968). Although they may be locally common, coots were found in only 25 Atlas blocks and confirmed in 11.

Large cattail marshes, with rather extensive areas of open water, are the favored breeding habitat of the coot in Pennsylvania. Because of the limited number of such marshes, and the small breeding population of coots in the state, the species was ranked 18th by the OTC and received Rare status. Current breeding populations seem low everywhere across the Commonwealth. Fortunately, habitat management schemes that provide optimal habitat for many ducks and other waterbirds, like the Pied-billed Grebe and Common Moorhen, tend to favor American Coots. RCL

*Marsh Wren (**Cistothorus palustris**)*

The Marsh Wren breeds in large fresh and brackish marshes with patches of tall herbaceous vegetation such as cattails, sedges, or rushes. They also occasionally nest along the shores of rivers, if stands of cattails or sedges are available. They are "area sensitive," nesting primarily in marshes greater than four hectares.

Reid (1992b) provided numerous historical records documenting that Marsh Wrens were at one time relatively abundant throughout Pennsylvania, where suitable habitat conditions existed. As is true for other obligate marsh dwellers, the greatest numbers of Marsh Wrens were reported from the glaciated portions of the state and the southeastern coastal plain. By the 1960s, declines were evident. Poole (1964) described the Marsh Wren as a rare transient and locally distributed breeding resident. During the Breeding Bird Atlas, Marsh Wrens were reported in 77 blocks, with confirmed breeding in 22 blocks. The largest number of confirmed records were from Crawford County.

The Marsh Wren is currently listed as Candidate-Rare. Although not currently threatened with extirpation, recent population declines, its patchy distribution, and dependence on emergent wetlands suggest it could be in trouble in parts of the state. MCB

*Swainson's Thrush (**Catharus ustulatus**)*

The Swainson's Thrush, a bird more typical of northern forests, is Pennsylvania's rarest nesting thrush and one of its scarcest forest species. Before deforestation of the state's uplands, this bird was apparently widespread and locally common in the north, especially in Sullivan and Clinton counties (Warren 1890; Dwight 1892; Cope 1901; Todd 1940).

Conifers are an important component of Swainson's Thrush nesting habitat (Bent 1949). Early in the twentieth century, extensive logging and fires nearly eliminated pines and hemlock from Pennsylvania's forests (Considine and Powell 1982), severely reducing its range.

The Swainson's Thrush is rare, but probably recovering, in Pennsylvania. It earned its Candidate-Rare status by being reported as probable or confirmed in only 21 blocks—less than one percent of the state (Brauning 1992b). In some blocks several territorial Swainson's Thrushes could be found, but in other blocks this species did not occur every year (pers. obs.). In recent years, most nesting Swainson's Thrushes have been found above 1500 feet in moist woods with hemlocks. Swainson's Thrush lives not only in old growth conifer forests like Heart's Content in Warren County, but also at the edges of clearcuts, in old conifer plantings and second-growth forests with dense hemlock stands. DAG

*Summer Tanager (**Piranga rubra**)*

Summer Tanagers have occurred in small numbers in Pennsylvania for many years. Nesting by this southern species is confined to seven southeastern and four southwestern counties (Poole, unpub. ms.). The species is found in upland forests, particularly open oak and pine forests. At the turn of the century nesting occurred in the southeast, but since 1975, nesting has been restricted to the southwestern corner of Pennsylvania. Summer Tanagers have been present in Greene County for at least 15 years (Ickes 1992b).

The Summer Tanager, like the Blue Grosbeak, is listed as a Candidate-Rare bird primarily because of its low numbers and localized distribution; both are found in appropriate habitat in southern corners of Pennsylvania. Populations appear stable throughout the Summer Tanager's range, although a downward trend is apparent for the ten years ending in 1988 (Sauer and Droege 1990). Pennsylvania's Summer Tanagers are vulnerable to land-use changes in the relatively small area in the state (Greene County) with a viable population. This neotropical migrant's breeding range may be shrinking in the eastern United States, which will likely result in a reduction of Pennsylvania's population. DWB

*Blue Grosbeak (**Guiraca caerulea**)*

Pennsylvania is at the northern edge of the Blue Grosbeak's range. Locally, such as in southern Lancaster County, it has been present for at least a century (Beck 1924). The Blue Grosbeak is found in open brushy areas, old fields and woodland edges, but is not closely associated with any particularly habitat characteristic (Schutsky 1992c). The occurrence of this species around the Philadelphia International Airport reflects its tolerance of diverse habitats.

With the lowest ranking score and highest number of Atlas blocks for its status category, this species may be one of the least threatened of the special concern birds. The Blue Grosbeak is listed as Candidate-Rare because of its small, localized distribution and association with ephemeral habitats. The species' current range, southeastern Pennsylvania, has experienced considerable suburban and commercial development that threatens to eliminate suitable habitat. Despite these threats, the Blue Grosbeak is likely to remain in the state and may expand its breeding distribution. DWB

CANDIDATE-UNDETERMINED

*Cattle Egret (**Bubulcus ibis**)*

The first nesting of the Cattle Egret was reported in 1975, when 772 nests were counted on Rookery Island (Schutsky 1976) in the Susquehanna River. The birds were apparently nesting for some years prior to this observation (Schutsky 1992e). This island is the only known site where Cattle Egrets nested in Pennsylvania (Schutsky 1992e). The location put the birds within easy reach of prime agricultural foraging grounds in Lancaster, York, and Dauphin counties (Wood 1979).

The Cattle Egret is currently listed as Candidate-Undetermined, because of its dynamic and sometimes nomadic nature. This species is a prime example of the vulnerability associated with an extremely localized nesting population. In 1981 more than 7,500 individuals were counted at Rookery Island (Schutsky 1992e). By 1982, the number had declined to 4,500 individuals. A serious decline continued until 1989 when no nests were recorded and few individuals observed. This site remained abandoned through 1993. Possible reasons for the decline include the effects of drought, successional changes in vegetation, disruption of the prey base, changes in the accessibility by predators, and human disturbance (Schutsky 1992e).

Although the Cattle Egret is listed as status Undetermined in Pennsylvania, its numbers continue to increase in other parts of its range in North America. TLM

*Northern Pintail (**Anas acuta**)*

The Northern Pintail is a widespread migrant across Pennsylvania and has nested here sporadically. Nesting was suspected at Pymatuning for several years following the discovery of the first nests found in the state by Fricke in 1934 (Grimm 1952). The only other documented nesting came from the opposite corner of the state at the John Heinz National Wildlife Refuge, Philadelphia County, in 1966 (Miller 1966). Breeding was not confirmed at the time of the Atlas, although there were several summer sightings. Summering individuals are rather frequent, but do not necessarily indicate a breeding population. The Northern Pintail nests primarily across much of Canada and south into the prairie states of the U.S. (AOU 1983).

Pintails nest in a variety of habitats, but particularly shallow marshes and small ponds. Although a limited amount of suitable wetlands appeared to exist, primarily in Crawford County, this habitat was not well surveyed during the Atlas. As is the case with most of the waterfowl currently listed as Undetermined, this designation for pintails may be attributed to our limited knowledge of nesting birds in Pennsylvania's wetland habitats. DWB

*Northern Shoveler (**Anas clypeata**)*

The Northern Shoveler breeds primarily in western North America, but may nest opportunistically and locally in the East. Like many species of waterfowl, the first evidence that shovelers bred in Pennsylvania came from the newly flooded Pymatuning Reservoir on 27 May 1935 (Trimble 1940; Todd 1940). Since then, proof of nesting was obtained on an irregular basis in the Pymatuning region, with published records from the reservoir in 1936 (Trimble 1940; Grimm 1952) and from Conneaut Marsh in 1963 (Leberman 1963). Breeding was not confirmed on these traditional Crawford County breeding grounds during the Atlas project, but single broods of flightless young were subsequently seen at both Conneaut Marsh (pers. obs.) and Pymatuning (R.F. Leberman, pers. comm.) in 1991. The lone Atlas nesting confirmation came from Philadelphia County, where the species was first reported as nesting at the John Heinz National Wildlife Refuge in the 1960s (Hartman 1992b). Elsewhere, the only other Pennsylvania breeding record was from Middle Creek Wildlife Management Area, where a brood of shovelers was noted during the late 1970s (Hartman 1992b).

During the breeding season, Northern Shovelers prefer shallow, muddy, freshwater lakes or ponds, surrounded by considerable emergent marsh vegetation (AOU 1983). The scarcity of such habitats limits the potential breeding distribution in Pennsylvania. RCL

*Gadwall (**Anas strepera**)*

In North America, the Gadwall nests primarily in the western and central regions of the continent, but, beginning in the 1930s, breeding began to occur at scattered localities in the Great Lakes region and south along the Atlantic coast to North Carolina (Palmer 1976). Among the earliest evidence of such eastward expansion was a record from the then newly created Pymatuning Reservoir, where on 18 May 1934 Fricke flushed a female from a nest just west of Linesville. A series of breeding records from that locality followed through at least 1941 (Trimble 1940; Todd 1940; Grimm 1952). Subsequently, field observations of summering Gadwall (and other less common species of breeding waterfowl) were reported, but there are very few published records. A pair of Gadwalls nested at Conneaut Marsh near Geneva, Crawford County in 1964 (Leberman 1964); the species was documented near Butler, Butler County between 1957 and 1961 (Fingerhood 1992g).

Gadwalls usually nest in grassy cover near a large marsh that has some open water, or in the vicinity of a large lake with considerable emergent vegetation. The species was not confirmed during the Atlas project, but there were several "possible" records from northwestern Pennsylvania. A pair also was observed at Lake Somerset, Somerset County. As noted by Fingerhood (1992g), "The Gadwall may be one of the very few species that probably nested during the Atlas period but was overlooked." A careful and systematic search for the species within its historic Pennsylvania breeding grounds is badly needed to confirm whether or not Gadwall still nest there. RCL

*American Wigeon (**Anas americana**)*

Although the American Wigeon had long been known as a common migrant through Pennsylvania, none of the early writers suggested that the species might be found breeding within the state. With the flooding of Pymatuning Swamp in Crawford County during the early 1930s, however, ideal conditions for nesting waterfowl were created—at the same time that disastrous drought and duststorms were following extensive drainage and agricultural operations in the pothole country of the Midwest (Trimble 1940). Mated wigeons were first seen at Pymatuning in the spring of 1936; later that year, and again in 1938, B.L. Oudette reported finding adults with young (Trimble 1940; Todd 1940). Grimm (1952) found no evidence of wigeons breeding at Pymatuning during his subsequent field work there. Indeed no further confirmation of nesting was forthcoming until, during the Atlas, a brood of eight half-grown young was seen at Pymatuning by Ronald Leberman and Mary Leberman in July 1986 (Hartman 1992c).

At the southern edge of its breeding range in Pennsylvania, the American Wigeon appears to be little more than a casual, infrequent nester that is probably limited to the Pymatuning region. The true extent of breeding, however, is somewhat obscured by the presence of numerous non-breeding summer residents. This lack of adequate information on the species in Pennsylvania during the breeding season warrants its listing as status Undetermined. Much apparently suitable habitat, in the form of large marshes with stable water levels, still exists in the northwestern corner of the state. A careful and comprehensive census of waterfowl currently nesting in these marshes, however, is badly needed. RCL

*Ruddy Duck (**Oxyura jamaicensis**)*

Although primarily a breeding bird of western North America, the Ruddy Duck is well known as an opportunistic breeder in the East. All Pennsylvania nesting records are from the Pymatuning Reservoir, Crawford County, where breeding was first confirmed by J.K. Terres, who saw a brood near Linesville in July 1935. The first nest was then found by Fricke on 19 June 1936 (Trimble 1940; Todd 1940). Although Trimble (1940) wrote that the number of summering birds continued to increase over the next few years, Grimm (1952) indicated that he knew of no further nesting records after about 1940. Fingerhood (1992h) followed Grimm (1952) in dating the last Pennsylvania breeding of the Ruddy Duck at about 1940. One published record suggests Ruddy Ducks were breeding south of the spillway at Pymatuning during the summer of 1965 (Harrison and Harrison 1965). And breeding was again confirmed in 1969 when adults and downy young were seen at the Linesville Fish Hatchery and near Ford Island on several occasions during that summer (Leberman 1969). Since then, the few summer records from the Pymatuning region and elsewhere in the Comonwealth were either inconclusive, or probably represent non-breeding birds.

Ruddy Ducks prefer large freshwater marshes, where the nest is usually built over shallow water, within thick stands of emergent aquatics like cattails and reeds (Palmer 1976); a scarce and declining habitat in Pennsylvania. Because of the rarity of such marshes in the state, and the small and extremely erratic nature of the breeding population at Pymatuning, the Ruddy Duck received the seventh highest ranking value. The species was not confirmed nesting during the Atlas project; an inconclusive result, however, because access to much of the historic nesting area was not available to Atlas volunteers during that period. Further observation, over a period of years, is required to accurately determine the current status of this species within the Commonwealth. RCL

*Northern Bobwhite (**Colinus virginianus**)*

The Northern Bobwhite population experienced a decline which began over 100 years ago (Ickes 1992c) and accelerated in the 1970s. Once found "over the lower half of the state" (Poole 1964), viable populations of this species were probably restricted to two or three south-central counties by the completion of the Atlas. Even there, however, populations are unstable and have sharply declined on standardized calling counts in recent years (B. Shope pers. comm.).

The status of this species was particularly difficult to determine because of the large number of quail that were released each year by sportsmen's organizations and private landowners. Records of Bobwhite quail in a relatively large number of Atlas blocks (the second highest of any special concern bird), and in nearly 90 percent of the state's counties was largely attributed to such releases. Most counties do not support sustainable quail populations. The Pennsylvania Game Commission discontinued restocking efforts in the 1940s (Beuchner 1950).

A number of possibilities have been suggested to explain the dramatic decline of this species here and across much of its North American range. Bobwhite quail occur widely across southeastern United States in brushlands, open woodlands, and agricultural fields and pastures, but population trends are sharply negative across much of its range (Robbins et al. 1986). Modern agricultural practices, including increased pesticide use and larger fields, apparently have reduced the suitability of available habitat (Roseberry and Klimstra 1984). Further analysis of Northern Bobwhite populations in their remaining native range in Pennsylvania, where its hunting season is closed, should be conducted to determine its size and viability. DWB

Long-eared Owl (Asio otus)

Although we have a much better understanding of populations, status, and distribution of most birds now than 10 years ago, the Long-eared Owl remains one of the most enigmatic of Pennsylvania's birds. Six nesting locations were confirmed during the Atlas project (Santner 1992b). Nesting locations were widely scattered and not concentrated within any specific geographic area. The preferred habitat includes young conifers, often in groves, for roosting and nest sites positioned adjacent to open fields and pastures for foraging.

The Long-eared Owl is difficult to survey and probably more widespread than surveys suggest (Gill 1985; Santner 1992b). It appears that the species was more widespread earlier in this century (e.g., Sutton 1928a) and may have undergone a major reduction in abundance. As a result, the Long-eared Owl maintains its Undetermined status designation from the previous list. Sufficient evidence of the extent of breeding will come only through direct and intensive nocturnal surveys. DWB

*Northern Saw-whet Owl (**Aegolius acadicus**)*

The Northern Saw-whet Owl has always been considered rare and hard-to-find in Pennsylvania (Warren 1890; Poole 1964; Wood 1979). Although some individuals can be very tame, the reclusiveness of this owl has made its breeding range and abundance difficult to determine. With the exception of a brief period in early spring, this nocturnal species is quiet on its breeding ground. The Atlas added greatly to our knowledge of the saw-whet's breeding range, but ornithologists still do not feel certain about its abundance. Thus, the Northern Saw-whet Owl was classified as Candidate-Undetermined.

The Northern Saw-whet Owl is generally associated with high-elevation moist woodlands (Bent 1938; Todd 1940; Gross 1992c), where it seems to prosper where there is generous undergrowth, either as conifers or shrubs, to provide cover for hunting and protection from predation (Hayward and Garton 1984; Marks and Doremus 1988). The species is less restricted in habitat choice than generally appreciated and sometimes nests near human habitation in Pennsylvania (Todd 1940; Gross 1992c). The Atlas found the saw-whet to be rare and local, but more widespread than previously recorded. It was found in only two percent of the state's Atlas blocks, almost exclusively at higher elevations (greater than 1000 feet), in northern counties.

Like some other nocturnal, forest birds, the Northern Saw-whet Owl will need more study in order to fully understand its status. The boreal forests this species inhabits have greatly diminished by human activities. DAG

*Common Nighthawk (**Chordeiles minor**)*

Common Nighthawks place their nests exclusively on bare, exposed locations. Before European settlement, it was probably widely scattered and restricted to patches of pare ground or rock outcrops (Harlow 1913). After discovery of nests on building roofs in Philadelphia in 1869 (Turnbull 1869), nighthawks spread to many urban areas and probably increased in numbers. A major shift in habitat and distribution occurred as flat gravel roofs became commonplace during the mid-1800s. Nighthawks gradually disappeared from natural sites and now are known to nest in Pennsylvania only on man-made structures, although natural sites are still known on eastern Long Island and in the Adirondacks in New York state (Sibley 1988).

There has been widespread concern over population declines in the northeastern United States in recent years, although no survey adequately monitors this species. Reports indicate the near disappearance of the species from some mid-sized cities in the state (Paxton et al. 1990). The Common Nighthawk is listed as a species of special concern in New York (Vickery 1991). In Pennsylvania, it was placed on the Candidate list as Undetermined because of the lack of specific population data and the general concern about its decline.

Re-roofing without gravel may be responsible for population declines locally (Paxton et al. 1990). Further monitoring will be necessary to determine population status. DWB

*Whip-poor-will (**Caprimulgus vociferus**)*

Even novice naturalists know that the call of the Whip-poor-will is heard less often than it once was in Pennsylvania. The species' decline was noted fairly early in the century, especially where woods recovered from logging (Todd 1940). This night bird most commonly resides in second-growth and scrubby woodlands, particularly where there are clearings (Todd 1940; Poole 1964). It may not have been very common or widespread previous to colonization in the primeval forests of this region (Todd 1940; Hall 1983).

Most Pennsylvania ornithologists agree that the Whip-poor-will has diminished, but there is little agreement on the extent of this decrease or its causes. This uncertainty led to its classification as Candidate-Undetermined. A diminished supply of Saturnine moths, habitat reduction, and the use of pesticides have all been offered as reasons for the Whip-poor-will's decline (Tate 1981; Kibbe 1985).

It is also possible that the regrowth and maturization of Pennsylvania's forests, coupled with changed agricultural practices, have reduced its range nearer to its precolonial population size. Perhaps some of these speculations could be answered with more research and population monitoring of this well-known, but little-studied night bird. DAG

Dickcissel (Spiza americana)

Formerly extirpated in Pennsylvania, the Dickcissel is listed as Candidate-Undetermined because recent breeding records of the species have been mostly sporadic. The history of the Dickcissel in Pennsylvania was detailed by Mulvihill (1988, 1992). The Dickcissel was a regular and locally common breeding bird in Pennsylvania during most of the nineteenth century. Audubon and Wilson described the species as being "plentiful" and "abound[ing] in the neighborhood of Philadelphia" in the early 1800s. Shortly before the end of the 1800s the Dickcissel abruptly and mysteriously disappeared from the entire eastern periphery of its range, including Pennsylvania (Rhoads 1903).

Throughout most of this century, the species occurred only sporadically in Pennsylvania, mostly outside the breeding season. A few birds may have nested near Lititz, Lancaster County in the mid-1930s (Poole, unpubl. ms.), but the Dickcissel was not officially returned to the list of Pennsylvania's breeding birds until the first year of the Atlas project, when W. Fye found it nesting near Knox, Clarion County (Bell 1984). Then, possibly in response to severe drought conditions across their normal midwestern breeding range during the summer of 1988, Dickcissels invaded the eastern United States, especially western Pennsylvania, eastern Virginia and Maryland (Mulvihill 1988). In Pennsylvania, this "prairie" species occupies hayfields, alfalfa fields, and strip mines reclaimed with various grasses and legumes. Dickcissels were observed in 39 Atlas blocks in 1988, with five cases of confirmed nesting. They were not found in the majority of these blocks in subsequent years.

An apparent exception to the Dickcissel's generally sporadic presence in Pennsylvania in the 1900s is the species' fairly regular pattern of occurrence locally in southcentral Pennsylvania. A small number of Dickcissels has been observed almost annually during the breeding season in Franklin and Fulton counties since the mid-1960s and there have been a few instances of confirmed nesting (J.K. Gabler, pers. comm.). These counties are approximately contiguous with areas in Maryland and West Virginia where the species also has been observed during several successive nesting seasons in recent decades (Stewart and Robbins 1958; Hall 1983).

Determining the Dickcissel's status in Pennsylvania will require more information. Before it can be upgraded, a pattern of regular breeding must be established. Areas of suitable habitat in southcentral Pennsylvania should be closely monitored for nesting activity by species. RSM

Henslow's Sparrow (Ammodramus henslowii)

The Henslow's Sparrow is an excellent example of the change in perception of breeding bird populations and distribution as a result of the Breeding Bird Atlas. It was previously listed as Threatened (Gill 1985). Atlas results reflect a much wider distribution than previously suspected (Reid 1992a) and more blocks than for most Special Concern species.

Following compilation of Atlas data, the Henslow's Sparrow has been assigned to a number of status categories, including secure. The Henslow's Sparrow's status is listed here as Undetermined primarily because of its irregular occurrence over much of Pennsylvania. The distinctive successional stage used makes this one of the rarest of the grassland species. Futhermore, the transitory nature of the preferred grasslands results in little site fidelity by Henslow's Sparrows in most habitats.

Changing agricultural practices have reduced suitable habitat for this, as well as many other grassland species. The decline of farm land acreage, particularly pasture, and the reversion of old fields to woodland has resulted in the loss of available habitat. However, in western Pennsylvania reclaimed surface mines planted in grasses provide extensive, and relatively stable, habitat for this and other grassland species.

Monitoring this species is difficult. Because of the sparse population of Henslow's Sparrows statewide, they are detected on very few BBS or Game Commission Grassland BBS routes. DWB

Red Crossbill (Loxia curvirostra)

One of Pennsylvania's most enigmatic and erratic birds, the Red Crossbill is an opportunistic consumer of conifer seeds (Benkman 1987). In Pennsylvania and adjacent states, it has been most often associated with pines, especially eastern white pine (*Pinus strobus*) (Todd 1940; Dickerman 1987; Groth 1993). If sufficiently abundant food supplies are available, Red Crossbills will nest almost any time, even when snow covers the ground, but usually in the period from mid-winter to mid-summer (Peterson 1988; Benkman 1990). Most Pennsylvania breeding records have been at higher elevations, but they have also occurred in lowland pine barrens (Fingerhood 1992i).

The status of the Red Crossbill in Pennsylvania has always been controversial. Warren (1890) and Stone (1894) documented breeding in several northern counties. Todd (1940) doubted some claims by others, but confirmed nesting in the state himself. Reports of crossbill nesting declined through this century with only two confirmed nestings in recent years. Ginaven found a pair feeding young on 30 June 1980 at Leonard Harrison State Park, Tioga County (Fingerhood 1992i) and a nest was found near Lopez, Sullivan County on 12 March 1993 (pers. obs.). This nest was apparently abandoned after the next day's blizzard. During the Atlas, nesting was not confirmed, but observers found Red Crossbills in at least six high elevation locations (Fingerhood 1992; pers. obs.). Leberman reported the species at the village of Savage, near Mt. Davis in the summer of 1986 (Hall 1986).

The Red Crossbill is classified Candidate-Undetermined because of its uncertain status in the state and its indefinite taxonomy. Based on call notes and morphology, there are at least eight distinct Red Crossbill populations in North America (Groth 1993). At least three types visited New York during the 1984-85 invasion (Peterson 1988; Groth 1993) and two types were documented nesting in the southern Appalachians (Groth 1988). The crossbill may be poorly reported as a nesting bird due to the remoteness of its habitat, its unpredictability, and its reputation as an invasive northern species. Red Crossbills and other conifer-dependent birds require extensive, healthy, mature stands of native conifers to sustain their populations (Benkman 1993). DAG

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LITERATURE CITED

American Ornithologists' Union. 1957. Check-list of North American Birds. 5th edition. Lord Baltimore Press, Baltimore, MD.

American Ornithologists' Union. 1983. Check-list of North American Birds. 6th ed. Allen Press, Lawrence, KS.

Amico, T.M., R.M. Schutsky and J.E. Witmer. 1984. Annotated list. pp. 125-174 *In:* Birds of Lancaster County, Pennsylvania. (H.B. Morrin, ed. chairman). Lancaster County Bird Club, Lancaster, PA.

Andrle, R.F. and J.R. Carroll (eds.) 1988. The Atlas of Breeding Birds in New York State. Cornell Univ. Press, Ithaca, NY.

Askins, R.A., J.F. Lynch and R. Greenber. 1990. Population declines in migratory birds in eastern North America. Current Ornithology 7:1-57.

Audubon, J.J. and J.B. Chevalier. 1840-1944. The Birds of America. Vols. 1-7. Reprint 1967. Dover Publications, NY.

Bailey, W.L. 1916. Yellow-bellied Flycatcher (*Empidonax flaviventris*) breeding on the Pocono Mountain, Penna. Auk 33:200.

Baird, S.F. 1845. Catalogue of birds found in the neighborhood of Carlisle, Cumberland County, Pennsylvania. The Literary Record and J. of the Linnaean Assoc. of Pennsylvania College 1:249-257.

Beck, H.H. 1924. A chapter on the ornithology of Lancaster County, Pennsylvania, with supplementary notes on the mammals. pp. 1-39. *In:* Lancaster County, Pennsylvania—a history. Lewis Historical Publishing Company, New York.

Bednarz, J. and T. Kimmel. 1992. Northern Goshawk. pp. 100-101. *In:* Atlas of Breeding Birds in Pennsylvania. (D.W. Brauning, ed.). Univ. of Pittsburgh Press, Pittsburgh, PA.

Bell, R.K. 1984. Dickcissel nest found in Clarion County, Pennsylvania. Redstart 51:68-69.

Benkman, C.W. 1987. Crossbill foraging behavior, bill structure, and patterns of food profitability. Wilson Bull. 99:351-368.

Benkman, C.W. 1990. Intake rates and the timing of crossbill reproduction. Auk 107:376-386.

Benkman, C.W. 1993. Logging, conifers, and the conservation of crossbills. Conservation Biology 7:473-479.

Bent, A.C. 1938. Life Histories of North American of Prey, Part 2. U.S. National Museum Bull., No. 170, Washington, D.C.

Bent, A.C. 1949. Life Histories of North American Thrushes, Kinglets, and Their Allies. U.S. National Museum Bull., No. 196, Washington, D.C.

Beuchner, H.K. 1950. An evaluation of restocking with penreared bobwhite. J. Wildl. Manage. 14:369.

Blumpton, A.K. 1989. Factors affecting Loggerhead Shrike mortality in Virginia. Unpub. MS thesis. Virginia Polytechnic Institute, Blacksburg, 85 pp.

Brauning, D.W. 1991. Report of the Pennsylvania Species of Special Concern: Ornithological Technical Committee of the Pennsylvania Biological Survey. Pennsylvania Birds 5(2):63.

Brauning, D.W. (ed.). 1992a. Atlas of Breeding Birds in Pennsylvania. Univ. of Pittsburgh Press, Pittsburgh, PA.

Brauning, D.W. 1992b. Swainson's Thrush. pp. 338-339. *In:* Atlas of Breeding Birds in Pennsylvania. (D.W. Brauning, ed.). Univ. Pittsburgh Press, Pittsburgh, PA.

Brauning, D. and C. Dooley. 1991. Recent history and current status of nesting Peregrine Falcons, (*Falco peregrinus*) in Pennsylvania. Pennsylvania Birds 5:59-61.

Brauning, D.W. and B. Peebles. 1992. Recent history and current status of nesting Bald Eagles, *Haliaeetus leucocephalus*, in Pennsylvania. Pennsylvania Birds 6:2-5.

Brooks, M. 1938. Bachman's Sparrow in the north-central portion of its range. Wilson Bull. 50:86-109.

Brooks, M. 1941. Bachman's Sparrow in Fayette County, Pennsylvania. Cardinal 5:145.

Brooks, M. 1947. Interrelations of House Wren and Bewick's Wren. Auk 64:624.

Brooks, R.P. and M.J. Croonquist. 1990. Wetland, habitat, and trophic response guilds for wildlife species in Pennsylvania. J. of the Pennsylvania Acad. of Science 64(2):93-102.

Buckwalter, M. 1988. Short-eared Owls in Clarion County. Pennsylvania Birds 2:55-56.

Bush, W.L. 1989. Black Tern (*Chlidonias niger*) nesting platform and habitat study in Crawford and Erie Counties, Pennsylvania. Unpub. thesis. Allegheny College, Meadville, PA.

Cade, T.J. 1988. Peregrine recovery in the United States. pp. 331-342. *In:* Conservation Studies on Raptors (I. Newton and R.D. Chandellor, eds.). ICBP Technical Publication No. 5. International Council for Bird Preservation, London.

Cade, T.J. and B. Burnham. 1993. Eastern Peregrines raise many young. The Peregrine Fund, World Center for Birds of Prey Newsletter 23:3.

Cadman, M.D., P.F.J. Eagles and F.M. Helleiner (eds.). 1987. Atlas of the Breeding Birds of Ontario. Univ. of Waterloo Press, Waterloo, Ontario.

Christy, B.H. 1924a. Bewick's Wren in Allegheny County. Cardinal 1:12-15.

Christy, B.H. 1924b. Warblers of the Big Travis. Cardinal 1:8-14.

Christy, B.H. 1929. Notes [Bachman's Sparrow near Sewickley]. Cardinal 2(5):130.

Considine, T.J. and D.S. Powell. 1980. Forest statistics for Pennsylvania—1978. U.S. Department of Agriculture. Forest Service Resource Bulletin NE-65. Northeast Forest Experimental Station, PA, Broomall.

Cope, F.R., Jr. 1901. Observations on the summer birds of parts of Clinton and Potter counties, Pennsylvania. Cassinia 5:8-21.

Debes, V.A. 1934. Coots breeding on the Delaware Marshes below Philadelphia. Auk 51:231-232.

Department of Interior. 1991. Endangered and Threatened wildlife and plants: Animal candidate review for listing as endangered or threatened species, proposed rules. Federal Register 56(225):58804-58836.

Dickerman, R.W. 1987. The "old northeastern" subspecies of Red Crossbill. American Birds 41:189-194.

Droege, S. and J.R. Sauer. 1990. North American breeding bird survey annual summary 1989. U.S. Fish and Wildlife Service, Washington, D.C.

Dunn, J. 1989. Colonial Nesting Bird Survey. Annual Job Report. Pennsylvania Game Commission. Harrisburg, PA.

Dwight, J. 1892. Summer birds of the crest of the Pennsylvania Alleghenies. Auk 9:129-141.

Fimreite, N.R., W. Fyfe and J.A. Keith. 1970. Mercury contamination of Canadian prairie seed eaters and their avian predators. Canadian J. Field-Naturalist 84:269-276.

Fingerhood, E. 1990. Philadelphia report. Pennsylvania Birds 4:80-82.

Fingerhood, E.D. 1992a. Piping Plover. p. 432. *In:* Atlas of Breeding Birds in Pennsylvania. (D.W. Brauning, ed.). Univ. of Pittsburgh Press, Pittsburgh, PA.

Fingerhood, E.D. 1992b. Common Tern. pp. 432-433. *In:* Atlas of Breeding Birds in Pennsylvania. (D.W. Brauning, ed.). Univ. of Pittsburgh Press, Pittsburgh, PA.

Fingerhood, E.D. 1992c. Greater Prairie-Chicken. pp. 431-432. *In:* Atlas of Breeding Birds in Pennsylvania. (D.W. Brauning, ed.). Univ. of Pittsburgh Press, Pittsburgh, PA.

Fingerhood, E.D. 1992d. Passenger Pigeon. pp. 434-435. *In:* Atlas of Breeding Birds in Pennsylvania. (D.W. Brauning, ed.). Univ. of Pittsburgh Press, Pittsburgh, PA.

Fingerhood, E.D. 1992e. Bewick's Wren. pp. 435-436. *In:* Atlas of Breeding Birds in Pennsylvania. (D.W. Brauning, ed.). Univ. of Pittsburgh Press, Pittsburgh, PA.

Fingerhood, E.D. 1992f. Bachman's Sparrow. pp. 436-437. *In:* Atlas of Breeding Birds in Pennsylvania. (D.W. Brauning, ed.). Univ. of Pittsburgh Press, Pittsburgh, PA.

Fingerhood, E.D. 1992g. Gadwall. p. 428. *In:* Atlas of Breeding Birds in Pennsylvania. (D.W. Brauning, ed.). Univ. of Pittsburgh Press, Pittsburgh, PA.

Fingerhood, E.D. 1992h. Ruddy Duck pp. 430-431. *In:* Atlas of Breeding Birds in Pennsylvania. (D.W. Brauning, ed.). Univ. of Pittsburgh Press, Pittsburgh, PA.

Fingerhood, E.D. 1992i. Red Crossbill. pp. 437-438. *In:* Atlas of Breeding Birds in Pennsylvania. (D.W. Brauning, ed.) Univ. of Pittsburgh Press, Pittsburgh, PA.

French, J.C. 1919. The Passenger Pigeon in Pennsylvania: Its Remarkable History, Habits and Extinction with Interesting Side Lights on the Folk and Forest Lore of the Alleghanian Region of the Old Keystone State. Altoona, PA.

Genoways, H.H. and F.J. Brenner (eds.). 1985. Species of Special Concern in Pennsylvania. Special Publication No. 11. Carnegie Museum of Natural History, Pittsburgh, PA.

Gibbs, J.P. and S.M. Melvin. 1992a. American Bittern (*Botaurus lentiginosus*). pp. 51-69. *In:* Migratory Nongame Birds of Management Concern in the Northeast. (K.J. Schneider and D.M. Pence, eds.). U.S. Department of Interior, Fish and Wildlife Service, Newton Corner, MA.

Gibbs, J.P. and S.M. Melvin. 1992b. Least Bittern (*Ixobrychus exilis*). pp. 71-88. *In:* Migratory Nongame Birds of Management Concern in the Northeast. (K.J. Schneider and D.M. Pence, eds.). U.S. Department of Interior, Fish and Wildlife Service, Newton Corner, MA.

Gibbs, J.P. and S.M. Melvin. 1992c. Sedge Wren (*Cistothorus platensis*). pp. 191-209. *In:* Migratory Nongame Birds of Management Concern in the Northeast. (K.J. Schneider and D.M. Pence, eds.). U.S. Department of Interior, Fish and Wildlife Service, Newton Corner, MA.

Gill, F.B. (ed.) 1985. Birds. pp. 299-351. *In:* Species of Special Concern in Pennsylvania. (H.H. Genoways and F.J. Brenner, eds.). Special Publication No. 11. Carnegie Museum, Pittsburgh, PA.

Goodrich, L. 1992. Northern Harrier. pp. 94-95. *In:* Atlas of Breeding Birds in Pennsylvania. (D.W. Brauning, ed.). Univ. of Pittsburgh Press, Pittsburgh, PA.

Grier, J.W., J.B. Elder, F.J. Gramlich, N.F. Green, J.V. Kussman, J.E. Mathisen and J.P. Mattsson. 1983. Northern States Bald Eagle Recovery Plan. Prepared by the Northern States Bald Eagle Recovery Team, J.W. Grier, leader. U.S. Fish and Wildlife Service, Denver, CO.

Grimm. W.C. 1952. Birds of the Pymatuning Region. Pennsylvania Game Commission, Harrisburg, PA.

Gross, A.O. 1932. Heath Hen. pp. 264-280. *In:* Life Histories of North American Gallinaceous Birds. (A.C. Bent, ed.). U.S. National Museum Bull, No. 162. Smithsonian Inst. Press, Washington, D.C.

Gross, D.A. 1991. Yellow-bellied Flycatcher *Empidonax flaviventris* nesting in Pennsylvania with a review of its history, distribution, ecology, behavior, and conservation problems. Pennsylvania Birds 5:107-113.

Gross, D.A. 1992a. Yellow-bellied Flycatcher. pp. 198-199. *In:* Atlas of Breeding Birds in Pennsylvania. (D.W. Brauning, ed.). Univ. of Pittsburgh Press, Pittsburgh, PA

Gross, D.A. 1992b. Olive-sided Flycatcher. pp. 194-195. *In:* Atlas of Breeding Birds in Pennsylvania. (D.W. Brauning, ed.). Univ. of Pittsburgh Press, Pittsburgh, PA

Gross, D.A. 1992c. Northern Saw-whet Owl. pp. 164-165. *In:* Atlas of Breeding Birds in Pennsylvania. (D.W. Brauning, ed.). Univ. of Pittsburgh Press, Pittsburgh, PA

Groth, J.G. 1988. Resolution of cryptic species in Appalachian Red Crossbills. Condor 90:745-760.

Groth, J.G. 1993. Evolutionary differentiation in morphology, vocalizations, and allozymes among nomadic sibling species in the North American Red Crossbill (*Loxia curvirostra*) complex. Univ. of California Press, Vol. 127. Berkeley, CA.

Hall, G.A. 1983. Birds of West Virginia: Ecology and Distribution. Special Publication No. 7. Carnegie Museum of Natural History, Pittsburgh, PA.

Hall, G.A. 1986. Appalachian Region. American Birds 40:1202-1205.

Hamerstrom, F. and M. Kopeny. 1981. Harrier nest-site vegetation. Raptor Research 15:86-88.

Hands, H.M., R.D. Drobney and M.R. Ryan. 1989. Status of the Common Barn-Owl in the Northcentral United States. U.S. Fish and Wildlife Service, Twin Cities, MN.

Harlow, R.F. 1913. The Breeding Birds of Pennsylvania. Unpublished M.S. thesis. Pennsylvania State Univ., Univ. Park, PA.

Harlow, R.F. 1918. Notes on the breeding birds of Pennsylvania and New Jersey. Auk 35:18-147.

Harrison, C. 1978. A Field Guide to the Nests, Eggs and Nestlings of North American Birds. William Collins Sons & Co., Glasgow, UK.

Harrison, H.H. 1975. A Field Guide to Birds' Nests. Houghton Mifflin Company, Boston, MA.

Harrison, H.H. and M. Harrison. 1965. 1965 Nesting notes from the Pymatuning area. Sandpiper, 8:2-5.

Hartman, F.E. 1992a. Green-winged Teal. pp. 70-71. *In:* Atlas of Breeding Birds in Pennsylvania. (D.W. Brauning, ed.). Univ. of Pittsburgh Press, Pittsburgh, PA.

Hartman, F.E. 1992b. Northern Shoveler. pp. 78-79. *In:* Atlas of Breeding Birds in Pennsylvania. (D.W. Brauning, ed.). Univ. of Pittsburgh Press, Pittsburgh, PA.

Hartman, F.E. 1992c. American Wigeon. pp. 80-81. *In:* Atlas of Breeding Birds in Pennsylvania. (D.W. Brauning, ed.). Univ. of Pittsburgh Press, Pittsburgh, PA.

Hayward, G.D. and E.O. Garton. 1984. Roost habitat selection by three small forest owls. Wilson Bull. 96:690-692.

Hickey, J.J. (ed.) 1969. Peregrine Falcon Populations: Their Biology and Decline. Univ. of Wisconsin Press, Madison, WS.

Hunter, S., D.W. Brauning, R. Chambers and A. Kennell. In press. Habitat and status of the Loggerhead Shrike in Pennsylvania. Proceedings of the International Shrike Symposium, 1993.

Ickes, R. 1992a. Pied-billed Grebe. pp. 44-45. *In:* Atlas of Breeding Birds in Pennsylvania. (D.W. Brauning, ed.). Univ. of Pittsburgh Press, Pittsburgh, PA.

Ickes, R. 1992b. Summer Tanager. pp. 358-359. *In:* Atlas of Breeding Birds in Pennsylvania. (D.W. Brauning, ed.). Univ. of Pittsburgh Press, Pittsburgh, PA.

Ickes, R. 1992c. Northern Bobwhite. pp. 118-119. *In:* Atlas of Breeding Birds in Pennsylvania. (D.W. Brauning, ed.). Univ. of Pittsburgh Press, Pittsburgh, PA.

Kennell, A. 1992. First confirmed shrike nesting in Pennsylvania since 1934. Pennsylvania Birds 6(2):65-66.

Kibbe, D.P. 1985. Whip-poor-will. pp. 146-147. *In:* The Atlas of Breeding Birds of Vermont. (S.B. Laughlin and D.P. Kibbe, eds.). Univ. Press of New England, Hanover, NH.

Kirkland, G.L. and P.M. Krim. 1990. Survey of the statuses of the mammals of Pennsylvania. J. of the Pennsylvania Acad. of Science 64(1):33-45.

Kortright, F.H. 1942. The Ducks, Geese and Swans of North America. The American Wildlife Institute, Washington, D.C.

Kroodsma, D.E. 1973. Coexistence of Bewick's Wrens and House Wrens in Oregon. Auk 90:341-352.

Leberman, R.C. 1963. Field notes summer season 1963, area no. 3. Sandpiper 6:18-19.

Leberman, R.C. 1964. Field notes summer and fall season 1964, area no. 2. Sandpiper 6:16-18.

Leberman, R.C. 1968. Field notes summer and fall season 1968, area no. 2. Sandpiper 11:12-15.

Leberman, R.C. 1969. Field notes, summer and autumn 1969, area no. 2. Sandpiper 12:13-17.

Leberman, R.C. 1992a. Black Tern. pp. 144-145. *In:* Atlas of Breeding Birds in Pennsylvania. (D.W. Brauning, ed.). Univ. of Pittsburgh Press, Pittsburgh, PA.

Leberman, R.C. 1992b. American Bittern. pp. 46-47. *In:* Atlas of Breeding Birds in Pennsylvania. (D.W. Brauning, ed.). Univ. of Pittsburgh Press, Pittsburgh, PA.

Leberman, R.C. 1992c. Least Bittern. 48-49. *In:* Atlas of Breeding Birds in Pennsylvania. (D.W. Brauning, ed.). Univ. of Pittsburgh Press, Pittsburgh, PA.

Leberman, R.C. 1992d. Common Snipe. pp. 140-141. *In:* Atlas of Breeding Birds in Pennsylvania. (D.W. Brauning, ed.). Univ. of Pittsburgh Press, Pittsburgh, PA.

Leberman, R.C. 1992e. Sedge Wren. pp. 256-257. *In:* Atlas of Breeding Birds in Pennsylvania. (D.W. Brauning, ed.). Univ. of Pittsburgh Press, Pittsburgh, PA.

Leberman, R.C. 1992f. Prothonotary Warbler. pp. 334-335. *In:* Atlas of Breeding Birds in Pennsylvania. (D.W. Brauning, ed.). Univ. of Pittsburgh Press, Pittsburgh, PA.

Marchant, J.H., R. Hudson, S.P. Carter and P.A. Whittington. 1990. Population Trends in British Breeding Birds. British Trust for Ornithology, Tring, UK.

Marks, J.S. and J.H. Doremus. 1988. Breeding-season diet of Northern Saw-whet Owls in southwestern Idaho. Wilson Bull. 100:690-694.

Marshall, J.T. 1988. Birds lost from a giant sequoia forest during fifty years. Condor 90:359-372.

Martin, T. 1992. Breeding productivity considerations: What are the appropriate habitat features for management? pp. 455-473. *In:* Ecology and Conservation of Neotropical Migrant Landbirds. (J.M. Hagan III and D.W. Johnson, eds.). Smithsonian Inst. Press, Washington, D.C.

Master, T. 1992. Short-eared Owl. pp. 164-165. *In:* Atlas of Breeding Birds in Pennsylvania. (D.W. Brauning, ed.). Univ. of Pittsburgh Press, Pittsburgh, PA.

Meanley, B. 1992. King Rail. *In:* The Birds of North America, No. 3. (A. Poole, P. Stettenheim and F. Gill, eds). Acad. of Natural Sci., Philadelphia. The American Ornithologists Union, Washington, D.C.

Mellon, R. 1990. An Ornithological History of the Delaware Valley Region. Cassinia 63:36-56.

Mengel, R.M. 1956. The Birds of Kentucky. Ornithol. Monog. No. 3. American Ornithologists' Union, Washington, D.C.

Miller, J.C. 1966. A nesting record of the Pintail at Tinicum Wildlife Preserve. Cassinia 49:30.

Miller, J.C. 1979. Snowy Egret nesting in Philadelphia, Pennsylvania. Cassinia 58:22.

Miller, J.C. and C.E. Price, Jr. 1959. Birds of Tinicum. Cassinia, 44:3-15.

Miller, R.F. 1933. The breeding birds of Philadelphia, Pa. Oologist, 50:86-95.

Mulvihill, R.S. 1987. [Review of] The Breeding Bird Survey: Its First Fifteen Years, 1965-1979. Wilson Bull. 99:925-928.

Mulvihill, R.S. 1988. The occurrence of Dickcissels (*Spiza americana*) in western Pennsylvania during the 1988 nesting season—its possible bearing on the species' unusual history in eastern North America. Pennsylvania Birds 2:83-87.

Mulvihill, R.S. 1992. Dickcissel. pp. 370-371. *In:* Atlas of Breeding Birds in Pennsylvania. (D.W. Brauning, ed.). Univ. of Pittsburgh Press, Pittsburgh, PA.

Novak, P.G. 1989. Breeding Ecology and Status of the Loggerhead Shrike (*Lanius ludovicianus*) in New York State. Unpublished MS Thesis. Ithaca, Cornell Univ., NY.

Odum, E.P. and D.W. Johnston. 1951. The House Wren breeding in Georgia: an analysis of a range extension. Auk 68:357-366.

Palmer, R.S. 1962. Handbook of North American Birds: vol. 1, Loons through Flamingos. Yale Univ. Press, New Haven and London.

Palmer, R.S. 1976. Handbook of North American Birds: vol. 3, Waterfowl. Yale Univ. Press, New Haven and London.

Paxton, E.O., W.J. Boyle Jr. and D.A. Cutler. 1990. Hudson-Delware Region, the nesting season. Am. Birds 44:1116-1120.

Pendleton, B.G. (ed.) 1989. Proceedings of the Northeast Raptor Management Symposium and Workshop. Scientific and Technical Series, No. 13. Institute for Wildlife Research, National Wildlife Federation.

Peterjohn, B.G. and D.L. Rice (eds.). 1991. The Ohio Breeding Bird Atlas. Ohio Department of Natural Resources, Columbus, OH.

Peterson, J.M.C. 1988. Red Crossbill. pp. 490-492. *In:* The Atlas of Breeding Birds in New York State. (R.F. Andrle and J.R. Carroll, eds.). Cornell Univ. Press, Ithaca, NY.

Peterson, J.M.C. and C. Fichtel. 1992. Olive-sided Flycatcher, *Contopus borealis*. pp. 353-367. *In:* Migratory Nongame Birds of Management Concern in the Northeast. (K.J. Schneider and D.M. Pence, eds.). U.S. Department of Interior, Fish and Wildlife Service, Newton Corner, MA.

Poole, E.L. 1949. The extinct heath hen. Frontiers 13:68-70.

Poole, E.L. 1964. Pennsylvania Birds, an Annotated List. Livingston Publishing Co., Narberth, PA.

Poole, E.L. Unpublished Manuscript. Acad. of Natural Science, Philadelphia, PA 19103.

Reid, W. 1992a. Henslow's Sparrow. pp. 386-387. *In:* Atlas of Breeding Birds in Pennsylvania. (D.W. Brauning, ed.). Univ. of Pittsburgh Press, Pittsburgh, PA.

Reid, W. 1992b. Marsh Wren. pp. 258-259. *In:* Atlas of Breeding Birds in Pennsylvania. (D.W. Brauning, ed.). Univ. of Pittsburgh Press, Pittsburgh, PA.

Reynolds, R.T. 1983. Management of Western Coniferous Forest Habitat for Nesting Accipiter Hawks. U.S.D.A. Forest Service General Technical Report RM-102, Rocky Mt. Forest and Range Experiment Station, Ft. Collins, CO.

Rhoads, S.N. 1903. Exit the Dickcissel—a remarkable case of local extinction. Cassinia 7:17-28.

Robbins, C.S., D. Bystrak and P.H. Geissler. 1986. The Breeding Bird Survey: Its First Fifteen Years, 1965-1979. U.S. Fish and Wildlife Serv. Resource. Publ., No. 157. U.S. Fish and Wildlife Service, Washington, D.C.

Roseberry, J.L. and W.D. Klimstra. 1984. Population Ecology of the Bobwhite. S. Illinois Univ. Press, Carbondale, IL.

Root, R.B. 1969. Interspecific territoriality between Bewick's and House wrens. Auk 86:125-127.

Rymon, L.M. 1989. Osprey Restoration in three northeastern states. pp. 259-263. *In:* Proceedings of the Northeast Raptor Management Symposium and Workshop. (B.G. Pendleton, ed.). Scientific and Technical Series, No. 13. Institute for Wildlife Research, National Wildlife Federation, Washington, D.C.

Rymon, L.M. 1992. Osprey. pp. 90-91. *In:* Atlas of Breeding Birds in Pennsylvania. (D.W. Brauning, ed.). Univ. of Pittsburgh Press, Pittsburgh, PA.

Sager, R. and G. Sager 1991. County Reports: Somerset County. Pennsylvania Birds 5(3):139-140.

Santner, S. 1992a. Barn Owl. pp. 154-155. *In:* Atlas of Breeding Birds in Pennsylvania. (D.W. Brauning, ed.). Univ. of Pittsburgh Press, Pittsburgh, PA.

Santner, S. 1992b. Long-eared Owl. pp. 162-163. *In:* Atlas of Breeding Birds in Pennsylvania. (D.W. Brauning, ed.). Univ. of Pittsburgh Press, Pittsburgh, PA.

Sauer, J.R. and S. Droege. 1992. Geographic patterns in population trends of Neotropical migrants in North America. pp. 26-42. *In:* Ecology and Conservation of Neotropical Migrant Landbirds. (J.M. Hagan II and D.W. Johson, eds.). Smithsonian Inst., Press, Washington, D.C.

Schorger, A.W. 1973. The Passenger Pigeon: Its Natural History and Exctinction. Univ. of Oklahoma Press, Norman, OK.

Schutsky, R.M. 1976. Glossy Ibis, Cattle Egret and Snowy Egret: three new Pennsylvania breeding birds. Cassinia 56:3-5.

Schutsky, R.M. 1992a. Great Egret. pp. 52-53. *In:* Atlas of Breeding Birds in Pennsylvania. (D.W. Brauning, ed.). Univ. of Pittsburgh Press, Pittsburgh, PA.

Schutsky, R.M. 1992b. Yellow-crowned Night-Heron. pp. 62-63. *In:* Atlas of Breeding Birds in Pennsylvania. (D.W. Brauning, ed.). Univ. of Pittsburgh Press, Pittsburgh, PA.

Schutsky, R.M. 1992c. Blue Grosbeak. pp. 366-367. *In:* Atlas of Breeding Birds in Pennsylvania. (D.W. Brauning, ed.). Univ. of Pittsburgh Press, Pittsburgh, PA.

Schutsky, R.M. 1992d. Snowy Egret. pp. 54-55. *In:* Atlas of Breeding Birds in Pennsylvania. (D.W. Brauning, ed.). Univ. of Pittsburgh Press, Pittsburgh, PA.

Schutsky, R.M. 1992e. Cattle Egret. pp. 56-57. *In:* Atlas of Breeding Birds in Pennsylvania. (D.W. Brauning, ed.). Univ. of Pittsburgh Press, Pittsburgh, PA.

Serrantino, P. 1992. Northern Harrier, *Circus cyaneus*. pp. 89-117. *In:* Migratory Nongame Birds of Management Concern in the Northeast (K.J. Schneider and D.M. Pensce, eds.). U.S. Department of Interior, Fish and Wildlife Services, Newton Corner, MA.

Sibley, S.C. 1988. Common Nighthawk. pp. 214-215. *In:* The Atlas of Breeding Birds in New York State. (R.F. Andrle and J.R. Carroll, eds.). Cornell Univ. Press, Ithaca, NY.

Smith, J.L. 1980. Decline of the Bewick's Wren. Redstart 47:77-82.

Spitzer, P.R. 1989. Osprey. pp. 22-29. *In:* Proceedings of the Northeast Raptor Management Symposium and Workshop. (B.G. Pendleton, ed.). Scientific and Technical Series, No. 13. Institute for Wildlife Research, National Wildlife Federation, Washington, D.C.

Stewart, R.E. and C.S. Robbins. 1958. Birds of Maryland and the District of Columbia. North American Fauna, No. 62. U.S. Govt. Printing Office, Washington, D.C.

Stone, W.S. 1894. Birds of Eastern Pennsylvania and New Jersey. Delaware Valley Ornithological Club, Philadelphia, PA.

Stull, J., J.A. Stull and G.M. McWilliams. 1985. Birds of Erie County, Pennsylvania, Including Presque Isle. Allegheny Press, Elgin, PA.

Sutton, G.M. 1923. Notes on the nesting of the Wilson's Snipe in Crawford County, Pennsylvania. Wilson Bull. 35:191-202.

Sutton, G.M. 1928a. An Introduction to the Birds of Pennsylvania. J.H. McFarland Co., Harrisburg, PA.

Sutton, G.M. 1928b. The birds of Pymatuning Swamp and Conneaut Lake, Crawford County, Pennsylvania. Annals of the Carnegie Museum 18:19-219.

Tate, J. 1981. The blue list for 1981. American Birds 35:3-10.

Tate, J. 1986. The blue list for 1986. American Birds 40:227-36.

Terborgh, J.W. 1980. The conservation status of neotropical migrants: present and future. pp. 21-30. *In:* Migrant birds in the Neotropics: Ecology, Behavior, Distribution, and Conservation. (A. Keast and E.S. Morton, eds.). Smithsonian Inst. Press, Washington, D.C.

Tiner, R.W., Jr. and J.T. Finn. 1986. Status and Recent Trends of Wetlands in Five Mid-Atlantic States: Delaware, Maryland, Pennsylvania, Virginia and West Virginia. U.S. Fish and Wildlife Service. Region 5, National Wetlands Inventory Project and U.S. E.P.A. Region III.

Todd, W.E.C. 1904. The Birds of Erie and Presque Isle, Erie County, Pennsylvania. Annals Carnegie Museum 2:481-596.

Todd, W.E.C. 1940. Birds of Western Pennsylvania. Univ. of Pittsburgh Press, Pittsburgh, PA.

Trimble, R. 1937. Some recent developments in the Pymatuning region, western Pennsylvania. Cardinal 4:102-108.

Trimble, R. 1940. Changes in bird life at Pymatuning Lake, Pennsylvania. Annals of the Carnegie Museum 28:83-132.

Turnbull, W.P. 1869. The Birds of Eastern Pennsylvania and New Jersey. Henry Grambo and Co., Philadelphia, PA.

U.S. Fish and Wildlife Service. 1987. Migratory Nongame Birds of Management Concern in the United States: The 1987 List. U.S. Depart. Inter., Fish and Wildlife Service, Office of Migratory Bird Management, Washington, D.C.

U.S. Fish and Wildlife Service. 1988. Great Lakes Northern Great Plains Piping Plover Recovery Plan. U.S. Fish and Wildlife Service, Twin Cities, MN.

Vickery, P.D. 1991. A regional analysis of endangered, threatened, and special-concern birds in the northeastern United States. Transactions of the Northeastern Section, Wildlife Society 48:1-10.

Wallace, G.J. 1948. The Barn Owl in Michigan. Tech. Bulletin 208. Michigan State Univ., MI.

Warren, B.H. 1890. Report on the Birds of Pennsylvania. 2nd ed. Pennsylvania State Board of Agriculture, Harrisburg, PA.

Whitmore, R.C. 1977. Habitat partitioning in a community of passerine birds. Wilson Bull. 89:253-265.
Wood, M. 1979. Birds of Pennsylvania: When and Where to Find Them. (Rev. ed.). Pennsylvania State Univ., University Park, PA.

APPENDIXES

APPENDIX 1. OTC Member listing (1987-1991)

Charles Bier	Daniel Klem
Daniel Brauning	Terry Master
Margaret Brittingham	Robert Leberman
Stanley Senner	Jean Stull
Frank Gill	Robert Schutsky
Laurie Goodrich	Paul Schwalbe
Douglas Gross	Merrill Wood
Frank Haas	D. Scott Wood
Barbara Haas	Richard Yahner

The members of the first committee were: Ralph Bell, Frank Gill, John Ginaven, Joseph Grom, Robert Leberman, Jean Stull, James Stull, David Pearson, Merrill Wood, Phillips Street, Alexander Nagy, Frank Haas, and Barbara Haas.

APPENDIX 2.

SPECIES STATUS REVIEW FORM

Pennsylvania Biological Survey - Ornithological Technical Committee

This form has been developed to evaluate changes in status of native birds in Pennsylvania. Completed forms may be submitted to any member of the Ornithological Technical Committee to propose additions or changes to Pennsylvania's list of special concern birds.

SPECIES UNDER CONSIDERATION

Common Name: Current Status:

Scientific Name: Recommended Status:

REPORT SUBMITTED BY

Name: Date:

Address: Telephone:

STATUS DEFINITIONS (Abbreviated)

EXTIRPATED: Species that disappeared from Pennsylvania since 1600 but still is extant elsewhere. The OTC constrains Extirpated to having bred in Pennsylvania for at least 10 years and to having been gone from the state for 10 years.

ENDANGERED: Species in imminent danger of extinction throughout their range in Pennsylvania, if the deleterious factors affecting them continue to operate. Species listed as Extirpated and rediscovered nesting are automatically reclassified as Endangered.

THREATENED: Species that may become endangered within the foreseeable future throughout their range in Pennsylvania, unless the factors affecting them are abated.

CANDIDATE: Species that are real or potential candidates for Endangered or Threatened status; this includes species for which the listing of Endangered or Threatened status may be appropriate but for which conclusive data on biological vulnerability or threats are not currently available.

AT RISK: Although relatively abundant, species that are particularly vulnerable to certain types of exploitation or environmental modification.

RARE: Species existing in one or a few restricted geographic areas or habitats, or in low numbers over relatively broad areas of Pennsylvania.

UNDETERMINED: Species for which there is insufficient data available to provide adequate assessment, but for which populations are considered at some risk.

GUIDELINES FOR LISTING

1. Species may be considered for listing which are wild, free-ranging or naturally occurring in Pennsylvania.
2. Species listed by the U.S. Fish and Wildlife Service as Threatened or Endangered shall be listed in their respective, or higher categories.
3. Birds listed as species of Special Concern must have nested for 10 consecutive years in the state and conform to one of the definitions listed previously.

SPECIES DOCUMENTATION

1. Legal status in surrounding states and province, and estimated population

   New York

   New Jersey

   Delaware

   Maryland

   West Virginia

   Ohio

   Ontario

SPECIES DISTRIBUTION

2. Indicate the distribution

   Globally

   North America

   Pennsylvania

3. Indicate Pennsylvania's position within global range:
   central peripheral disjunct

4. Historic changes in distribution in Pennsylvania (number, locality, regularity, and confidence of reports).

   Historic (before 1940)

   Recent (since 1940 until present)

POPULATION SIZE AND TRENDS

5. Relative abundance within Pennsylvania and across range (circle one from each column):

Within PA	*Throughout*
Abundant	Abundant
Common	Common
Locally common	Locally common
Uncommon	Uncommon
Rare	Rare

6. Number of Breeding Bird Atlas blocks (1983-89) the species was reported in:

   Number of counties in which probable or confirmed breeding was documented:

7. Indicate the number of average individuals of this species per Breeding Bird Survey route in PA:

   Number of routes recording species:

   Population trend (% change per year) Significance level:

   Are there other population trend data available? Identify sources and indicate trend information:

   Date source: Declining

   Stable

   Increasing

   Unknown

8. Current Abundance (estimate the number of breeding individuals or size of area occupied):

   Identify data sources.

   If this species is *not* monitored by any current survey, why not?

HABITAT FEATURES IN PENNSYLVANIA

9. Breeding habitat (circle):

Forest	Forested wetland	Urban
Scrub/shrub	Scrub/shrub wetland	
Grassland	Emergent wetland	

   Describe specific habitat used:

10. Habitat losses in recent past (over past 50 yrs.) (amount and location):

11. Probable habitat losses in future (amount, location and type)

12. Current protection status of occupied habitat:

    Comments

    Unknown

    Believed to be none protected

    At least one location protected

    Several locations protected

    Many or most locations protected

    Other (explain)

13. Area sensitivity:

    Area sensitive

    Area neutral

    Edge

POPULATION BIOLOGY
(Provide documentation or citation where possible)

14. Population threats (Contaminants, predation, competition, disease, direct disturbance from recreation, collection, harvest, etc.) (identify one):

    Degree of threat

    Very threatened, species directly exploited or threatened by natural or man-caused forces

    Moderately threatened

    Little threat, self

    Unknown

    Documentation and Comments

15. What is this species' tolerance to human activity?

    Sensitive

    Fairly resistant

    Tolerant

    Unknown

16. Identify reproductive parameters:

    Age to sexual maturity

    Annual reproductive potential (including double-broodedness)

    Reproductive life-span

    Other factors

17. Reproductive status and stability in Pennsylvania:

Reproduces in Pennsylvania? Y N

In how many of the following years:

past 2 years

past 10 years

past 15 years

Does not breed or is migratory

TAXONOMIC STATUS

18. Taxon uniqueness:

Polytopic species (subspecies)

Monotypic species in a polytopic genus

Monotypic species in a monotypic genus

Monotypic species in a monotypic family

19. Security of taxonomic units (relative threats to closely related species):

No closely related species are rare

More than one subspecies is rare

More than one species within genus is rare

20. Additional documentation:

21. Attachments:

Narrative

Relevant reports or papers

List of literature cited

Submitted to: Date:

Journal of the Pennsylvania Academy of Science 68(1): 29-33, 1994.

NEMATICIDAL COMPOUNDS FROM RAPESEED (*BRASSICA NAPUS* AND *B. CAMPESTRIS*)[1]

GEORGE N. JING[2] and JOHN M. HALBRENDT[3]

Department of Plant Pathology
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The Pennsylvania State University
Biglerville, PA 17307

ABSTRACT

Rapeseed extracts were prepared by a method for total glucosinolate extraction. These extracts were evaluated for toxicity with a bioassay using the free-living nematode *Caenorhabditis elegans* and the plant-parasitic nematode *Xiphinema americanum*. Freshly hatched juveniles (0-12 h) of *C. elegans* were assayed for mortality and development after exposure for 72 h in a dilution series with and without the addition of thioglucosidase. Extracts of seeds and foliage of different *Brassica* cultivars were evaluated and results showed a wide range of toxicity. The toxicity was cultivar and growth stage dependent. The sensitivity of *X. americanum* to the toxins facilitated the calculation of LD_{50} data which ranged from 3.46-12.76%. These data support the hypothesis that isothiocyanates and/or related compounds produced by hydrolysis of glucosinolates are responsible for the death or inhibition of nematodes.
[J PA Acad Sci 68(1):29-33, 1994]

INTRODUCTION

Plant-parasitic nematodes are economically important in agriculture because they reduce the yield and quality of food and fiber crops. In the United States the economic loss resulting from plant-parasitic nematode damage is estimated at $5.8 billion annually (Sasser, 1989). Many nematicides are suspect as environmental or human health hazards, and there is currently great interest in the development of environmentally sound alternative control measures agains plant-parasitic nematodes.

Various types of biological control and cultural practices are being studied. Crop rotation with nonhost or toxic plants to reduce nematode numbers is an old practice that is currently being reevaluated and improved as a control practice. Marigold (*Tagetes* spp.) has been shown to suppress populations of root-lesion (*Pratylenchus* spp.) and root-knot (*Meloidogyne* spp.) nematodes to levels that approximated disinfestation with a nematicide (Tyler, 1938; Slootweg, 1965; Hackney and Dickerson, 1975). Other plants that have been used for nematode control include *Asparagus* spp. (Rhode, 1960), *Crotalaria* spp. (Good et al. 1965) and *Brassica* spp. (Ellengby, 1945). Chemical analysis of these plants has identified compounds with nematicidal activity such as alkaloids, phenolics, sesquiterpenes, diterpenes, polyacetylenes, thienyl derivatives or sulfur containing compounds (Gommers and Bakker, 1988). These are secondary products of metabolism which in many cases do not have known physiological or morphological functions. This implies that some plants have evolved chemical systems to evade pathogens or pests.

Glucosinolates are sulfur-containing glycosides that are characteristic of the Brassicaceae. Plants of this family in clude oilseed rape, mustard, canola and rapeseed (henceforth referred to as rapeseed in this paper). Glucosinolates constitute a class of about 100 compounds with a common functional group and a variable side chain (R) that can be aliphatic, aromatic, or heteroaromatic (Lazzeri et al. 1993). These compounds are spatially separated in plant cells from the enzyme myrosinase (thioglucosidase). Upon tissue damage or decomposition, thioglucosidase hydrolyzes glucosinolates to produce D-glucose, a sulfate ion, and a series of compounds that may include isothiocyanates, thiocyanates, and nitriles depending on R and the pH of the medium, (Duncan, 1991). The use of Cruciferous soil amendments (green manure) to reduce populations of nematodes or fungal resting spores has produced positive results (Papavizas, 1966, 1967; Mojtahedi, 1991; Johnson et al. 1992). These reports show that some cultivars are more effective than others. However, it is not known whether glucosinolate degradation products or modification of the soil environment by the green manure are responsible for the effects. This paper provides evidence to show that glucosinolate degradation products are responsible for nematode mortality and that this effect is cultivar dependent.

[1]Received for publication 10 September 1993; accepted 8 December 1993.
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[3]Assistant Professor, The Pennsylvania State University

MATERIALS AND METHODS

Preparation of Plant Extracts

Plant extracts were prepared by a modification of the protocol used for glucosinolate extraction (Buchner, 1987). Ten grams of plant tissue (seeds, foliage, or roots) were added to 200 ml of 80% boiling methanol-water mixture and heated for 10 minutes. After cooling, the tissue was ground into a slurry using a Tissuemizer (model SDT 182, Tekmar Company, Ohio). The slurry was transferred to 25 ml plastic conical centrifuge tubes and centrifuged at 3000 x g for 10 minutes. The supernatant was concentrated by heating below 40 C on a hot plate. Volume of extract was adjusted to 1ml/g of tissue used. Extracts were prepared from seeds and 4- and 6-week-old-plants.

Preparation of Test Animals

Caenorhabditis elegans obtained from the Caenorhabditis Genetic Research Center, Columbia, Missouri was maintained on water agar and fed with three drops of yeast suspension every 4-5 days (Samoiloff, 1990). Freshly hatched first stage juveniles (250-350 μm long) were obtained by transferring gravid females onto fresh water agar plates and incubating for 12 h at 23 C in the dark. The juveniles were washed from plates with a sodium citrate buffer and transferred to autoanalysis cups for the bioassay.

Mixed stages of the plant-parasitic nematode *Xiphinema americanum* were extracted from greenhouse populations using the Baermann funnel technique (Flegg and Hooper, 1970) and collected within 18-20 h. The nematodes were held in water at 4-6 C and the bioassay performed within 48 h after collection.

The Caenorhabditis elegans Bioassay

A bioassay based on growth and development of first stage of juveniles of *C. elegans* was used to evaluate toxicity (Jing and Halbrendt, 1992). Treatments consisted of a dilution series of the rapeseed extracts in a liquid growth medium with and without thioglucosidase (activity: 1.0 μ mole glucose from sinigrin per minute at pH 6.0 and 25 C). The tests were performed in autoanalysis cups (1 ml) with 12 nematodes per cup and eight cups per dilution. Four of the replicate treatment cups were treated with 60 μl of 10 mg/ml of thioglucosidase and the others were left untreated. The growth medium alone, growth medium plus solvent, and growth medium plus thioglucosidase served as controls. Cups were incubated in the dark at 23C for 72 h.

Nematodes were assayed for mortality by visual observation and counting. Death was defined as total lack of movement in response to a probing needle. Live nematodes were heat killed at 45 C and length measurements of 10 individuals from each cup were made at 80x with the aid of video imaging software on a MacIntosh II Computer. Data were evaluated by an analysis of variance (Turkey - Kramer, P =.05).

The Xiphinema americanum Bioassay

Sensitivity of the plant parasitic nematode, *X. americanum* to extracts was evaluated by preparing an extract dilution series with 50 mM sodium citrate buffer (pH 5.5). Nematodes were distributed into autoanalysis cups in same manner as with *C. elegans.* For each concentration, 12 cups of 10 nematodes each were prepared. Six cups were treated with thioglucosidase and the remaining six were not. The cups were incubated at 23 C for 36 h in the dark. Controls included buffer alone and buffer plus thioglucosidase. The number of dead nematodes were determined using the same method as for *C. elegans* at the end of 36 h. Mortality data were analyzed using a POLO-PC program (LeOra Software, Berekeley, California) that converts dosage response data to probits. The lethal dose that killed 50% of the nematodes (LD_{50}) and slopes of the dosage response curves were then compared.

RESULTS

Effects of Rapeseed Extracts on Caenorhabditis elegans

All extracts killed *C. elegans* at high concentrations but low concentrations killed or inhibited development only when treated with thioglucosidase (Tables 1, 2, 3). At very dilute concentrations there were no differences in nematode development regardless of addition of thioglucosidase. The enzyme or solvent alone had no toxic effect on the nematodes.

Caenorhabditis elegans has a rapid life cycle and develops from egg to sexually mature adult in 3 days at 23 C. In response to rapeseed extracts, *C. elegans* development was arrested at different stages depending upon the rapeseed cultivar and the concentration. The resulting development categories provided a convenient system for evaluating toxicity of the extracts.

Freshly hatched juveniles (0-12 h) ranged from 250-350 μm long. After 72 h, the following observations were made on nematodes in extracts treated with thioglucosidase. All nematodes which measured less than 400 μm long were dead. Those which ranged from 400-500 μm, were dead or poorly developed and slow moving. Nematodes which measured 550-850 μm were active but only about a fifth of these were capable of reproduction. Those above 850 μm in length appeared healthy and reproduced.

Results showed that toxicity varied with plant growth stage. Extracts from seeds were the most toxic followed by 6- and 4-week-old plants. The order of toxicity differed for the cultivars at different growth stages. At 6 weeks, extract from cultivar 'Humus' was the most toxic followed by 'Westar', 'Liborius', Wild Mustard, 'Parkland' and 'Tobin' (Table 2). The toxicity of seed extracts decreased according to the following sequence, Humus, Westar, Liborius, Tobin, Wild Mustard and Parkland (Table 3).

Toxicity of Rapeseed Extracts to Xiphinema americanum

Xiphinema americanum was more sensitve to rapeseed toxin than *C. elegans.* The LD_{50} of extract at a 95% confidence interval differed for cultivars and plant growth stages (Table 4). The concentrations ranged from 0.85%-3.30% extract for seeds, 3.46%-12.76% for six-week-old foliage and 6.27%-17.41% for 4-week-old foliage (Table 4). For each cultivar, the slope of the mortality curve increased while the corresponding LD_{50} decreased with growth stage (4-week-old, 6-week-old, and seed). Cultivar Humus was always the most toxic as indicated by the steepest slope (47.6, 15.04, 10.52 for seeds, 6-week, and 4-week old foliage respectively) and the lowest $LD_{50}s$ (0.88, 3.46, 6.27 for seed, 6-week and 4-week-old foliage respectively).

DISCUSSION

Plant extracts were prepared by a method for glucosinolate extraction in which endogenous thioglucosidase was denatured by heating. Evidence that glucosinolates were the compounds present in extracts was provided by the fact that extracts only became toxic when a commercial preparation of thioglucosidase was added. Nematode mortality at high extract concentration appeared to be a consequence of high osmotic strength of the medium rather than toxic activity. This same effect was observed when nematodes were assayed against corn extract which is not known to be nematicidal (data not shown).

Glucosinolates are not known to be biochemically active but hydrolysis by thioglucosidase results in production of various active decomposition products including D-glucose, sulfate, isothiocyanates, nitriles, thiocyanates, and other toxic compounds (Fenwick et al. 1983; Vierheilig and Ocampo, 1990). The isothiocyanates (ITC) are the most toxic of the glucosinolate degradation products, having general biocidal properties as a result of interaction with proteins (Wood, 1975; Kawakishi and Kaneko, 1987). Metham-Sodium (Sodium N-methyldithiocarbamate) a commercial pesticide degrades in soil to produce a related compound, methyl isothiocyanate (Miller, 1988) which is used as a soil fumigant and is capable of providing complete soil sterilization. Our data supports the hypothesis that, isothiocyanates and/or related compounds produced by hydrolysis of glucosinolates are responsible for the death and/or growth inhibition of nematodes in these bioassays.

It is thought that plants evolved the glucosinolate-thioglucosidase system as a defense mechanism to deter pathogens and pests. Of over 100 known glucosinolates

TABLE 1. Mean lengths (μm) of *Caenorhabditis elegans* after incubation of first stage juveniles for 72 h at 23 C in concentrations of extracts from four-week-old *Brassica* foliage with and without the addition of thioglucosidase.

Extract Concentration	CULTIVAR											
	Humus		Westar		Liborius		Mustard		Parkland		Tobin	
(% v/v)	+Enzy	−Enzy	+Enzy	−Enzy	+Enzy	−Enzy	+Enzy	−Enzy	+Enzy	−Enzy	+Enzy	−Enzy
20	320.7†	316.8a	317.1a	312.9a	312.8a	315.5a	314.9a	317.9a	315.1a	316.5a	313.9a	316.3a
10	324.1a	467.0b	359.8b	991.1d	539.8b	988.8d	536.3b	1000.0d	534.5b	987.1d	449.6b	985.0d
6.7	999.4d	997.9d	997.3d	1006.6d	997.6d	992.2d	1005.9d	1010.0d	989.9d	1000.5d	996.1d	987.5d
S.C.*	924.9c	937.7c	924.9c	937.7c	924.9c	937.7c	924.9c	937.7c	924.9c	937.7c	924.9c	937.7c

† Means of 40 measurements, four replications each with 10 nematodes. Means within each column and between the two rows for each cultivar followed by the same letter are not significantly different ($p < 0.05$) according to the Tukey-Kramer test. Only means for the lowest concentration that stopped nematode development as first stage juveniles to means of the highest concentration in which nematodes reproduced have been reported.
*S.C. = Solvent Control

TABLE 2. Mean lengths (μm) of *Caenorhabditis elegans* after incubation for 72 h at 23 C in concentrations of extracts from six-week-old *Brassica* foliage with and without the addition of thioglucosidase.

Extract Concentration	CULTIVAR											
	Humus		Westar		Liborius		Mustard		Parkland		Tobin	
(% V/V)	+Enzy	−Enzy	+Enzy	−Enzy	+Enzy	−Enzy	+Enzy	−Enzy	+Enzy	−Enzy	+Enzy	−Enzy
20	316.44a	317.21a	312.78a	313.70a	312.90a	315.07a	314.14a	314.69a	313.61a	314.56a	314.25a	324.56a
10	314.46a	505.51c	315.83a	1003.6d	314.80a	998.86e	314.96a	992.95c	528.60b	983.28e	316.62a	992.77d
6.7	316.21a	970.91de	322.08a	998.15d	494.73b	1001.5e	993.22c	978.73c	992.64e	976.88de	521.76b	992.35d
5.0	316.62a	968.17de	521.76b	989.72d	994.45e	978.67e	—	—	—	—	—	—
4.0	427.01b	966.31de	996.15d	983.28d	—	—	—	—	—	—	—	—
3.3	532.12c	985.04ef	—	—	—	—	—	—	—	—	—	—
2.9	1004.93f	1006.48f	—	—	—	—	—	—	—	—	—	—
S.C.*	944.38d	952.24d	944.38c	952.24c	944.38c	952.24cd	944.38b	952.24b	944.38c	952.24cd	944.38c	952.24c

† Means of 40 measurements, four replications each with 10 nematodes. Means within each column and between the two rows for each cultivar followed by the same letter are not significantly different ($p < 0.05$) according to the Tukey-Kramer test. Only means for the lowest concentration that stopped nematode development as first stage juveniles to means of the highest concentration in which nematodes reproduced have been reported.
* S.C. = Solvent Control
— = Extracts tested at these concentations were not significantly different from the last data set (excluding the S.C.) within each column.

identified from the Brassicaceae, about 30 have been characterized in rapeseed (Fenwick et al. 1983; Larson, 1980). In this study, differences in the activity of extracts (or glucosinolates) were cultivar and growth stage dependent. These differences may be due to the amount and/or type of glucosinolates present in the different cultivars and growth stages. Evidence for variation in glucosinolate profiles has been reported in the literature (Sang et al. 1984). A recent study on glucosinolates and their reaction products showed that very minor structural differences in glucosinolates tested caused profound differences in nematicidal activity (Lazzeri et al. 1993). Such structural differences are the result of modifications in the amino acid-derived side chains. For example, indolyl glucosinolates derived from tryptophan will react differently from allyl glucosinolates derived from methionine.

The LD_{50} is the concentration of extract required to kill 50% of the nematodes under test while the slope of the dosage response curve shows the nematode inhibition properties of the extract under conditions of changing dosage. A steep slope indicates that a small increase in dose leads to a considerable increase in nematode mortality. Therefore the extract with the smallest LD_{50} value and the steepest slope is the most toxic. From the results presented in Tables 1-4, enzyme treated extracts from *Brassica napus* cv. Humus were the most toxic. Analysis of the glucosinolate content of the seeds showed that Humus has the highest concentration of glucosinolates (ca. 78 μmol/g seed).

This research shows that nematicidal compounds are produced by the action of thioglucosidase on rapeseed extracts. This is strong evidence that glucosinolates are involved.

Quantification and characterization of glucosinolates and their degradation products may provide a means of selecting rapeseed plants that can be used effectively to control nematodes. Presumably the incorporation of rapeseed into the soil as a green manure will provide greater nematode control than a rotation crop since it is the decomposition products which are toxic. Current field studies will determine if this practice can serve as a practical alternative to synthetic nematicides for control of plant-parasitic nematodes.

TABLE 3. Mean lengths of *Caenorhabditis elegans* (μm) after incubation for 72 h at 23 C in concentrations of extracts from *Brassica* seeds with and without the addition of thioglucosidase.

	CULTIVAR											
Concentration	Humus		Westar		Liborius		Mustard		Parkland		Tobin	
(% V/V)	+Enzy	−Enzy	+Enzy	−Enzy	+Enzy	−Enzy	+Enzy	−Enzy	+Enzy	−Enzy	+Enzy	−Enzy
3.3	—	—	—	—	—	—	—	—	317.9a†	318.7a	—	—
2.5	—	—	—	—	315.5a	317.4a	319.5a	322.1a	325.8a	474.9b	310.4a	314.5a
2.0	—	—	311.1a	315.5a	323.8a	470.3c	321.5a	471.7c	564.1c	997.0e	337.0b	700.3c
1.67	311.1a	315.5a	325.2a	485.6c	350.3a	684.7e	399.0b	986.7e	1000.7e	1005.3e	398.8b	991.5e
1.43	320.0a	466.6c	408.5b	1001.6e	401.1b	1003.1g	992.7e	988.7e	—	—	380.4b	987.8e
1.25	340.6a	719.7e	544.3d	988.7e	568.6d	997.4g	—	—	—	—	994.7e	996.6e
1.10	338.1a	985.0g	1001.4e	1008.3e	1004.0e	1010.4g	—	—	—	—	—	—
1.0	387.5b	986.1g	—	—	—	—	—	—	—	—	—	—
0.91	563.4d	988.6g	—	—	—	—	—	—	—	—	—	—
0.83	990.6g	995.7g	—	—	—	—	—	—	—	—	—	—
S.C.*	921.0f	914.5f	932.0e	914.5e	932.0f	914.5f	932.0d	914.5d	932.0d	914.5d	932.0d	914.5d

† Means of 40 measurements, four replications each with 10 nematodes. Means within each column and between the two rows for each cultivar followed by the same letter are not significantly different (p<0.05) according to the Tukey-Kramer test. Only means for the lowest concentration that stopped nematode development as first stage juveniles to means of the highest concentration in which nematodes reproduced have been reported.
* S.C. = Solvent Control
— = Extracts tested at these concentations were not significantly different from the previous or next data set (excluding the S.C.) within each column.

TABLE 4. Effect of various rapeseed extracts treated with thioglucosidase on the mortality of *Xiphinema americanum*.

	Four-week old plant				Six-week old plant				Seeds			
Cultivar†	n*	c#	Slope@ (±SE)	LD50,% (95% CL)	n*	c#	Slope@ (±SE)	LD50,% (95% CL)	n*	c#	Slope@ (±SE)	LD50,% (95% CL)
Humus	180	0	10.52ab	6.27	300	1	15.04ab	3.46	360	2	47.60d	0.85
			(1.41)	(5.99-6.62)			(1.50)	(3.36-3.58)			(4.56)	(0.84-0.86)
Liborius	180	1	9.13ab	7.00	240	2	8.56a	6.35	420	1	28.7c	1.19
			(1.11)	(6.52-7.52)			(0.89)	(5.84-6.94)			(2.46)	(1.17-1.21)
Tobin	180	2	6.12a	17.41	180	1	6.65a	11.66	420	0	19.04b	1.39
			(1.05)	(15.53-19.67)			(0.80)	(10.65-12.83)			(1.59)	(1.37-1.42)
Westar	180	0	6.41a	13.78	180	2	10.81ab	8.07	420	0	15.57ab	1.36
			(0.74)	(12.27-15.69)			(1.30)	(7.49-8.74)			(1.28)	(1.33-1.39)
Mustard	180	0	7.65a	12.27	180	1	9.21ab	12.76	420	2	11.72ab	2.35
			(0.85)	(11.19-13.63)			(1.37)	(11.58-14.00)			(1.46)	(2.25-2.44)
Parkland	—	—	—	—	—	—	—	—	360	2	10.44ab	3.30
											(0.98)	(3.17-3.44)

† Extracts from different cultivars of rapeseed (*B. napus* = Humus, Westar, Liborius; *B. campestris* = Tobin and Parkland; Mustard = wild mustard
* Number of nematodes tested
\# Control mortality out of 60 nematodes
@ Values followed by the same letter are not significantly different ($P \leq 0.05$) according to the Tukey Kramer test

ACKNOWLEDGEMENT

We gratefully acknowledge financial support from the Pennsylvania Academy of Science.

REFERENCES

1. Buchner, R. 1987. Comparison of procedures for optimum extraction, purification and analysis of desulfindolyl glucosinolates. In J.P. Wathelet (ed.). Glucosinolates in rapeseed: Analytical Aspects. Matinus Nijhoff Pub., page 76.
2. Duncan, A.J. 1991. Glucosinolates. In: Toxic substances in crop plants. J.P. Felix D'Mello, C.M. Duffers and J.H. Duffs, eds. The Royal Society of Chemistry, page 127.
3. Ellengby, C. 1945. The influence of crucifers and mustard oil on the emergence of larvae of the potato root ellworm, *Heterodera rostochiensis* Wollen. Annals of Applied Biology, 32:67-70.
4. Fenwick, G.R., R.K. Heany and W.J. Mullin. 1983. Glucosinolates and their breakdown products in food and food plants. CRC. Critical Review in Food Science and Nutrition, 18:123-201.
5. Flegg, J.J.M. and D.J. Hooper. 1970. Extraction of free-living stages from soil. In: Laboratory Methods for work with Plant and Soil Nematodes, J.F. Southey, ed., page 5.
6. Good, J.M., N.A. Minton and C.A. Jaworki. 1965. Relative susceptibility of selected cover crops and coastal bermudagrass to plant nematodes. Phytopathology, 55:1026-1030.
7. Gommers, J.F. and J. Bakker. 1988. Physiological diseases induced by plants responses or products. In: Diseases of Nematodes, G.O. Poiinar, Jr. and H.B. Jansson, eds. CRC press, 1:3-22.
8. Hackney, R.W. and O.J. Dickerson. 1975. Marigold, Casto bean, and Chrysanthemum on controls of *Meloidogyne incognita* and *Pratylenchus alleni.* J. Nematology, 7:84-90.
9. Jing, G.N. and J.M. Halbrendt. 1992. Evaluation of rapeseed extract toxicity using a *Caenorhabditis elegans* bioassay. Journal of Nematology, 24:600-601. (Abstr.)
10. Johnson, A.W., A.M. Golden, D.L. Auld and D.R. Summer. 1992. Effects of rapeseed and vetch as green manure crops and fallow on nematodes and soilborne pathogens. Journal of Nematology, 24:127-132.
11. Kawakishi, S. and T. Kaneko. 1987. Interaction of proteins with allyl isothiocyanates. Journal of Agriculture and Food Chemistry, 35:85-88.
12. Larson, P.O. 1980. Glucosinolates. In: Stumpf P.K. Tolbert, N.E. Conn., E.E. (eds.). The Biochemistry of plants. Academic Press, N.Y., 7:501-525.
13. Lazzeri, L., R. Tacconi and S. Palmieri. 1993. In vitro activity of some glucosinolates and their reaction products towards a population of the nematode *Heterodera schachtii*. Journal of Agricultural and Food Chemistry, 41:825-829.
14. Miller, D.B. 1988. Determination of methylisothiocyanate by HPLC trapping and derivatization procedure. LC-GC, 6:842-846.
15. Mojtahedi, H., G.S. Santo, A.N. Hang and J.H. Wilson. 1991. Suppression of root-knot nematode populations with selected rapeseed cultivars as green manure. Journal of nematology, 23:179-1174.
16. Papavizas, G.C. 1966. Suppression of Aphanomyces root rot of peas by cruciferous amendments. Phytopathology 56:1071-1075.
17. Papavizas, G.C. 1967. Comparison of treatments suggested for control of Aphanomyces root rot of peas. Plant Disease Reporter, 51:125-127.
18. Rohde, R.A. 1960. Acetylcholinesterase in plant-parasitic nematodes and anticholinetterase from *Asparagus.* Proceedings of the Helminthological Society of Washington, 27:121-123.
19. Samoiloff, M. 1990. The nematode toxicity assay using *Panagrellus redivivus.* Toxicity Assessment: An International Journal, 5:309-318.
20. Sang, J.P., I.R. Muchinton, P.K. Johnstone and R.W. Truscott. 1984. Glucosinolates profiles in seed, root and leaf tissue of cabbage, mustard, rapeseed, raddish and Swede. Canadian Journal of Plant Science, 64:77-93.
21. Sasser, J.N. 1989. Plant Parastic Nematodes: The Farmer's Hidden Enemy. University Graphics, North Carolina State University, Raleigh, NC, 115 pp.
22. Slootweg, A.F. 1965. Root rot of bulbs caused by *Pratylenchus* and *Hoplolaimus* spp. Nematologica, 1:192-201.
23. Tyler, J. 1938. Proceedings of the root-knot nematode held at Atlanta, Georgia. Plant Disease Reporter, 109:133.
24. Vierheilig, H. and J.A. Ocampo. 1990. Effects of isothiocyanates on germination of spores of *Glomus mosseae.* Soil Biology and Biochemistry, 22:1161-1162.
25. Ward, J.T., W.D. Basford, J.H. Hawkins and J.M. Hollday (ed.). 1985. The choice of a combinable break crop. In: Oilseed Rape. Farming Press Ltd. Iswich, Suffolk, 1-28.
26. Wood, J.L. 1975. Biochemistry. In: A.A. Newman (ed.). Chemistry and Biochemistry of Thiocyanic Acid and its Derivatives. Academic Press, London, 156-221.

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BIOLOGY OF SUBYEARLING CARP (*CYPRINUS CARPIO*) IN THE JUNIATA RIVER, PENNSYLVANIA[1]

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ABSTRACT

We examined aspects of the early life history of carp (*Cyprinus carpio*) in the Juniata River, Pennsylvania. Subyearling carp were found only during one year, 1991, in four years of extensive sampling on the Juniata River. Carp reproduction in the Juniata River may be minimal during some years and may be enhanced by low flows during late spring. Subyearling carp occupied shallow areas with low flow and were associated with submergent vegetation. In June, the growth of subyearling carp exceeded one millimeter per day. Chironomids were the major food consumed during both day and night periods. Subyearling carp were piscivorous since larval American shad (*Alosa sapidissima*) and larval cyprinids comprised a small portion of their diet. Significantly fewer stomachs were empty during the day than at night suggesting that subyearling carp are principally diurnal feeders.

[J PA Acad Sci 68(1):34-36, 1994]

INTRODUCTION

Carp (*Cypinus carpio*), a native of Asia and possibly eastern Europe (Panek 1987), were first introduced into North America in 1876 (Fritz 1987). By 1885, carp had become sufficiently abundant in some waters to support commercial fisheries (Fritz 1987). Presently carp are widely distributed below the 50th parallel in North America (Allen 1980). In Pennsylvania, carp are common throughout the major watersheds but occur less frequently toward the headwaters (Cooper 1983). Carp occur in much of the Susquehanna River basin and the state record (23.6 kg) was taken in the Juniata River. Though common in Pennsylvania, little information exists on the biology of carp in this region. As a contribution to a better understanding of the early life history of the carp in Pennsylvania, we examined aspects of habitat use, growth, and diel feeding of subyearling carp in the Juniata River, a major tributary (about 8,700 km^2) of the Susquehanna River.

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MATERIALS AND METHODS

Extensive sampling was conducted in a variety of habitats in the Juniata River from 1989 to 1992, in a 35 km reach from above Thompsontown (Juniata County) to below Amity Hall (Perry County), Pennsylvania. The river is about 150 m wide in this area and averages 1 m in depth. Seining and electrofishing collections from 1989 to 1992 yielded subyearling carp only in 1991, near Thompsontown. Collections were made in late spring during the day (1300-1500 hours) and at night (2300-0030 hours). Specimens were preserved in 10% formalin in the field and transferred to 70% ethyl alcohol after 2 weeks.

The total length (millimeters) of each fish was recorded prior to stomach analysis. Food items were identified under microscopic examination. Aquatic macroinvertebrates were identified to family and terrestrial invertebrates to order using a dissecting microscope (power 7x - 60x). The relative contribution of each prey group was determined on the basis of dry weight. This involved drying a representative number of each prey group for 24 hours at 105°C. The dietary composition of subyearling carp was determined for both day and night periods. Similarity in diet of carp between day and night periods was examined using the equation of Morisita (1959) and Horn (1966). Chi-square analyses ($P<0.05$) were used to determine whether the percent of empty stomachs differed by time of day.

RESULTS

We collected 486 subyearling carp during late spring in 1991. The water temperatures in the Juniata River at this time ranged from 21° to 30°C. The subyearling carp were in shallow nearshore areas with little or no flow. Almost all carp (> 90%) were associated with submergent vegetation. Carp averaged 17 mm when first collected on May 31 (Table 1) and by mid-June averaged almost 39 mm in length. Growth rate (mm/d) calculated for successive 18-d intervals averaged 1.22 mm/d (Table 1).

The diets of 377 subyearling carp from both day (158) and night (219) periods were examined. During both periods chironomid larvae dominated the diet of carp (Table 2). Chironomid larvae composed 84.8% of the diurnal diet and 78.2% of the nocturnal diet of subyearling carp. Chironomids (i.e., larvae, pupae, adults) contributed 93.7% of the diurnal diet and 83.4% of the nocturnal diet. Fish larvae, American shad (*Alosa sapidissima*) and cyprinids, comprised 3.4% of the diurnal diet and 1% of the nocturnal diet of carp (Table 2). The percent of empty stomachs of subyearling carp during the night (40.6%) was significantly different ($P<0.05$) than during the day (16.5%). Diet overlap between diurnal and nocturnal periods was 0.99.

TABLE 1. Growth information on 486 subyearling carp collected during late spring in the Juniata River, Pennsylvania.

Date	No. of fish	Average total length (mm)	Range	Daily growth increment (mm/d)
05-31-91	18	17.0	13-21	1.35
06-04-91	139	22.4	14-33	1.03
06-07-91	275	25.5	15-36	0.88
06-11-91	34	29.0	18-40	1.63
06-17-91	20	38.8	28-53	

TABLE 2. Percentage dry weight dietary composition of 377 subyearling carp in the Juniata River, Pennsylvania in late spring during day (n = 158) and night (n = 219) periods.

Aquatic taxon	Dry weight (%) Dry	Night
Oligochaeta	1.4	—
Hydracarina	—	2.6
Ostracoda	—	0.8
Plecoptera		
Perilidae	0.4	—
Ephemeroptera		
Heptageniidae	—	0.8
Unidentified	—	2.2
Tricoptera		
Hydropsychidae	—	2.2
Leptoceridae	0.6	0.9
Unidentified	—	2.2
Hemiptera		
Corixidae	—	0.6
Diptera		
Chironomidae (L)	84.8	78.2
Chironomidae (P)	2.3	0.8
Chironomidae (A)	6.6	4.4
Heleidae	0.5	1.7
Teleostei		
Alosa sapidissima (L)	2.8	1.0
Cyrininidae (L)	0.6	—
Terrestrial taxon		
Coleoptera	—	0.8
Diptera	—	0.8

L = Larvae; P = Pupae; A = Adult

DISCUSSION

Our yearly sampling included the use of two gear types in numerous habitats throughout the 35 km reach of the Juniata River. Consequently, it was surprising that subyearling carp were collected only in 1991. It is possible that carp reproduction is minimal during some years in the Juniata River. Subyearling smallmouth bass (*Micropterus dolomieu*) were found in the same habitat as subyearling carp in 1991. Although subyearling smallmouth bass were collected during each year (1989-1992), their numbers were considerably higher in 1991 than in other years, indicating greater spawning success. It is possible that river conditions, which led to greater spawning success by smallmouth bass in 1991, also benefited carp reproduction. Low discharges in the Juniata River in spring may favor spawning success by carp and smallmouth bass. Mean daily discharge during May 1991 was less than the other years and represented only 28% of the 1989 discharge, 52% of the 1990 discharge, and 92% of the 1992 discharge (U.S. Geological Survey 1989-1992).

The habitat used by subyearling carp in the Juniata River is similar to that previously reported for the species. Becker (1983) reported that carp up to 76 mm use shallow, weedy habitats. The size of subyearling carp in the Juniata River in June is within the range reported for other waterbodies for the same time period. In his review of the literature, Carlander (1969) reported mean total lengths of 36, 46, and 99 mm of subyearling carp in June. Becker (1983) reported an average length of 46 mm of carp in the Wisconsin River (WI) in June.

Although considerable information exists on the food habits of adult carp, little is available on the diet of subyearling fish. Some of the available dietary information on carp was generated, at least in part, to examine the potential impacts of carp feeding activity on other fishes. Perceived problems caused by carp included competition with game fish, increased turbidity caused by carp feeding activity, and predation on the eggs of other fishes. Since these impacts would mainly be caused by adult fish, the feeding ecology of subyearling carp was seldom examined in these investigations.

The diet of 377 subyearling carp in the Juniata River in June consisted primarily of chironomids during both day and night periods. Previous investigators, who collectively examined the diets of only 230 subyearling carp, found that zooplankton (mainly copepods, cladocerans, and ostracods) was the major dietary component of subyearling carp (Greeley 1927; Moore 1952; Moen 1953; Summerflet et al.

1970). Chironomids were generally the second most common food item of carp in these studies. Summerflet et al. (1970) observed monthly variation in the diet of subyearling carp.

Piscivory by subyearling carp has previously been reported (Kudrynska 1962, as cited in Becker 1983). Although we also observed piscivory by subyearling carp on both larval American shad and cyprinids, the predation on shad larvae is somewhat misleading. Our observations on the early life history of carp were generated under the context of a study to examine predation on recently released American shad larvae in the Juniata River. Consequently, most collections of subyearling carp were made within 2 hours of the release of 245,000 to 439,000 shad larvae. Consumption of American shad larvae suggests that subyearling carp are feeding opportunistically on an abundant prey. Similar opportunistic feeding by the principally herbivorous central stoneroller (*Campostoma anomalum*) on larval American shad has previously been observed (Johnson and Dropkin 1992).

The diet overlap between day and night of subyearling carp was exceptionally high (0.99). Zaret and Rand (1971) suggested that values greater than 0.6 indicate significant overlap. Although the diet composition was nearly identical between day and night, significant differences in the number of empty stomachs of carp between day and night periods suggest that most food was consumed during the day. Prior to this study little, if any, information existed on the diel feeding activity of subyearling carp.

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LITERATURE CITED

Allen, A.W. 1980. Common carp (*Cyprinus carpio*) Linnaeus. In Lee, D.S., C.R. Gilbert, C.H. Hocutt, R.E. Jenkins, D.E. McAllister, and J.R. Stauffer, Jr., [eds.]. Atlas of North American Freshwater Fishes. North Carolina State Mus. Nat. Hist. Publ. 1980-12, 152.

Becker, G.C. 1983. Fishes of Wisconsin. The University of Wisconsin Press, Madison, WI. 1052 pp.

Carlander, K.D. 1969. Handbook of freshwater fishery biology. Volume I. The Iowa State University Press, Ames, IA. 752 pp.

Cooper, E.L. 1983. Fishes of Pennsylvania and the northeastern United States. Pennsylvania State University Press, University Park, PA. 243 pp.

Fritz, A.W. 1987. Commercial fishing for carp. In: Cooper, E.L. [ed.], Carp in North America. Am. Fish. Soc., Bethesda, MD, 17-30.

Greenley, J.R. 1927. Fishes of the Genesee region with annotated list. In: A biological Suvey of the Genesee River System. New York State Cons. Dept. Suppl. to 16th Ann. Rep. 1926, 47-66.

Horn, H.S. 1966. Measurement of "overlap" in comparative ecological studies. Amer. Natur. 100:419-24.

Johnson, J.H. and D.S. Dropkin. 1992. Piscivory by the central stoneroller (*Campostoma anomalum*). J. Penn. Acad. Sci., 66:90-1.

Kudrynska, O.I. 1962. Cannibalism among the larvae and fry of the carp. Biol. Abstr. (6):21356.

Morisita, M. 1959. Measuring of interspecific association and similarity between communities. Mem. Foc. Sci., Kyushu Univ., Ser. E. (Biology) 3:65-80.

Moen, T. 1953. Food habits of carp in northwest Iowa lakes. Iowa Acad. Sci. Proc., 60:665-86.

Moore, R.L. 1952. The food of carp, *Cyprinus carpio* Linnaeus, in some northeastern Colorado reservoirs. M.S. Thesis, Colo. State Univ., Fort Collins. 88 pp.

Panek, F.M. 1987. Biology and ecology of carp. In: Cooper, E.L. [ed.], Carp in North America. Amer. Fish. Soc., Bethesda, MD, 1-15.

Summerfelt, R.C., P.E. Mauck and G. Mensinger. 1970. Food habits of carp, *Cyprinus carpio* L., in five Oklahoma reservoirs. Proc. Ann. Conf. Southeast. Assoc. Game Fish Comm. 24:352-77.

U.S. Geological Survey. 1989-92. Water resources data for Pennsylvania, Water years 1989-92. Volume 2, Susquehanna and Potomac River basins. U.S. Geological Survey Water-Data Report, Lemoyne, PA.

Zaret, T.M. and A.S. Rand. 1971. Competition in tropical stream fishes: support for the competitive exclusion principle. Ecol. 52:336-42.

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ABUNDANCE OF COTTONTAILS AT A STATE GAME LANDS UNIT IRRIGATED WITH WASTEWATER[1]

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ABSTRACT

We captured 330 eastern cottontails (*Sylvilagus floridanus*) before and during the time secondary-treated effluent (wastewater) was applied to the Toftrees portion of State Game Lands 176, Centre County, Pennsylvania. At least 15 cottontails were captured in 7 of 9 years during 1974-1982 prior to 1983 when no wastewater was applied on the study area. After 1983, less than 15 cottontails were captured per year during 1986-1990. The percentage of juveniles in the population declined from 34 percent prior to 1983 to 20 percent after 1983. Suitable habitat for cottontails also declined because small woody stems in the understory decreased due to breakage from ice formation during winter irrigation. Increased surface water, persistent moist conditions at the forest floor, and decreased numbers of small woody stems may have adversely affected cottontail abundance.
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INTRODUCTION

The eastern portion of State Game Lands 176 near the Toftrees residential area has been used for renovating chlorinated sewage effluent (wastewater) on farm and forest environments since 1963 (Parizek et al. 1967). Wastewater was spray irrigated on 8 ha from 1963 to 1983. In 1983, the size of the affected area was increased to 150 ha that is irrigated throughout the year (Sopper 1986).

Historically, State Game Lands 176 was well known to local hunters for its cottontail population, and several previous studies on cottontails were conducted near State Game Lands 176. For example, Arnold (1950) estimated the fall population at 70 to 188 cottontails in 1948 and 145 to 196 cottontails in 1949 at a 32-ha area located approximately 1 km from the wastewater site. Neil (1951) estimated a fall population of 123 cottontails on 37 ha. Neil (1951) reported an overall capture success of 4.9 cottontails per 100 trapnights from March 1950 through March 1951.

We monitored the cottontail population because nutrients and water from wastewater irrigation could markedly alter species composition and structure of the plant community and thereby affect cottontail production. The purpose of our report is to present data on abundance, age composition, and distribution of cottontail rabbits at the wastewater-irrigated area during 1974-1990.

STUDY AREA AND METHODS

The study area was located in Centre County, 5 km northwest of State College, Pennsylvania (40° 50′ N, 77° 53′ W). The area is part of the Nittany Valley between Bald Eagle and Nittany Mountains in the Appalachian Province (Keener and Park 1986). Topography varies from gentle to moderately rolling, and elevation ranges from 360 to 450 m above sea level. Soils at the area are deep and well drained and are primarily Morrison Sandy Loam and Hagerstown Clay Loam (Parizek et al. 1967).

The regional climate has been characterized by Sopper and Richenderfer (1979) as a mixture of dry midwestern and humid eastern seaboard climates. The mean annual precipitation during 1951-1980 was 96 cm (NOAA 1985). Wastewater was applied to forests at a rate of 5 cm per week for at least 26 weeks per year throughout the spray-irrigation area.

Forests, croplands, and old fields were the principal habitat types on the study area (Figure 1). Forests were of

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mixed hardwoods and small pockets of conifers, including several plantations (Matula 1983). During the 1950's and early 1960's, primarily multiflora rose (*Rosa multiflora*), autumn olive (*Elaeagnus umbellata*), Asiatic crabapple (*Pyrus* sp.), Tartarian honeysuckle (*Lonicera tatarica*), and a variety of grasses were planted by the Pennsylvania Game Commission (Althoff and Storm 1989). Corn, oats, and alfalfa were planted and harvested by The Pennsylvania State University farm operations.

We placed 102 traps within a 32-ha rectangular area in the central part of the study area (Figure 1). This 32-ha area was not spray-irrigated with wastewater prior to 1983. However, after expansion of the spray field in 1983, the entire area has been used for wastewater irrigation.

Wooden box traps used to capture cottontails (Taber and Cowan 1971) were spaced about 30 m apart. We trapped for 20 days during each fall (Sep-Oct) from 1974 through 1990. Trap sites were classified as either forest cover (>30 m from the nearest farm-forest interface) or edge cover (≤30 m from a farm-forest interface).

Each cottontail was weighed to the nearest gram. Those weighing ≤880 g were classified as juveniles and those >880 g were classified as adults. Pelage patterns on the forehead and rump were used to identify the species (Holdermann 1978, Litvaitis et al. 1991).

Weather data were obtained from records for the State College station reported by the National Oceanic and Atmospheric Administration. These data were used to determine the average minimum monthly temperature and average total monthly snowfall for January, February, and March from 1970 through 1990. The data on frequency of capture of cottontails in farm-forest edge versus forest interior was compared using a chi-square test.

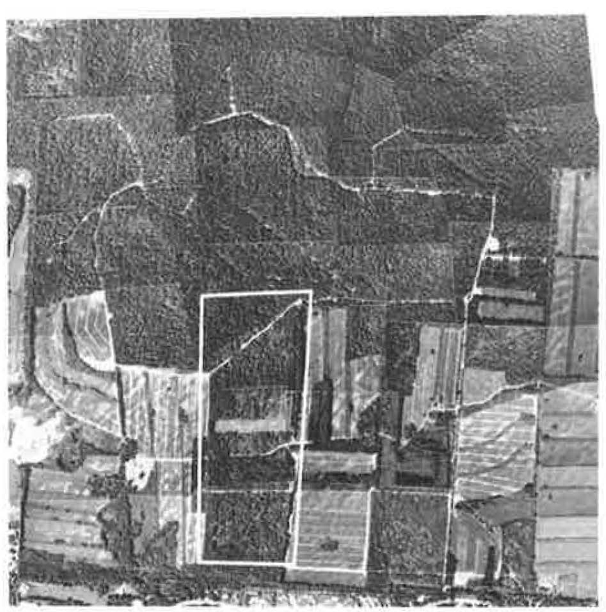

FIGURE 1. Toftrees section of State Game Lands 176 located 5 km northwest of State College, Pennsylvania; the 32-ha trapping grid is depicted by rectangle encompassed by the bold line; scale 25.4 mm = 307 m; photograph taken during September 1982 when the pipelines were in place, and 6 months before irrigation started in April 1983.

RESULTS AND DISCUSSION

The eastern cottontail was the only species of cottontail captured. We did not capture any New England cottontails (*Sylvilagus transitionalis*) even though they were captured 5 km west of the wastewater area on the Barrens section of State Game Lands 176 (G.L. Storm, unpubl. data).

The number of eastern cottontails captured during fall markedly declined from 1974 to 1990. At least 15 cottontails were captured in 7 of 9 years during 1974-1982 prior to 1983 when no wastewater was applied to the trapping site. After 1983, less than 15 cottontails were captured per year during 1986-1990 (Figure 2).

The percentage of juveniles in the population declined from 34% during a 6-year period (1977-1982) prior to irrigation to 20% during a 6-year period (1984-1989) after irrigation was initiated. These data indicated that production or survival of juveniles declined as the overall population declined. However, the total number of captures (Figure 3) and the proportion of juvenile cottontails also declined after 1983 at the Barrens study site where wastewater was not applied (G.L. Storm, unpubl. data). Other

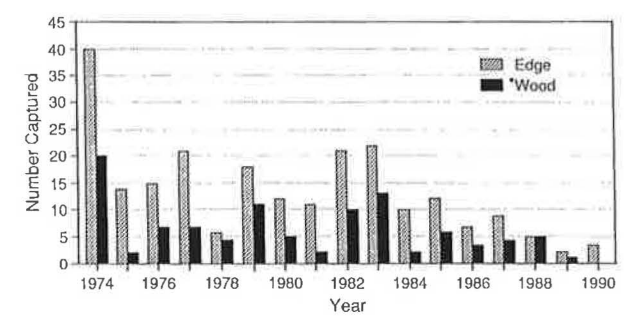

FIGURE 2. The number of eastern cottontails captured at the wastewater study area at traps located within an edge (≤30 m of a farm-forest interface) and within woods (>30 m from the nearest farm-forest interface) during fall 1974-1990.

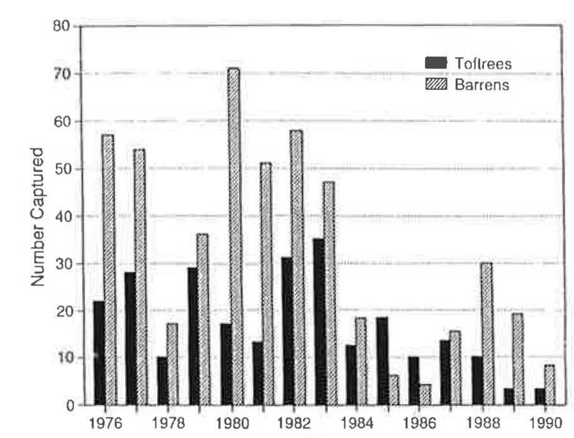

FIGURE 3. The number of cottontails captured during fall at the wastewater (Toftrees) and Barrens sections of State Game Lands 176 during 1976-1990.

factors, in addition to wastewater were apparently affecting these local populations and need to be identified to evaluate cottontail responses to ecological conditions at the wastewater site.

Fluctuations in cottontail populations are not very predictable, although high and low levels at 8- to 10-year intervals have been reported (Bailey 1968, Edwards et al. 1981). The causative factors affecting abundance of local populations are not well known. Weather, diseases and parasites, and changes in land use and habitat are cited as major factors affecting cottontail abundance (Storm and Shope 1989). Recent (1980 to present) changes in land use in the landscapes surrounding State Game Lands 176 due to increased urban development have been dramatic. However, research is needed to determine if changes at the landscape level markedly influence wildlife populations on gamelands in central Pennsylvania.

Our study was not designed to determine cause and effect relationships between cottontail abundance and climatic conditions. Except for 1978, climatic conditions did not appear to affect cottontail abundance during some years. The highest amount of snowfall and the lowest temperature during 1974-1990 occurred in winter (Jan-Mar) of 1978 (Figure 4). The weather conditions in winter of 1978 coincided with low cottontail abundance during fall 1978 at our study site (Figure 2), and a reported low number of cottontails harvested by hunters in Pennsylvania (Shope 1989).

The amount of snowfall, especially in late winter and early spring, may reduce production by eliminating the first litters in spring (Havera 1973). Applegate and Trout (1976) reported above normal rainfall adversely affected survival of first litters during spring. Normal or below normal rainfall early in the breeding season is considered a positive condition for rabbit production (E.C. Soutierre, Remington Farms, pers. commun.). However, prolonged periods of drought in summer may adversely affect reproduction by young-of-year, and may even terminate breeding (Sheffer 1957).

The quality of habitat for cottontail production apparently declined during our study. Fo example, the amount of surface water increased from 3.8 ha in 1983 to 5.1 ha in 1990 (Figure 5 and 6). This increase in surface water may not be significant given the total area (150 ha) of the spray field. However, the majority of the surface water that

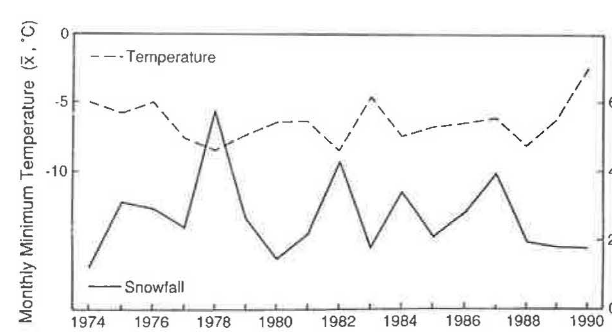

FIGURE 4. Minimum temperature and total snowfall during winter of 1974 through 1990; based on average for January, February, and March.

developed after 1983 occurred within our trapping grid (Figure 6). Whether the increase in surface water had a marked effect on rabbit production is not known.

Because newborn cottontails are reared in depressions extending 13 cm below the ground surface (Merritt 1987), steady application of wastewater and moist conditions at ground level may adversely affect production. However, data are not available to support or refute such a relationship between microhabitat and cottontail production. Whether adult females constructed nests in areas bordering the irrigated area, or selected small isolated sites without pipelines was not determined during the present study. Further research is warranted to determine if nests constructed by pregnant females and survival of young cottontails are adversely affected by the wastewater irrigation system.

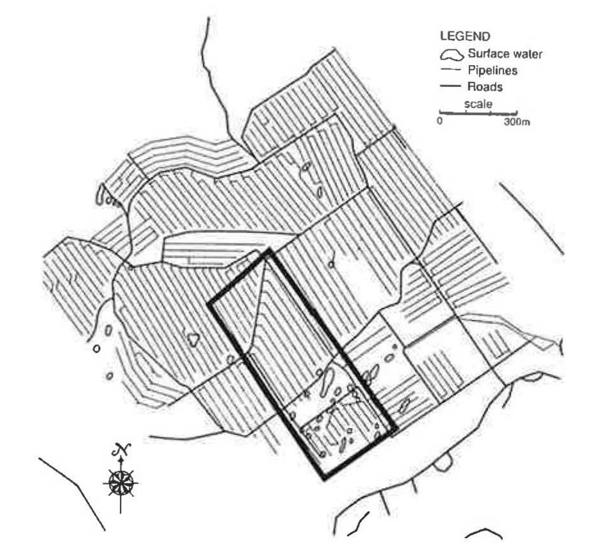

FIGURE 5. The size and distribution of surface water areas at the wastewater study area prior to 1983; 32-ha trapping grid is depicted by rectangle encompassed in bold line.

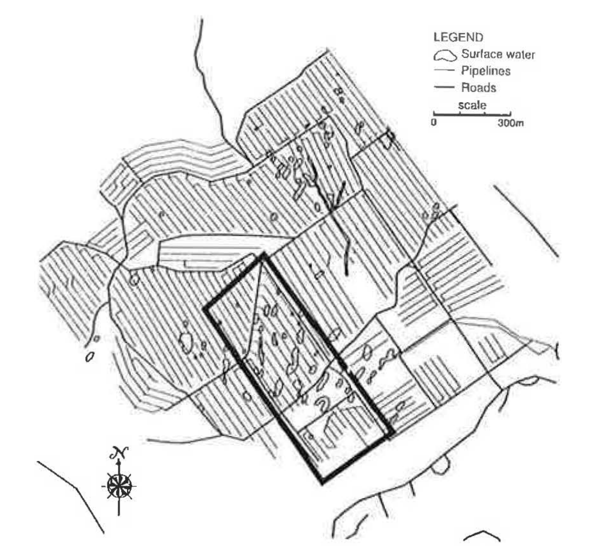

FIGURE 6. The size and distribution of surface water areas at the wastewater study area after 1983; 32-ha trapping grid is depicted by rectangle encompassed in bold line.

Small woody vegetation in the forest understory declined in areas irrigated with wastewater. Studies conducted prior to 1983 on small (1 to 2 ha) plots by Dressler and Wood (1976) and Lewis and Samson (1981) indicated a reduction in small woody stems due to ice damage in winter. Since 1983, the loss of small woody stems to breakage from ice during winter irrigation has been confirmed at our study area. Mastrota et al. (1989) reported that the density of understory trees and shrubs was lower on irrigated than non-irrigated sites. Rollfinke and Yahner (1990) reported that the number of woody stems <2.5 cm in diameter was 3 times lower on irrigated compared to non-irrigated sites. This reduction in small woody trees and shrubs due to breakage from ice, along with general aging of the forest, has resulted in less suitable habitat for a species that is adapted to landscapes with grassy fields and young woody plant communities.

The number of cottontails captured in traps located at or near a farm-forest edge was higher (X^2 = 48.10, 1 df, $P < 0.001$) than at traps located within a forest. This difference held for each year except during 1988 when only 5 cottontails were captured in each category (Figure 2). Only 3 cottontails were captured during fall 1990 and all were caught at the farm-forest edge.

CONCLUSIONS

Abundance of eastern cottontails at the wastewater area declined to low levels following expansion of the spray field in 1983. Except for 1978, changes in cottontail abundance did not appear to be markedly affected by weather. The decline in abundance during the fall of 1978 occurred after a prolonged period of snow cover and low temperature during January, February, and March of 1978.

Suitable habitat for cottontails declined during the present study. The increase in surface water and the persistent moist conditions at the forest floor throughout the area may adversely affect cottontail production. And, a decline in small woody stems due to breakage from ice during irrigation in winter may continue to reduce suitable habitat for cottontails. However, cause and effect relations between cottontail abundance and habitat conditions at the ground and understory strata were not elucidated during our study.

Whether cottontail production could be restored to former (before 1983) levels by maintaining more young plant communities in the wastewater area is currently not known. This question could be addressed by harvesting trees under a prescribed silvicultural program, and by long-term monitoring of cottontails. Our research on cottontails at the Barrens section of State Game Lands 176 indicated that 1-ha clearcuts had only a minor positive effect on cottontail abundance during 1977 through 1990 (G.L. Storm, unpubl. data). However, both the size of patches with suitable cover and juxtaposition of plant cover types may be major factors influencing cottontail production (Storm and Shope 1989). Future studies directed at assessing cottontail production should not only evaluate habitat suitability within patches, but also the size, distribution, and diversity of patches at the landscape scale.

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LITERATURE CITED

Althoff, D.P. and G.L. Storm. 1989. Daytime spatial characteristics of cottontail rabbits in central Pennsylvania. J. Mamm. 70:820-824.

Applegate, J.E. and J.R. Trout. 1976. Weather and the harvest of cottontails in New Jersey. J. Wildl. Manage. 40:658-662.

Arnold, D.A. 1950. Cottontail population and mortality in central Pennsylvania. M.S. thesis. The Pennsylvania State College, University Park. 134 pp.

Bailey, J.A. 1968. Regionwide fluctuations in the abundance of cottontails, N. Am. Wildl. Nat. Res. Conf. 33:265-277.

Dressler, R.L. and G.W. Wood. 1976. Deer habitat response to irrigation with municipal wastewater. J. Wildl. Manage. 40:639-644.

Edwards, W.R., S.P. Havera, R.F. Labisky, J.A. Ellis and R.E. Warner. 1981. The abundance of cottontails in relation to agricultural land use in Illinois (U.S.A.) 1956-1978, with comments on mechanism of regulation. Pages 761-789 *In* K. Myers and C.D. MacInnes (eds.), Proc. World Lagomorph Conf., Univ. Guelph, Ontario, Canada.

Havera, S.P. 1973. The relationship of Illinois weather and agriculture to the eastern cottontail rabbit. Ill. State Water Surv. Tech. Rep. 4. 92 pp.

Holdermann, D.A. 1978. The distribution and abundance of eastern cottontail (*Sylvilagus floridanus*) and New England cottontail (*S. transitionalis*) populations on a grouse management area in central Pennsylvania. M.S. thesis. The Pennsylvania State Univ., University Park. 82 pp.

Keener, C.S. and M.M. Park. 1986. An overview of the vascular plant geography of Pennsylvania, pp. 111-144. *In*: S.K. Majumdar, F.J. Brenner, and A.F. Rhoads (eds.), Endangered and threatened species programs in Pennsylvania and other states: causes, issues and management. The Pennsylvania Acad. of Sci., Typehouse of Easton, Phillipsburg, N.J.

Lewis, S.J. and F.B. Samson. 1981. Use of upland forests by birds following spray-irrigation with municipal wastewater. Environmental Pollution (Series A) 26:267-273.

Litvaitis, J.A., D.L. Verbyla and M.K. Litvaitis. 1991. A field method to differentiate New England and eastern cottontails. Trans. Northeast Sec. The Wildl. Society, 48:11-14.

Mastrota, F.N., R.H. Yahner and G.L. Storm. 1989. Small mammal communities in a mixed-oak forest irrigated with wastewater. Am. Midl. Nat. 122:388-393.

Matula, G.J. 1983. Physiological characteristics of cottontail rabbits from two localities in central Pennsylvania. Ph.D. thesis. The Pennsylvania State Univ., University Park. 168 pp.

Merritt, J.F. 1987. Guide to the mammals of Pennsylvania. University of Pittsburgh Press, Pittsburgh, PA, xviii + 408 pp.

Neil, R.K. 1951. Cottontail population, movement and mortality study in central Pennsylvania. M.S. thesis, The Pennsylvania State College, University Park. 102 pp.

NOAA. 1985. Climates of the states. Vol. 2, Gale Research Co., Detroit, Michigan. 1572 pp.

Parizek, R.R., L.T. Kardos, W.E. Sopper, E.A. Myers, D.E. Davis, M.A. Farrell and J.B. Nesbitt. 1967. Wastewater renovation and conservation. The Pennsylvania State Studies No. 23. The Pennsylvania State Univ., University Park. 71 pp.

Rollfinke, B.F. and R.H. Yahner. 1990. Community structure and composition of breeding and wintering birds in a wastewater-irrigated oak forest. J. Wildl. Manage. 54:493-500.

Sheffer, D.E. 1957. Rabbit propagation experiment. Md. Conserv. 35:608.

Shope, W.K. 1989. Game-take survey. Pa. Game News 60:41-42.

Sopper, W.E. 1986. Penn State's "living filter": twenty-three years of operation, pp. 406-419. *In*: D.W. Cole, C.L. Henry, and W.L. Nutter (eds.), The Forest alternative for treatment and utilization of municipal and industrial Wastes. University of Washington Press, Seattle.

________ and J.L. Richenderfer. 1979. Effect of municipal wastewater irrigation on the physical properties of the soil, pp. 179-195. *In*: W.E. Sopper and S.N. Kerr (eds.), Utilization of municipal sewage effluent and sludge on forest and disturbed land. Pennsylvnaia State University Press, University Park.

Storm, G.L. and W.K. Shope. 1989. Cottontail populations in changing farm/forest habitats, pp. 122-145. *In*: J.C. Finley and M.C. Brittingham (eds.), Timber Management and Its Effects on Wildlife, Proceed. of the 1989 Penn State Forest Resources Issues Conf., The Pennsylvania State Univ., University Park.

Taber, R.D. and I.M. Cowan. 1971. Capturing and marking wild animals, pp. 217-317. *In*: R.H. Giles (ed.), Wildlife management techniques. The Wildlife Soc., Washington, D.C.

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MINIMUM-CHANGE CATEGORIES FOR DYNAMIC TEMPORAL CHOROPLETH MAPS[1]

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ABSTRACT

A dynamic choropleth map is a temporally-ordered sequence of cartographic "snapshots," each representing an instant or period of time. Each map in the series typically appears on the screen for so brief a time that the viewer cannot examine details. A single classification is applied to the entire sequence so that a substantial rise or fall in value should trigger a change in category. If the classification has only two or three categories, and if areal units change categories infrequently, the viewer should be able to identify major historical and geographic trends. A bin-scoring method for evaluating potential category breaks can help the map author minimize trivial and unwarranted category changes that reflect comparatively small changes in value. [J PA Acad Sci 68(1):42-47, 1994]

INTRODUCTION

This paper addresses the problem of selecting class intervals for dynamic temporal choropleth maps. This is an important problem because the map designer might want to avoid a wildly fluctuating, visually busy display on which minor fluctuations in value obscure more significant changes. This paper raises several questions: How might a systematic method identify class intervals that minimize category change in dynamic cartography? How conceptually and computationally complex are such procedures, and to what extent can they make dynamic maps more intelligible and informative?

A typical dynamic spatial-temporal choropleth map (Figure 1) consists of (1) a fixed base map of shaded-area polygons; (2) a title identifying the distribution portrayed; (3) a dynamic time line, calendar, clock, year counter, or similar graphic or numeric device for showing the direction and pace of time; and (4) a key linking several time-invariant category intervals to a progressive, light-to-dark sequence of fill colors with little, if any, variation in hue. For every instant or period of time, the classification assigns each polygon the fill color appropriate for its data value, so that the resulting mosaic of filled polygons portrays the distribution's spatial pattern of low, medium, and high data values. The dynamic map is thus a temporally-ordered sequence of cartographic "snapshots" (Monmonier, 1990).

Keeping category breaks constant allows the map to register a change whenever, in the transition from one time to the next, an areal unit's data value rises or falls to another category. Linking the map to a dynamic graphic time scale thus allows an efficient, visually effective representation of a spatial-temporal process (Koussoulakou and Kraak, 1992). Yet the map author must be wary of a visually noisy, constantly changing display that overwhelms the viewer's eye-brain system with a complex multitude of category changes largely reflecting minor variations. Equally troublesome is a classification that fails to register the times and locations of substantial shifts in value.

In its goal of meaningful category breaks for a temporal choropleth map, this research has few precedents. In measuring the temporal stability of mapped patterns in order to influence the selection of category breaks, it extends the pioneering work of George Jenks, who developed a computational procedure for selecting maximally homogeneous categories for static choropleth maps by generating and evaluating progressively more accurate trial solutions (Jenks and Caspall, 1971). Although the author (Monmonier, 1982) later refined Jenks's approach to reduce computational effort as well as to accommodate designer preferences for round-number and inherently meaningful category breaks, the present paper is the first to extend the class-interval problem to spatial-temporal data and to add temporal stability as a design objective.

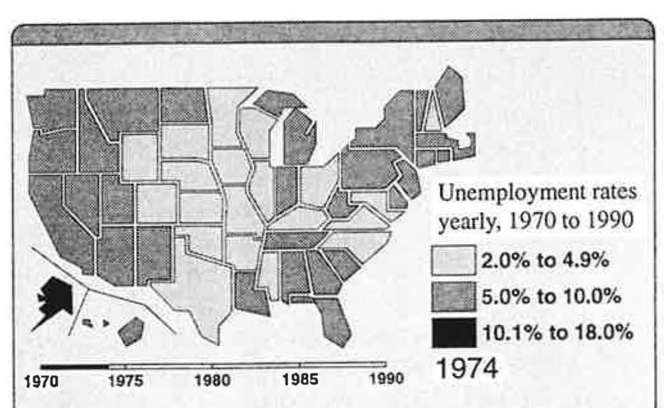

FIGURE 1. Elements of a dynamic spatial-temporal choropleth map. The dynamic time line and year counter identify the example as a cartographic snapshot for 1974.

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This paper begins by developing a procedure for identifying category breaks that minimize visual change. It then applies this process to a demonstration data set, examines the sensitivity of results to the procedure's various parameters, and discusses the implications of this demonstration for the use and further development of the method.

METHOD

Classification begins by treating the overall range of data values as a one-dimensional vector of *bins*, each representing a potential location for a category break. After initializing the bins with values of zero, the procedure addresses each pair of temporally adjacent "snapshots" in the dynamic cartographic sequence by scoring each data interval for usefulness as a class break and accumulating these scores in their appropriate bins. Each transition from one time to the next thus adds a utility rating to each bin. The pattern of final accumulated scores is a basis for selecting an appropriate number of categories as well as for balancing measured utility with the need to avoid closely clustered category breaks.

The vector of bins (Figure 2) must represent the complete range of data values, from the smallest value recorded for any instant or period of time to the largest value in the data set. The map author specifies a *level of resolution*, which divides the range of data values into a finite number of bins. For example, if the map author calls for whole-number class intervals, and if data values range from 7 to 17, there need be only 10 bins, representing the intervals 7-8, 8-9, and so forth, up to 16-17. But if the map author chooses to carry class intervals to the first decimal place, the range 7.0 to 17.0 would require 100 bins, running from 7.0-7.1 through 16.9-17.0. Because each small interval along the overall range is a potential location for a category break, the procedure uses each location's bin to accumulate information about its utility. Thus, a single break based on a high estimated utility for the bin 9.9-10.0 would define a classification with two categories, 7.0-9.9 and 10.0-17.0.

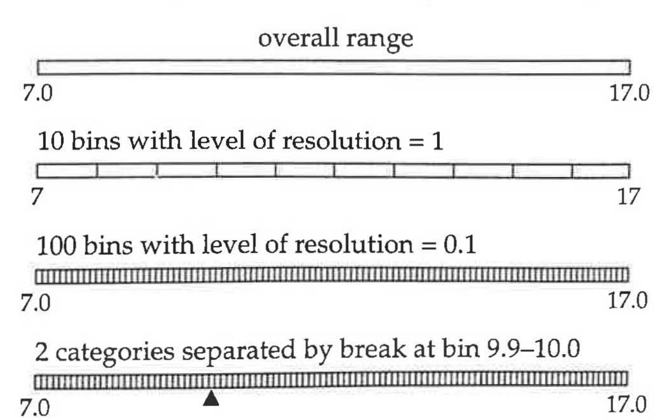

FIGURE 2. Vector of bins for accumulating utility scores. Number of bins depends on the level of resolution chosen by the map author and the difference between overall maximum and minimum data values.

Figure 3 describes the scoring process for the transition between two adjacent times t_1 and t_2. The horizontal axis represents the overall range of the data, and the vertical axis represents time. The four arrows represent typical changes in value for individual areal units. (For the United States, there would be 50 such arrows.) Arrows point to the right for an increase, and to the left for a decrease. An arrow pointing directly upward represents no change, whereas a large deviation of the arrow to the right or left reflects a relatively substantial change. All bins directly below the arrow receive a score, the value of which depends on four parameters. For a relatively trivial (yet non-zero) change, with an absolute value less than or equal to Δ_1, the procedure subtracts an amount M- from all bins below the arrow, thereby assigning demerits that reflect the disutility of a category break in this part of the range. In contrast, for a relatively substantial change, with an absolute value greater than or equal to Δ_2, the procedure adds an amount M+ to all bins beneath the arrow, to reflect the utility of a category break along this portion of the range. Nothing is accumulated in the bins for areas that registered either no change between t_1 and t_2 or only a moderate change, between the thresholds Δ_1 and Δ_2. Bins either below the lowest data value or above the greatest value for either time are not affected. (Although theoretically determined values for the four parameters might be useful, their derivation was deferred pending a broader assessment of the overall technique).

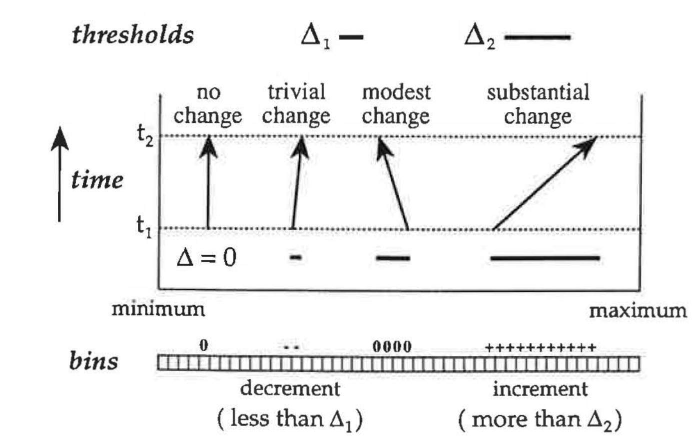

FIGURE 3. Minimum and maximum thresholds Δ_1 and Δ_2 distinguish trivial and substantial changes for which demerits M- and merits M+ (respectively) are accumulated in the bins between data values for adjacent times t_1 and t_2. No accumulation occurs when the values at t_1 and t_2 are equal or the change was between Δ_1 and Δ_2.

In this manner, the procedure assesses and accumulates merits and demerits for all pairs of temporally adjacent cartographic snapshots. If the data represent 21 individual years, for example, it accumulates binned scores for 20 separate year-to-year transitions.

DATA

Trial runs based on a set of test data served three objectives: (1) to explore the sensitivity of solutions to the values of the four parameters, (2) to demonstrate how the binned scores can be used to establish category breaks, and (3) to serve as a basis for discussing how and why category change might be minimized.

The data for these trial runs were yearly average civilian unemployment rates estimated for the 50 United States and for the 21-year period 1970 through 1990. As displayed in Figure 4, state-level unemployment rates ranged from 2.0 percent for Florida in 1973 to 18.0 percent for West Virginia in 1983. In general, unemployment in the United States (represented by the bold line on the graph) was under 6 percent through 1974, jumped sharply in 1975, declined steadily through 1979, rose progressively toward a higher level in 1982 and 1983, and then fell back to less than 6 percent by 1988. But the national trend is merely the average of a multitude of regional trends and local anomalies reflected by the complex zig-zag lines in Figure 4. The difficulty of identifying clear yet meaningful minimum-change breaks in the data raises the question: Can class intervals have a significant effect on the visual stability of a dynamic spatial-temporal map?

To examine separately the relative contributions of demerits for small changes and merits for large changes, separate sets of binned scores were generated for the minimum and maximum thresholds (Δ_1 and Δ_2). The first set is based on a demerit value M- of -1.0, and the second set is based on a merit parameter M + of 1.0. (To separate demerits from merits, I set M + to zero for the first series of calculations and set M- to zero for the second.) A final trial provided a composite solution based on representative values of all four parameters. Because the data were reported to the nearest tenth of a percent, and because a conscientious map author would not automatically round class intervals to the nearest whole-number percentages—especially for a range between only 2.0 and 18.0 percent—the level of resolution was set at 0.1, which divides the range into exactly 160 bins.

RESULTS

The first set of trials included nine solutions for which the minimum threshold Δ_1 ranged from 0.1 to 0.9 in increments of 0.1, and four solutions for which the threshold ranged from 1 to 4 in increments of 1. As shown in Figure 5 for the first group, the pattern of demerits descends from both ends of the range, with extremely negative demerits most prominent between 5.0 and 6.5 percent—the interval around which most state unemployment rates fluctuated

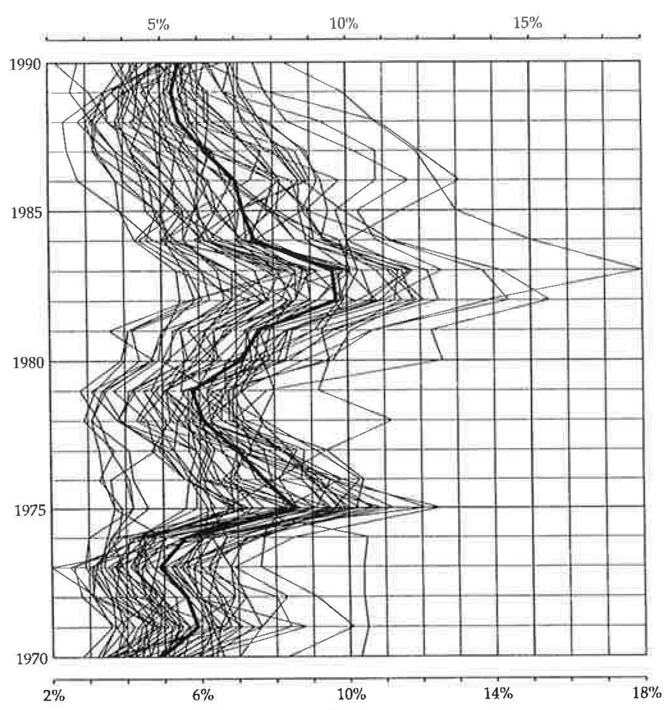

FIGURE 4. Time-series graph showing trends in yearly average unemployment rate, for each state and the United States as a whole (thick line), for the 21-year period 1970 through 1990.

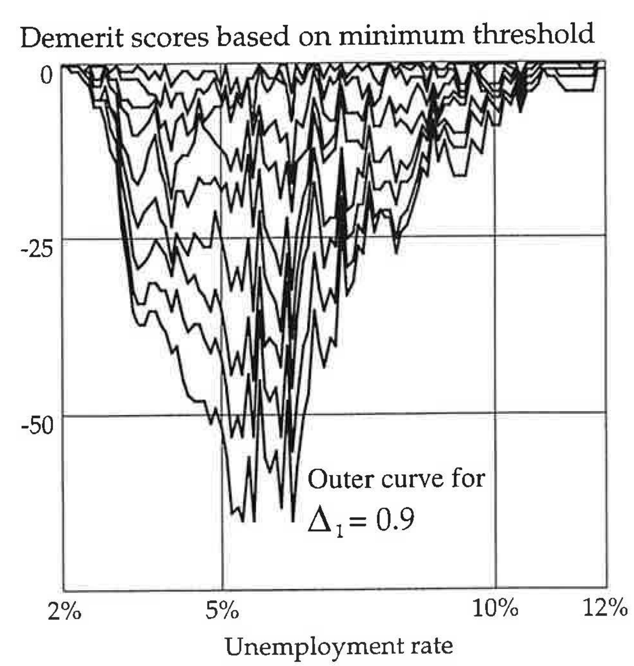

FIGURE 5. Pattern of demerits accumulated for bins between 2.0 and 12.0 percent with minimum threshold Δ_1 ranging in increments of 0.1 from 0.1 (uppermost, innermost curve) to 0.9 (lowermost, outermost curve). The horizontal scales of Figures 5-8 are truncated because both merits and demerits were zero or minimally insignificant for bins representing unemployment rates greater than 12 percent.

in the early and late 1970s as well as in the late 1980s. Especially noteworthy are the substantial rises and falls at several places along the demerit curve; these abrupt variations suggest that displacing a class break a few tenths of a percent might reduce by 20 or more the number of category changes. In general, though, the demerit curves slope more steeply downward from the lower end of the range than from the upper end, which is zero or nearly so for unemployment rates greater than 11 percent. Although increasing the minimum threshold treats more changes as "trivial," accumulates many more demerits, and pushes the curve of binned scores even lower, the patterns of inflections and incisions are strikingly similar—the product-moment correlations between the upper and lower sets of scores graphed in Figure 5 is 0.70.

Similar patterns are still apparent in Figure 6, which illustrates the effects of awarding demerits for changes as great as 4.0 percent. In general, increasing the minimum threshold forces the curve not only lower but also to the right, that is, toward the higher end of the range, where moderately large changes in the unemployment rate have been more common. Because of this skew, the bivariate correlation between the uppermost curve in Figure 5, reflecting a minimum threshold of 0.1, and the lowermost curve in Figure 6, reflecting a minimum threshold of 4, drops to only 0.51.

The second set of trials included six solutions for which the maximum threshold Δ_2 ranged from 1 to 6 in increments of 1. As Figure 7 illustrates, the pattern of accumulated merit scores rises at about the same rate from both ends of the truncated range, with a higher, more prominent peak for a maximum threshold of 1, and a vague, comparatively insignificant curve for maximum thresholds of 5 and 6, which few year-to-year state-level changes exceeded. Raising the maximum threshold yields a smoother, less jagged pattern of scores and forces the peak toward the upper end of the range, where large changes have been more common. In general, the curves in Figure 7 are less jagged than those in Figures 5 and 6, indicating that the merits awarded substantial changes vary less from bin to bin than the demerits awarded trivial changes.

Figure 8 illustrates how demerits and merits might be combined and used to influence the selection of class intervals. The curve represents binned scores accumulated with demerits of -1 assigned for changes less than or equal to 0.9 and merits of + 1 assigned for changes greater than or equal to 4. Negative scores outnumber positive ones because "trivial" changes, thus defined, are more common than "substantial" changes. The resulting scores are thus more suited for avoiding meretricious changes in category than for assuring that class breaks point out major changes.

In general, the higher a category break lies on the curve, the more temporally stable the resulting map. Consider, for example, a three-class map with one break below 3 percent and the other break above 9 percent. With both breaks well away from the low part of the curve, the map would have a comparatively stable pattern. But because its low and high categories would have few members, the map would be much less informative than if these extreme categories were broader. For this reason, the map author eager to balance informativeness with temporal stability might note the sharp upward jerk in Figure 8 for the bin between 5.6 and 5.7. A lower category running from 2.0 to 5.6 percent yields 22 fewer trivial changes than a lower category running from

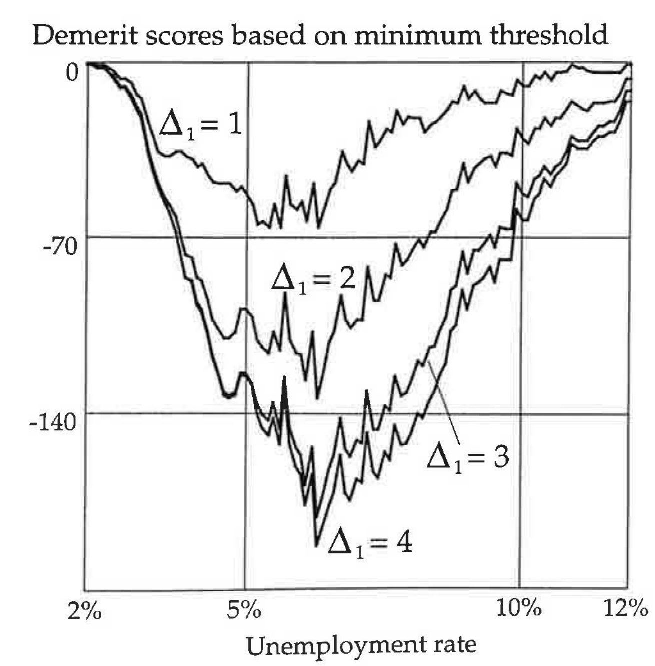

FIGURE 6. Pattern of demerits accumulated for bins between 2.0 and 12.0 percent with minimum threshold Δ_1 ranging in increments of 1 from 1 (uppermost, innermost curve) to 4 (lowermost, outermost curve).

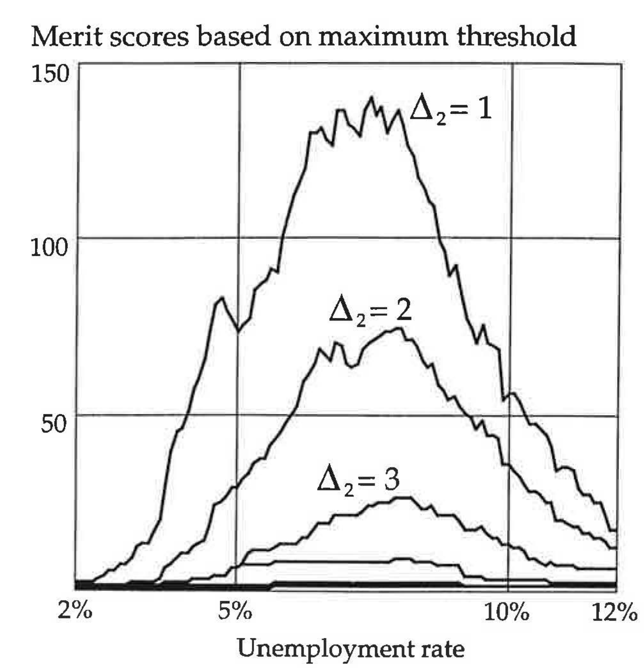

FIGURE 7. Pattern of merits accumulated for bins between 2.0 and 12.0 percent with maximum threshold Δ_2 ranging in increments of 1 from 1 (uppermost, outermost curve) to 6 (lowermost, innermost curve). The three lowermost curves (for Δ_2 of 4, 5, and 6) are too low and flat to accommodate labels.

2.0 to 5.5 percent. Similarly, an upper category from 8.9 to 18.0 would yield 10 fewer trivial breaks than an upper category from 9.3 to 18.0. But whether such small improvements in temporal stability warrant consideration is questionable, especially if trivial shifts account for a small proportion of all category transitions. With the United States unemployment data, for instance, the "best" three-category solution based on Figure 8 (with intervals 2.0-5.6, 5.7-8.8, and 8.9-18.0) acutally yielded a visually busier map (with 264 category shifts) than the "worst" three-category solution (with intervals 2.0-5.5, 5.6-9.2, and 9.3-18.0 producing only 249 category shifts.) Yet as paradoxical as this comparison of category shifts might seem, the first solution will have fewer "trivial" transitions and thus better represent the data than the second.

DISCUSSION

Although other test data sets might yield more compelling and impressive results, this exercise has usefully demonstrated that bin scoring can find whatever category breaks yield fewer inconsequential category changes than neighboring breaks. Yet, as these results also indicate, a break with fewer trivial category changes need not yield a less busy, more temporally stable dynamic cartographic time series. Moreover, a substantial improvement is not guaranteed—while the bin-scoring method can identify relatively stable, more meaningful solutions, the data might not yield a "best" solution that is markedly more stable than a "worst" solution.

The demonstration examined but one bin-scoring approach, namely, assigning merits (instead of demerits) to breaks representing large year-to-year changes in value. But because large changes affect many bins, across a large part of the range, merits tend to have little impact on the pattern of binned scores. Although assigning merits to major shifts is theoretically justified because it promotes a more meaningful temporal map, in practice adding merits to the bins might not warrant the added complexity.

Further modifications are possible. Scoring could weigh more heavily shifts in value than conform to the overall trend by rising when the national average rises and falling when the nation as a whole falls. Yet the map author who considers anomalies more significant than general trends could chose to weigh contrarian shifts (anomalous changes significantly out of step with the nation as a whole) more heavily. Another modification might assign greater import to shifts at the lower end of the range, thereby recognizing, for example, that a 2-percent rise in the unemployment rate from 2 to 4 percent is proportionately more significant than a 2-percent increase from 16 to 18 percent. An enhanced scoring method might also ignore or discount temporary fluctuations (represented by the "spike" on the left side of Figure 9) so that category changes tend to reflect salient or steady shifts in value. Abrupt but lasting changes are more noteworthy, and a small change in value that is part of a gradual, long-term transition is hardly "trivial." The method might also consider the relative size of ah areal unit as well as its isolation from other places having a category change; after all, if the map author wants a visually stable map, it is more important for a class break to avoid a minor change in value when the area symbol is large and visually prominent than when the symbol is either comparatively small or adjacent to other symbols with a similar change in category.

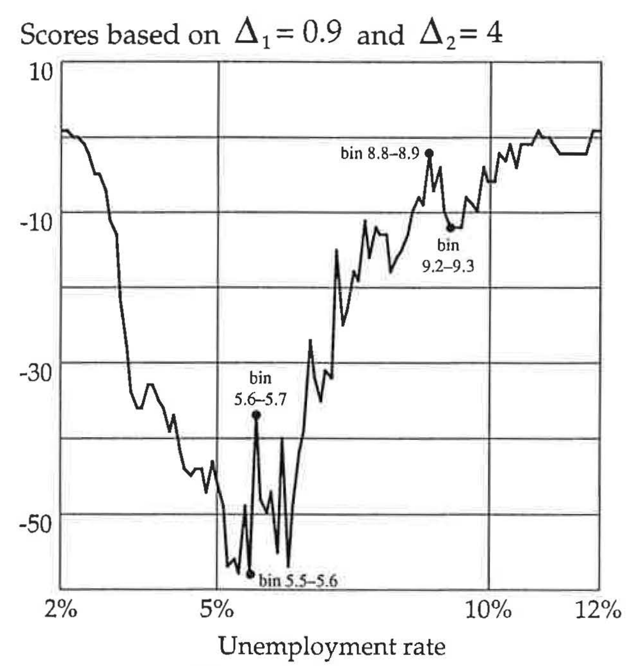

FIGURE 8. Pattern of binned scores for a composite evaluation with a minimum of threshold of 0.9 used to assess demerits of -1.0 for small, more trivial value changes and a maximum threshold of 4 used to assign merits of 1.0 for more substantial shifts.

CONCLUSIONS

Further experimentation with a variety of representative or artificial data sets might suggest guidelines for selecting thresholds and for setting the relative merits and demerits awarded various situations. These guidelines could be useful to map authors intimidated by the apparent complexity of bin scoring and its various options. Graphs such as Figure 8 and interactive previewing of the visual effects of various category breaks are important, though, because the method ought not be applied blindly. Bin scoring can be a useful tool for making map authors aware of the visual consequences of decisions about category breaks.

In general, a map author concerned about temporal stability might either select relatively narrow intervals for the extreme categories or present the highest and lowest categories as separate cartographic time series. Experimentation guided by graphs such as Figure 8 might well suggest the need for more than one dynamic map. If more than one temporal two-category map is required, the method presented here could be helpful in identifying appropriate category breaks.

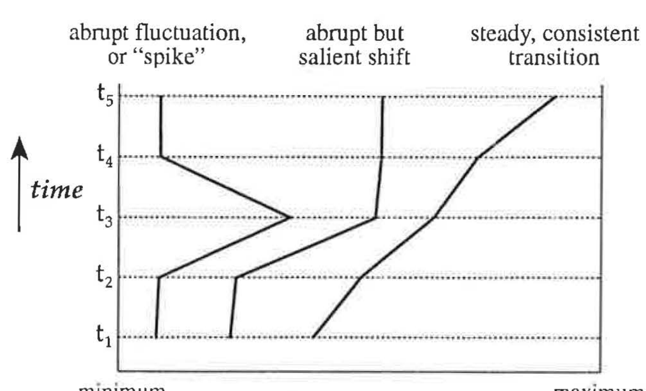

FIGURE 9. Three prototypical shifts in value that the bin-scoring method might identify and weigh differently.

LITERATURE CITED

Jenks, G.F. and F.C. Caspall. 1971. Error on choroplethic maps: definition, measurement, reduction. Annals of the Association of American Geographers 61:217-244.

Koussoulakou, A. and M.J. Kraak. 1992. Spatio-temporal maps and cartographic communication. The Cartographic Journal 29:101-108.

Monmonier, M. 1982. Flat laxity, optimization, and rounding in the selection of class intervals. Cartographica 19(1):16-27.

________. 1990. Strategies for the visualization of geographic time-series data. Cartographica 27(1):30-45.

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Books

1. *Energy, Environment, and the Economy,* 1981. ISBN: 0-9606670-0-8. Editor: Shyamal K. Majumdar.
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