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A survey of the herpetofauna of Northampton County, Pennsylvania

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ABSTRACT

The herpetofauna of Northampton County, Pennsylvania was surveyed for three years (1994-1997) by secondary and intermediate school teachers and 250 student volunteers to analyze the abundance, diversity, and distributional patterns of species in relation to human land-use patterns. Survey participants reported 2,363 individuals and 39 breeding sites representing 38 species from a total of 958 sites. A few species make up the majority of the site and individual records whereas many species have low abundances in the county. Comparison to human land-use using a computerized geographic information system (GIS) showed that areas of relatively low human usage (parks and rural residential areas) had high numbers of sites and individuals. Agricultural land had high numbers of sites and individuals but low numbers of sites and individuals per unit area. Areas of high human use (industrial, urban residential, commercial, and vacant) had the lowest numbers of sites (9.9%) and individuals (9.5%). Only 12 species occurred in more than five of the 10 major land-use categories. Of the 38 species, 20 occupy three or fewer land-use categories.

INTRODUCTION

A random survey of amphibians and reptiles was conducted by intermediate and secondary school students and their teachers with help from a small team of volunteers and graduate students. The objective of the survey was to determine where the animals actually occurred without bias provided by knowledge of habitat preferences and ecology and without the restrictions imposed by private land boundaries.

Surveys of the distributions of organisms are the basis for all hypotheses about organismal diversity (e.g., Andrewartha and Birch, 1954; MacArthur, 1972) and hypotheses of current human impacts on both diversity and distributions of organisms (e.g., Green, 1997a). But the distributions of some kinds of organisms are far better known than others. Of the major vertebrate clades, amphibians and reptiles (in the traditional sense) are most easily surveyed in eastern North America because they can be surveyed without special equipment and data collection generally does not require the degree of expertise required for other groups, such as birds (Jones, 1987). Nevertheless, despite the ease with which they can be found and identified, our knowledge of distributional patterns of most amphibian and reptilian species is surprisingly vague when one looks at geographic precision beyond the level characteristic of the best state distributional surveys (e.g., Smith, 1961; Fowlie, 1965; Webb, 1970; Mount, 1975; Vogt, 1981; McCoy, 1982; Nussbaum et al., 1983; Dixon, 1987; Johnson, 1987; Ashton and Ashton, 1988; Dundee and Rossman, 1989; Hunter et al., 1992; Klemens, 1993).

Current concepts of herpetofaunal distribution are based primarily on accumulated museum records, like those used to synthesize distributional patterns in Pennsylvania by McCoy (1982), records of occurrence within a defined geographic area, such as the recent herptofaunal survey of Maine by Hunter et al. (1992), and assumptions built on suspected habitat preferences for the various species comprising a region's herpetofauna (e.g., Jones, 1988; Karns, 1988; Clarke, 1956-57). In the latter studies, although small areas were analyzed in detail, only preselected sites or road surveys were used. Hence, overall patterns of distribution of herpetofauna in a particular geographic area are never described in detail. Reasons for this are obscure but probably relate to the fact that small geographic areas are not biologically meaningful (except possibly for rare or endangered species with small ranges) and detailed surveys that include privately owned land are logistically unfeasible. Hence, there are few detailed herpetofaunal surveys (or surveys of any other major group of organisms) for geographic areas in the range of 100-10,000 km^2, large enough to be biologically interesting but small enough to be surveyed in detail.

Analyses of animal distributions over most of the northeastern United States and southern Canada are now made extremely difficult because most of the land is privately owned and public access is increasingly restricted. This factor, combined with the sheer size of the area involved, undoubtedly underlay the recruitment of 250 volunteers for the Maine Amphibian and Reptile Atlas Project (Hunter et al., 1992) which mapped distributions of all species by townships. Brodman and Kilmurry (1998) used college students to survey amphibian breeding sites in Jasper County, Indiana. Breeding sites were compared to soil associations, vegetation type, and permanence of water in wetlands. The latter appears to be the only previous county-wide survey of a major part of a herpetofauna using volunteers to help collect the data. Most prior distributional analyses were based on field surveys conducted primarily by the authors (e.g., Mount, 1975; Lee, 1980; Johnson, 1987). Current and future surveys of densely settled areas will depend increasingly on volunteers and designs similar to that used by Hunter et al. (1992) and Brodman and Kilmurry (1998). This report gives one of many possible surveying approaches combined with computer-based GIS (geographic information systems) analysis of distributional data.

In a random survey of this type, the results can provide an estimate not only of distribution but also of relative abundance and relative diversity of species on a county-wide basis. Correlating distribution and abundance to land use patterns provides an estimate of how human impacts on the environment may relate to herpetofaunal distributions.

MATERIALS AND METHODS

Study Area

Northampton County is described as an "industrialized, urbanized county"(Staley, 1974) located on the extreme eastern border of Pennsylvania between its northern and southern boundaries (fig. 1). It has an area of 969 square km (96,867 hectares). The Delaware River, which drains most of the county, forms the eastern border. The Lehigh River, which runs into the Delaware River in the city of Easton, forms the northern part of the western border. All of the streams in the county are tributaries of the Lehigh or Delaware Rivers. The crest of Blue Mountain, along which the Appalachian Trail is located, forms the northern border. The old industrial cities of Bethlehem and Easton are the two largest municipalities in the county.

Northampton County was separated from Bucks County in 1752 and was primarily a farming area. During the 20th century, the region became one of the nation's leading steel-, slate-, and cement-producing areas, although agriculture is still widespread. As part of the Lehigh Valley area, 247,105 people live in Northampton County (http://brain.hbg.psu.edu/psdc), giving it the fourth highest population density in Pennsylvania in 1990. The county is a mixture of industrial, urban, and agricultural lands with some protected land (4.5%) set aside for recreation (national, state, and county parks) and hunting (state game lands). Despite the recent downsizing or loss of a number of major industrial concerns, this area is undergoing rapid population growth (21.4%

projected population growth from 1990 to 2020) and development due in part to its proximity to New York and Philadelphia. Most of the land in the county is now under private ownership.

The climate is described as mild and the average annual temperature is 10°C. Average January temperatures (the coldest month) range from -8°C minimum to 2°C maximum whereas the average monthly minimum in July (the hottest month) is 16°C and the maximum is 28°C. The average annual rainfall is 110 cm (Cuff et al., 1989).

Northampton County lies at the southern edge of the Ridge and Valley Province of the Appalachian Highlands. The highest elevation in the county is 501 meters at the crest of Blue Mountain and the lowest is 41 meters where the Delaware River leaves the county. Four major landforms occur in the area: (1) steep, high, generally narrow, Silurian sandstone ridges along the northern border; (2) rolling, dissected uplands underlain by Ordovician shale; (3) a gently rolling valley underlain by Cambrian limestones; and (4) eroded mountains on the southern edge of the county underlain by granite and gneiss of the Reading Prong. A major geologic formation in the southern portion of the county is a carbonate rock sequence composed of the Beekmantown, Allentown, and Leithsville limestones and dolomites, which have been quarried as lime for farming and clay for bricks. Another valuable formation extending over much of the center of the county is the Ordovician-Jacksonburg limestone, which is used for producing cement. The Martinsburg Formation in the northern tier of the county is economically important in slate production (Staley, 1974). The limestones neutralize water runoff and hence most streams running south from Blue Mountain through the county have moderate to good water quality despite the low pH (4.1- 4.3) of precipitation in the region.

Prior Records of County Herpetofauna

Of the 73 species native to Pennsylvania, 42 (table 1) have been historically recorded in or near Northampton County (McCoy, 1982). These include 12 species of salamanders, 11 species of frogs, eight species of turtles, and 11 species of snakes. Of these, two species of frogs (*Acris crepitans* and *Pseudacris triseriata*), one species of turtle (*Sternotherus odoratus*), and one species of snake (*Crotalus horridus*) were not actually recorded in the county. Two species of lizards (*Eumeces fasciatus, Sceloporus undulatus*), neither of which was historically recorded in the county, have been reported recently from sites within the county but confirmation has not yet been obtained.

Surveying Methods

Surveying was done by volunteers between September, 1994 and August, 1997. Most volunteers were intermediate and secondary school teachers and their students who conducted surveys through classroom and independent projects. Both teachers and their students were instructed on identification of local herpetofauna, and students were asked to survey near their homes. Included in the instruction to students were lessons in map reading and on locating positions in the environment on maps. Sites submitted by students were checked by teachers and any species seen that could not be readily identified were retained for identification by an experienced field biologist and then released.

Contributions from student volunteers allowed us to gain site data from private property that could not normally be surveyed. Also, by recruiting teachers and students from six of the eight school districts located in Northampton County, volunteers could potentially survey most areas of the county. Ten teachers, approximately 250 students, local volunteers, and the project leaders (Knepper and Cundall) reported site locality data throughout the three years of the survey.

Field techniques used by volunteers involved unspecialized methods of visual surveying and checking beneath ground cover in areas sampled. Individuals who found and identified specimens submitted data cards or marked copies of school district maps (see below). Information on the cards or maps included the name of the collector, the species found, and the date and time when the species was found. Data cards also gave the township or municipality and the distance to the nearest road and road intersection. Maps showed sites as dots that were transferred to ArcView files. Participants were asked to locate the site to within approximately 10 m, but a more realistic estimate is accuracy to the nearest 50 m. If more than one specimen of a species was recorded at a site, the number of specimens was noted. In the case of breeding sites (identified by calling males, presence of eggs, or presence of larvae), numbers were estimated and the site was recorded as a breeding site.

Training Volunteers

Teachers were trained to take part in the survey with their students through a series of workshops conducted throughout the first two years of the survey. Teachers were provided with field guides (Conant and Collins, 1991), audio tapes of frog calls (Elliott, 1992), Northampton County road maps (Pennsylvania Department of Transportation, 1992), local topographic maps (USGS 7.5" quadrangles), data cards, and written instructions for reporting data. Live specimens, preserved specimens, and slides of local species from the Carnegie Museum of Natural History collection were used in training teachers in the use of field guides. Field techniques were demonstrated during field trips to sites within Jacobsburg State Park at both the initiation of the project in the fall of 1994 and during a spring, 1995 workshop to observe breeding amphibians.

Teachers were given instruction at workshops for proper recording of site locality data. Three slide collections were made accessible to teachers for use in instructing their students on identification of species. Numerous requests from teachers were also honored to instruct students firsthand on identification. In these cases, students looked at slides, preserved specimens, and some live specimens. Teachers were advised to contact one of the project leaders or members of the Lehigh Valley Herpetological Society involved in the project if verification of a species was necessary. Verification was not needed for much of the data reported by volunteers because these data came from common species which are easily identifiable.

Teachers used a variety of methods to show students how to provide specific site localities. The project was used by most teachers to develop map reading skills in their students. Most teachers used a series of lessons to evaluate the effectiveness of their teaching before students began collecting site data for amphibians and reptiles. During the course of the project, one of the teachers (L. Ott) discovered that students could locate positions on a school district map with greater ease than providing distance from the nearest road. From this point on, we provided all of the active teachers in the project with copies of maps of their school districts to give to students. About half of the data from this point on came in as dots on maps rather than as distance data on cards.

Data Analysis

Sampling was meant to be as random as possible. The goal was to collect data from as much of the county as possible and from areas of varied human land-use so that data could subsequently be compared to land-use.

One element of the surveying methods critical to the interpretation of the results is that no records were made of areas actually surveyed because no reasonable method of recording areas surveyed by volunteers could be found. To estimate the area of the county effectively surveyed, locality points on ArcView maps were enlarged to areas of 2.9 km^2 to give some overlap of sites. This gave a general idea of areas sampled rather than specific localities. Because *Plethodon cinereus* was the most abundant species in the county and was found in all but one of the land-use categories, it was used as a basis for comparing areas surveyed for other amphibian (fig. 2) and reptilian species (fig. 3). The total area covered by the enlarged data points were used to estimate the percentage of the county surveyed.

Site data received throughout the three years of the survey were tabulated on a Lotus spreadsheet. Information entered on spreadsheets for each species included: number of specimens, name of collector, affiliation of collector, and description of location. Using the descriptions of localities for amphibian and reptilian species, sites for each species were compiled into separate ArcView files for each species using an ARC/INFO generated coverage of county roads and bodies of water (Lehigh/Northampton County Joint Planning Commission) as the template for recording the points. An attribute table was compiled for each map that included the number of individuals, land-use code, land-use type, and presence or absence of woodland for each site. For breeding sites, the number of individuals was estimated based on call intensity; however, the numbers of individuals for 10 *Pseudacris crucifer* sites were not estimated by individuals reporting the data. Only one individual was assumed to be present at each of these sites, so the estimated number of individuals for *Pseudacris crucifer* (tables 2 and 8) may be much lower than the actual number of individuals. Land-use information was gained from 1) parcel maps (see below), and 2) woodland boundary maps showing wooded areas of one acre or more, both map types in ARC/INFO format and obtained from the Northampton County tax assessment office.

Land-use and woodland boundary maps were overlain with species distribution maps. Tabulation of data from map overlays included specific site data (numbers of individuals, whether eggs, larvae, or breeding activity were noted), woodland character of sites (+ for sites inside woodland boundaries, – for sites outside), and the land-use code and category of the parcel containing the site. Parcels boundaries are based on property ownership and deed records. Each parcel for the county is coded for land-use from approximately 450 different land-use categories. Categories used by county offices are intended for zoning and tax purposes and may or may not be accurate ecological indicators. In order to extract ecological indicators from land-use information, land- use categories were broadened into ten major land-use types based on levels and types of human usage.

The ten major land-use categories (and abbreviations for each) that were used for analysis were:

Ag— Agricultural— Land that has been cleared for agricultural purposes. These areas are widespread throughout the county and would fall into a relatively high human-usage category. Because much of this land is cleared, little ground cover would be available for most species. Aquatic areas within edges of agricultural land often receive runoff from fertilizers and pesticides used for planting. Cuff et al. (1989) show loss of almost half the active farms (in terms of independently owned farms) in the county between 1964 and 1982. Although this does necessarily equate with loss of agricultural land area, some loss has occurred through development of agricultural land for urban and rural housing, a trend that has continued since 1982. Nevertheless, much of the county remains cleared land.

Rur Res—Rural residential— A large portion of the county (7.5%) is represented in this category. This includes residences outside municipalities which may retain substantial wooded areas.

Because of these significant wooded areas and hedgerows, rural residential areas are considered to have moderate human usage.

Urb Res— Urban residential— This includes residential areas inside the cities of Bethlehem and Easton, and the boroughs of Nazareth, Bangor, Northampton, and Wind Gap. Wooded areas consist mainly of hedge rows. Urban residential areas have high human usage due to high road density and minimal retention of wooded areas.

Park—National, state, county, or town park— Parks within Northampton County are fairly well preserved and although many have major roadways through them, they retain significant wooded areas as well as bodies of water. Most of the parks within the county have low human usage and provide a variety of habitats for many herpetological species.

SGL— State game lands— These areas are maintained by the Pennsylvania Game Commission for hunting purposes and are largely wooded areas. Most state game lands in the county are located in the northern portions along the ridge and base of the Blue Mountain. These areas have low human usage. Aquatic areas within the state game lands primarily consist of mountain springs and vernal ponds, so highly aquatic species would not be expected to occur here.

Private— Private, institutional property— These are areas owned by universities, schools, or churches that have some significant wooded areas as well as hedge rows. These areas may have varied levels of human usage, depending on the size of the parcel, the level to which the wooded areas have been cleared, and the nature of the institution on the property. For example, extensive wooded areas around Lehigh University are used sparingly by students and show less disturbance than some of the parks in the county.

Comm— Commercial— This includes areas near office buildings, shopping centers, and other commercially used areas. These are areas of high human usage because most commercial areas have been paved over as parking lots.

Indus— Industrial— These are areas maintained by one of the local industries (such as the steel or cement producing industries) or utility companies. Industrial areas have high human usage and significant clearing of wooded areas, and often high levels of contamination by a variety of potential toxins.

Lcan Dcan— Locations along the Lehigh canal and Delaware canal— The Delaware canal lies just to the west of the Delaware River along the southeastern border of the county. The Lehigh canal runs along the Lehigh River through much of the northwestern border of the county and enters the county again in Bethlehem and runs eastward to enter the Delaware River in Easton. Many parts of both canals provide potential habitat for a number of aquatic and semiaquatic species, particularly turtles, snakes, and frogs. Although some of the existing portions of the Lehigh and Delaware canals are located in urban regions and are used heavily for recreation (fishing, biking, jogging), considerable areas adjacent to both canals remain wooded and have suffered relatively little recent disturbance.

Vac— Vacant— Vacant areas are those areas that are not currently agricultural, residential, commercial, or industrial. However, they could have been any of these in the past. Some of these areas hold significant wooded areas while others have been cleared. Human usage of vacant areas varies significantly depending the history of the site.

Most of the land use categories adopted fell into the same major categories listed by the Northampton County tax assessment office. Those that did not included parks, canals, and the subdivision of rural and urban residential areas. In the case of parks, land originally privately owned has been included in two county parks, a state park, and a federal recreation area during this century. This land is now registered as government-owned and this ownership category in combination with the position of the parcel in the county was used to determine which parcels were categorized as parks. Canal areas currently include parcels in a wide variety of land-use codes from local government to one of a host of residential categories. The designation of canal areas for the purpose of this project are based entirely on their association with the Lehigh or Delaware canal. Additionally, the tax assessment office coding system does not distinguish between rural and urban residential areas. Residential areas were divided into rural and urban areas based on whether data points fell within (urban) or outside (rural) city or borough boundaries.

To calculate the relative areas of the county occupied by each land-use category, ARC/INFO land-use maps from the Lehigh/Northampton Counties Joint Planning Commission were used in place of parcel maps from the tax assessment office. Categories used by the joint planning commission overlapped our categories except for 1) canal and vacant areas which fall into a collection of land-use categories that collectively account for 6.37% of the total area of the county, and 2) residential areas, which are not separated into rural and urban by the Joint Planning Commission coverage. To separate these two, polygons were drawn around residential regions of cities and boroughs and these areas were subtracted from the total residential area. Relative abundances and diversities of species within each land-use category were tabulated on the assumption that relative sampling effort within each category approximated the relative area occupied by that category in the county.

RESULTS

Area Surveyed

When all sites were enlarged to 2.9 km^2, the total area covered by the sites was approximately 47% of the county. Using the same approach, and assuming that *Plethodon cinereus* occurs where most other species could occur, only 68.35% of areas surveyed for other amphibian species actually overlapped with *P. cinereus* areas (fig. 2), meaning that about one third of other amphibian sites were not found in areas housing *P. cinereus*. Comparison with reptilian sites showed that 73.46% of areas housing reptiles overlapped sites containing *P. cinereus* (fig. 3). Conversely, 74.34% of all *P. cinereus* sites overlapped other amphibian sites and 49.56% of all *P. cinereus* sites overlapped reptilian sites.

Species Abundances

A total of 958 sites was recorded throughout the three years of the survey which included 2,363 individual specimens as well as 39 breeding sites. Of the 42 species that were anticipated to occur in the county using historical records, 37 were reported, including 11 of 12 species of salamanders, nine of 11 species of frogs, nine of 11 snake species, and each of the eight species of turtles. (table 1). Additionally, one species was found that had not been anticipated for the county (*Trachemys scripta*). Species with historical distributions in or near Northampton County that were not reported here included *Ambystoma jeffersonianum, Acris crepitans, Pseudacris triseriata, Heterodon platyrhinos,* and *Agkistrodon contortrix.*

Five species (*Eurycea bislineata, Plethodon cinereus, Bufo americanus, Rana clamitans,* and *Thamnophis sirtalis*) made up the majority (57%) of site records. Species with more than 100 individuals reported included *Plethodon cinereus, Pseudacris crucifer, Rana sylvatica, Eurycea bislineata, Rana clamitans, Bufo americanus,* and *Desmognathus fuscus.* These seven species comprised 82.7% of individuals reported (table 2). Of the four taxonomic groups for which data were recorded, salamanders were recorded most commonly (51.6% sites, 50.2% individuals), followed by frogs (29.4% sites, 42.1% individuals), turtles (10.1% sites, 4.0% individuals), and snakes (8.9% sites, 3.7% individuals).

Nineteen species had less than ten sites reported (table 3). Of these, eight species had sites reported in relatively isolated regions of the county. *Ambystoma opacum, Elaphe obsoleta,* and *Crotalus horridus* were reported only along the base of the ridge in the northern portions of the county. *Graptemys geographica* was reported only in the eastern sections of the Lehigh Canal. This species had historically been recorded only in the Delaware River (Arndt and Potter, 1973). *Clemmys muhlenbergii* was reported only from the southeastern parts of the county. *Hemidactylium scutatum* was reported only from Bear Swamp in the northeastern part of the county. *Clemmys guttata* was reported only from a fish hatchery in the northeastern part of the county. *Storeria dekayi* was reported only from Jacobsburg State Park in the center of the county. With the exception of *G. geographica*, all of these species were found in areas that remain heavily wooded.

Species reported from a large number of sites (table 3) were nearly the same as those with high numbers of individuals (table 2). Comparing relative rankings in the two lists for species represented by ten or more individuals, *Plethodon cinereus* is the most abundant and the most widespread species. Apart from *Plethodon cinereus*, the only two species sharing the same ranking on both lists is *Eurycea bislineata* and *Nerodia sipedon*. Eleven species differ by less than three rank orders (*Pseudotriton ruber, Diadophis punctatus, Rana catesbeiana, Desmognathus fuscus, Chrysemys picta, Rana clamitans, Rana palustris, Chelydra serpentina,, Trachemys scripta, Bufo americanus* X *woodhousii* hybrids, and *Lampropeltis triangulum*). Of the three species that differ by three rank orders, *Notophthalmus viridescens* falls higher in the number of individuals rank, indicating that this species tends to have more individuals at fewer sites, whereas the other two (*Thamnophis sirtalis* and *Terrapene carolina*) tended to have fewer individuals at more sites. Of the remaining six species, two (*Pseudacris crucifer* and *Rana sylvatica*) ranked higher in individuals than in sites, indicating that some or many sites contained many individuals. Four species (*Bufo americanus, Clemmys insculpta, Plethodon glutinosus,* and *Ambystoma maculatum*) ranked lower for individuals than for sites.

Comparison of Land-use Categories

Wooded Areas.— In comparison to wooded areas of 1 acre or more, total numbers of sites for amphibians and reptiles are evenly distributed between wooded and non-wooded areas (table 4). For wooded areas, 52% of site data and 55% of individuals were found in wooded areas. For salamanders, 63.4% of sites and 61% of individuals were found in wooded areas. Data for frogs showed 44.7% of sites, 43.4% of individuals, and 73.5% of breeding sites were found in wooded areas. Conversely, the majority of turtle sites (74.2%) and individuals (74.2%) as well as snake sites (58.9%) and individuals (52.8%) were reported from non-wooded areas.

Land-use Categories.— All ten of the land-use categories contained at least one amphibian or reptilian species (table 5). Agricultural, rural residential, and park areas had 72% of sites and 73% of individuals located within them. Areas with the fewest sites located within them include industrial, urban residential, commercial, and vacant areas with eight, 23, 27, and 37 sites located within them, respectively. Only 9.5% of individuals came from one of these four areas.

The only taxonomic group that was reported in all ten major land-use categories was frogs. Salamanders were recorded in all land-use categories except canal areas, turtles were found everywhere except industrial areas, and at least one snake was found in all categories except industrial areas. Because of their strong representation in the data, both amphibian groups largely determine the relative contents of individuals and sites for each of the major land-use categories. Among amphibians, 74.3% of salamander sites and 70% of individuals were located within agricultural, rural residential, and park areas. Sixty five percent of frog localities lie in agricultural or rural residential areas, 14.5% in parks. Whereas industrial, vacant, and urban residential areas each had less than ten sites for frogs, salamanders are better represented in both urban residential and vacant areas, primarily due to the ubiquity of *Plethodon cinereus*.

Reptile distributions show some patterns that differ from those for amphibians. For example, 56% of turtle records came from the canal areas within the county. None of these records were for the terrestrial species, *Terrapene carolina* and *Clemmys insculpta*. Rural residential areas, agricultural areas, and parks contained the next most abundant numbers of sites for turtles. Other land-use areas had less than five records of turtles. Patterns of distribution of snake localities loosely parallel those of frogs. One-third of all snake localities were from agricultural areas while 39% of sites for snakes came from rural residential areas or parks. Other land-use categories had less than ten specimens each.

When the numbers of sites in each land-use category is compared to the area (table 6) of each category (table 7), a different pattern emerges. Whereas agricultural areas had the second highest number of sites, they have the lowest number of sites per square kilometer. Agricultural areas make up 74 percent of the county, so a high number of sites is not surprising. The per unit area data for individuals shows similar results (table 8). Agricultural areas have the second lowest number of individuals per square kilometer. The category with the lowest number of individuals per square kilometer is urban residential areas. Rural residential areas remain rich in sites and individuals when compared to area, with 3.5 sites and 15.9 individuals per square kilometer. Parks had the highest number of sites and the second highest number of individuals per square kilometer. However, parks make up only 2.4% of the county. Private areas, which show the greatest number of individuals per square kilometer, represent only 1.2% of the total area in the county and this area includes the land around all of the schools participating in the survey. Commercial areas also had high numbers of sites and individuals per unit area. These areas had low numbers of overall sites, but the overall area for commercial sites is so small (only 5.3 km^2) that the number of sites and individuals per unit area results in high numbers. Industrial areas had a low number of sites per unit area, but a relatively high number of individuals because one of the frog sites was a large breeding population. Urban residential areas remain low in abundance for both sites and individuals.

Species Distributions

No species occurred everywhere or in all land-use categories (table 3). Species found at large numbers of sites generally occur in the greatest diversity of sites as reflected by numbers of land-use categories represented (for all species, Pearson correlation coefficient between number of sites and number of land use categories = 0.61 [$P<0.01$]). Similarly, the more abundant species typically occur in the greatest number of land-use categories (for all species, Pearson correlation coefficient between number of individuals and number of land use categories = 0.59 [$P<0.01$]). *Ambystoma maculatum, Chrysemys picta,* and *Trachemys scripta* were exceptions to this trend. These species were found at many sites but in only three land-use areas. In contrast, *Nerodia sipedon* and *Lampropeltis triangulum* were found at relatively few sites but these sites were distributed among five land-use categories. An overview of table 3 suggests that about a third of the species found during the survey occur in more than half of the available land-use categories and the majority of this third are amphibian species.

Species Richness and Land-use

In addition to having the highest number of sites, agricultural areas, rural residential areas, and parks also had the highest species richness (total number of species) with 27, 29, and 30 species, respectively. State game lands had 14 species, private areas had 12, vacant areas had 11, urban residential, canal, and commercial areas each had eight, and industrial areas had only three. These general trends in species diversity across land-use categories parallel trends in abundance.

Numbers of species for each of the four taxonomic groups in each of the major land-use categories are summarized in figure 4. The general trend for each of the taxonomic groups follows the same trend as that of all species together. Species diversity declines as human usage levels reflected by each category increase. Virtually all of the land-use categories support at least one species from each taxonomic group with the exception of industrial areas, which had no snakes or turtles, commercial areas, which had no turtles, and canal areas, which had no salamanders.

DISCUSSION

Data Collection

The intent of this study was to gain as much data as randomly as possible. Because students were asked to search areas around their homes, and because the only field technique demonstrated was searching under loose cover, it is assumed that areas surveyed represent those most accessible to students searching on foot. This approach increased the probability that sites in most major land-use categories were surveyed. Some records were acquired from areas that students were taken to by their parents but these appear to represent a minority (estimated to be less than 10%) of the total site records. Another assumption of the survey was that many amphibian and reptilian species can be found using the surveying techniques demonstrated.

Relatively few sites for breeding frog populations (approximately 15) were reported by volunteers during this survey. Most of the breeding sites were reported by the project leaders. This lack of breeding sites reported by volunteers indicates a weakness in the data collection and estimates for amphibian (particularly frog) species are probably grossly underestimated. Initial concerns that relatively rare species and species with specific habitat requirements would not be found by these methods seem groundless inasmuch as seven of the 16 least common species (including *Hemidactylium scutatum, Clemmys muhlenbergii,* and *Crotalus horridus*) were found only by volunteers despite considerable field effort by the project leaders. An additional five of the least common species were found by both the project leaders and the volunteers. In the absence of evidence suggesting strong selectivity in data acquisition, the relative abundances of species in the data (table 2) are assumed to reflect the approximate abundances of these species in the county.

The initial intent to recruit volunteers from all of the eight school districts within the county led to the assumption that most areas in the county would be equally surveyed by volunteers. Patterns in the distribution of data points (figs. 2 and 3) show concentrations of points around school districts in which teachers and students contributed greater effort towards the survey and in areas that were surveyed by the project leaders. Given that more than half the county lies outside the area covered by enlarged data points (figs. 2 and 3), most of this area is assumed not to have been surveyed rather than devoid of herpetofauna. However, there is no way of verifying this because there was no documentation of areas surveyed and no species were found.

Species Abundances

Species abundances loosely correlate with the prey type for many of the species reported in the survey. With the exception of *Thamnophis sirtalis* and *Chrysemys picta*, species with more than 50 individuals reported are insectivorous (table 2). Although not insectivorous, *Thamnophis sirtalis* feeds on a variety of abundant prey, including earthworms and amphibians (Wright and

Wright, 1957). *Chrysemys picta* also has a diet which includes a variety of aquatic plants and animals (Ernst and Barbour, 1972). Some insectivores as well as the non-specialized feeders were reported in relatively low numbers, suggesting that these species have microhabitat requirements that override trophic-level constraints on their abundance, or that their microhabitat requirements greatly reduce the probability of their being found using the survey techniques used in the study.

Some closely related species differ greatly in abundance and distribution. For instance, *Plethodon cinereus* and *Plethodon glutinosus* are both insectivorous, woodland species, but *Plethodon cinereus* is approximately ten times more abundant in sites and individuals reported. *Plethodon cinereus* was found in all but one of the land-use areas whereas *P. glutinosus* was either absent from or reported in low numbers from areas of high human usage (urban residential, commercial, and industrial). *Eurycea bislineata* and *Eurycea longicauda* also showed drastic differences in abundance despite the fact that they are both insectivorous, stream-side salamanders (table 1).

Although *Plethodon cinereus* is the most abundant and widespread herpetofaunal species in Northampton County, figures given for its relative abundance (table 2) may seriously underestimate its actual population size in the county. Population densities for this species range from 0.21 per m^2 (Klein, 1960) to 2.2 per m^2 (Jaeger, 1980) and previous plot samples from areas in Northampton County (Cundall, unpublished class data collected 1979-1995) have shown similar results. However, a number of studies have shown large subsurface populations (Fraser, 1976) that would not be sampled during a single surface survey. Assuming that only 23 km^2 (approximate area covered by parks) was ideal habitat for *P. cinereus*, and assuming Klein's previous population density (among the lowest cited by Petranka (1998)), our sample size for this species should have approximated 5×10^6. Because the total number of individuals actually found is 0.023% of this estimate, and because *P. cinereus* occurs in almost all land-use categories, it is impossible to determine the orders of magnitude separating actual population size from the estimates of this survey.

The three most abundant salamander species in Northampton County (*P. cinereus, E. bislineata,* and *D. fuscus*) account for 88.5% of the total number of salamanders found. This distribution of relative abundance is similar to but less extreme than relative abundances found for the same species in the Cuyahoga Valley National Recreation Area between Akron and Cleveland (Varhegyi et. al., 1998). However, in Northampton County *P. cinereus* is by far the most abundant, whereas in the Cuyahoga Valley, it was the least abundant of the three species.

Abundances for some frog species (table 2) also probably underestimate relative species abundances due to the low numbers of records for spring-breeding populations. The majority of amphibian populations reported by Brodman and Kilmurry (1998) were for calling anurans detected by auditory surveys while road cruising in Jasper County, Indiana. Most of the student volunteers participating in the Northampton county survey were not only too young to drive but probably restricted in their ability to survey at night. Eleven of 34 recorded breeding sites for frogs are represented in abundance records by a single frog because no estimate was provided of the number of calling males. Ten of these 11 sites contained *Pseudacris crucifer.* The 16 sites containing *P. crucifer* in which the number of males are estimated had an average of 47 males per site. Thus, abundance records for this species, as for *P. cinereus*, may underestimate its relative and absolute abundance.

For some species, movement patterns may result in low abundances. Some species known to forage widely, particularly the large snake species (Bushar et. al., 1998; Weatherhead and Hoysak, 1989), had very low numbers of sites and individuals. Individuals from a number of species (*Pseudacris crucifer, Rana sylvatica, Rana clamitans, Bufo americanus, Thamnophis sirtalis, Rana catesbeiana, Ambystoma maculatum, Trachemys scripta, Terrapene carolina,* *Eurycea longicauda, Lampropeltis triangulum, Bufo woodhousii, Clemmys muhlengergii, Crotalus horridus, Ambystoma opacum, Elaphe obsoleta*) were reported on roads in the county. Some of these individuals were apparently killed by vehicles while crossing roads. Amphibians (particularly frog species) were often recorded crossing roads in the spring while traveling to breeding sites. Forman and Alexander (1998) cite increasing road density as an important factor that may impact local biodiversity. Roads near wetlands and ponds appear to have the highest rate of roadkills, with amphibian species being most adversely affected. As roads are added to the landscape, large populations are repeatedly subdivided into smaller island populations and adults of species that forage widely or disperse to breeding or egg-laying sites suffer increased mortality as traffic density increases.

Land-use Influences on Distributions

Comparison of land-use types (tables 7 and 8) shows, in general, higher densities of sites and individuals in areas of low human usage (parks and rural residential) and low densities in areas of high human usage (agricultural, industrial, and urban residential). Parks have a disproportionate number of individuals and sites, and diversity of species relative to the total area of this land-use type in the county. This indicates that parks overall provide ideal conditions for many species.

Although the original land-use maps used for analysis did not distinguish between rural and urban residential areas, there are important ecological differences between these two areas. The two were set apart by creating a separate coverage for urban areas based on the location of residential areas inside city or borough limits. Residential areas outside city or borough limits were designated rural. Some parcels that were placed into one of these two categories may have fit better into the other. However, the fact that more species and many individuals are in rural residential areas indicates that these two residential types are ecologically different.

Bonin et al. (1997) found that agricultural areas containing forest and old field provided more suitable habitat for anuran species than areas of intensive agriculture. Brodman and Kilmurry (1998) also found that areas used for primary cropland supported a disproportionately low number of amphibian breeding sites. When looking at the large percentage of Northampton County (74%) zoned for agriculture, it is not surprising that a large number of sites were reported in these areas. Reasons for these high numbers may be that most areas in the county that are zoned for agriculture have been used for this purpose for centuries, so some species may have adapted to these areas. Also, areas zoned for agriculture may not necessarily be currently used for intensive agriculture. Despite the fact that agricultural areas are rich in total sites and individuals, their relatively low site and individual densities (tables 7 and 8) suggests agricultural land supports limited density and diversity of herpetofauna, as found by Brodman and Kilmury (1998).

State game land areas in the county were expected to have a high abundance of species and individuals due to the highly wooded nature of these areas. However, species diversity (number of species) and abundance was relatively low. One possible explanation for this is that the sampling effort in state game lands was relatively low. Also, the habitat incorporated into the game lands, although wooded, is not ideal for highly aquatic species. The state game lands are located along the slope and base of the ridge, so aquatic areas consist mainly of mountain springs and vernal ponds. On the other hand, some species (*Crotalus horridus* and *Ambystoma opacum*) were found only along the ridge.

Areas of high human usage (industrial, urban residential, and commercial) had low species diversities. Although low in diversity, data from these areas show that some species do survive varying degrees of ecological disturbance. These species include *Plethodon cinereus, Eurycea bislineata, Pseudacris crucifer,* and *Thamnophis sirtalis.* Some other species are supported in only one of these areas. Commercial areas support five frog species. Reasons for this are unclear.

Whereas, canal areas also showed a low overall species richness (8 species), five of these species were aquatic turtle species. Canals may provide optimal conditions for aquatic turtles but not many other species.

Comparison to Historical Data

McCoy (1982) provides the most comprehensive historical overview of amphibian and reptilian species distributions in Pennsylvania using museum and literature records. These records date back more than 200 years, yet (except for *Plethodon cinereus* [12 records]) there are less than ten historical records for each species in Northampton County.

Although the number of historical records in the county is small, some species (*Plethodon cinereus, Bufo americanus, Rana clamitans, Eurycea bislineata, Thamnophis sirtalis, Pseudacris crucifer, Plethodon glutinosus, Rana sylvatica, Desmognathus fuscus, Rana palustris, Notophthalmus viridescens,* and *Lampropeltis triangulum*) appear to have been widespread throughout the county. These species appear to retain relatively wide distributions throughout the county. Other species (*Ambystoma maculatum, Chrysemys picta, Rana catesbeiana, Chelydra serpentina, Terrapene carolina, Pseudotriton ruber, Nerodia sipedon , Bufo woodhousii, Diadophis punctatus, Clemmys insculpta, Gyrinophilus porphyriticus, Hyla versicolor, Graptemys geographica,* and *Thamnophis sauritus*) had few historical sites within the county. This survey has given us a better understanding of the distributions of these species within the county because some appear to be more widespread (although some remain in isolated areas) than their historical distributions. *Sternotherus odoratus* and *Crotalus horridus* were distributed in areas surrounding Northampton County but had not been recorded previously in the county. *Trachemy scripta* had not been recorded previously in the county. Evidence for breeding populations of *T. scripta* in Northampton includes the fact that it was the second most abundant turtle species reported and hatchlings were found along the Lehigh canal. Some species appeared either more widespread historically or appeared in locations that no longer seem to house them. These are *Eurycea longicauda, Rana pipiens, Clemmys muhlenbergii, Elaphe obsoleta, Ambystoma opacum, Hemidactylium scutatum, Clemmys guttata* and *Storeria dekayi*. Three species (*Ambystoma jeffersonianum, Heterodon platyrhinos,* and *Agkistrodon contortrix*) were recorded historically in Northampton county but were not found in the parts of the county surveyed.

Without some initial database and long-term monitoring of amphibian and reptilian species, it is difficult to assess whether apparent declines in populations are, in fact, permanent declines or temporary variations in population dynamics. Reports of global declines in amphibian species have inspired monitoring programs to assess changes in abundance of amphibian populations (Bishop et al., 1997). Green (1997b) cites a number of potential reasons for this possible decline. Large scale geographic problems include excessive UV-B radiation, hyperacidity, pesticides, and global warming. Local causes of population loss could include habitat destruction, fragmentation, urban encroachment, and agricultural development.

Bishop et al. (1997) state that call count monitoring as well as other surveys which look at more cryptic species will potentially improve our insight on fluctuations in amphibian populations. This study provides us with baseline data to observe future trends in local amphibian and reptilian populations. Although there are limitations to this surveying method, it also provides a model for surveying that combines education of the public on local species, access to data for numerous types of areas, and utilization of geographic information system technology to assess human effects on local populations.

Table 1: Total numbers of sites and individual specimens for each species

Species	Number of sites	Number of specimens
Salamanders		
Ambystoma jeffersonianum	0	0
Ambystoma maculatum	51	48(2#)(1@)
Ambystoma opacum	1	2
Notophthalmus viridescens viridescens	19	58
Desmognathus fuscus fuscus	30	142
Eurycea bislineata bislineata	51	164
Eurycea longicauda longicauda	3	12
Gyrinophilus porphyriticus porphyriticus	5	7
Hemidactylium scutatum scutatum	1	1
Plethodon cinereus	295	1168
Plethodon glutinosus	27	36
Pseudotriton ruber ruber	11	27
Total Salamanders	**494**	**1665(2#)(1@)**
Frogs		
Bufo americanus americanus	88	114(3*)
Bufo a. americanus X *woodhousii fowleri*	9	12
Bufo woodhousii fowleri	6	8
Hyla versicolor	4	3(1*)(1#)
Acris crepitans crepitans	0	0
Pseudacris triseriata feriarum	0	0
Pseudacris crucifer	34	6(28*)
Rana catesbeiana	27	57
Rana clamitans melanota	62	162
Rana palustris	23	40
Rana pipiens	3	3
Rana sylvatica	26	37(2*)(1@)
Total Frogs	**282**	**442(34*)(1#)(1@)**

Table 1: Total numbers of sites and individual specimens for each species

Species	Number of sites	Number of specimens
Turtles		
Chelydra serpentina	16	20
Sternotherus odoratus	2	2
Clemmys guttata	1	3
Clemmys insculpta	6	6
Clemmys muhlenbergii	3	4
Chrysemys picta	33	58
Graptemys geographica	3	4
Terrapene carolina carolina	15	15
Trachemys scripta elegans	18	20
Total Turtles	**97**	**132**
Snakes		
Diadophis punctatus edwardsii	8	16
Heterodon platyrhinos	0	0
Agkistrodon contortrix contortrix	0	0
Crotalus horridus	2	3
Coluber constrictor constrictor	2	6
Elaphe obsoleta obsoleta	2	2
Lampropeltis triangulum triangulum	7	11
Nerodia sipedon sipedon	11	17
Storeria dekayi dekayi	1	1
Thamnophis sauritus sauritus	2	2
Thamnophis sirtalis sirtalis	50	66
Total Snakes	**85**	**125**
Total	**958**	**2363(34*)(3#)(2@)**

Numbers with a * in parentheses indicate breeding sites

Numbers with a # in parentheses indicate locations where eggs were found

Numbers with a @ in parentheses indicate locations where larvae were found

Table 2: Decreasing number of individuals for each species reported throughout the survey period

The percent of the total number of individuals for each species is indicated in the third column. The diet for each of the species is indicated in the last column.

Species	Number of Individuals	% of total	Rank	Diet
Plethodon cinereus	1168	35.11	1	Small invertebrates (5)
Pseudacris crucifer	703 ◇	21.13	2	Small invertebrates (2)*
Rana sylvatica	263 ◇	7.91	3	Small invertebrates (2)*
Eurycea bislineata bislineata	164	4.93	4	Small invertebrates (5)
Rana clamitans melanota	162	4.87	5	Variety of invertebrates (1)*
Bufo americanus americanus	150 ◇	4.51	6	Variety of invertebrates (4)
Desmognathus fuscus fuscus	142	4.27	7	Terrestrial/ semiterrestrial invertebrates (5)
Thamnophis sirtalis sirtalis	66	1.98	8	Earthworms, frogs, mice, toads, insects, fish, salamanders, yound birds, molluscs (6)
Notophthalmus viridescens viridescens	58	1.74	9	Small invertebrates (5)
Chrysemys picta	58	1.74	9	Omnivorous (3)
Rana catesbeiana	57	1.71	10	Variety of prey (1)
Ambystoma maculatum	51	1.53	11	Small invertebrates/ earthworms (Larvae- zooplankton) (5)
Rana palustris	40	1.20	12	Small invertebrates (2)*
Plethodon glutinosus	36	1.08	13	Variety of invertebrate prey (5)
Pseudotriton ruber ruber	27	0.81	14	Other salamanders/ variety of invertebrates (5)
Chelydra serpentina	20	0.60	15	Omnivorous (3)
Trachemys scripta elegans	20	0.60	15	Omnivorous, non-specialized (3)
Nerodia sipedon sipedon	17	0.51	16	Fish, frogs, salamanders, crustaceans, insects, small mammals (6)
Diadophis punctatus edwardsii	16	0.48	17	Insects, earthworms, toads, frogs, salamanders, other snakes, lizards (6)
Terrapene carolina carolina	15	0.45	18	Omnivorous (3)
Eurycea longicauda longicauda	12	0.36	19	Variety of invertebrates (5)

Table 2: Decreasing number of individuals for each species reported throughout the survey period

Species	Number of Individuals	% of total	Rank	Diet
Bufo a. americanus X *woodhousii fowleri*	12	0.36	19	Variety of invertebrates (4)
Lampropeltis triangulum triangulum	11	0.33	20	Small mammals, snakes, lizards, amphibians, birds and their eggs, insects (6)
Desmognathus ochrophaeus	10	0.30	21	Variety of invertebrates (5)
Bufo woodhousii fowleri	8	0.24	22	Variety of invertebrates (4)
Gyrinophilus porphyriticus porphyriticus	7	0.21	23	Other salamanders/ variety of invertebrates (5)
Clemmys insculpta	6	0.18	24	Omnivorous (3)
Coluber constrictor constrictor	6	0.18	24	Small mammals, snakes, lizards (6)
Hyla versicolor	5	0.15	25	Small invertebrates (2)*
Clemmys muhlenbergii	4	0.12	26	Omnivorous (3)
Graptemys geographica	4	0.12	26	Freshwater invertebrates/ carrion/ some plant matter (3)
Rana pipiens	3	0.09	27	Small invertebrates (2)*
Clemmys guttata	3	0.09	27	Omnivorous (3)
Crotalus horridus	3	0.09	27	Mainly small mammals, some birds (6)
Ambystoma opacum	2	0.06	28	Small invertebrates, earthworms (Larvae- macrozooplankton, amphibian larvae and eggs) (5)*
Sternotherus odoratus	2	0.06	28	Omnivorous (3)
Elaphe obsoleta obsoleta	2	0.06	28	Mammals, nestling birds, lizards, amphibians (6)
Thamnophis sauritus sauritus	2	0.06	28	Insects, toads, frogs, mice, spiders, salamanders, and fish (6)
Hemidactylium scutatum scutatum	1	0.03	29	Variety of invertebrates (5)
Storeria dekayi dekayi	1	0.03	29	Earthworms, slugs, snails, insects, small treefrogs, fish (6)

◇Indicates that breeding sites were reported for these species so numbers of individuals were estimated from call counts

Literature sources for diets are indicated in parentheses

* Indicates that diet was assumed using information for confamilial species

Sources: 1. Conant and Collins, 1991; 2. Duellman and Trueb, 1986; 3. Ernst and Barbour, 1972; 4. Klemens, 1993; 5. Petranka, 1998; 6. Wright and Wright, 1957

Table 3: Decreasing number of sites reported for each species throughout the survey period

The percent of the total number of sites for each species is indicated in the third column; the fourth column has the rank for numbers of sites; and the last column shows the number of land-use types in which each species was found

Species	Number of Sites	% of total	Rank	Number of Land-use Types
Plethodon cinereus	295	30.79	1	9
Bufo americanus americanus	88	9.19	2	8
Rana clamitans melanota	62	6.47	3	7
Ambystoma maculatum	51	5.32	4	3
Eurycea bislineata bislineata	51	5.32	4	8
Thamnophis sirtalis sirtalis	50	5.22	5	8
Pseudacris crucifer	34	3.55	6	8
Chrysemys picta	33	3.44	7	3
Desmognathus fuscus fuscus	30	3.13	8	6
Plethodon glutinosus	27	2.82	9	6
Rana catesbeiana	27	2.82	9	6
Rana sylvatica	26	2.71	10	5
Rana palustris	23	2.40	11	6
Notophthalmus viridescens viridescens	19	1.98	12	6
Trachemys scripta elegans	18	1.88	13	3
Chelydra serpentina	16	1.67	14	4
Terrapene carolina carolina	15	1.57	15	6
Pseudotriton ruber ruber	11	1.15	16	4
Nerodia sipedon sipedon	11	1.15	16	5
Bufo a. americanus X *woodhousii fowleri*	9	0.94	17	3
Diadophis punctatus edwardsii	8	0.84	18	4
Lampropeltis triangulum triangulum	7	0.73	19	5
Bufo woodhousii fowleri	6	0.63	20	2
Clemmys insculpta	6	0.63	20	3
Gyrinophilus porphyriticus porphyriticus	5	0.52	21	2
Hyla versicolor	4	0.42	22	2
Eurycea longicauda longicauda	3	0.31	23	2

Table 3: Decreasing number of sites reported for each species throughout the survey period

Species	Number of Sites	% of total	Rank	Number of Land-use Types
Rana pipiens	3	0.31	23	3
Clemmys muhlenbergii	3	0.31	23	2
Graptemys geographica	3	0.31	23	1
Sternotherus odoratus	2	0.21	24	2
Crotalus horridus	2	0.21	24	2
Coluber constrictor constrictor	2	0.21	24	2
Elaphe obsoleta obsoleta	2	0.21	24	2
Thamnophis sauritus sauritus	2	0.21	24	2
Ambystoma opacum	1	0.10	25	1
Hemidactylium scutatum scutatum	1	0.10	25	1
Clemmys guttata	1	0.10	25	1
Storeria dekayi dekayi	1	0.10	25	1

Table 4: Total numbers of sites and individual specimens found on wooded areas of 1 acre or more.

Species	Wooded	Unwooded
Salamanders		
Ambystoma maculatum	38(36)(1#)(1@)	13(12)(1#)
Ambystoma opacum	1(2)	0(0)
Notophthalmus viridescens viridescens	11(48)	8(10)
Desmognathus fuscus fuscus	21(125)	9(17)
Eurycea bislineata bislineata	32(99)	19(65)
Eurycea longicauda longicauda	2(11)	1(1)
Gyrinophilus porphyriticus porphyriticus	4(6)	1(1)
Hemidactylium scutatum scutatum	1(1)	0(0)
Plethodon cinereus	172(645)	123(523)
Plethodon glutinosus	22(28)	5(8)
Pseudotriton ruber ruber	9(11)	2(16)
Total Salamanders	**313(1012)(1#)(1@)**	**181(653)(1#)**
Frogs		
Bufo americanus americanus	35(42)(1*)	53(72)(2*)
Bufo a. americanus X *woodhousii fowleri*	3(5)	6(7)
Bufo woodhousii fowleri	1(1)	5(7)
Hyla versicolor	2(2)(1#)	2(1)(1*)
Pseudacris crucifer	10(4)(6*)	24(2)(22*)
Rana catesbeiana	8(13)	19(44)
Rana clamitans melanota	33(72)	29(90)
Rana palustris	12(23)	11(17)
Rana pipiens	2(2)	1(1)
Rana sylvatica	20(28)(2*)(1@)	6(9)
Total Frogs	**126(192)(9*)(1#)(1@)**	**156(250)(25*)**

Table 4: Total numbers of sites and individual specimens found on wooded areas of 1 acre or more.

Species	Wooded	Unwooded
Turtles		
Chelydra serpentina	4(5)	12(15)
Sternotherus odoratus	1(1)	1(1)
Clemmys guttata	1(3)	0(0)
Clemmys insculpta	2(2)	4(4)
Clemmys muhlenbergii	2(3)	1(1)
Chrysemys picta	6(11)	27(47)
Graptemys geographica	0(0)	3(4)
Terrapene carolina carolina	8(8)	7(7)
Trachemys scripta elegans	1(1)	17(19)
Total Turtles	**25(34)**	**72(98)**
Snakes		
Diadophis punctatus edwardsii	4(12)	4(4)
Crotalus horridus	1(1)	1(2)
Coluber constrictor constrictor	1(1)	1(5)
Elaphe obsoleta obsoleta	1(1)	1(1)
Lampropeltis triangulum triangulum	3(5)	4(6)
Nerodia sipedon sipedon	6(10)	5(7)
Storeria dekayi dekayi	1(1)	0(0)
Thamnophis sauritus sauritus	0(0)	2(2)
Thamnophis sirtalis sirtalis	18(28)	32(38)
Total Snakes	**35(59)**	**50(65)**
Total	**499(1297)(9*)(2#)(2@)**	**459(1066)(25*)(1#)**

Numbers of sites are listed first followed by the number of individuals in parentheses.

Numbers with a * in parentheses indicate breeding sites.

Numbers with a # in parentheses indicate locations where eggs were found.

Numbers with a @ in parentheses indicate locations where larvae were found.

Table 5: Total numbers of sites and individual specimens in comparison to land use type

Species	Ag	Rur Res	Urb Res	Park	SGL	Vac	Lcan Dcan	Private	Comm	Indus
Salamanders										
Ambystoma maculatum	6(6)	4(4)		41(38)(2#)(1@)						
Ambystoma opacum				1(2)						
Notophthalmus viridescens viridescens	2(5)	5(5)	1(1)	2(2)	8(42)			1(3)		
Desmognathus fuscus fuscus	8(17)	4(31)		10(57)	4(30)	3(3)		1(4)		
Eurycea bislineata bislineata	11(28)	10(24)	1(2)	17(52)	1(1)	4(14)		5(40)	2(3)	
Eurycea longicauda longicauda		2(11)		1(1)						
Gyrinophilus porphyriticus porphyriticus		2(2)		3(5)						
Hemidactylium scutatum scutatum				1(1)						
Plethodon cinereus	73(294)	97(254)	14(29)	35(266)	8(14)	14(44)		42(240)	6(13)	6(14)
Plethodon glutinosus	7(7)	8(11)		7(13)	2(2)			1(1)		1(1)
Pseudotriton ruber ruber	2(2)	5(19)		3(4)				1(2)		
Total Salamanders	**109(359)**	**137(361)**	**16(32)**	**121(441)(2#)(1@)**	**23(89)**	**22(62)**	**0(0)**	**51(290)**	**8(16)**	**7(15)**
Frogs										
Bufo americanus americanus	29(34)(2*)	31(40)(1*)		7(10)	4(5)	1(5)	2(2)	7(7)	7(11)	
Bufo a. americanus X woodhousii fowleri	2(2)	6(9)		1(1)						
Bufo woodhousii fowleri	2(4)	4(4)								
Hyla versicolor	1(1*)	3(3)(1#)								
Pseudacris crucifer	15(5)(10*)	12(12*)	1(1*)	1(1)		1(1*)		2(2*)	1(1*)	1(1*)
Rana catesbeiana	6(7)	8(37)		5(5)		1(1)	6(6)		1(1)	
Rana clamitans melanota	30(50)	11(52)		10(41)	1(1)	5(12)		1(1)	4(5)	
Rana palustris	9(15)	3(3)		6(17)		1(1)	3(3)		1(1)	
Rana pipiens	1(1)	1(1)						1(1)		
Rana sylvatica	3(5)	5(4)(1*)	2(3)	11(20)(1*)(1@)	5(5)					
Total Frogs	**98(123)(13*)**	**84(153)(14*)(1#)**	**3(3)(1*)**	**41(95)(1*)(1@)**	**10(11)**	**9(19)(1*)**	**11(11)**	**11(9)(2*)**	**14(18)(1*)**	**1(1*)**
Total Amphibians	**207(482)(13*)**	**221(514)(14*)(1#)**	**19(35)(1*)**	**162(536)(1*)(2#)(2@)**	**33(100)**	**31(81)(1*)**	**11(11)**	**62(299)(2*)**	**22(34)(1*)**	**8(15)(1*)**

Table 5: Total numbers of sites and individual specimens in comparison to land use type

Species	Ag	Rur Res	Urb Res	Park	SGL	Vac	Lcan Dcan	Private	Comm	Indus
Turtles										
Chelydra serpentina	2(2)	3(6)		3(3)			8(9)			
Sternotherus odoratus						1(1)	1(1)			
Clemmys guttata		1(3)								
Clemmys insculpta	2(2)	3(3)		1(1)						
Clemmys muhlenbergii	2(2)	1(2)								
Chrysemys picta		3(6)		3(11)			27(41)			
Graptemys geographica							3(4)			
Terrapene carolina carolina	5(5)	5(5)	1(1)	2(2)	1(1)			1(1)		
Trachemys scripta elegans		2(2)		1(1)			15(17)			
Total Turtles	**11(11)**	**18(27)**	**1(1)**	**10(18)**	**1(1)**	**1(1)**	**54(72)**	**1(1)**	**0(0)**	**0(0)**
Snakes										
Diadophis punctatus edwardsii	2(3)	2(2)		3(10)	1(1)					
Crotalus horridus	1(2)				1(1)					
Coluber constrictor constrictor	1(1)			1(5)						
Elaphe obsoleta obsoleta	1(1)				1(1)					
Lampropeltis triangulum triangulum	1(1)	2(2)	1(1)	2(4)	1(3)					
Nerodia sipedon sipedon	2(5)	4(6)		2(2)		2(3)	1(1)			
Storeria dekayi dekayi				1(1)						
Thamnophis sauritus sauritus		1(1)		1(1)						
Thamnophis sirtalis sirtalis	20(28)	9(14)	2(2)	5(6)	3(3)	3(3)		3(3)	5(7)	
Total Snakes	**28(41)**	**18(25)**	**3(3)**	**15(29)**	**7(9)**	**5(6)**	**1(1)**	**3(3)**	**5(7)**	**0(0)**
Total Reptiles	**39(52)**	**36(52)**	**4(4)**	**25(47)**	**8(10)**	**6(7)**	**55(73)**	**4(4)**	**5(7)**	**0(0)**
Total	**246(534)(13*)**	**257(566)(14*)(1#)**	**23(39)(1*)**	**187(583)(1*)(2#)(2@)**	**41(110)**	**37(88)(1*)**	**66(84)**	**66(303)(2*)**	**27(41)(1*)**	**8(15)(1*)**

Numbers of sites are listed first followed by the numbers of individuals

Numbers with a * in parentheses indicate breeding sites

Numbers with a # in parentheses indicate locations where eggs were found

Numbers with a @ in parentheses indicate locations where larvae were found

Table 6: Areas and percent of Northampton county represented for each land-use category

	Area (sq. km)	Percent of county
Agricultural	717.45	74.04
Parks	23.24	2.40
Urban Residential	48.35	4.99
Rural Residential	73.15	7.55
Industrial	17.46	1.80
Private	11.62	1.20
Commercial	5.32	0.55
State Game Lands	20.64	2.13

Table 7: Number of sites per square kilometer for eight of the ten land-use types

	Ag	Rur Res	Urb Res	Park	SGL	Private	Comm	Indus
Salamanders	0.152	1.873	0.331	5.207	1.114	4.389	1.504	0.401
Frogs	0.137	1.148	0.062	1.764	0.484	0.947	2.632	0.057
Turtles	0.015	0.246	0.021	0.430	0.048	0.086	0	0
Snakes	0.039	0.246	0.062	0.645	0.339	0.430	0.940	0
Total	**0.343**	**3.513**	**0.476**	**8.046**	**1.793**	**5.680**	**5.075**	**0.458**

Table 8: Number of individuals per square kilometer for eight of the ten land-use types

	Ag	Rur Res	Urb Res	Park	SGL	Private	Comm	Indus
Salamanders	0.500	4.935	0.662	19.105	4.312	24.957	3.008	0.859
Frogs	0.316	10.280	0.083	5.207	0.533	9.466	7.143	5.727
Turtles	0.015	0.369	0.021	0.775	0.048	0.086	0	0
Snakes	0.057	0.342	0.062	1.248	0.436	0.258	1.316	0
Total	**0.889**	**15.926**	**0.827**	**26.334**	**5.329**	**34.768**	**11.466**	**6.586**

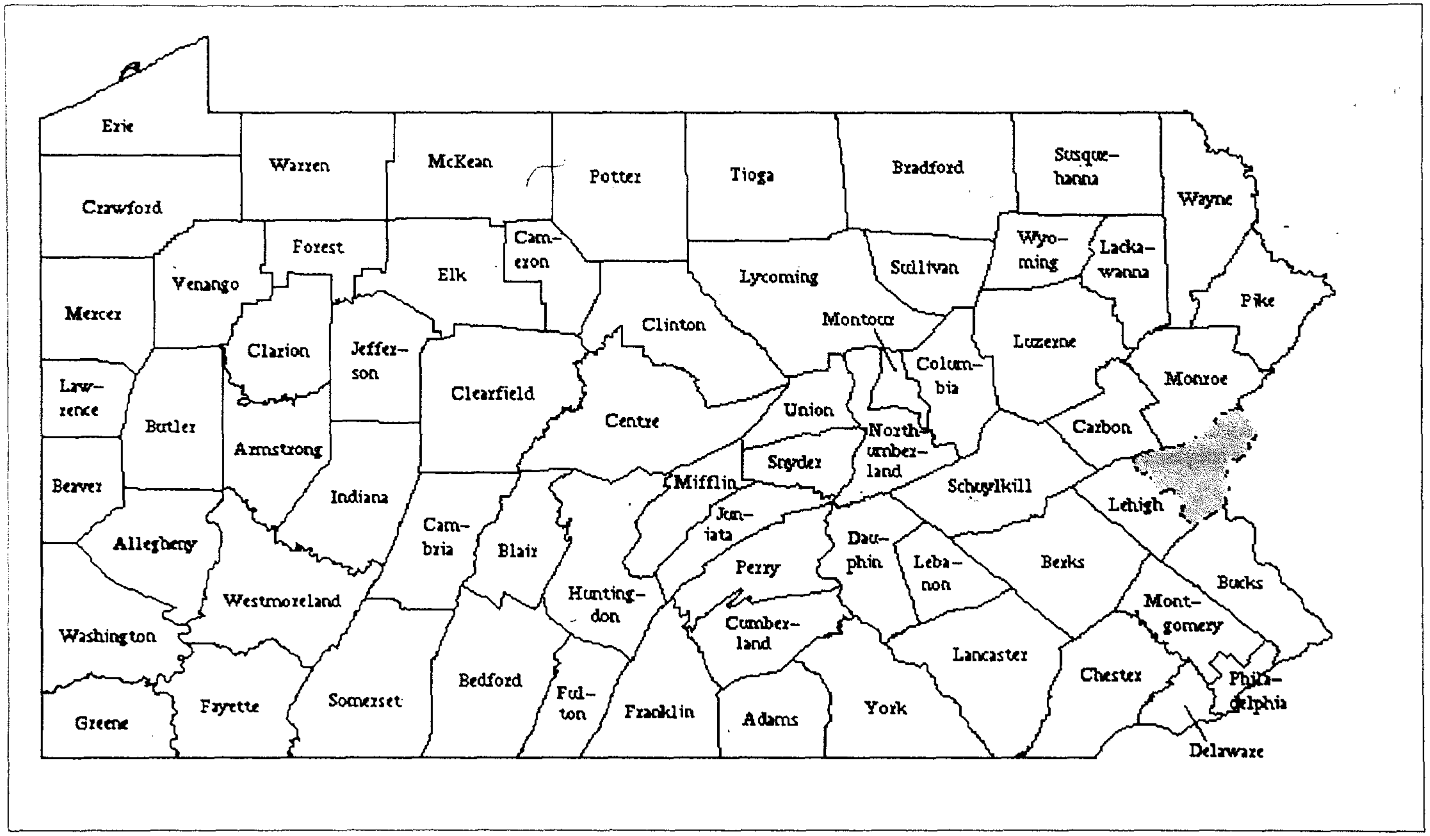

Figure 1: Map showing location of Northampton County in Pennsylvania. Northampton County is shaded in on the eastern border

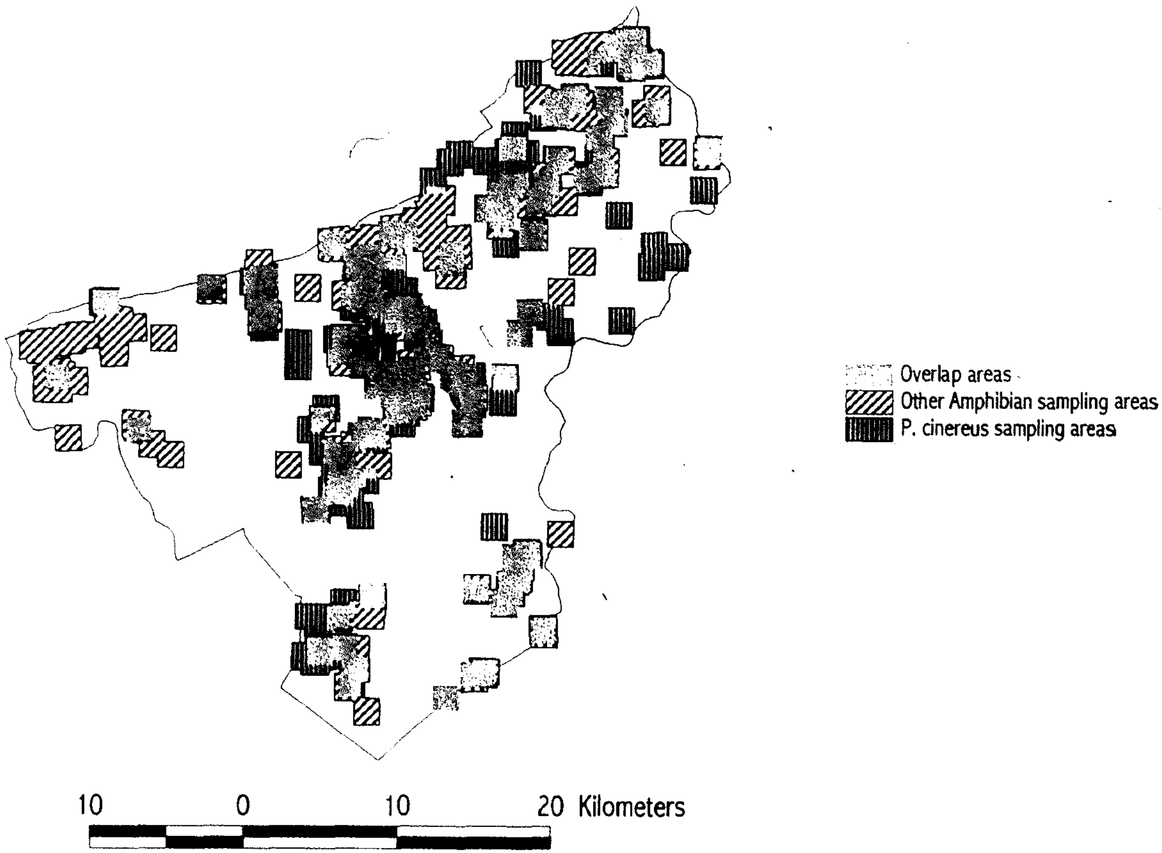

Figure 2: Map of areas where *Plethodon cinereus* sites were recorded (vertical lines) versus areas where other amphibian species were recorded (diagonal lines). Areas that are shaded in indicate overlap between *P. cinereus* and other amphibian groups.

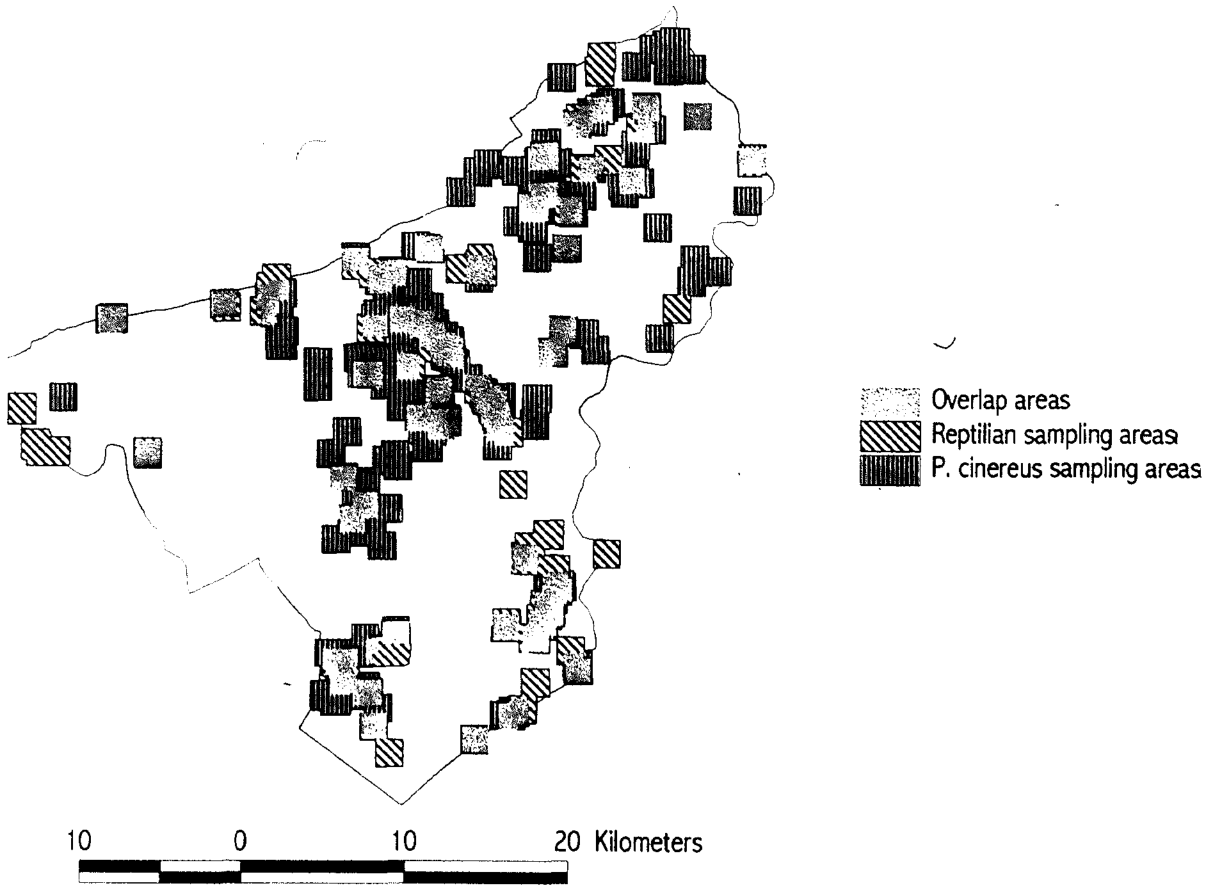

Figure 3: Map of areas where *Plethodon cinereus* sites were recorded (vertical lines) versus areas where reptilian species were recorded (diagonal lines). Areas that are shaded in indicate overlap between *P. cinereus* and reptilian sites.

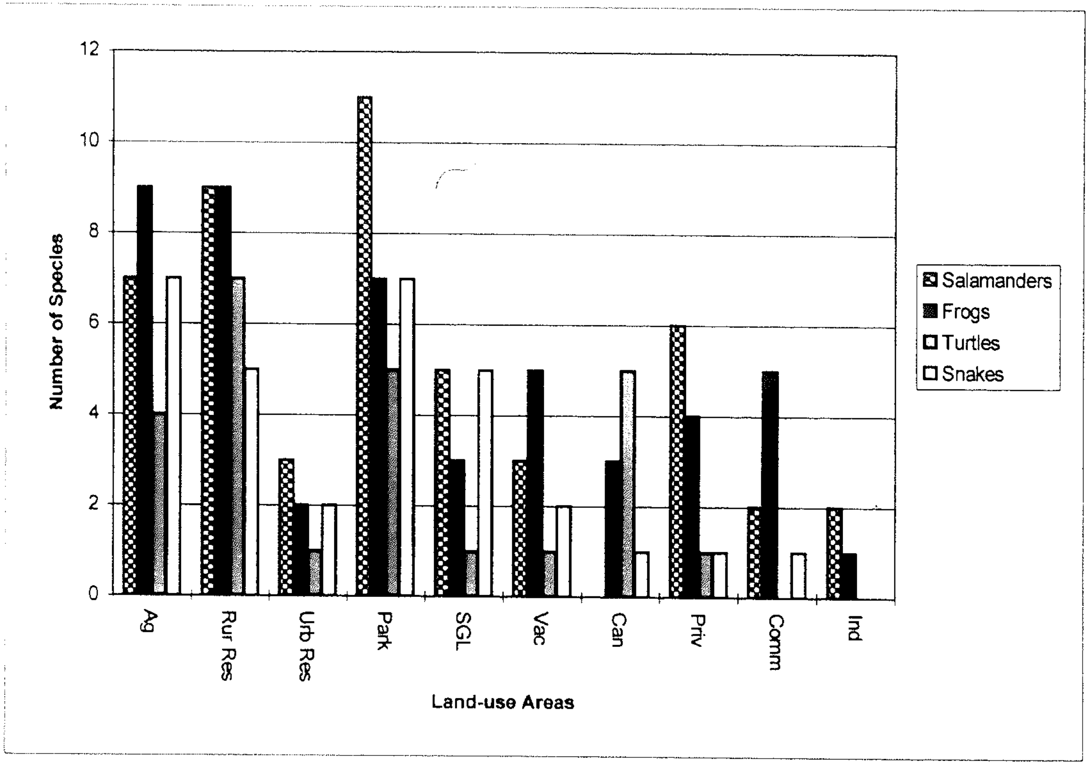

Figure 4: Bar graph showing the number of species for each taxonomic group present in each of the ten major land-use categories

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Jeanne McHugh Knepper was born in Lehighton, Pennsylvania on March 15, 1971, and was raised in Lansford, Pennsylvania. Her parents are Francis and Patricia McHugh of Lansford, Pennsylvania.

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END

OF

TITLE