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Shyamal K. Majumdar, Ph.D.
Editor
Department of Biology
Lafayette College
Easton, PA 18042

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STOMACH CONTENTS OF THE SHIELD DARTER, *PERCINA PELTATA* (STAUFFER) FROM PINE CREEK, LYCOMING COUNTY, PA[1]

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ABSTRACT

Foods of the shield darter, *Percina peltata* are reported for the first time. Ninety-seven specimens from Pine creek, Lycoming County, Pennsylvania were studied. Stomach contents were enumerated and found to contain predominantely Heptagenidae, Hydropsychidae, and Chironomidae. The data suggested little correlation between total length or age with variety of food items found in the stomachs. Larger and older fishes contained greater numbers of food items. Among these specimens age class I⁺ ranged 60.9 - 79.5 mm TL and age class II⁺ from 78 - 94 mm TL. In addition, data suggested no significant difference between sexes with regard to stomach contents.
[J PA Acad Sci 66(2):55-57, 1992]

INTRODUCTION

The shield darter, *Percina peltata* (Stauffer) inhabits moderate sized streams and rivers of the Atlantic coastal region from New York to North Carolina (Malick, 1979). In Pennsylvania, this fish is sometimes locally abundant in the Delaware and Susquehanna River drainage. It prefers streams with moderate water current that pass over rubble and gravel bottoms (Cooper, 1983).

There have been no previous studies on the diet of the shield darter (Sherk, unpublished data). In captivity, New (1966) fed this fish white worms (*Enchytraea albidus*) to sustain them for his extensive behavioral study. New (1966) suggested that worms may not be an adequate diet for this species. Loos and Woolcott (1969) fed this fish chopped earthworms during their study. Cooper (1983) hypothesized aquatic insects are important for this species' diet. There has been no published work comparing diet to relative size, sex, or age.

This may relate to the fact that large numbers of *Percina peltata* in collections are rare. The loan of materials from Pennsylvania State University helped to make this preliminary study possible.

The purpose of this paper is (1) to report the stomach contents of the shield darter from Pine Creek in Lycoming County, and (2) to determine possible differences in stomach contents relative to size, sex, and age.

MATERIALS AND METHODS

Specimens were loaned from Pennsylvania State University's fish museum. They had been collected by siene, initially preserved in 10% formalin, transferred to 45% isopropanol for storage and catalogued as follows: PSU 1369, 50 specimens, 22 July 1971; PSU 2063, 14 specimens, 25 August 1971; PSU 1274, 33 specimens, 22 August 1988. Each specimen was weighed (grams) on a Mettler P.C. 400 digital scale, and measured to the nearest millimeter total length. Sex was determined by external observation of abdominal scutes on males and confirmed upon dissection by the presence of the sex organs which were readily visible. Scales were removed from the left side above the lateral line and below the first dorsal, mounted between slides, and annuli counted with the aid of a Bioscope projector. Agreement on annuli counts by both authors was necessary and samples showing regenerated scales were not included.

The stomach was removed from each specimen, placed in 40% isopropanol, and labeled with an identifying number that corresponded to the specimen. The stomachs were opened in a grided petri dish under a 7-45x power binocular microscope, contents removed and items identified. When possible, invertebrates were identified to family using Merritt and Cummings (1978), Pennak (1953), and our personal knowledge. Partially digested food items were counted when a head capsule or identifiable incomplete invertebrate was present.

Possible correlations between stomach contents and weight, length, sex, and age were determined via a computer program, Statistical Package of the Social Sciences (SPSS) at York College. Statistical analysis involving a two-tailed test was used to find if any of the above fell within the correlation coefficients (-1.00 to 1.00). Specimens with empty stomachs and invertebrates of low frequency occurrence were excluded from calculations.

[1]Received for publication 28 February 1992; accepted 12 May 1992.

RESULTS AND CONCLUSIONS

Length frequencies by sex and age are presented in Figure 1. Eighty-seven specimens could be aged. There was no overlap in length frequencies of the I^+ (67 specimens) 60.9 - 79.5 mm TL and the II^+ (20 specimens) 78 - 93.9 mm TL age groups. Males in both age groups had a higher mean total length (I^+ males 74 mm TL; II^+ males 88; I^+ females 71; II^+ females 83).

Eighty of the 97 stomachs (83%) contained food (Table 1, Figure 2). The most abundant food items were Heptageniidae, Chironomidae, and Hydropsychidae which made up 91% of the 1687 foods identified. Plecoptera and Simillidae, comprising the next 7.6%, were observed only in stomachs from July specimens. The remaining 1.4% of stomach contents (pooled in Figure 2) included Diptera, Elimiidae, Tipulidae, Oligochaeta, eggs, and debris. Generally, foods with higher percent compositions also had high frequencies of occurrence among the specimens.

The SPSS analysis suggested no correlation when total items were compared on the basis of weight, length, sex, and age. Correlations using the dominant three taxa (Heptageniidae, Hydropsychidae, and Chironomidae) indicated a significant difference for Chironomides in males. Also Chironomides were more frequently found in stomachs of I^+ age group. All other coefficients came close to zero (not significant). This suggests no difference between Heptageniidae and Hydropsychidae in stomachs of other age classes and sex.

Raw data and tests verified the obvious. Older fishes were longer and heavier; younger and thus smaller fish select Chironomidae (smaller particle size), while larger fish are more opportunistic.

TABLE 1. Food of the *Percina pelta* from Pine Creek, Lycoming County, PA.

Date	August 1988				July 1971				August 1971				Combined			
Stomachs Examined	33				50				14				97			
Stomachs with food	30				42				8				80			
Item	N	x	% Occ	%t	N	x	% Occ	%t	N	x	% Occ	%t	N	x	% Occ	%t
HEPTAGENIIDAE	29	17.4	96	85	37	32.9	88	40	6	2.6	75	66	72	11.8	90	56
HYDROPSYCHIDAE	13	2	43	4	27	3.5	64	8					40	1.5	56	7
CHIRONOMIDAE	11	5.1	36	9	31	13.2	73	38	3	2	37	25	48	5.9	50	28
Ephermaptera	1	1	3	*	3	1	7	*					4	0.5	0.05	*
Oligocheata	1												1	*	*	*
Plecoptera					7	8.7	16	*					7	0.7	8.7	*
SIMULLIDAE					12	5.7	28	.01					12	0.86	15	*
Diptera					1	1	2	*					1	*	*	*
ELIMIDAE					1	1	2	*					1	*	*	*
TIPULIDAE					1	1	2	*					1	*	*	*
eggs	1	1	3	*									1	*	*	*
debris									2	1	25	8	2	*	*	*
unknown					1	1	2	*					1	*	*	*

N = Number of stomachs containing food item;
x = Average number per stomachs;
% Occ = Percent Occurrence for date(s);
%t = Percent volume of all food for date(s);
* = Less than .01.

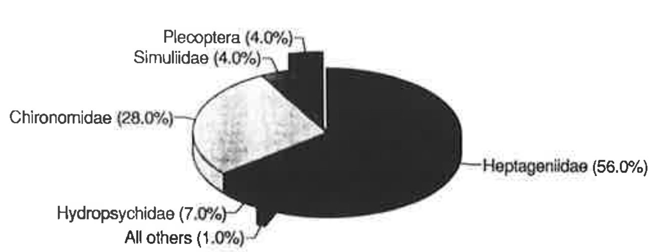

FIGURE 1. Length frequencies of *Percina peltata* for specimens showing range, mean, and standard deviation by age group and sex.

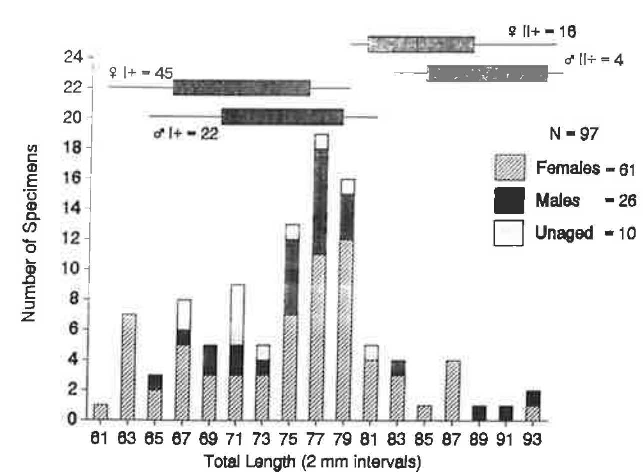

FIGURE 2. Percent composition of dominant taxa found in stomachs of *Percina peltata*.

Stomach contents of shield darter from Pine Creek contained typical bottom organisms which would support Cooper's (1983) hypothesis. Feeding may be based on the abundance of available organisms. The three dominant invertebrate taxa were found in 50% to 90% of stomachs (Table 1). For both August dates food items and numbers were low. Whether or not the diet reflects opportunism or selectivity will require further study. An interesting observation was that most of our specimens (collected July and August) had a few circuli beyond a clear annulus. This agrees with New (1966) who postulated annulus formation occurred shortly after spawning which he gave as May or June.

ACKNOWLEDGEMENTS

With sincere appreciation to Dr. Jay R. Stauffer, Jr. of Pennsylvania State University for donating the specimens; Dr. David T. Polk, Leroy Sterner, Thomas Sherk for help with aspects of the study. York College Biology Department supplied laboratory space and financial assistance.

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Journal of the Pennsylvania Academy of Science 66(2): 58-62, 1992.

A COMPARISON OF FISH AND MACROINVERTEBRATE COMMUNITIES BETWEEN AN UNPOLLUTED STREAM AND THE RECOVERY ZONE OF A STREAM RECEIVING ACID MINE DRAINAGE[1]

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ABSTRACT

Selected physiochemical parameters, benthic macroinvertebrate, and fish communities of two similar Southwestern Pennsylvania warm-water streams were studied over a six month period. One was relatively undisturbed and served as the control. The other represents the recovery zone of an acid mine drainage point-source. Iron and sulfate levels were found to be elevated in the recovery zone stream, and macroinvertebrate diversity and standing crop were depressed relative to the control. Both streams were electrofished utilizing the removal method. Electrofishing data were used to calculate diversity and estimates of fish numbers and biomass. The control had a Shannon-Weaver diversity, $\bar{d}$, of 2.8, and supported 41.0 kg/ha of fish, compared to a $\bar{d}$ of 1.8 and 11.4 kg/ha in the recovery zone stream.
[J PA Acad Sci 66(2):58-62, 1992]

INTRODUCTION

The impact of acid mine drainage, (AMD), on the surface waters of the Appalachian region, and Pennsylvania in particular, has been well documented by numerous authors (Weed and Rutschky 1971; Letterman and Mitsch 1978; Moon and Lucostic 1979; Kimmel et al. 1981; Kimmel 1983). Pennsylvania alone has in excess of 4,000 km. of acidified streams (Weed and Rutschky 1971). In Southwestern Pennsylvania, AMD has resulted from the deep or surface mining of bituminous coals. Site-specific hydrogeologic conditions, and the exposure of iron sulfide minerals such as pyrite or marcasite to water, air, and iron oxidizing bacterial strains combine to produce a complex effluent. This effluent, while primarily characterized by elevated sulfate and iron levels, may also contain a variety of heavy metal ions and dissolved solids (Letterman and Mitch 1978; Kimmel 1970, 1983; Cohen and Gorman 1991).

[1]Received for publication 5 April 1992; accepted 16 June 1992.

The immediate impact which this AMD has upon the receiving stream's water is a function of many complex factors. Perhaps most important of these is the stream's natural ability to buffer the increased hydronium ion concentration. The degree of buffering capacity any given stream exhibits is directly related to the abundance of carbonate-bearing rock units and their hydrogeologic orientation in its watershed.

If the carbonate buffer system of a stream can neutralize the increased hydronium ion concentrations resulting from AMD inputs, pH and oxygen values will remain near normal, and the ferrous iron, Fe (II), will be oxidized to the ferric form, Fe (III). This results in the formation of a ferric hydroxide precipitate, $Fe(OH)_3$ (Weed and Rutschky 1972; Kimmel et al. 1981). Indeed, the rate at which this precipitate, commonly known as "yellow-boy", forms is directly related to the pH of the receiving waters; and the precipitate forms "rapidly" in alkaline waters (Letterman and Mitch 1978; Moon and Lucostic 1979).

In addition to "yellow-boy", other precipitates, such as calcium sulfate, $CaSO_4$, may also form (Weed and Rutscky 1971; Cohen and Gorman 1991). The visible formation of these precipitates actually represents the "chemical recovery zone" of the receiving waters, as the physiologically toxic ferrous iron is oxidized to the physically detrimental ferric form and subsequently removed from solution (Kimmel et al. 1981). Another factor in this "chemical recovery" is related to the presence of heavy metal ions, whose solubilities are largely dependent upon pH, and remain low while alkalinity remains. Additionally, iron coprecipitates with these trace metals, removing them from solution (Johnson and Thornton 1987).

While the removal of the physiologically toxic forms of the metallic constituents of AMD by precipitation can be viewed as "chemical recovery", these precipitates create other problems by coating the substrate. This physical "smothering" of the substrate is known not only to reduce a stream's primary productivity, but also its benthos and fish populations as well (Weed and Rutschky 1971).

The purpose of this research was to examine and compare macroinvertebrate and fish community structures, as well as water quality, between an unpolluted stream and the recovery zone of another nearby AMD impacted stream.

Because of similarities in their hydrogeology, and the fact that both are tributaries of the Monongahela, a major river, the assumption was made that biotic conditions, in terms of species present and biomass, should, under natural conditions, be similar. The AMD-polluted stream had been examined previously, in terms of macroinvertebrate populations, and reported to be depauperate (Moon and Lucostic 1979). It was, however, known to be supporting a fish population of unknown quantity and composition.

STUDY AREA

Both streams in this study are dendritic tributaries of the Monongahela River, entering 15 km apart, near Brownsville, Fayette County, in southwestern Pennsylvania. These are warm, hard-water streams underlain by sandstone, shale, limestone, and coal. Tenmile Creek, the relatively undisturbed stream, was sampled 9.3 km from its mouth, where it forms the Washington-Greene County line. Its drainage area there is approximately 215² km, and the average gradient is 2.7 m/km (Pa. DER 1977). The stream bed within this area ranged from gravel to small boulder sizes, with some finer materials in the pools. Redstone Creek, the AMD polluted stream, was sampled in Fayette County, 10.6 km from its mouth, where its drainage area is approximately 160² km; its average gradient is 5.6 m/km (Pa. DER 1977). The stream bed within this area also ranged from gravel to small boulder sizes. However, as this station was located in the recovery zone 9.5 km downstream from a point source of AMD due to an abandoned deep mine, mining induced siltation, and a heavy coating of ferric hydroxide precipitate were also present. Additionally, there was evidence of improperly treated domestic sewage inputs.

METHODS

Comparative samplings were conducted at both streams between April and October 1991. Water levels in these streams fell continually throughout the period due to the presence of drought conditions.

Physiochemical

Five pairs of water samples were collected during the period. Temperature was determined in the field, with the other parameters being analyzed in the laboratory within 24 hours. Total alkalinity and dissolved oxygen were determined via titration, and pH was determined electrometically, following procedures described by APHA *Standard Methods.* Total iron and sulfate were determined photometrically by a Hach DREL/5 Portable Engineer's Laboratory.

Macroinvertebrates

Benthic macroinvertebrates were sampled during 3 periods by placing 5 Hester-Dendy artificial substrate samplers transversely across similar riffle areas in each stream, where they would remain for a 2 week period before collection. These 5 samplers were then grouped as 1 composite, preserved in alcohol, returned to the laboratory, and those organisms which had colonized them were identified to family level using keys by Lehmkuhl (1979) and Merrit and Cummins (1984), enumerated, then oven dried at 105°C for 6 hours before dry weight was determined. Shannon-Weaver diversity, $\bar{d}$, was also calculated for each composite sample, as well as a grouped total diversity for each stream (Wilhm and Dorris 1968; Klemm et al. 1990).

Fish

A similar pool-riffle area sequence was electrofished in each stream utilizing the 3 run removal method described by Zippen (1958). All fish captured were preserved in alcohol, returned to the laboratory, identified to species using keys by Cooper (1983) and Pflieger (1978), weighed, and enumerated. Shannon-Weaver diversity was then calculated from this raw data. Population estimates were calculated, and biomass estimates made based on sample mean weights for each species. All species present in each stream, excluding Darters and Madtoms, (not included due to sampling difficulties), were grouped and a total population estimate calculated. Based on this estimate and the grand mean weight, a total fish biomass estimate was made for each stream.

RESULTS

Physiochemical

Table 1 shows the means and ranges of those physiochemical parameters studied. Conditions present in Tenmile Creek, the control stream, were all within the normal ranges for a warm-water stream in this area (Pa. DER 1982). In Redstone Creek, due to its high natural alkalinity, the AMD discharged by the deep mine point source is quickly neutralized, therefore pH at the sampling station, located 9.5 km downstream, remained at acceptable levels. Total iron levels at high flow rates were found to be elevated beyond the state criteria of less than 1.5 mg/1 (Pa. DER 1982). However, as the pH remains high this iron is in the non-physiologically toxic ferric form. Sulfate levels also were elevated beyond the state criteria of less than 250 mg/1 (Pa. DER 1982). However, sulfates are not toxic to fish until concentrations of several g/1 (McKee and Wolf 1963).

Benthic Macroinvertebrates

A visual comparison of macroinvertebrate community structure between the two streams is provided by Figures 1 and 2.

Macroinvertebrate sample dry weights are compared in Figure 3.

TABLE 1. Means and ranges of selected phsyicochemical parameters of the study streams, April to Oct., 1991.

Site	Tenmile Creek		Redstone Creek	
Temp., °C	20.7	(9.5-28.0)	18.3	(9.5-23.0)
pH	7.8	(7.5-8.9)	7.6	(6.8-8.2)
Total Alk. as mg/l $CaCO_3$	140.0	(112.0-162.0)	107.8	(81.0-195.0)
Total Iron mg/l	0.15	(0.11-0.18)	1.42	(0.34-5.20)
Sulfate mg/l	122.4	(58.0-200.0)	383.0	(160.0-580.0)
Dis. Oxygen mg/l	7.7	(6.6-10.0)	8.1	(7.3-9.5)
Dis. Oxygen % Rel. Saturation	83.6	(69-96)	84.6	(70-92)

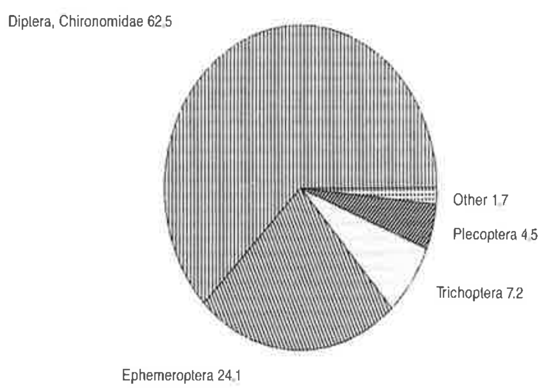

FIGURE 1. Tenmile Creek macroinvertebrate community structure as percent comp. by order. Shannon-Weaver diversity = 1.7.

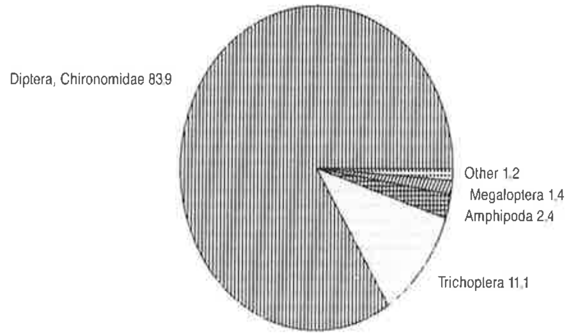

FIGURE 2. Redstone Creek macroinvertebrate community structure, as percent composition by order. Shannon-Weaver diversity = 0.9.

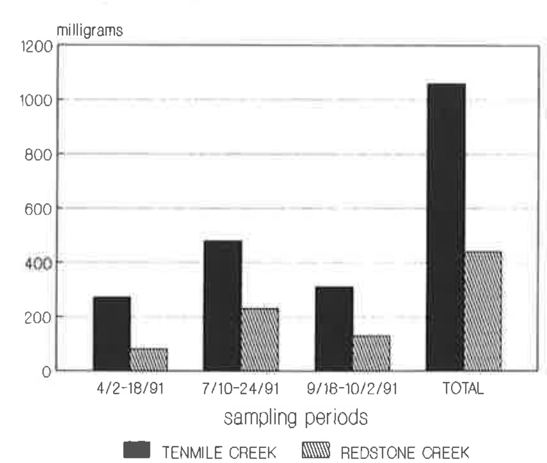

FIGURE 3. Comparison of macroinvertebrate sample dry weights.

Fish

Data on fish species present and diversity for each stream are presented in Table 2.

Results of fish species collections by relative biomass are shown in Figures 4 and 5.

Results of calculated biomass estimates for the two streams are shown by Figure 6.

DISCUSSION

Five pairs of water samples were collected over a range of flow rates from spring-time high flows to late summer drought influenced low flows, and as such should reflect essentially the entire range of those parameters assessed. The results for Tenmile Creek reflected normal levels for healthy streams in the area. Those same parameters, however, when tested for Redstone Creek, were indicative of the recovery zone of a hard water stream receiving AMD. The substantial buffering capacity of this stream served to keep the pH near normal, but total iron and sulfate levels were elevated, and a heavy ferric hydroxide precipitate coated the substrate. Oxygen levels were near normal for this type of stream.

The high water quality of Tenmile Creek was reflected by the numbers and diversity of macroinvertebrates which colonized the Hester-Dendy artificial substrate samplers. These sampling devices show a degree of selectivity, and rely largely on drift for colonization. Drift was probably minimal during the last sampling period used, because of low flows. However, the data presented are valid for comparative purposes. Samples taken from Redstone Creek

TABLE 2. Fish species and diversity for each stream.
Present X Not captured O

	Tenmile Cr.		Redstone Cr.
Campostoma anomalum (Rafinesque) Central Stoneroller	X		X
Catostomus commersoni (Lacepede) White Sucker	O		X
Etheostoma blennioides (Rafinesque) Greenside Darter	X	*	X
Etheostoma caeruleum (Storer) Rainbow Darter	X	*	O
Hypentelium nigricans (Lesueur) Northern Hog Sucker	X	*	O
Noturus flavus Rafinesque) Stonecat Madtom	X	*	O
Micropterus dolomieui (Lucepede) Smallmouth Bass	X		X
Notropis atherinoides (Rafinesque) Emerald Shiner	X		X
Pimephales notatus (Rafinesque) Bluntnose Minnow	X		O
Shannon-Weaver diversity as calculated from raw sample data.	$\bar{d}$ = 2.8		$\bar{d}$ = 1.8

*These species were present in Tenmile Creek and thus included in diversity calculations, but excluded from population estimates due to sampling difficulties as a result of their benthic habits.

indicated a stressed benthic macroinvertebrate community as evidenced by the absence of sensitive families and a low Shannon-Weaver Diversity, $\bar{d}$ = 0.9, as compared to a Shannon-Weaver of $\bar{d}$ = 1.7 for Tenmile Creek. Total dry weight of macroinvertebrates was also much higher (1060 mg compared to 440 mg) for Tenmile Creek.

The primary concern of this study was a comparison of the fish populations present in these two streams. Because of the similarity of their watersheds, and the approximately equal distance of the sampling stations from their respective confluences with the Monongahela River, the hypothesis tested was that their natural fish populations should be similar in terms of species composition and biomass totals. This obviously was not the case.

Diversity indices were calculated based upon the raw data produced by electrofishing similar sections of the two streams. Tenmile Creek had a Shannon-Weaver diversity, $\bar{d}$ = 2.8, with 8 species present, whereas Redstone had a $\bar{d}$ = 1.8, with 5 species present. Those species absent from Redstone included the Rainbow Darter, Stonecat Madtom, and Northern Hog Sucker, all with benthic habits, and therefore a sensitivity to substrate disruptions. A mutual exclusivity was found between the two streams with regard to sucker species; Tenmile had the reportedly intolerant Northern Hog Sucker, while Redstone had the more tolerant White sucker (Cooper 1983) (Pflieger 1978).

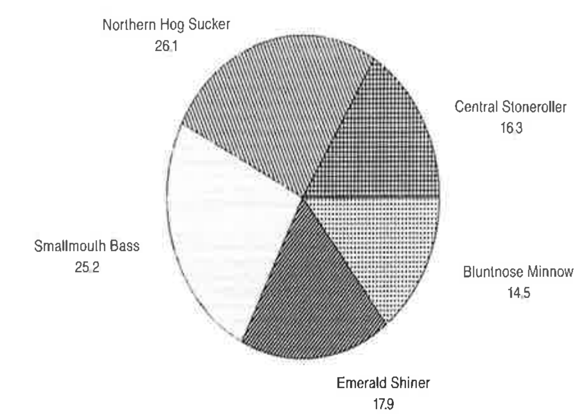

FIGURE 4. Tenmile Creek relative species composition by percent of biomass. Shannon-Weaver diversity = 2.8.

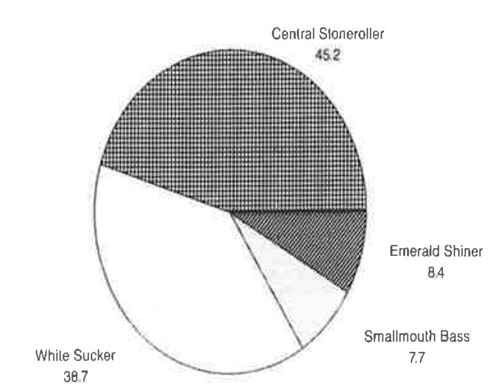

FIGURE 5. Redstone Creek relative species composition by percent of biomass. Shannon-Weaver diversity = 1.8.

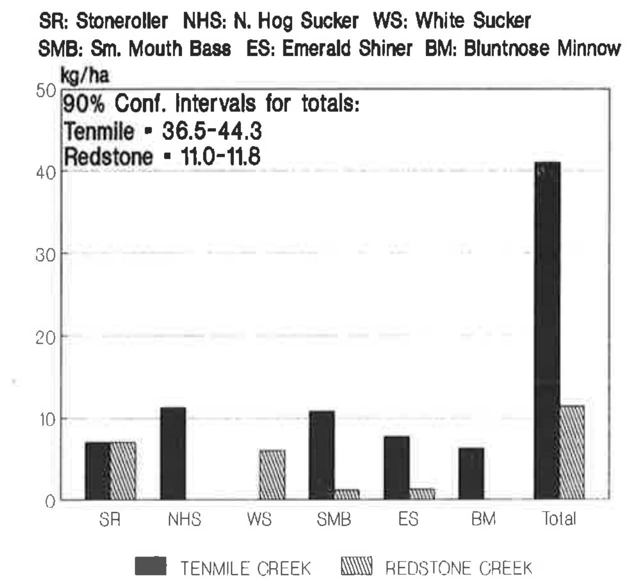

FIGURE 6. Comparison of fish species biomass estimates.

Population estimates were calculated for each species from each stream, excluding the Greenside and Rainbow Darters, and the Stonecat Madtom, due to their benthic habits, which make accurate sampling by electrofishing impossible (Larimore 1961). These population estimates were then multiplied by the species sample means to produce biomass estimates. Since the hypothesis that the two streams should be similar in terms of fish numbers and biomass was rejected, and since the water quality at the sampling station used in Redstone Creek was not sufficiently degraded to reduce fish populations, we conclude that the destruction of the substrate as a result of the deposition of metallic precipitates was a primary causative factor in reducing fish populations. Extrapolating the biomass data to numbers and biomass per ha revealed that Tenmile Creek had 9990 fish/ha and 41.0 kg/ha and 11.4 kg/ha of fish biomass. This represented a fish biomass reduction of 72.2 percent. Inclusion of the Darters and Madtoms in these estimates would have further increased the differences observed.

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HISTOLOGICAL AND MORPHOLOGICAL ATTRIBUTES OF THE BYSSUS OF THE ZEBRA MUSSEL, *DREISSENA POLYMORPHA* (PALLAS)[1]

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ABSTRACT

Scanning electron microscope (SEM) observations and histo-chemical staining of byssi of zebra mussels, *Dreissena polymorpha*, provides information regarding composition and associated morphology. Observation, of ethanol cryo-fractured specimens, indicate that the interior of byssal threads are composed of a cortex with longitudinal fibers covered by sheaths. Observation of plaques, however, reveal a shealth covering an interior cavity which is apparently filled with an adhesive material. Examination of the histo-chemical composition of byssi using a Picro-ponceau and hematoxylin staining procedure indicate that the root, stem, and cortexes of plaques are composed of collagenous fibers, while threads consisted of elastic fibers. In addition, there was an adhesive substance at the end of plaques, a sheath around individual threads, and basophilic secretion granules associated with roots. These secretory granules could be used to produce and secrete an elastic substance that form threads. Collagenous and elastic fibers would provide strength and flexibility to absorb energy imparted by water currents and hold molluscs firmly to substratum. [J PA Acad Sci 66(2):63-67, 1992]

INTRODUCTION

The zebra mussel, *Dreissena polymorpha*, a freshwater bivalve mollusc is thought to have been introduced into Lake St. Claire in 1986 from the ballast discharge of transoceanic ships (Griffiths, et al. 1991). They are currently found in all of the five Great Lakes and numerous connecting waterways (O'Neill and MacNeill 1991). The ability of the zebra mussel to attach to nearly any hard surface, by using up to 200 byssal thread per mussel (Clarke 1952), has led to its classification as a biofouling organism. The colonization of the zebra mussel, afforded by it tremendous attachment abilities, has had a considerable impact on municipal and industrial water facilities.

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The byssus, the portion of the zebra mussel that is used for attachment, is vital to the success of the mussel attachment to hard substrata. Morphologically the byssus of *Mytilus edulis*, as described by Brown (1952), consists of four primary parts (Smeathers and Vincent 1979):
(1) the *root* which is embedded in the byssus gland at the posterior basal region of the foot;
(2) the *stem* which extends distally from the root and to which the byssal threads are attached;
(3) the *threads* which extend distally from the stem and end in a plaque;
(4) the *plaque* (or adhesive disk) which is found at the distal end of the thread where it is attached to the substratum.

The byssus of *Mytilus* sp is formed from the secretions of the various glands in the foot (Purchon 1968); it is thought that the byssus consists mainly of a substance closely resembling collagen (Lane and Nott 1975). X-ray diffraction patterns by Fitton-Jackson et al. (1953) and amino acid analyses by Pujol et al. (1970) confirm that the byssus contains a protein similar to collagen. Also, studies done by Vitellaro-Zuccarello et al. (1983) on the byssal threads of *Mytilus* sp. suggest that collagen may be located in the matrix of the proximal portion of the thread, but that the filaments (within the matrix) could be responsible for the elastic properties.

Waite (1983) observed that in *M. edulis*, as the foot moved over the substratum, mucus was secreted by the ventral groove of the foot. Tamarin et al. (1976) indicated that, in *M. californianus*, the mucus adhesive secretion consists of a layer ~ 50 μm thick. This adhesive secretion is followed by a collagenous secretion. The presence of collagen in the plaque apparently serves the simple (albeit important) purpose of anchoring the thread in the cement.

In *Mytilus* sp, after the initial secretions, the foot causes the secretion of elastin material which is molded by the distal depression of the ventral groove of the foot (Brown 1952), and splays over the collagen and elastin forming the plaque (Waite 1983). Once a plaque has been formed, an individual thread, which is of fluid consistency, is extruded from the ventral groove (Smyth 1954, Waite 1983). The liquid undergoes a hardening and tanning process to become a thread. Brown (1952) noted that the sheath enclosing byssal threads of *M. edulis* was quinone tanned. Smyth (1954) explained that *en route* to the byssus gland, threads of *M. edulis* were covered by a secretion of the enzyme, polyphenol oxidase, which catalyzed the tanning reaction. A similar tanning process is likely to occur in threads of *D. polymorpha* because the thin outer layer of thread material that came in contact with such an enzyme would undergo tanning, thus forming a separate layer (Steele 1991).

Despite the overwhelming concern for the colonization of zebra mussels in the Great Lakes, little work has been done to study the internal morphology and chemical composition of its byssus. Eckroat, et al. [1992], using scanning electron microscopical observations, described the structural characteristics of the exterior surfaces of the byssi of *D. polymorpha.* The primary purpose of the current study was to determine the histo-chemical composition, as well as to describe the importance and the relationship of this composition to the overall morphology and formation of the byssus of *D. polymorpha.*

MATERIALS AND METHODS

Specimens of *D. polymorpha* were collected from floating docks at Lampe Marina, located at the East end of Presque Isle at Erie, Pennsylvania, during October of 1990. Mussels were maintained in laboratory aquaria at 15°C and fed an alga mixture (*Chlorella* sp.) daily.

Specimens were prepared for histological examination by the following procedure. The byssus was removed from the mollusc (Figure 1), fixed in 10% formalin for 24 hours, and dehydrated through a series of increasing concentrations of ethanol (80% to 100%). The ethanol was then removed from the specimen with three changes of toluene, followed by two changes of paraffin to clear the toluene from the tissue. After clearing, the byssus was embedded in a paraffin block and sectioned at 6-10μm with an A.O. model 620 microtome. Following sectioning, the tissue was adhered to a slide using a dissolved gelatin (275 Bloom) solution and placed on a slide warmer for 10 min. at 70°C. Slides were then placed in two changes of toluene to clear the paraffin, and hydrated through a series of decreasing concentrations of ethanol into water. Finally, the specimens were stained using a Picro-ponceau and hematoxylin staining procedure (Humason 1979) to histochemically distinguished between elastic fibers (yellow) and collagenous fibers (red).

The following procedures were used to prepare specimens for scanning electron microscopical observation: Specimens were immersed in buffered 5% glutaraldehyde (pH 7.2) at 5°C for 24 hours, dehydrated in a graded series of ethanol, and critical point dried using carbon dioxide as the transitional solvent. In addition, some specimens were fixed and dehydrated as described above then immersed in liquid nitrogen and ethanol cryofractured (allowing observations of internal morphology), as described by Klomparens et al. (1986). After being returned to 100% ethanol to remove any condensation, specimens were critical point dried as described above. Specimens were then mounted, sputter coated with a 10 to 15 nm layer of gold-palladium, examined and photographed with a Hitachi S-570 scanning electron microscope.

RESULTS

Scanning electron microscope observations indicated that the threads of *D. polymorpha* branched from the stem at about the same proximal-distal location and emerged from the foot (Figure 2). Some of the threads of specimens subjected to the freeze fracture process revealed two distinct thread parts: an interior cortex and an exterior surface sheath. Internal fibers ran longitudinally in the thread cortex (Figure 3). Observation of a portion of the sheath that peeled from a cryofractured thread revealed that the sheath was a separate layer with longitudinal striations on its inner surface (Figure 4). In addition, this displacement of the sheath exposed the interior fibers of the thread cortex. An additional specimen had a portion of its plaque sheath

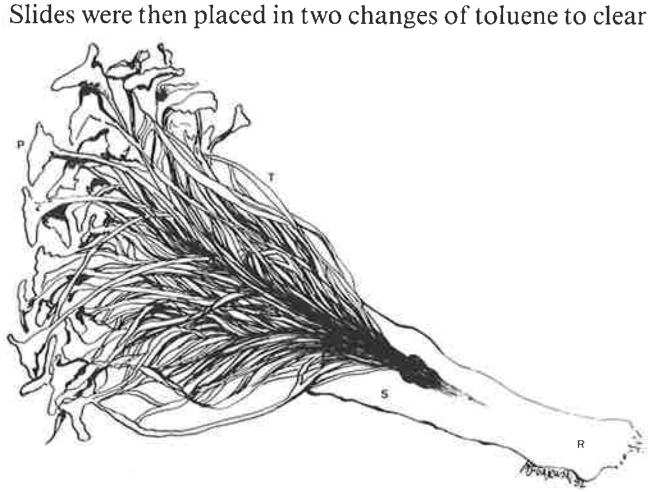


FIGURE 1. General morphology of the byssus of *D. polymorpha* after being dissected from the mollusc. Inicated are the root (R), stem (S), threads (T), and plaques (P). Not drawn to scale.

FIGURE 2. Byssal threads (T) with distally located plaques (P) emerging from the foot (F) (20 X). Line scale = .15 mm.

damaged (Figure 5) revealing that the plaque of *D. polymorpha* is covered by a separate sheath. On the left side of the damaged area, resulting in an opening, the plaque's sheath can be seen in cross section when viewed at higher magnification.

FIGURE 3. Freeze-fractured byssal thread showing fibers (F) of the cortex (2200 X). Line scale = 1.36 μm.

FIGURE 4. Freeze-fractured byssal thread (T) with peeled sheath (Sh) (2200 X). Line scale = 1.36 μm.

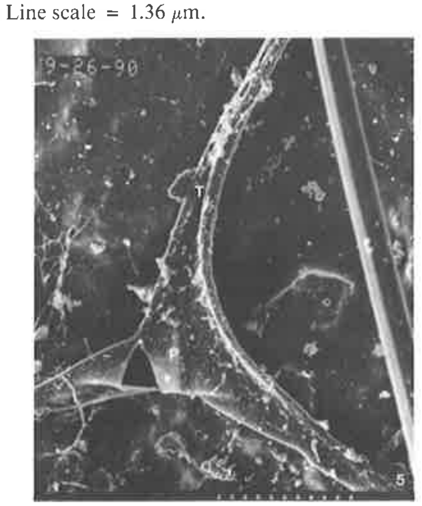
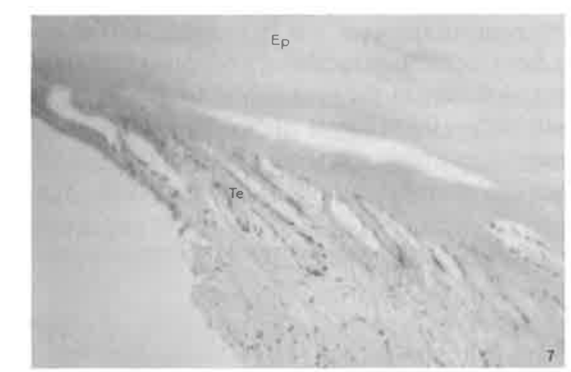
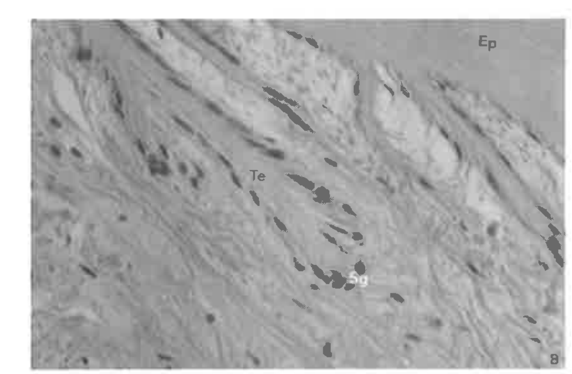


FIGURE 5. Thread (T) with damaged plaque (P) (500 X). Line scale = 6μm.

Picro-ponceau and hematoxylin staining of the histological sections indicated that the byssus of *D. polymorpha* was histochemically composed of both elastic fibers and collagenous fibers (Figure 6). Specifically, the root contained scattered elastic fibers within a collagenous infrastructure. In addition, within the root there were, for lack of a confirmed identification, what will be called basophilic secretion granules. In the root these granules are randomly scattered. However, near the interface of the root and the stem, the arrangement of these granules becomes more ordered, and line the "tributaries" of elastin from the root, which lead into the "reserve pool" of elastin in the stem (Figures 6-8).





FIGURES 6-8. Longitudinal secion (6μm) of root (R), stem (S), and threads (T) of a byssus. Additional structures observed in these sections are the secretion granules (Sg), tributaries of elasin (Te), elastin pool (Ep), and the surrounding collagenous infrastructure.
(6) Overview of a byssus (50 X).
(7) Tributaries of elastin, lined by secretion granules, leading into the elastin pool (275 X).
(8) Similar view as Figure 7, specifically showing the oblique orientation of the secretion granules relative to the tributary of elastin (425 X).

Within the stem, in addition to the "reserve pool" of elastin, there are collagenous "cuffs" that lie at the distal opening of the stem. The staining of the byssus indicates that the threads are homogeneously composed of elastic fibers surrounded by a thin sheath. The plaque is composed of elastic fibers continuing from the threads and splaying over a collagenous substance and adhesive layer, which frequently contain entrapped diatoms (Figure 9). A summary of the histochemical composition of the structural components of the bysus of *D. polymorpha* is found in Table 1.

DISCUSSION

Plaque attachment by *D. polymorpha* to the substrata is an important factor for the survival of the zebra mussel, therefore, it seems appropriate to discuss how the scanning electron micrographs and histochemical results obtained relate to previously proposed mechanisms of plaque secretion and attachment. Eckroat et al. [1992] indicated that as *D. polymorpha* prepared to form byssal threads, it moved along the surface of the substratum with its foot, searching for an attachment site. The process involves formation and detachment of temporary threads with the eventual secretion of permanent attachment threads and plaques when a permanent attachment site is located. As the mussel moves from location to location, a mucus is secreted from the ventral groove in the foot.

Some of the plaques of *D. polymorpha* observed using scanning electron microscopy appeared hollow revealing the presence of a plaque sheath. Benedict et al. (1986), however, observed that the inner plaque matrix of *M. edulis* was "spongy" in appearance. Furthermore, Waite (1986) stated that in *M. californianus* and *M. edulis*, the plaque was composed of an adhesive foam material. Therefore, it is likely that the interior of the plaque of *D. polymporpha* is filled with an adhesive material. In the apparently hollow specimens observed, this material may have been washed away during preparation, or vacant spaces may have formed during secretion of the plaque. Stained longitudinal sections of the plaque in *D. polymorpha* (Figure 9), showed a thin, distinct distal layer, which in studies of *M. californianus* was identified as a mucus/adhesive layer (Tamarin et al. 1976). This may also hold true in *D. polymorpha* as diatoms were observed entrapped within the non-staining distal layer (Figure 9). In addition, a collagenous substance occupied the cortex of the plaque. This is consistent with the observations of Tamarin et al. (1976) in *M. californianus* where the collagenous secretion has the reported purpose of anchoring the thread in the mucus/adhesive. Eckroat et al. [1992] observed that after the plaque was secreted to provide an attachment to the substratum, a clear fluid thread became visible. Longitudinal sections through the byssus indicate that the plaque is a continuation of the thread and that the thread is splayed at the distal end where it comes in contact with the initial collagenous and adhesive secretions.

Observations made using the scanning electron microscope in the present study identify the sheath of *D. polymorpha* byssal threads as a separate, outer layer covering the cortex. Brown (1952) noted that the sheath enclosing the byssus threads of *M. edulis* was quinone tanned, Smyth (1954) indicated that the tanning reaction is catalyzed by the enzyme, polyphenol oxidase. A similar tanning process is likely to occur in the threads of *D. polymorpha* because the thin, outer layer of thread material that would come in contact with such an enzyme would undergo tanning, thus forming a separate layer as observed in Figure 4. This tanned layer (the sheath) would differ in appearance from the deeper, untanned longitudinal fibers of the cortex embedded in a matrix.

The Picro-ponceau stain indicated that the byssal threads of *D. polymorpha* were homogeneously composed of elastic fibers, whereas in *Mytilus* sp, Vitellaro-Zuccarello et al. (1983) suggested collagen was located in the matrix of the proximal portion of the thread, but that the filaments (within the matrix) could be responsible for its elastic properties. Stained sections of the threads also indicated the presence of a sheath, which confirms the observations of Steele (1991) using scanning electron microscopy.

Morphological characteristics of the stained byssal sections allow the proposition of the following hypothetical steps involved with the adherence of the thread/plaque unit of *D. polymorpha*: (1) the foot secretes a thin layer of adhesive, followed by a layer of collagenous material; and (2) liquid elastin is then released through the ventral groove of the foot, which splays over the collagenous/adhesive layer forming the thread/plaque continuum.

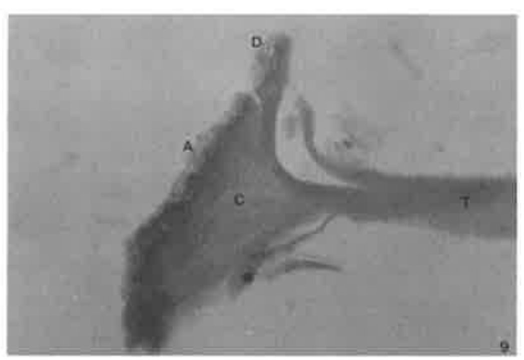


FIGURE 9. Longitudinal section (10 μm) of a thread (T) splaying over collagenous cortex (C) and adhesive (A) forming a plaque (400 X). Note diatoms (D) trapped within the adhesive layer.

TABLE 1. Histochemical composition of the structural components of the byssus of *Dreissena polymorpha*.

Structure	Composition: Elastin	Collagen
Plaque	X	X
Threads	X	
Stem	X	
Root	X	X

A proposed mechanism for thread formation and secretion, based upon byssal morphology, is as follows: (1) the localization of an "elastin pool" in the stem, supplied by tributaries of elastin which are lined by basophilic secretion granules, provides a reservoir from which threads are secreted through the stem and the collagenous cuffs; and (2) the ventral groove of the foot, which surrounds the stem, may "squeeze" the stem (and the "elastin pool" which is kept in constant supply by the basophilic secretion granules), causing elastin to be secreted from the elastin pool and thereby allowing the formation of the threads.

Scanning electron micrographs, histological sectioning and histochemical staining has provided information regarding the morphology, composition and formation of the byssus of *D. polymorpha*. It seems intuitively obvious that an understanding of byssi will be an important component of any mechanism which would use the byssus as a point of control. Thus, the current information will augment available knowledge and may eventually contribute to the development of a mechanism for controlling the zebra mussel.

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THE TRICHOPTERA (CADDISFLIES) OF PENNSYLVANIA: AN ANNOTATED CHECKLIST*

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ABSTRACT

A total of 312 species of caddisflies (Trichoptera) in 20 families and 60 genera were found to occur in Pennsylvania. These records were the results of collections from light trapping adults during 1989-91, reviewing major collections and extensive collections in the Erie area over the past twenty years. Ninety-two species are new records for Pennsylvania. This paper is a synopsis of the report entitled "Trichoptera Biodiversity of Pennsylvania" submitted to the Pennsylvania Fish Commission and the Wild Resource Conservation Fund that contained county distribution maps for each species along with annotated collection data. [J PA Acad Sci 66(2):68-78, 1992]

INTRODUCTION

The caddisflies of Pennsylvania have been studied by numerous individuals since the 1800's beginning with Thomas Say (1828) and followed by Hyland (1948), Sykora et al. (1976), Sykora (1989), Weaver and Sykora (1979), Weaver (1988), and Swegman et al. (1981). The later studies provided comprehensive reports at specific sites or with specific families; the Rhyacophilidae and Lepidostomatidae being collected extensively by Sykora and Weaver. Swegman et al. (1981) collected 85 species from Linesville Creek from 1972-77 at the Pymatuning Laboratory of Ecology in Crawford County, University of Pittsburgh, and Seward and Swegman (unpublished) at the Bear Run Nature Reserve in Fayette County during 1976-77 collecting 47 species. Sykora (1989) completed a survey of Trichoptera of U.S. Army Corps of Engineers supervised reservoir outflows in western Pennsylvania.

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Other monographs on caddisflies with numerous collections from Pennsylvania provided records; Brachycentridae (Flint, 1984), Uenoidae (Vineyard, personal comm.), Odontoceridae (Parker and Wiggins, 1985), Molannidae (Fuller, personal comm.), the genus *Cheumatopsyche* (Gordon, 1974), the genus *Ceraclea* (Morse, 1975), the genus *Pycnopsyche* (Wojtowicz, 1982), and the genus *Rhyacophila* (Weaver and Sykora, 1979).

Since one of the authors, E.C. Masteller, had extensive collections from northwest Pennsylvania taken over the past twenty years, it was decided to bring together this data with those studies referred to above from Pennsylvania. Collections from the different physiographic provinces of Pennsylvania were then completed to provide a comprehensive list of caddisflies from Pennsylvania with their locations of occurrence throughout the Commonwealth.

Regional North American records of species numbers in particular states or provinces are: New York - 170 (Betten, 1934), New Hampshire - 251 (Morse and Blickle, 1953 and 1957), Massachusetts - 181 (Neves, 1979), Maine - at least 220 (Blickle and Morse, 1964 and 1966), Virginia - 239 (Parker and Voshell, 1981), Alabama - 342 (Harris et al., 1991), Arkansas - 153 (Unziker et al., 1970), Illinois - 183 (Ross, 1944), Michigan - 181 (Leonard and Leonard, 1949), Wisconsin - 208 (Longridge and Hilsenhoff, 1973), Kentucky - 181 (Resh, 1975), and Tennessee - 298 (Etnier and Schuster, 1979).

METHODS

A grant was obtained from the Wild Resource Conservation Fund to support this study. A literature search was conducted to locate references for Pennsylvania species of caddisflies. Then the collection at the Frost Museum of The Pennsylvania State University was checked for records and all unidentified material currated. Collections were reviewed at the Royal Ontario Museum in Toronto, Canada, The Pennsylvania Department of Agriculture collection in Harrisburg, PA, Stroud Water Research Center, Avondale,

PA, The Philadelphia Academy of Natural Science and the National Museum of Natural History, Smithsonian Institution, Washington, D.C. as well as the personal collection of John Weaver at the University of New Hampshire. This study involved over 130 black light trap collections from 14 of the 15 physiographic provinces in Pennsylvania during 1990-91.

RESULTS

In this paper, the species list for Pennsylvania is presented (Table 1) and new records in the literature indicated by "*". There are 57 species in Pennsylvania that are considered uncommon which had five or fewer occurrences. Seven species indicated by **"h"** (Table 1) are considered historic records, which have no occurrence in the past forty years. Collection for ninety-two species not previously recorded in the literature along with eleven historic records are presented in Table II. County maps with species occurrences were developed in the original report (Masteller and Flint, 1992) to the sponsor. Figure 1 indicates the collection sites with physiographic provinces of Pennsylvania (Rizza and Hughes, 1982). Figure 2 indicates the counties in Pennsylvania where collections were made by the senior author.

Records are for adults except when noted otherwise. Voucher specimens were preserved in 70% ethyl alcohol or pinned as adults and placed at the National Museum of Natural History, Smithsonian Institution, The Pennsylvania Department of Agriculture, Bureau of Plant Industry, and the Academy of Natural Sciences of Philadelphia.

TABLE I. Trichoptera list of species occurring in Pennsylvania.

PENNSYLVANIA TRICHOPTERA

	BERAEIDAE
	Beraea fontana Wiggins
*	*B. nigritta* Banks
	BRACHYCENTRIDAE
	Adicrophleps hitchcocki Flint
	Brachycentrus appalachia Flint
h	*B. incanus* Hagen
h	*B. lateralis* (Say)
h	*B. nigrosoma* (Banks)
h	*B. numerosus* (Say)
	B. solomoni Flint
	Micrasema charonis Banks
*	*M. rusticum* McLachlan
*	*M. wataga* Ross
	CALAMOCERATIDAE
	Heteroplectron americanum (Walker)
	GLOSSOSOMATIDAE
	Agapetus minutus Sibley
	A. pinatus Ross
*	*A. rossi* Denning
*	*A. tomus* Ross
	Glossosoma intermedium (Klapalek)
	G. nigrior Banks
	Protoptila maculata (Hagen)
	P. palina Ross

TABLE I. *continued*

	GOERIDAE
	Goera calcarata Banks
*	*G. fuscula* Banks
	G. stylata Ross
	Goerita betteni Ross
	HELICOPSYCHIDAE
	Helicopsyche borealis (Hagen)
	HYDROPSYCHIDAE
	Cheumatopsyche aphanta Ross
	C. campyla Ross
*	*C. ela* Denning
*	*C. geora* Denning
	C. gracilis Banks
*	*C. gyra* Ross
	C. halima Denning
*	*C. harwoodi enigma* Ross & Gordon
	C. harwoodi harwoodi Denning
*	*C. helma* Ross
*	*C. miniscula* Banks
	C. oxa Ross
	C. pasella Ross
	C. pettiti Banks
	C. pinaca Ross
	C. sordida Hagen
	C. speciosa Banks
	C. vannotei Gordon
*	*C. wrighti* Ross
*	*Diplectrona metaqui* Ross
	D. modesta Banks
	Homoplectra monticola Flint
	Hydropsyche alhedra Ross
	H. alternans (Walker)
	H. betteni Ross
	H. bifida Banks
	H. bronta Ross
*	*H. brunneipennis* Flint & Butler
*	*H. cheilonis* Ross
	H. confusa (Walker)
	H. dicantha Ross
*	*H. hageni* Banks
*	*H. impula* Denning
*	*H. leonardi* Ross
	H. morosa (Hagen)
*	*H. opthalmica* Flint
	H. orris Ross
	H. phalerata Hagen
*	*H. placoda* Ross
	H. scalaris Hagen
	H. slossonae Banks
	H. sparna Ross
*	*H. valanis* Ross
	H. ventura Ross
*	*H. venularis* Banks
*	*H. walkeri* Betten & Mosely
	Macrostemum zebratum (Hagen)
	Parapsyche apicalis (Banks)
	Potamyia flava (Hagen)
	HYDROPTILIDAE
	Agraylea multipunctata Curtis
	Dibusa angata Ross
*	*Hydroptila ajax* Ross
*	*H. alabama* Harris & Kelley
*	*H. amoena* Ross
*	*H. ampoda* Ross
*	*H. angusta* Ross
*	*H. armata* Ross
*	*H. callia* Denning

TABLE I. continued

* H. chattanooga Frazer & Harris
H. consimilis Morton
* H. delineata Morton
* H. dentata Ross
* H. fiskei Blickle & Morse
* H. grandiosa Ross
* H. gunda Milne
H. hamata Morton
H. jackmanni Blickle
* H. metoeca Blickle & Morse
H. perdita Morton
* H. quinola Ross
* H. remita Blickle & Morse
H. rono Ross
H. spatulata Morton
H. spinata Blickle & Morse
H. strepha Ross
* H. talladega Harris
* H. waskesia Ross
H. waubesiana Betten
Ithythrichia clavata Morton
* Leucotrichia pictipes (Banks)
h Mayatrichia ayama Mosely
Neotrichia okopa Ross
Ochrotrichia confusa (Morton)
* O. denningi Blickle & Morse
* O. graysoni Parker & Voshell
* O. shawnee (Ross)
O. spinosa (Ross)
* O. tarsalis (Hagen)
O. wojcickyi Blickle
Orthotrichia aegerfasciella (Chambers)
O. cristata Morton
* Oxyethira aeola Ross
* O. dualis Morton
O. forcipata Mosely
O. grisea Betten
* O. michiganensis Mosely
* O. pallida (Banks)
* O. rivicola Blickle & Morse
* O. sida Blickle & Morse
* O. zeronia Ross
Palaeagapetus celsus (Ross)
Stactobiella delira (Ross)
S. martynovi Blickle & Denning
* S. palmata (Ross)
LEPIDOSTOMATIDAE
Lepidostoma americanum (Banks)
L. bryanti (Banks)
L. carrolli Flint
L. costale (Banks)
L. frosti (Milne)
L. griseum (Banks)
L. latipenne (Banks)
L. lydia Ross
L. ontario Ross
* L. pictile (Banks)
L. sackeni (Banks)
* L. serratum Flint & Wiggins
L. sommermanae Ross
L. togatum (Hagen)
L. vernale (Banks)
Theliopsyche grisea (Hagen)
LEPTOCERIDAE
* Ceraclea alabamae Harris
C. alagma (Ross)
C. albosticta (Hagen)

TABLE I. continued

C. ancyla (Vorhies)
C. cancellata (Betten)
C. diluta (Hagen)
C. flava (Banks)
C. maculata (Banks)
h* C. mentiea (Walker)
* C. punctata (Banks)
C. resurgens (Walker)
C. ruthae (Flint)
C. slossonae (Banks)
C. tarsipunctata (Vorhies)
C. transversa (Hagen)
C. wetzeli (Ross)
Leptocerus americanus (Banks)
Mystacides interjecta Banks
M. sepulchralis (Walker)
Nectopsyche albida (Walker)
N. candida (Hagen)
N. exquisita (Walker)
Oecetis avara (Banks)
O. cinerascens (Hagen)
O. ditissa Ross
h* O. eddlestoni (Ross)
O. immobilis (Hagen)
O. inconspicua (Walker)
O. nocturna Ross
O. osteni Milne
O. persimilis (Walker)
O. scala Milne
h Setodes guttatus (Banks)
S. incertus (Walker)
S. oligius (Ross)
S. oxapius (Ross)
h* Triaenodes abus Milne
T. baris Ross
T. dipsius Ross
T. flavescens Banks
* T. ignitus (Walker)
T. injustus (Hagen)
* T. marginatus Sibley
T. nox Ross
* T. pernus Ross
T. tardus Milne
LIMNEPHILIDAE
* Anabolia bimaculata (Walker)
A. consocia (Walker)
Apatania blacki Sykora & Weaver
* A. incerta (Banks)
* A. nigra (Walker)
Frenesia difficilis (Walker)
F. missa (Milne)
Glyphopsyche irrorata (Fabricius)
Hesperophylax designatus (Walker)
Hydatophylax argus (Harris)
Ironoquia lyrata (Ross)
I. parvula (Banks)
I. punctatissima (Walker)
Limnephilus indivisus Walker
L. moestus Banks
L. ornatus Banks
L. rhombicus (Linnaeus)
L. sericeus (Say)
L. submonilifer Walker
Nemotaulius hostilis (Hagen)
Platycentropus radiatus (Say)
* Pseudostenophylax sparsus (Banks)
P. uniformis (Betten)

TABLE I. continued

Psychoglypha subborealis (Banks)
Pycnopsyche circularis (Provancher)
P. conspersa Banks
P. divergens (Walker)
P. gentilis (McLachlan)
P. guttifer (Walker)
P. lepida (Hagen)
P. luculenta (Betten)
P. scabripennis (Rambur)
P. subfasciata (Say)
MOLANNIDAE
Molanna blenda Sibley
h* M. flavicornis Banks
M. tryphena Betten
* M. ulmerina Navas
M. uniophila Vorhies
ODONTOCERIDAE
Psilotreta frontalis Banks
P. indecisa (Walker)
P. labida Ross
P. rufa (Hagen)
PHILOPOTAMIDAE
Chimarra aterrima Hagen
C. obscura (Walker)
C. socia Hagen
Dolophilodes distinctus (Walker)
Wormaldia moesta (Banks)
W. shawnee (Ross)
PHRYGANEIDAE
Agrypnia vestita (Walker)
Banksiola crotchi Banks
B. dossuaria (Say)
* Oligostomis ocelligera (Walker)
h* O. pardalis (Walker)
Phryganea cinerea Walker
P. sayi Milne
Ptilostomis ocellifera (Walker)
P. postica (Walker)
P. semifasciata (Say)
POLYCENTROPODIDAE
Cyrnellus fraternus (Banks)
* Neureclipsis bimaculata (Linnaeus)
N. crepuscularis (Walker)
Nyctiophylax affinis (Banks)
* N. banksi Morse
* N. celta Denning
* N. denningi Morse
N. moestus Banks
* N. nephophilus Flint
* N. uncus Ross
Phylocentropus lucidus (Hagen)
P. placidus (Banks)
* Polycentropus barri Ross & Yamamoto
P. blicklei Ross & Yamamoto
P. carolinensis Banks
P. centralis Banks
* P. chenoides Ross & Yamamoto
P. cinereus Hagen
P. clinei (Milne)
* P. colei Ross
P. confusus Hagen
P. crassicornis Walker
P. elarus (Ross)
P. flavus (Banks)
P. interruptus (Banks)
P. maculatus Banks
P. nascotius Ross

TABLE I. continued

P. pentus Ross
P. pixi Ross
P. remotus Banks
* P. rickeri Yamamoto
PSYCHOMYIIDAE
Lype diversa (Banks)
Psychomyia flavida Hagen
* P. nomada (Ross)
RHYACOPHILIDAE
Rhyacophila atrata Banks
R. banksi Ross
* R. brunnea Banks
R. carolina Banks
R. carpenteri Milne
R. formosa Banks
R. fuscula (Walker)
R. glaberrima Ulmer
R. invaria (Walker)
R. ledra Ross
R. lobifera Betten
* R. mainensis Banks
R. manistee Ross
R. minora Banks
R. nigrita Banks
R. otica Etnier & Way
R. torva Hagen
R. vibox Milne
SERICOSTOMATIDAE
* Agarodes grisea Banks
UENOIDAE
Neophylax aniqua Ross
N. concinnus McLachlan
N. consimilis Betten
* N. fuscus Banks
* N. mitchelli Carpenter
N. oligius Ross
N. ornatus Banks
* N. stolus Ross
N. wigginsi Sykora & Weaver

* = New state record. **h** = Historic record.

Records Reported in Error from Pennsylvania but Persisting in Literature

HYDROPSYCHIDAE
Hydropsyche simulans Ross, [misidentified in literature, Hoffman, et al. 1946]
HYDROPTILIDAE
Ochrotrichia potomus Denning & Blickle (1972-1977), [possible misidentification (Blickle, R.L., 1979)]
RHYACOPHILIDAE
Rhyacophila parantra Ross, [previously reported by M&F 1979 should be R. banksi Ross]

TABLE II. PENNSYLVANIA TRICHOPTERA. New records - Annotated List of Species (99 indicates missing data)

BERAEIDAE
Beraea nigritta Banks
Chester Co., White Clay Creek, 3 ♂ - 2 ♀, 20 June 1978, **DHF.**
BRACHYCENTRIDAE
Micrasema rusticum McLachlan
Centre Co., Slab Cabin Run, 9 ♂ - 2 ♀, 17 June 1982, **PHA.**
Warren Co., Allegheny River, 1 ♂, 14 June 1988, **JLS.**
Micrasema wataga Ross
Cameron Co., Sinnemahoning River, 4 ♂ - 6 ♀, 2 July 1988, **ECM.**
Carbon Co., Tobyhanna Creek, 3 ♂, 29 June 1991, **ECM-MPP.**

TABLE II. *(continued)*

Centre Co., Roaring Run, 1 ♂, 13 August 1981, **PHA.**
Clinton Co., Kettle Creek, 3 ♂, 12 July 1989, **ECM-MAL.**
Forest Co., Tionesta Creek, 1 ♂ - 2 ♀, 18 June 1987, **ECM.**
Pike Co., Adams Creek, 1 ♂, 8 July 1989, **ECM**
Warren Co., Tanbark Trail, 1 ♂, 27 June 1989, **ECM-CAD.**
GLOSSOSOMATIDAE
Agapetus rossi Denning
Cameron Co., Sinnemahoning, 5 ♂ - 39 ♀, 2 July 1988, **ECM.**
Tioga Co., Pine Creek, 1 ♂, 6 July 1989, **ECM.**
Agapetus tomus Ross
Somerset Co., Whites Creek, 3 ♂ - 2 ♀, 15 August 1990, **ECM.**
Westmoreland Co., Powder Mill Run, 3 spec., 26 August 1975, **JLS.**
GOERIDAE
Goera fuscula Banks
Franklin Co., Trout Run, btwn. Blue & Kittany Mt., 99 larvae, 12 April 1977, **JSW.**
HYDROPSYCHIDAE
Cheumatopsyche ela Denning
Clarion Co., Clarion River, 4 ♂, 20 July 1989, **ECM.**
Dauphin Co., Susquehanna River, 99 spec., 1 July 1977, **JSW.**
Forest Co., Hunters Creek, 99 spec., 5 June 1976, **JSW.**
Juniata Co., Juniata River, 1 ♂, 30 June 1990, **ECM-JMS.**
Pike Co., Dingmans Creek, 1 ♂, 8 July 1989, **ECM.**
Cheumatopsyche geora Denning
Centre Co., Slab Cabin Run, 5 ♂ - 5 ♀, 6 June 1982, **PHA.**
Cheumatopsyche gyra Ross
Indiana Co., Yellow Creek, 2 ♂, 17 July 1989, **ECM.**
Leasure Run, 3 ♂, 2 August 1989, **ECM-MAL.**
Venango Co., Muskrat Creek, 2 ♂, 18 July 1987, **ECM-TB.**
Cheumatopsyche harwoodi enigma Ross & Gordon
Montour Co., Chillisquaque Creek, 1 ♂, 17 June 1990, **ECM-JMS.**
Cheumatopsyche helma Ross
Wyoming Co., Meshoppen Creek, 3 ♂, 20 July 1989, **ECM-MAL.**
Cheumatopsyche miniscula Banks
Cameron Co., Sinnemahoning River, 28 ♂ - 3 ♀, 2 July 1988, **ECM.**
ibid. 1 ♂, 27 July 1989, **ECM.**
Clinton Co., Bush Dam, 43 ♂, 12 July 1989, **ECM-MAL.**
Columbia Co., Fishing Creek, 1 ♂, 17 June 1990. **ECM-JMS.**
Cumberland Co., Conodoguinet Creek, 1 ♂, 31 July 1990, **ECM-JMS.**
Juanita Co., Juanita River, 3 ♂, 30 June 1990. **ECM-JMS.**
Lycoming Co., Williamsport, 1 ♂, 26 June 1946, **PSU.**
Monroe Co., Bushkill Creek, 6 ♂, 8 June 1990, **ECM-JMS.**
Pike Co., Dingmans Creek, 5 ♂ - 2 ♀, 6 June 1988, **ECM.**
Potter Co., Kettle Creek, 1 ♂, 12 July 1989, **ECM-MAL.**
Tioga Co., Pine Creek, 32 ♂ - 1 ♀, 6 July 1989, **ECM.**
ibid. 9 ♂, 8 June 1990, **ECM-JMS.**
Union Co., Cherry Run, 12 ♂, 19 July 1989, **ECM.**
Wyoming Co., Meshoppen Creek, 12 ♂, 20 July 1989, **ECM-MAL.**
Cheumatopsyche pinaca Ross
Adams Co., Biglerville, 99 ♂, 9 July 1980 **S & Q.**
Cumberland Co., Mountain Creek, 1 ♂, 30 July 1990, **ECM-JMS.**
Cheumatopsyche wrighti Ross
Center Co., State College, 1 ♂, 23 June 1956, **PSU.**
Howard, 2 ♂, 16 June - 22 July 1975, **VH.**
ibid. 2 ♂, 30 May 1977, **VH.**
ibid. 1 ♂, 6 July 1978, **VH.**
Crawford Co., West Branch Caldwell Creek, 3 ♂, 16 June 1989, **ECM-JEC.**
Huntingdon Co., Colerain Park, 4♂, 14 July 1952, **PSU.**
Warriors Mark Run, 2 ♂, 1 August 1989, **ECM-MAL.**
Mercer Co., Deer Creek, 10 ♂, 23 June 1989, **ECM.**
Mifflin Co., Reedsville Gap, 1 ♂, 19 May 1975, **MAF.**
Potter Co., Kettle Creek, 6 ♂, 19 June 1990, **ECM-JMS.**
Somerset Co., Whites Creek, 1 ♂, 15 August 1990, **ECM.**
Union Co., Penns Creek, 2 ♂, 19 July 1989, **ECM.**
Venango Co., Sugar Creek, 1 ♂, 18 June 1989, **ECM-JEC.**
Warren Co., Hemlock Run, 1 ♂, 19 July 1987, **ECM.**

TABLE II. *(continued)*

Wyoming Co., Meshoppen Creek, 3 ♂, 10 September 1989, **ECM-MAL.**
Diplectrona metaqui Ross
Fayette Co., Bear Run, 1 larvae, 11 March 1977, **RMS.**
Lancaster Co., Steelsville, 99 larvae, 2 March 1978, **JSW.**
Hydropsyche brunneipennis Flint & Butler
Venango Co., Muskrat Creek, 1 ♂, 18 July 1987, **ECM-TB.**
Allegheny River, 1 ♂, 27 July 1990. **ECM.**
Hydropsyche cheilonis Ross
Beaver Co., Raccoon Creek State Park, 13 ♂, 29 July 1989, **ECM-MAL.**
Indiana Co., Leasure Run, 1 ♂, 2 August 1989, **ECM-MAL.**
Juniata Co., Tuscarora Creek, 1 ♂, 30 June 1990, **ECM-JMS.**
Hydropsyche hageni Banks
Berks Co., Tulpehocken Creek, 4 ♂, 7 June 1990, **ECM-JMS.**
Cumberland Co., Brandtsville, 99 undet, 2 May 1948, **CF.**
Conodoguinet Creek, 12 ♂, 31 July 1990, **ECM-JMS.**
Dauphin Co., At Arcs, Harrisburg, 1 ♂, 17 August 1905, **PDA.**
Juniata Co., Juniata River, 3 ♂, 30 June 1990, **ECM-JMS.**
Montgomery Co., Perkiomen Creek, 1 ♂, 8 August 1989, **ECM-CAD.**
Venango Co., French Creek, 25 ♂, 27 July 1990, **ECM.**
Wyoming Co., Meshoppen Creek, 1 ♂, 10 September 1989, **ECM-MAL.**
Hydropsyche impula Denning
Adams Co., Biglerville, 1 ♂, 3 July 1980, **S & Q.**
Dauphin Co., At Arcs, Harrisburg, 1 ♂, 17 August 1980, **PDA.**
York Co., Davidsburg, 1 ♂, 7 July 1962, **PJS.**
Hydropsyche leonardi Ross
Bucks Co., Delaware River, 4 ♂, 9 July 1989, **ECM.**
Huntington Co., Little Juniata River, 1 ♂, 1 August 1989, **ECM-MAL.**
Union Co., New Berlin, 1 ♂, 99 April 1954, **EMC.**
Penns Creek, 1 ♂, 19 July 1989, **ECM.**
Warren Co., Allegheny Rvr., Allegheny Nat. For., 1 ♂, 14 August 1987, **ECM-USNM.**
Hydropsyche opthalmica Flint
Bucks Co., Delaware River, 10 ♂, 9 July 1989, **ECM.**
Cumberland Co., Conodoguinet Creek, 75 ♂ - 2 ♀, 31 July 1990, **ECM-JMS.**
Dauphin Co., Harrisburg, 1 ♂, 20 July 1967, **PDA.**
Montgomery Co., Perkiomen Creek, 1 ♂, 8 August 1989, **ECM-CAD.**
Tioga Co., Pine Creek, 4 ♂ - 1 ♀, 6 July 1989, **ECM.**
Hydrophsyche orris Ross
Mercer Co., Shenango River Lake, 33 ♂, 17 June 1987, **JLS.**
ibid. 28 ♂, 17 July 1987, **JLS.**
ibid. 34 ♂, 12 August 1987, **JLS.**
Hydropsyche placoda Ross
Dauphin Co., Harrisburg, 1 ♂, 12 May 1905, **PDA.**
Mercer Co., Deer Creek, 1 ♂, 23 June 1989, **ECM.**
Hydropsyche valanis Ross
Dauphin Co., Susquehanna River, Hwy. 322, 99 undet, 1 July 1977, **JSW.**
Fulton Co., Cowan's Gap State Park at USNM, 1 ♂, 1 August 1968, **TJS.**
Montgomery Co., King of Prussia at INHS, 1 ♂, 1 July 1963, **SSR.**
Hydropsyche venularis Banks
Bucks Co., Delaware River, 1 ♂, 9 July 1989, **ECM.**
Pike Co., Adams Creek, 1 ♂, 8 July 1989, **ECM.**
Dingmans Creek, 1 ♂, 9 September 1989, **ECM.**
Tioga Co., Pine Creek, 2 ♂, 6 July 1989, **ECM.**
Hydropsyche walkeri Betten & Mosely
Armstrong Co., Mahoning Creek Lake, 1 ♂, 16 June 1987, **JLS.**
Bedford Co., Bedford, 99 Undet, 20 July 1980, **CM.**
Bucks Co., Delaware River, 45 ♂, 9 July 1989, **ECM.**
Cameron Co., Hunts Run of Sinnemahoning, 1 ♂, 2 July 1988, **ECM.**
Carbon Co., Tobyhanna Creek, 1 ♂, 29 June 1991, **ECM-JMS.**
Centre Co., State College, 2 ♂, 23 June 1956, **PSU.**
Benner Springs, 1 ♂, 10 June 1966, **PSU.**
State College, 1 ♂, 9 August 1983, **VH.**
Clarion Co., Clarion River, 66 ♂, 20 July 1989, **ECM.**

TABLE II. *(continued)*

Clarion River Spring, Hwy. Route 36, 1 ♂, 20 July 1989, **ECM.**
Clinton Co., Kettle Creek, 2 ♂, 12 July 1989, **ECM.**
Dauphin Co., Harrisburg, 99 spec., 22 June - 7 September 1967, **PDA.**
ibid. 99 spec., 1 July 1977, **JSW.**
Erie Co., PSU-Behrend College, 4 ♂, 10 June - 1 July 1974, **ECM.**
Forest Co., Tionesta Dam, 3 ♂, 18 June 1987, **ECM-JMS.**
Otter Creek, 3 ♂, 1 July 1990, **ECM-JMS.**
Jefferson Co., Sandy Lick Creek, 3 ♂, 15 July 1989, **ECM-MAL.**
Lawrence Co., Slippery Rock Creek, 11 ♂ - 2 ♀, 22 June 1989, **ECM.**
Mercer Co., Deer Creek, 1 ♂, 23 June 1989, **ECM.**
Northumberland Co., Susquehanna River, 1 ♂, 17 June 1990, **ECM-JMS.**
Tioga Co., Pine Creek, 1 ♂, 8 June 1990, **ECM.**
Union Co., Cherry Run, 4 ♂, 19 July 1989, **ECM.**
Venango Co., Muskrat Creek, 117 ♂, 18 July 1987, **ECM-TB.**
Sugar Creek, 1 ♂, 18 June 1989, **ECM-CAD.**
Muskrat Creek, 7 ♂, 25 June 1989, **ECM-CAD.**
French Creek, 6 ♂, 27 July 1990, **ECM.**
Warren Co., 2 miles S Warren, 19 ♂, 25 June 1987, **OSF.**
Hemlock Run, 35 ♂, 19 July 1987, **ECM.**
Hedgehog Run, 3 ♂, 1 August 1987, **ECM-TB.**
Allegheny River, Kinzua Dam, 2 ♂, 14 June-12 July 1988, **JLS.**
Tionesta Creek, 99 larvae, 6 June 1976, **JSW.**
Westmoreland Co., New Alexandria, 2 spec., 19 June 1963, **PDA.**
ibid. 2 spec., 21 June - 10 August 1964, **PDA.**
York Co., 5 mi. NW Davidsburg, 1 ♂, 25 June 1966, **PJS.**
HYDROPTILIDAE
Hydoptila ajax Ross
Armstrong Co., Crooked Creek Lake, 51♂, 13 June and 16 August 1988, **JLS.**
Beaver Co., Raccoon Creek State Park, 99 undet, 18 June 1976, **JLS.**
ibid. 99 ♂, 29 July 1989, **ECM-MAL.**
Indiana Co., Leasure Run, 6 ♂, 2 August 1989, **ECM-MAL.**
Warren Co., Allegheny River, 1 ♂, 14 August 1981, **ECM.**
Westmoreland Co., Loyalhanna Lake, 4 ♂, 16 July - 19 August 1988, **JLS.**
Hydroptila alabama Harris & Kelley
Carbon Co., Tobyhanna Creek, 1 ♂, 6 June 1990, **ECM-JMS.**
ibid. 1 ♂, 29 June 1991, **ECM-MPP.**
Hydroptila amoena Ross
Centre Co., Big spring, 5 ♂, 19 June 1976, **JSW.**
Cumberland Co., Yellow Breeches Creek, 25 ♂ - 16 ♀, 1 July 1977, **JSW.**
Erie Co., Fourmile Creek, 1 ♂, 11 July 1983, **ECM.**
Wyoming Co., Meshoppen Creek, 1 ♂, 20 July 1989, **ECM-MAL.**
Hydroptila ampoda Ross
Clearfield Co., Birch Run, S.B. Elliott State Park, 2 ♂, 2 June 1990, **ECM.**
Pike Co., Dingmans Creek, 1 ♂, 6 June 1988, **ECM.**
Somerset Co., Jones Mill Run, Laurel State Forest, 4 ♂, 23 June 1976, **JSW.**
Warren Co., Allegheny River, Allegheny National Forest, 1 ♂, 1 August 1987, **ECM.**
Hydroptila angusta Ross
Armstrong Co., Mahoning Creek Lake, 1 ♂, 12 August 1987, **JLS.**
Indiana Co., Leasure Run, 1 ♂, 2 August 1989, **ECM.**
Hydroptila armata Ross
Berks Co., Schuykill River, 5 ♂, 3 September 1990, **ECM-JMS.**
Crawford Co., French Creek, Saegertown, 1 ♂, 5 June 1990, **ECM.**
Erie Co., North East Exp. Sta., PSU, 99 spec., 13 August 1976, **GLJ.**
Greene Co., Dunkard Creek, 30 ♂, 29 June 1990, **ECM-MPP.**
Montgomery Co., Perkiomen Creek, 4 ♂, 8 August 1989, **ECM-CAD.**
Washington Co., Cherry Creek, 1 ♂, 30 June 1990, **ECM-MPP.**
York Co., 5 m. NW Davidsburg, 1 ♂ - 1 ♀, 22 September 1962, **PJS.**
Hydroptila callia Denning
Carbon Co., Tobyhanna Creek, 1 ♂, 29 June 1991, **ECM-MPP.**
Centre Co., State College, 1 ♂, 30 June 1953, **PSU.**

TABLE II. *(continued)*

Hydroptila chattanooga Frazer & Harris
Wyoming Co., Meshoppen Creek, 1 ♂, 10 September 1989, **ECM-MAL.**
Hydroptila delineata Morton
Armstrong Co., Mahoning Creek, 7 ♂, 16 June - 12 August 1987, **JLS.**
Crooked Creek Lake, 1 ♂, 16 August 1988, **JLS.**
Clarion Co., Clarion River, 1 ♂, 20 July 1989, **ECM.**
Clinton Co., Bush Dam, 1 ♂, 12 July 1989, **ECM.**
Columbia Co., Fishing Creek, 1 ♂, 17 July 1989, **ECM.**
Indiana Co., Leasure Run, 2 ♂, 2 August 1989, **ECM-MAL.**
Monroe Co., Bushkill Creek, 1 ♂, 4 September 1990, **ECM-JMS.**
Pike Co., Dingmans Creek, 1 ♂, 6 June 1988, **ECM.**
Warren Co., 2 mi. S. Warren, 4 ♂, 25 June 1987, **OSF.**
Hedgehog Run, 1 ♂, 1 August 1987, **ECM.**
Hydroptila dentata Ross
Centre Co., State College, 2 ♂, 99 August 1957, **PSU.**
Clarion Co., Clarion River, 4 ♂, 20 July 1989, **ECM.**
Clinton Co., Hyner Run State Park, 1 ♂, 10 July 1989, **ECM.**
Crawford Co., Woodcock Creek Lake, 1 ♂, 13 August 1987, **JLS.**
Sugar Creek, 1 ♂, 14 October 1989, **ECM-MAL.**
Caldwell Creek, 2 ♂, 21 September 1989, **ECM-MAL.**
Forest Co., Tionesta Dam, 16 ♂, 18 June - 12 August 1987, **JLS.**
Fulton Co., Cowan's Gap St. Pk. at USNM, 2 spec., 1 August 1968, **TJS.**
Tioga Co., Pine Creek, 11 ♂, 11 September 1989, **ECM-MAL.**
Venango Co., Muskrat Run, 3 ♂ - 22 ♀, 18 July 1987, **ECM-TB.**
ibid. 1 ♂, 25 June 1989, **ECM-CAD.**
Allegheny River, Franklin, 1 ♂, 27 July 1990, **ECM.**
Warren Co., Allegheny Rvr., Allegheny Nat. For., 15 spec., 1 August 1987, **ECM-USNM.**
Hedgehog Run, 1 ♂, 1 August 1987, **ECM-TB.**
Tanbark Trail, 1 ♂, 14 August 1987, **ECM-TB.**
East Branch Tionesta Creek, 1 ♂, 10 August 1989, **ECM.**
Hydroptila fiskei Blickle & Morse
Indiana Co., Little Mahoning Creek, 1 ♂, 2 August 1989, **ECM-MAL.**
Lancaster Co., Pine Creek, Christiana, 2 ♂, 19 September 1976, **JSW.**
Warren Co., Tionesta Creek, 1 ♂, 10 August 1989, **ECM.**
Westmoreland Co., Furnace Run, 99 spec., 16 May 1976, **JSW.**
Hydroptila grandiosa Ross
Armstrong Co., Crooked Creek Lake, 3 ♂, 16 August 1988, **JLS.**
Beaver Co., Raccoon Creek State Park, 2 ♂, 29 July 1989, **ECM-MAL.**
Berks Co., Schuylkill River, 1 ♂, 3 September 1990, **ECM-JMS.**
Crawford Co., Woodcock Creek Lake, 4 ♂, 13 August 1987, **JLS.**
Greene Co., Dunkard Creek, 86 ♂, 29 June 1990, **ECM-MPP.**
Indiana Co., Leasure Run, 24 ♂, 2 August 1989, **ECM-MAL.**
Lawrence Co., Slippery Rock Creek, 32 ♂, 22 June 1989, **ECM.**
Venango Co., Sugar Creek, 1 ♂, 18 June 1989, **ECM-JEC.**
Washington Co., Cherry Creek, 2 ♂, 30 June 1990, **ECM-MPP.**
Westmoreland Co., Loyalhanna Lake, 8 ♂, 12 June, 16 July 1988, **JLS**
Hydroptila gunda Milne
Berks Co., Schuylkill River, 1 ♂, 3 September 1990, **ECM-JMS.**
Cameron Co., Driftwood Branch, Sinnemahoning River, 1 ♂, 27 July 1989, **ECM.**
Chester Co., White Clay Creek, 5 spec., 4 Nov. 1968, **JWR-USNM.**
Glen Run, Atglen, 5 ♂, 3 June 1977, **JSW.**
Clinton Co., Kettle Creek, Bush Dam, 1 ♂, 12 July 1989, **ECM.**
Columbia Co., Fishing Creek, 4 ♂, 17 June 1990, **ECM-JMS.**
Cumberland Co., Mt. Creek, Pine Grove Furnace St. Pk., 1 ♂, 30 July 1990, **ECM-JMS.**
Lancaster Co., Pine Creek, Christiana, 2 ♂, 19 September 1976, **JSW.**
Susquehanna Co., East Branch Wyalusing Creek, 12 spec., 4 May 1969, **DHF.**
Snake Creek, 1 ♂, 5 September 1990, **ECM-JMS.**
Tioga Co., Pine Creek, 11 ♂, 6 July 1989, **ECM.**
ibid. 13 ♂, 1J September 1989, **ECM-MAL.**
ibid. 1 ♂, 6 September 1990, **ECM-JMS.**
Wyoming Co., Meshoppen Creek, 10 ♂, 10 September 1989, **ECM-MAL.**

TABLE II. *(continued)*

York Co., 5 mi. NW. Davidsburg, 1 ♂, 20 July 1962, **PJS.**
Hydroptila metoeca Blickle & Morse
Chester Co., Octorora Creek, 9 ♂ - 23 ♀, 18 May 1977, **JWS.**
Clarion Co., Clarion River, Gravel Lick Road, 1 ♂, 20 July 1989, **ECM.**
Fulton Co., Cowan's Gap State Park, 8 spec., 1 August 1968, **TJS.**
Indiana Co., Yellow Creek, 2 ♂, 17 July 1989, **ECM.**
Pike Co., Dingmans Creek, 3 spec., 6 June 1988, **ECM.**
Adams Creek, 1 ♂, 8 July 1989, **ECM.**
Warren Co., Allegheny Rvr., Allegheny Nat. For., 1 ♂, 1 August 1987, **ECM-USNM.**
Hedgehog Run, 1 ♂, 1 August 1987, **ECM-TB.**
Wyoming Co., Meshoppen Creek, 1 ♂, 10 September 1989, **ECM-MAL.**
Hydroptila quinola Ross
Warren Co., East Branch Tionesta Creek, 1 ♂, 10 August 1989, **ECM.**
Hydroptila remita Blickle & Morse
Fayette Co., Bear Run, 6 spec., 28 May 1978, **BGS-USNM.**
Bear Run, 48 ♂ - 7 ♀, 28 May 1978, **RMS.**
Hydroptila talladega Harris
Armstrong Co., Mahoning Creek Lake, 1 ♂, 24 May 1987, **JLS.**
Warren Co., New Berlin, 1 ♂, 25 June 1987, **OSF.**
2 mi. S. Warren, 1 ♂, 25 June 1987, **OSF.**
Hydroptila waskesia Ross
Greene Co., Dunkard Creek, 3 ♂, 29 June 1990, **ECM-MPP.**
Leucotrichia pictipes Banks
Lancaster Co., Octorara Creek, 99 spec., 17 May 1977, **JSW.**
Lawrence Co., Shenango River Lake, 1 ♂, 12 August 1987, **JLS.**
Mifflin Co., Kishacoquillas Creek Trib., 1 ♂ - 1 ♀, 7 August 1982, **PHA.**
Susquehanna Co., East Branch Wyalusing Creek, 35 spec., 28 May - 1 June 1969, **DHF.**
Tioga Co., Pine Creek, 1 ♂ - 9 ♀, 1 July 1978, **JSW.**
Ochrotrichia denningi Blickle & Morse
Forest Co., Tionesta Dam, 3 ♂, 18 June 1987, **JLS.**
Warren Co., Allegheny River, Kinzua Dam, 9 ♂ - 2 ♀, 18 July 1981, **ECM.**
ibid. 25 ♂, 12 July 1988, **JLS.**
ibid. 4 ♂ - 8 ♀, 19 July 1987, **ECM.**
Farnsworth Creek, 2 ♂, 25 July 1989, **ECM-MAL.**
Ochrotrichia graysoni Parker & Voshell
Clarion Co., Clarion River, Gravel Lick Road, 1 ♂, 20 July 1989, **ECM.**
Union Co., Cherry Run, 25 ♂ - 1 ♀, 19 July 1989, **ECM.**
Penns Creek, Weikert, 4 ♂, 19 July 1989, **ECM.**
Ochrotrichia shawnee (Ross)
Forest Co., Otter Creek, 1 ♂, 1 July 1990, **ECM-JMS.**
Potter Co., Genesee River, Harmontown, 25 ♂ - 1 ♀, 2 July 1978, **JSW.**
Ochrotrichia tarsalis (Hagen)
Armstrong Co., Crooked Creek Lake, 62 ♂, 13 June and 16 August 1988, **JLS.**
Mahoning Creek, 2 ♂ - 1 ♀, 12 August and 26 September 1987, **JLS.**
Cumberland Co., Yellow Breeches Creek, 1 ♂, 18 September 1976, **JSW.**
Westmoreland Co., Loyalhanna Lake, 20 ♂, 16 July, 12 August 1988, **JLS.**
Oxyethira aeola Ross
Luzerne Co., Lake Jean, Ricketts Glenn State Park, 2 ♂, 14 August 1989, **ECM.**
Oxyethira dualis Morton
Forest Co., Tionesta Dam, 1 ♂, 12 August 1987, **JLS.**
Oxyethira grisea Betten
Carbon Co., Hayes Creek on Lehigh River, 1 ♂, 1 June 1990, **ECM.**
Oxyethira michiganensis Mosely
Cumberland Co., Mt. Crk., Pine Grove Furnace St. Pk., 8 ♂ - 2 ♀, 30 July 1990, **ECM-JMS.**

TABLE II. *(continued)*

Elk Co., East Branch Clarion River, 2 ♂ - 3 ♀, 7 August 1987, **JLS.**
Fayette Co., Bear Run, 46 ♂ - 1 ♀, 28 May and 6 July 1978, **RMS & BGS.**
Pike Co., Dingmans Creek, 1 ♂ - 1 ♀, 9 September 1989, **ECM-MAL.**
Potter Co., Little Kettle Creek, 1 ♂, 19 July 1990, **ECM-JMS.**
Susquehanna Co., Elk Lake Creek, 6 ♂, 18 June 1990, **ECM-JMS.**
Venango Co., Muskrat Run, 5 ♂, 25 June 1989, **ECM-CAD.**
Westmoreland Co., Maul Springs, 2 ♂, 20 July 1977, **JSW.**
Oxyethira pallida (Banks)
Armstrong Co., Crooked Creek Lake, 2 ♂, 16 August 1988, **JLS.**
Centre Co., State College, 1 ♂, 22 September 1953, **PSU.**
Cumberland Co., Conodoguinet Creek, 1 ♂, 31 July 1990, **ECM-JMS.**
Huntingdon Co., Warriors Mark River, 1 ♂, 1 August 1989, **ECM-MAL.**
Indiana Co., Leasure Run, 13 ♂ - 99 ♀, 2 August 1989, **ECM-MAL.**
Wyoming Co., Meshoppen Creek, 8 ♂, 10 September 1989, **ECM-MAL.**
Oxyethira rivicola Blickle & Morse
Carbon Co., Tobyhanna Creek, 1 ♂, 6 June 1990, **ECM-JMS.**
Oxyethira sida Blickle & Morse
Carbon Co., Tobyhanna Creek, 1 ♂, 6 June 1990, **ECM-JMS.**
Oxyethira zeronia Ross
Luzerne Co., Lake Jean, Ricketts Glenn State Park, 1 ♂, 14 August 1989, **ECM.**
Stactobiella palmata (Ross)
Armstrong Co., Mahoning Creek Lake, 44 ♂, 16 June 1987, **JLS.**
Carbon Co., Tobyhanna Creek, 113 ♂, 6 June 1990, **ECM-JMS.**
Columbia Co., Fishing Creek, 1 ♂, 17 June 1990, **ECM-JMS.**
Crawford Co., French Creek, Saegertown, 2 ♂ - 2 ♀, 5 June 1990, **ECM.**
Forest Co., Tionesta Dam, 6 ♂, 18 June 1987, **JLS.**
Greene Co., Dunkard Creek, 1 ♂, 29 June 1990, **ECM-MPP.**
Somerset Co., Jones Mill Run, Laurel State Forest, 1 ♂ - 2 ♀, 23 June 1976, **JLS.**
Warren Co., Allegheny River, Kinzua Dam, 1 ♂, 18 July 1981, **ECM.**
2 m. S. Warren, 12 ♂ - 22 ♀, 25 June 1987, **OSF.**
Allegheny River, Kinzua Dam, 3 ♂, 12 July 1988, **JLS.**
LEPIDOSTOMATIDAE
Lepidostoma pictile (Banks)
Clinton Co., Lamar, 1 ♂, 2 June 1978, **DJS.**
Pike Co., Dingmans Creek, 2 ♂ - 17 ♀, 6 June 1988, **ECM.**
Lepidostoma serratum Flint & Wiggins
Chester Co., Stroud Water Research Center, 5 ♂, 13 - 21 September 1981, **DHF.**
LEPTOCERIDAE
Ceraclea alabamae Harris
Carbon Co., Tobyhanna Creek, 8 ♂ - 2 ♀, 29 June 1991, **ECM-MP.**
Ceraclea punctata (Banks)
Dauphin Co., At Arcs, Harrisburg, 1 spec., 17 August 1905, **PDA.**
Erie Co., PSU Behrend College, 2 ♀, 17 July 1974, **ECM.**
Triaenodes ignitus (Walker)
Butler Co., 2 spec., 26 June 1967, **KM.**
Cumberland Co., Mt. Creek, Pine Grove Furnace St. Pk., 1 ♂, 30 July 1990, **ECM-JMS.**
Shippensburg Reservoir, 1 ♂, 31 July 1990, **ECM-JMS.**
Dauphin Co., Harrisburg, 6 spec., 22 June - 14 July 1967, **PDA.**
Triaenodes marginatus Sibley
Bedford Co., Bedford, 1 ♂, 27 July 1980, **KM.**
Centre Co., Benner Springs, 1 ♂, 10 June 1966, **PSU.**
Howard, 99 ♂ & ♀, 20 June - 1 August 1980, **VH.**
Slab Cabin Run, Pine Grove Mills, 1 ♂, 6 June 1982, **PHA.**
Howard, 99 ♂, 13 - 27 June 1983, **VH.**
Chester Co., East Branch White Clay Creek, 1 ♂, 7 August 1971, **DHF.**
Cumberland Co., Letort Spring, 1 ♂ - 2 ♀, 18 July 1989, **ECM.**
Mt. Creek, Pine Grove Furnace State Park, 1 ♂, 30 July 1990, **ECM.**
Erie Co., Presque Isle, Erie, 1 ♂, 99 999 9999, **PSU.**
Lawrence Co., Slippery Rock Creek, 1 ♂, 22 June 1989, **ECM.**
Tioga Co., Pine Creek, 1 ♂, 11 September 1989, **ECM.**

TABLE II. *(continued)*

Triaenodes pernus Ross
Cumberland Co., Conodoguinet Creek, 12 ♂, 31 July 1990, **ECM-JMS.**
LIMNEPHILIDAE
Anabolia bimaculata (Walker)
Centre Co., Black Moshannon, 1 spec., 25 July 1974, **PSU.**
Apatania incerta (Banks)
Cameron Co., 2 mi. N Emporium, 15 spec., 23 April 1979, **OSF.**
Lycoming Co., Trout Run, 1 ♀, 9 May 1982, **PHA.**
Apatania nigra (Walker)
Wayne Co., Delaware River, 8 ♂ - 1 ♀, 21 April 1982, **DHF.**
Pseudostenophylax sparsus (Banks)
Berks Co., 1/4 mi. S. Eckville, 1 spec., 23 May 1968, **PDA.**
Centre Co., Cluster Spring, Haines Twp., 1 ♂, 20 July 1974, **PSU.**
State College, 4 ♂, 26 May 1977, **PSU.**
Howard, 1 ♀, 31 May 1978, **PSU.**
Fayette Co., Bear Run, 4 ♂, 28 May - 6 July 1978, **RMS.**
ibid. 1 larva, 11 March 1977, **RMS.**
Fulton Co., Aughwick Creek, 99 spec., 30 June 1989, **JSW.**
Lackawanna Co., Lackawanna, 1 ♂, 30 June 1975, **PSU.**
Pike Co., Dingmans Creek, 1 ♂, 8 July 1989, **ECM-MPP.**
Somerset Co., Kooser Run, 8 ♂ - 5 ♀, 8 - 23 June 1976, **JSW.**
Wayne Co., Dyberry Creek, 1 ♂, 9 June 1990, **ECM-MPP.**
Westmoreland Co., Maul Spring, 7 ♂, 21 May - 15 June 1976, **JSW.**
MOLANNIDAE
Molanna ulmerina Navas
Cameron Co., Driftwood Branch of Sinnemahoning River, 1 ♂, 27 July 1989, **ECM.**
Cumberland Co., Mt. Creek, Pine Grove Furnace St. Pk., 1 ♀, 30 July 1990, **ECM-JMS.**
Conodoguinet Creek, 27 ♂, 31 July 1990, **ECM-JMS.**
Monroe Co., Pocono Creek, 1 ♀, 1 August 1989, **ECM-CAD.**
Potter Co., Cross Fork, 3 ♂ - 15 ♀, 18 August 1989, **ECM-JMS.**
Little Kettle Creek, 3 ♂ - 1 ♀, 18 August 1989, **ECM.**
PHRYGANEIDAE
Oligostomis ocelligera (Walker)
Fayette Co., Bear Run, 2 larvae, 24 September - 19 November 1976, **RMS.**
Bear Run, 7 larvae, 26 June - 31 July 1977, **RMS.**
POLYCENTROPODIDAE
Neureclipsis bimaculata (Linnaeus)
Westmoreland Co., Loyalhanna Lake, 1 ♂ - 2 ♀, 16 July 1988, **JLS.**
Nyctiophylax banksi Morse
Forest Co., Tionesta Dam, 1 ♂, 17 July 1987, **JLS.**
Nyctiophylax celta Denning
Carbon Co., Tobyhanna Creek, 6 ♂ - 2 ♀, 29 June 1991, **ECM-MPP.**
Clinton Co., Kettle Creek, Bush Dam, 1 ♂, 12 July 1989, **ECM.**
Fayette Co., Ohiopyle, 5 ♀, 28 June 1949, **CB.**
Forest Co., South Branch Tionesta Creek, 1 ♂, 10 August 1989, **ECM.**
Huntingdon Co., Camp Barree, 99 ♂, 30 June 1944, **CB.**
Monroe Co., Bushkill Creek, 1 ♂, 8 June 1990, **ECM-JMS.**
Tioga Co., Pine Creek at Blackwell, 99 spec., 1 July 1921, **CB.**
Wyoming Co., Meshoppen Creek, 1 ♂, 20 July 1989, **ECM-MAL.**
Nyctiophylax denningi Morse
Chester Co., East Branch White Clay Creek, 4 ♂, 9 - 19 June 1972, **DHF.**
ibid. 2 ♂ - 3 ♀ - 1 spec., 27 - 29 June 1973. **DHF.**
East Branch White Clay Creek, London Grove, 1 ♂, 21 June 1978, **DHF.**
ibid. 1 ♂, 23 June 1979, **DHF.**
Nyctiophylax nephophilus Flint
Clinton Co., Lamar, 1 spec., 22 June 1978, **PSU.**
Union Co., Cherry Run, 9 ♂ - 1 ♀, 19 July 1989, **ECM.**
Nyctiophylax uncus Ross
Fayette Co., Ohiopyle, 1 ♂, 28 June 1948, **CB.**
Sullivan Co., Loyalsock Creek, 1 ♂, 7 July 1989, **ECM.**
Tioga Co., Pine Creek, 1 ♂, 8 June 1990, **ECM-MPP.**
Polycentropus barri Ross & Yamamoto
Chester Co., Glen Run, Atglen, 1 ♂, 18 June 1977, **JSW.**
Polycentropus chenoides Ross & Yamamoto

TABLE II. *(continued)*

Erie Co., Fourmile Creek, 2 ♂, 30 May 1980, **ECM.**
ibid. 1 ♂, 11 September 1980, **ECM.**
Polycentropus colei Ross
Westmoreland Co., Maul Spring, 99 spec., 9 July 1975, **JSW-JLS.**
Polycentropus rickeri Yamamoto
Erie Co., North East Experiment Station, PSU, 2 ♂, 16 July 1979, **GLJ.**
PSYCHOMYIIDAE
Psychomyia nomada (Ross)
Delaware Co., Westchester Pike, 2 spec., 8 June 1959, **PAS.**
Franklin Co., Caledonia, 3 ♂, 21 June 1948, **CB.**
ibid. 1 ♂, 30 June 1949, **CB.**
Potter Co., Genesee River, 1 ♂ - 3 ♀, 2 July 1978, **JSW.**
Little Kettle Creek, 1 ♂ - 99 ♀, 12 July 1989, **ECM.**
ibid. 7 ♂ - 1 ♀, 18 August 1989, **ECM.**
Tioga Co., Pine Creek, Ansonia, 3 ♂ - 5 ♀, 6 July 1989, **ECM.**
ibid. 4 ♂ - 6 ♀, 11 September 1989, **ECM-MAL.**
Pine Creek, 19 ♂, 8 June 1990, **ECM-MPP.**
ibid. 7 ♂, 6 September 1990, **ECM-JMS.**
Wayne Co., Delaware River, Dillontown, 20 spec., 14 July 1982, **DHF.**
Wyoming Co., Susquehanna River, Meshoppen, 1 spec., 29 August 1974, **PAS.**
Meshoppen Creek, 1 ♂, 10 September 1989, **ECM-MAL.**
RHYACOPHILIDAE
Rhyacophila brunnea Banks
Chester Co., East Branch White Clay Creek, 1 larva, 2 June 1980. **SWR.**
Rhyacophila mainensis Banks
Centre Co., The Rock, 1 ♂, 27 May 1941, **CB.**
Clinton Co., Fishing Creek, Lamar, 1 ♂, 28 May 1973, **PSU.**
Cumberland Co., Shippensburg Reservoir, 1 ♂ - 1 ♀, 31 July 1990, **ECM-JMS.**
Dauphin Co., Harrisburg, 1 spec., 1 June 1949, **EMC at PDA.**
Venango Co., Sugar Creek, 99 Larvae, 23 November 1982, **JB.**
SERICOSMATIDAE
Agarodes grisea Banks
Chester Co., Woods Branch, 2 ♀ - 2 spec., 10 - 27 June 1978, **DHF.**
UENOIDAE
Neophylax fuscus Banks
Crawford Co., Woodcock Creek Lake, 1 ♂, 16 October 1987, **JLS.**
Erie Co., PSU Behrend College, 5 ♂ - 1 ♀, 27 August 1973, **ECM.**
Huntingdon Co., Colerain Park, 1 ♂, 15 October 1944, **SWF.**
Perry Co., Buffalo Ridge, 1 ♂, 9 October 1965, **JWA.**
Sullivan Co., Lick Creek, Millview, 2 ♂ - 13 ♀, 27 September 1979, **ACG.**
Wyoming Co., Meshoppen Creek, Meshoppen, 3 ♂, 8 - 22 October 1979, **DHF.**
ibid 24 ♂ - 12 ♀, 3 - 15 October 1980, **DHF.**
Neophylax mitchelli Carpenter
Carbon Co., Swamp Run, 1 larva, 20 April 1968, **Y&O.**
Centre Co., Maddisonburg, 7 larva, 16 April 1968, **Y&O.**
Nittany, 4 Larvae, 16 April 1968, **Y&O.**
Chester Co., Bog Hollow Creek, 1 pupa, 12 April 1978, **DHF at ROM.**
ibid 1 ♂, 1 September 1978, **DHF at ROM.**
Bog Hollow Creek, Unionville, 2 ♂, 4 October 1978, **DHF at ROM.**
London Grove, 11 ♂ - 5 ♀, 23 September - 13 October 1980, **DHF at ROM.**
West Branch McCorkles Rock Creek, 9 ♂, 14 September 1981, **ROM.**
Dauphin Co., Clarks Valley, 1 ♂, 12 October 1950, **AC.**
Lancaster Co., New Holland, 99 spec., 6 October 1977, **JSW at ROM.**
McKean Co., 4 mi. S Betula, 1 larvae, 23 April 1979, **PJS.**
Northhampton Co., Portland, 2 pupae, 19 September 1958, **F&W.**
Philadelphia Co., Roxborough, 1 ♂, 17 September 1928, **FH.**
Somerset Co., Kooser State Park, 2 larvae, 19 March 1975, **B&F.**
Westmoreland Co., Maul Spring, 7 larvae, 19 March 1975, **B&F.**
Neophylax stolus Ross
Crawford Co., Caldwell Creek, 29 ♂ - 2 ♀, 24 August - 21 September 1989, **ECM-MAL.**

TABLE II. *(continued)*

French Creek, Saegertown, 1 ♂, 6 October 1990, **ECM.**
Mercer Co., Deer Creek, 1 ♂, 6 October 1989, **ECM.**
Tioga Co., Pine Creek, 1 ♂ - 1 ♀, 11 September 1989, **ECM-MAL.**
Warren Co., Caldwell Creek, 1 ♂ - 3 ♀, 21 September 1989, **ECM-MAL.**
Wyoming Co., Meshoppen Creek, 14 ♂ - 2 ♀, 10 September 1989, **ECM-MAL.**

Historic collections

BRACHYCENTRIDAE
Brachycentrus incanus (Hagen)
Dauphin Co., Susquehanna River, 2 ♂ - 4 ♀, 30 April 1905, **PDA.**
Dauphin Co., Harrisburg, 1 ♂, 8 May 1907, **PDA.**
Brachycentrus lateralis (Say)
Centre Co., Poe Paddy, 1 ♂, 2 May 1948, **PSU.**
Brachycentrus nigrosoma (Banks)
Bucks Co., Ralph Stover Park, 7 ♂ - 1 ♀, 1 May 1937, **JWHR at INHS.**
Brachycentrus numerosus (Say)
Centre Co., Poe Paddy, 9 ♀, 2 May 1948, **PSU.**
Huntington Co., Colerain Park, 3 ♀, 4 May 1952, **PSU.**
Lancaster Co., Octoraro Creek, 7 spec., 7 September 1943, **USNM.**
HYDROPTILIDAE
Mayatrichia ayama Mosely, listed in Ross, H.H., 1944.
LEPTOCERIDAE
Ceraclea mentiea (Walker)
Dauphin Co., At Arcs, Harrisburg, 8 spec., 12 June - 24 August 1905, **PDA.**
Oecetis eddlestoni (Ross)
Bradford Co., Susquehanna River, Sayre, 1 ♂, 29 July 1937, **JHD at INHS.**
Setodes guttatus (Banks)
Cumberland Co., Camphill, 1 Undet, 28 May 1905, **PDA.**
Dauphin Co., At Arcs, Harrisburg, 3 spec., 3 August 1905, **PDA.**
Triaenodes abus Milne
Lancaster Co., Ltl. Conestoga Ck., E. Petersburg, 10 spec., 10 June 1943, **JWP at USNM.**
MOLANNIDAE
Molanna flavicornis Banks
Erie Co., Presque Isle, 6 ♂, 8 August 1949, **EF at ROM.**
PHRYGANEIDAE
Oligostomis pardalis (Walker)
Perry Co., South Fork Camp, 1 ♂, 8 June 1938, **K&C at PDA.**

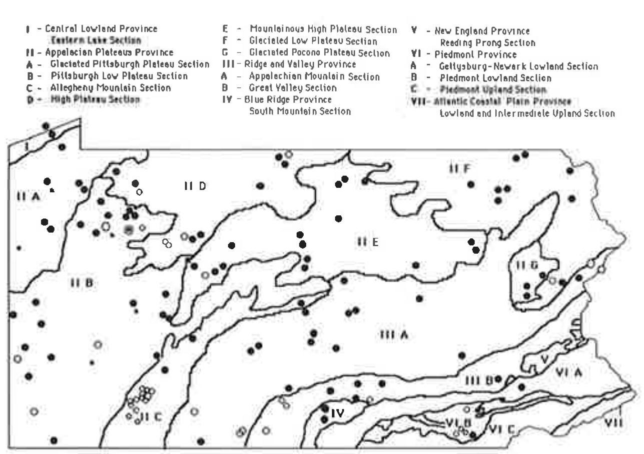

FIGURE 1. A physiographic province map adapted from Berg et al. 1989 for collection sites of the major studies of Pennsylvania Trichoptera.

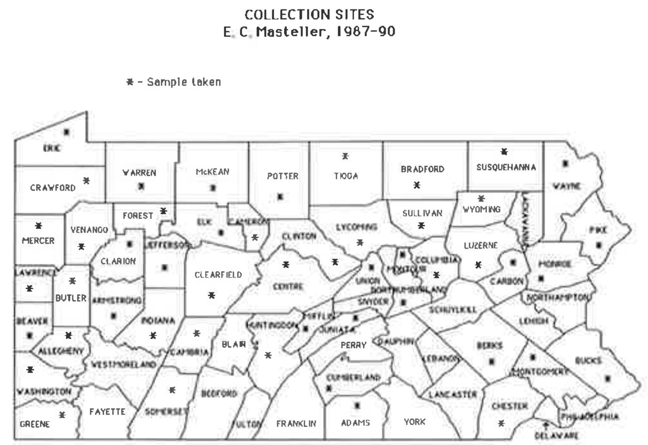

FIGURE 2. Collection sites of E.C. Masteller in Pennsylvania indicated by county.

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Code	Collector	Location or Source of Specimens or Records
AC	A. Champlain	PA Dept. of Ag., Bur. Plant Ind. (PDA)
ACG	A.C. Graham	Royal Ontario Museum (ROM)
B&F	R. Baumann & O.S. Flint Jr.	U.S. National Museum (USNM)
BGS	B.G. Swegman	Univ. Pittsburgh (1977-81) (U. Pitt.)
CB	C. Betten	Cornell - Comstock Entomol. Museum
CF	C. Fox	PDA
CM	C. McGinnet	PA Insect Survey - Bedford
DHF	D.H. Funk	Stroud Water Research, Avondale
DJS	Dave Shetlar	Pennsylvania State Univ. (PSU)
ECM	E.C. Masteller	Penn State Erie, Behrend College
ECM-CAD	Caren A. Dionisi	"
ECM-JEC	Jon E. Carey	"
ECM-MAL	Mark A. Lethaby	"
ECM-MPP	M.P. Plociniak	"
ECM-TB	Todd Bills	"
ECM-JMS	James Samuels	"
EF	Ed Fuller	ROM
EMC	E.M. Craighead	USNM
F&W	O.S. Flint Jr. & G. Wiggins	ROM
FH	F. Haimbach	Illinois Natural History Survey
GLJ	G.L. Jubb	North East Exp. Sta. PSU (VPI&SU)
JB	Jack Busch	Erie, PA at USNM
JHE	J.H. Eddleston	at Ill. Nat. Hist. Sur.
JLS	J.L. Sykora	U. Pitt. and U.S. Army Corp Engineers
JSW	J.S. Weaver	Univ. New Hampshire (PA 1975-77)
JWA	J.W. Adams	PA Dept. of Agriculture
JWHR	J.W.H. Rehn	PSU
JWP	J.W. Price	USNM
JWR	J.W. Richardson Jr.	Stroud Water Res. at Phil. Acad. Nat. Sci.
K&C	Kirk & A. Champlain	PA Dept of Agriculture
KM	Ken Manuel	Duke Power Co.
MAF	M.A. Farrel	PSU-Frost Entomol. Museum
OSF	O.S. Flint Jr.	USNM
PHA	Peter H. Adler	PSU 1981-1983
PJS	P.J. Spangler	USNM
RMS	R.M. Seward	Unit Pitt.-manuscript
S&Q	Starner & Quinn	PA Ins. Survey - Biglerville Exp. Sta. PSU
SSR	S.S. Roback	Phil. Acad. Nat. Sci. at Ill. Nat. Hist. Sur.
SWF	Stuart W. Frost	PSU
TJS	T.J. Spilman	USNM
VH	Verda Hass	PA Insect Survey - PSU
Y&O	Yamamoto & Odum	ROM

Code	Collection	Location of Specimens
PAS	The Academy of Natural Sciences of Philadelphia	Philadelphia
PDA	Pennsylvania Dept. of Agriculture, Bureau of Plant Ind.	Harrisburg, PA
PSU	Pennsylvania State Univ.	Frost Entomol. Mus., Univ. Park, PA
ROM	Royal Ontario Museum	Toronto, Canada
SWR	Stroud Water Research Center	Avondale, PA
USNM	National Museum of Natural History, Smithsonian Institution	Washington, D.C.
INHS	Illinois Natural History Survey	Urbana, IL

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DERMATOGLYPHICS IN ALZHEIMER'S DISEASE: A FAMILY STUDY[1]

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ABSTRACT

The dermatoglyphics of the fingers and hands of 120 families of presumed Alzheimer's patients in 15 counties of Western Pennsylvania were compared with normal controls. The patients showed a significant decrease in arches on their fingers and an overall increase of ulnar loops and the occurrance of bilateral digital pattern symmetry. The study confirmed the previously reported high frequency of 8, 9, or 10 ulnar loops in Alzhemier's patients but failed to confirm the other reported similarities with Down's syndrome. The dermatoglyphic parameters of the patients were compared with their brothers and sisters and their children as well as less closely related family members, but no specific trend in skin patterns could be noted. Almost half of the patients had at least one parent, sibling, or child with similar neurological problems. Data are given that suggest there may be a nationality connection to Alzheimer's Disease with certain nationalities being much more frequent among the patients and others being much less frequent than the frequencies found in the general population of the study area.
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INTRODUCTION

With the elderly portion of our national population increasing each year we are seeing an ever expanding number of individuals with Alzheimer's Disease. The search for the cause and cure of this disorder has led to a number of possible causes but not to a cure. The situation is further complicated in that obtaining an accurate diagnosis is difficult since there are a number of Organic Brain Syndromes, both reversible and nonreversible, whose symptoms resemble those of Senile Dementia of the Alzheimer's type (Katzman, 1986). It has been observed that relatives of a person with Alzheimer's Disease are more likely to develop this disorder than members of the general population. About 15% of the cases can be shown to be inherited by means of pedigree analysis and are referred to as Familial Alzheimer's Disease (FAD) (Goudsmit, et al. 1981). The results of a report by Groate, et al. (1991) suggest that beta amyloid peptide deposition in the brain is the central event in the pathogenesis of FAD. They further suggest that this could be caused by a point mutation in the Amyloid Precursor Protein gene. The other 85% of cases are designated "sporadic," but even a large number of these have at least one close relative with the disease. Thus there is evidence that genes may be involved in the cause of both forms of this disease.

The late age of onset of Alzheimer's Disease hampers pedigree analysis since many would-be victims succumb to accidental death or other organic diseases prior to symptoms of the disorder. Recent investigations have mapped both the gene for amyloid beta protein, which accumulates in Alzheimer's victims, and the possible gene for FAD to chromosome 21 (Barnes, 1987; Goldgaber, et al. 1987; Selkoe, et al. 1987; St. George-Hyslop, et al. 1987). Another way of showing a genetic connection would be to show an association between Alzheimer's Disease and characteristics known to be genetically determined. The human skin patterns (dermatoglyphics) are known to be controlled by genes (Holt, 1968; Schaumann and Alter, 1976; Loesch, 1983). Particular patterns have been shown by a number of authors to be associated with certain genetic disorders such as Down's Syndrome, diabetes, and congenital gastroenteritis (Walker, 1957; Sant, et al. 1984; Gottlieb and Schuster, 1986). Studies showing an association of skin patterns with neurological disorders such as multiple sclerosis and Alzheimer's Disease have been reported (Michel, 1987; 1988; Weinreb, 1985); and Goldenberg (1977) has reported that the autoimmune diseases rheumatoid arthritis and systemic lupus erythematosis have abnormal frequencies of certain skin patterns.

Although dermatoglyphic studies have been done on a number of genetic and suspected genetic disorders, very little has been done on the families of the afflicted individuals. This study was undertaken to examine the dermatoglyphic patterns of Alzheimer patients and as many of their relatives as could be located. The most favorable expectation of the study would be to verify those skin patterns found to be associated with Alzheimer's Disease and to identify high risk individuals in Alzheimer families. The least favorable situation would show no association whatsoever between skin patterns and Alzheimer's Disease.

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MATERIALS AND METHODS

Alzheimer patients and family members were located through Alzheimer's Disease Support Groups and County Area Agencies on Aging in Western Pennsylvania. All patients had been evaluated by their family physician and a neurologist and had undergone the usual battery of medical examinations. Finger and palm prints were obtained from a total of 574 individuals involving 120 families of presumed Alzheimer's patients and also from 106 controls. There were 82 patients available for dermatoglyphic analysis while in the remaining 38 families the patient was either deceased or unavailable for dermatoglyphic analysis. Patient history information on age of onset, nationality background, and relatives with similar neurological problems was supplied by a close relative of the patient.

Hand prints were obtained from each participant using a Faurot pad and sensitized paper. Both hands were printed and the data analyzed for each hand separately as well as both hands combined. The nomenclature adopted to describe the results of this study is that of Penrose (1968). Figure 1 is a diagram of a human palm illustrating palmar areas, axial and digital triradii, creases, and representative digital epidermal ridge patterns.

Each hand print was examined for the presence or absence of patterns in the hypothenar and thenar areas of the palm, the presence or absence of a simian crease, the type of pattern on each of the digits, total digital ridge count, patterns in the interdigital areas, summed atd angles, the orientation of palmar ridges as determined by Cummins' main line index, and bilateral digital pattern symmetry. This last parameter refers to digit number one of both hands having the same pattern, digit number two of both hands having the same pattern, etc., for each digit so that there is symmetry between the two hands. Double loops were classed as whorls since they are considered a subclass of this pattern. The interdigital areas are the distal regions of the palm between the digits and are designated I_1 through I_4.

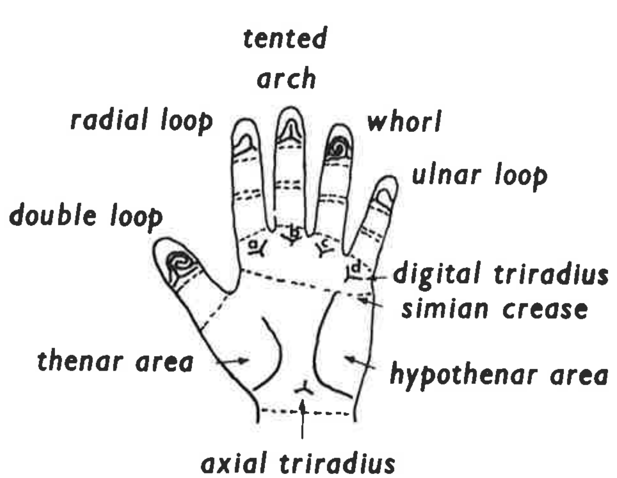

FIGURE 1. Diagram of palm showing palmar areas, triradii, and finger pattern types. (From K.E. Michel, *Proc. Pa. Acad. Sci.,* Vol. 61, 1987.)

Cummins' main line index makes use of the termination of the A and D main lines to determine the general orientation of the ridges of the palm. A high value indicates a horizontal orientation and a low value is obtained with a vertical orientation. The control population dermatoglyphics in this study were tested for homogeneity with a normal North American population of 200 males and 200 females (Schaumann and Alter, 1976) and found to be similar. The nationality background of the 120 patients was compared with the U.S. Census of Population for the 13 western Pennsylvania counties in this study. When mixed ancestry was encountered, each nationality was equally scored. The Alzheimer patient and family data were compared with the control population via the adjusted chi-square analysis or Student's t test.

RESULTS AND DISCUSSION

An analysis of the skin patterns in the palms of the patients (Table 1) failed to show the similarity to Down's Syndrome as reported by Weinreb (1985). Although there was a general decrease in interdigital (I) patterns as in the 1985 study it was not significant. Also the patients did not exhibit an increase in the atd angle or frequency of hypothenar patterns or simian creases. However, the frequencies of the finger patterns (Table 2) are in agreement with Weinreb. There is a significant increase of ulnar loops on the fingers with a large percentage of the patients having 8 or more ulnar loops and a concomittant decrease in arches, radial loops, and whorls. Bilateral digital symmetry was more than twice as common in the patients than in the control population with over one-third of them having this parameter.

TABLE 1. Palm Dermatoglyphic Characteristics of Alzheimer's Patients and Controls. Significant at $p < 0.05$ (*) or $p < 0.01$ (**).

Characteristic	Patient (N = 82)	Control (N = 106)
Hypothenar Pattern	42.3%	42.9%
I_1 Pattern	5.5%	1.9%
I_2 Pattern	1.8%	0.5%
I_3 Pattern	23.9%	29.7%
I_4 Pattern	17.8%	23.6%
Total I Patterns	12.3%	13.9%
Summed atd Angles	86.1°	89.0°
Summed Main Line Index	19.3	18.8

TABLE 2. Finger Dermatoglyphic Characteristics of Alzheimer's Patients and Controls. Significant at $p < 0.05$ (*) or $p < 0.01$ (**).

Characteristic	Patient (N = 82)	Control (N = 106)
Bilateral Digital Symmetry	35.0%**	15.1%
Arches	5.0%	7.1%
Ulnar Loops	67.8%**	60.5%
Radial Loops	3.3%	5.3%
Whorls	23.9%	27.1%
Total A, L_R, & W	32.3%**	39.5%
10 Ulnar Loops	17.5%**	2.8%
8-10 Ulnar Loops	53.8%*	35.8%
Total Ridge Count	164.3	182.6

The mean age of onset of the patients in this study was 67.9 years with a range of 45 to 87 years. Even though a few of the patients had an early age of onset and probably were familial (FAD), the bulk of the patient group had a later age of onset and were considered "sporadic." Yet 55.1% of the patients had a relative with a similar type of dementia while 49.2% of the patients had a first degree relative exhibiting symptoms of Alzheimer's Disease.

Examination of the dermatoglyphic characteristics of the relatives of the patients in this study (Tables 3 and 4) did not reveal a decrease in interdigital pattern frequency as seen in the patients but rather an increase, particularly in the I_2 and I_4 regions. The frequencies of the other palm characteristics were all normal. The relatives did not show the increase in bilateral digital symmetry seen in the patients nor did they have the significant increase of 8 or more ulnar loops on the fingers. All of the relatives exhibited a decreased frequency of arches on the fingers but only the sibs of patients showed the increase in ulnar loops with the concomittant decrease in arches, radial loops, and whorls as seen in the patients and in the study by Weinreb (1985). Some of these sibs may indeed be potential Alzheimer victims or perhaps just the bearers of very similar combinations of skin pattern genes to those of their Alzheimer brothers and sisters.

Family history information gathered included the nationality background of the patients. Certain nationalities seemed to be predominant among the patients and thus a comparison was made with the nationalities found in the census data from the counties in which these patients lived (Table 5). Patients with a nationality background from the British Isles, i.e., England, Ireland, Scotland and Wales, and from the Netherlands were found in a much higher frequency than these nationalities existed in the general population of the study area. Patients with a nationality background from Italy, Czechoslovakia, and Poland were seen in a much lower frequency than expected. This would not be unexpected if there is a genetic determinant in Alzheimer's Disease. Geographical, political, and religious boundaries tend to isolate genes. This is seen with the higher frequencies of Tay Sachs disease in individuals with Eastern European Jewish ancestry, cystic fibrosis in Europeans, thalassemia in the Italian population, and sickle cell anemia in Blacks.

TABLE 3. Palm Dermatoglyphic Characteristics of Relatives of Alzheimer's Patients. Significant at $p < 0.05$ (*) or $p < 0.01$ (**).

Characteristic	Children (N = 156)	Sibs (N = 70)	Others (N = 266)	Total (N = 492)	Control (N = 106)
Hypothenar Pattern	34.0%	52.2%	38.3%	38.9%	42.9%
I_1 Pattern	10.0%**	3.6%	6.6%*	7.3%**	1.9%
I_2 Pattern	1.6%	0.0%	2.8%	2.0%	0.5%
I_3 Pattern	37.9%	26.8%	35.2%	34.8%	29.7%
I_4 Pattern	27.2%	18.8%	35.9%**	30.7%*	23.6%
Total I Patterns	19.2%**	12.3%	20.1%**	19.2%**	13.9%
Summed atd Angles	86.2°	86.5°	85.7°	86.1°	89.0°
Summed Main Line Index	18.6	19.2	18.3	18.6	18.8

TABLE 4. Finger Dermatoglyphic Characteristics of Relatives of Alzheimer's Patients. Significant at $p < 0.05$ (*) or $p < 0.01$ (**).

Characteristic	Children (N = 156)	Sibs (N = 70)	Others (N = 266)	Total (N = 492)	Control (N = 106)
Bilateral Digital Symmetry	25.8%	23.2%	17.8%	21.1%	15.1%
Arches	4.4%**	5.4%	4.2%**	4.4%**	7.1%
Ulnar Loops	62.3%	65.7%*	62.0%	62.6%	60.5%
Radial Loops	4.3%	6.3%	5.0%	5.0%	5.3%
Whorls	29.0%	22.7%	28.8%	28.0%	27.1%
Total A, L_R, & W	37.7%	34.3%*	38.0%	37.4%	39.5%
10 Ulnar Loops	5.9%	5.8%	4.9%	5.3%	2.8%
8-10 Ulnar Loops	33.3%	34.8%	35.2%	34.6%	35.8%
Total Ridge Count	184.0	166.3	187.2	183.3	182.6

TABLE 5. Nationality Background of 120 Alzheimer's Patients Compared With Census Data From 13 Western Pennsylvania Counties. Significant at $p < 0.05$ (*) or $p < 0.01$ (**).

Nationality	Patients	Census
German	22.7%	17.9%
English	20.1%**	6.9%
Irish	19.1%**	9.5%
Scotch	9.3%**	3.0%
Italian	5.1%**	14.7%
Welsh	3.6%*	1.5%
Dutch	3.6%**	0.1%
Swedish	3.1%	1.5%
Czechoslovakian	2.6%**	11.2%
Polish	2.1%**	12.9%
Yugoslavian	2.1%	4.3%
Austrian	1.5%	3.5%
Russian	1.5%	3.1%
French	1.5%	1.4%
Other	2.1%**	8.6%

The general lack of similarity of dermatoglyphic characteristic frequencies between the Alzheimer's patients and their relatives suggests that skin pattern analysis may be a way of identifying potential victims in a family. Since most of the relatives do not have the characteristic patterns of Alzheimer's, those members that do may be at high risk. Dermatoglyphic analysis may be able to add one more parameter to the evaluation of suspected Alzheimer's patients.

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POPULATION CHANGE AND ITS COMPONENTS IN PENNSYLVANIA 1980-1990[1]

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ABSTRACT

Although Pennsylvania's population increased only slightly from 1980-1990, the pattern of change portrays noteworthy growth in many counties in the eastern half of the Commonwealth and decline throughout much of the west. Significant growth was restricted to the southeastern quadrant, a few counties in central Pennsylvania, and those bordering the Delaware River in the northeast. Loss of population, in addition to declines reported in almost all of the counties in western Pennsylvania, occurred along the northern tier and in much of the anthracite area. Analysis of the components of change—fertility, mortality, and net-migration—reveals significant differences in the role played by reproductive change in the demographic equation among counties which grew in population and, to a lesser extent, among those which declined. Changes in numbers of inhabitants and their components are related to location and selected demographic, social, and economic characteristics of the county populations.

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INTRODUCTION

From 1980 to 1990, the counties of Pennsylvania recorded a variety of growth experiences—a few growing apace in number of inhabitants to a rather large group declining by noteworthy numbers, and yet a third group in which loss by migration was exacerbated by "natural decrease," the number of deaths exceeding the number of births. Whereas populations of counties, metropolitan areas, and rural areas are included in the brief description of population change, this study concentrates on three county groups in an attempt to relate the more dramatic examples (of population change) to the components of change—fertility, mortality, and net-migration—and to an array of residential, demographic, social, and economic population characteristics. After describing the distribution of change, the focus of the work is turned to the three groups of county populations—one which grew most rapidly in number, a second group whose rate of decline exceeded all others, and a third in which reproductive change produced losses because the magnitude of deaths exceeded that of births.

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THE DISTRIBUTION OF POPULATION CHANGE

Figure 1 displays population change by county in Pennsylvania from 1980 to 1990. Clearly, growth was concentrated almost completely in the eastern half of the state, and gains of note are found in three counties of the northeast bordering the Delaware River, two of Philadelphia's suburban counties, and a few scattered in the east-central section of the Commonwealth. Losses were reported for almost all western counties, most of those in the northern tier, and the anthracite region. Among those in the highest-growth group are traditional suburban counties (Bucks and Chester in Philadelphia's orbit), a relatively small MSA (Lancaster), rural adjuncts to metropolitan areas (Adams and Perry counties), and counties associated with recreation, tourism, and retirement in the Poconos and upper Delaware Valley (Monroe, Pike, and Wayne).

Metropolitan counties, taken collectively, grew by a mere 0.5 percent (adding 49,484 persons to reach 10,077,002 inhabitants in 1990), whereas the population of all nonmetropolitan counties decreased in number by a little less than 2 percent (losing 31,736 persons and falling to 1,804,641 in 1990).[1] Among Pennsylvania's 15 metropolitan areas, nine registered gains, led by Lancaster which added over 60,000, York gaining more than 46,000, and Allentown-Bethlehem increasing by a little more than 44,000. (The data for the discussion of metropolitan population change are from the Office of Management and Budget 1990 and the Pennsylvania State Data Center 1991). Philadelphia added about 46,000, as well, but its relative growth amounted to little more than one percent, given the millions in its base population. On the loss side, the Pittsburgh Metro led, declining by more than 162,000 (-7.3 percent). Otherwise, only the Johnstown (-23,259) and Beaver (-18,348) MSAs lost more than 7,300 persons.[2]

It is worth noting that, while Pennsylvania's total metropolitan area increased to embrace 34 of the 67 counties and metropolitan population increased in number, albeit slightly, the Commonwealth remained the leading state in the nation in number of rural inhabitants. Pennsylvania's rural population numbered 3,693,348 in 1990, up by almost 1.5 percent over 1980, and accounted for 31 percent of the total population. Whereas Philadelphia City/County is completely urban and Allegheny, Delaware, and Montgomery counties had only 2, 4, and 8 percent rural population, respectively, seven counties remained totally rural in 1990. Those with 100 percent rural inhabitants included Forest, Fulton, Juniata, Pike, Sullivan, Susquehanna, and Wyoming (the Pennsylvania State Data Center 1992), the last of which, ironically, is part of the Scranton-Wilkes Barre Metropolitan Statistical Area. Not surprisingly, these seven counties ranked very low among the state's 67 in number of inhabitants (six of the seven having ranks ranging from 59th to 67th) with a combined population of less than 142,000 in 1990 (The Pennsylvania State Data Center 1991).

COUNTIES WITH LARGE GAINS OR LOSSES

Although the Commonwealth's population count changed little, gaining fewer than 18,000 inhabitants over the 1980s, growth in a few counties was most impressive. Table 1 lists the highest and lowest groups of counties in terms of relative population change, 1980-1990,[3] and shows components of change, as well. It is apparent that net-migration related much more closely to population growth or decline than either reproductive change or its components, births and deaths. Indeed, the three leading counties exemplify this—although shown in the highest group (Table 1) and ranked first, second, and third in net-migration rate, Pike, Monroe, and Wayne counties were ranked quite low in reproductive change due mostly to relatively high death rates. As vacation/retirement areas, the high death rates are a product of aged populations. The remainder of the leading growth counties had reproductive change, birth, and death rates at about expected levels. At the other extreme, counties in which rates of decline led the state, losses are rather well explained by the relatively great declines brought about essentially by net-migration that the generally small excess of births over deaths failed to offset.

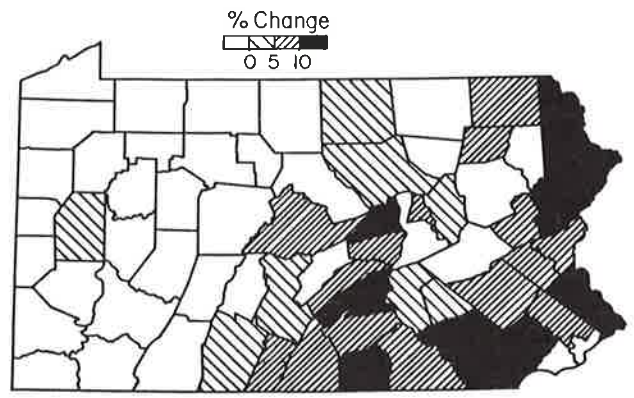

FIGURE 1. Population change in Pennsylvania by county, 1980-1990.

TABLE 1. Components of Population Change, 1980-1990, as a Percentage of 1980 Population
Selected Counties and the Commonwealth

	Population Change		Net-Migration		Reproductive Change		Births		Deaths*	
	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank
Counties in Highest Growth Group										
Pike	53.1	1	51.9	1	1.2	55	13.8	21	12.6	66
Monroe	37.9	2	34.0	2	3.9	24	14.6	13	10.6	49
Chester	18.9	3	11.2**	4	7.6	2	15.6	3	8.0	3
Lancaster	16.6	4	8.7	7	7.9	1	17.0	1	9.1	13
Perry	15.3	5	8.8	6	6.5	4	15.5	4	9.0	11
Adams	14.6	6	9.2	5	5.4	10	14.7	9	9.3	16
Wayne	13.4	7	11.2**	3	2.2	47	14.0	17	11.9	58
Bucks	12.9	8	5.5	12	7.4	3	15.2	5	7.8	2
Counties in Lowest Growth Group										
Allegheny	-7.8**	60	-9.2	57	1.4	53	12.2**	50	10.9	51
Venango	-7.8**	61	-10.5	62	2.6	42	12.8	40	10.2	38
Fayette	-8.8	62	-9.7	59	0.9	58	12.2**	51	11.3	56
Beaver	-9.0**	63	-11.2	63	2.2	46	11.9	58	9.7	25
Elk	-9.0**	64	-13.3	66	4.3	20	13.7	24	9.4	20
Lawrence	-10.2	65	-11.6	64	1.4	52	11.7	61	10.3	40
Cambria	-11.0	66	-11.7	65	0.7	59	11.2	63	10.5	46
Cameron	-11.4	67	-14.4	67	3.0	37	14.3	16	11.3	55
Pennsylvania	0.2	-	-3.1	-	3.3	-	13.6	-	10.3	-

Source: Computed by author from data provided by the Bureau of the Census, the Pennsylvania State Data Center, and the Pennsylvania Department of Health; the latter disclaims responsibility for any analyses, interpretations or conclusions.
*Deaths are ranked from lowest to highest rate.
**Although just one place is shown, decimals were carried out sufficiently to break ties in rank.

How do the counties which occupy the extreme groups differ? And if they do, what are their characteristics? Table 2 lists selected characteristics of age, education, and rural residence. The leading gainers split on age, as was stated earlier, with Pike, Monroe, and Wayne counties recording medians well above the state figure. Although the other group had medians generally above the state's, they were not dramatically so. Lancaster, Perry, and Adams counties, along with Wayne, exhibit high school graduation rates for their population 25 or older below the state's, whereas Chester and Bucks are shown to be well above that level. The low-growth group, except for highly ranked Allegheny County, was at or near par with the state in half the cases, and below it in the other three. The high-growth counties were clearly more nearly rural and, although the percentages are all quite low, well ahead of the low growth group in farm population. Overall, the high and low groups were distinctly different on only the latter traits—rural population and rural farm population—as age and education rates, although favoring the growing counties, were not very much different in the aggregate.

Turning to selected economic measures, Table 3 arrays the 16 selected counties in the order they appeared in the preceding table. The differences between the groups are

TABLE 2. Population Change, 1980-1990, and Selected Demographic, Social and Residential Characteristics*
Selected Counties and the Commonwealth

	Population Change		Median Age**		% High School Graduates		Rural Population All		Rural Population Farm	
	%	Rank	Years	Rank	%	Rank	%	Rank	%	Rank
Counties in Highest Growth Group										
Pike	53.1	1	39.1	67	65.0	21	100.0	1	0.8	52
Monroe	37.9	2	32.6	44	67.8	13	81.0	17	0.8	52
Chester	18.9	3	30.6	15	76.4	1	45.4	47	1.9	40
Lancaster	16.6	4	29.9	10	59.6	48	45.5	46	6.8	6
Perry	15.3	5	29.9	10	61.1	44	93.1	7	4.8	16
Adams	14.6	6	29.5	7	59.2	51	81.3	16	5.4	13
Wayne	13.4	7	33.4	55	62.1	38	85.4	10	5.7	9
Bucks	12.9	8	29.9	10	74.7	4	19.4	61	0.6	56
Counties in Lowest Growth Group										
Allegheny	-7.8	60	33.6	57	69.0	10	4.4	65	***	65
Venango	-7.8	61	31.6	28	64.9	23	56.6	37	1.1	45
Fayette	-8.8	62	32.8	49	57.8	59	67.9	31	0.9	49
Beaver	-9.0	63	32.7	45	64.8	25	24.1	60	0.5	59
Elk	-9.0	64	31.0	23	64.6	26	58.4	35	0.6	56
Lawrence	-10.2	65	32.8	49	63.2	35	52.0	40	2.0	35
Cambria	-11.0	66	31.7	32	61.1	44	46.9	44	0.6	56
Cameron	-11.4	67	33.9	60	64.5	28	57.5	36	0.2	63
Pennsylvania	0.2	-	32.1	-	64.7	-	30.7	-	1.3	-

Source: Computed from data provided by the Bureau of the Census and the Pennsylvania State Data Center.
*Characteristics shown are for 1980.
**Median ages are ranked from youngest to oldest.
***The percentage of rural farm population in Allegheny County was less than 0.1 percent in 1980.

TABLE 3. Population Change, 1980-1990, and Selected Economic Characteristics*
Selected Counties and the Commonwealth

	Population Change		Median Family Income		Families Below Poverty Level**		Family Income ≥$50,000		Unemployment**	
	%	Rank	$(000)	Rank	%	Rank	%	Rank	%	Rank
Counties in Highest Growth Group										
Pike	53.1	1	17.1	48	7.0	22	3.3	20	9.9	53
Monroe	37.9	2	18.5	32	6.3	16	2.7	33	7.1	21
Chester	18.9	3	25.5	2	4.7	2	10.3	2	4.6	5
Lancaster	16.6	4	20.6	16	6.0	13	4.1	9	4.2	2
Perry	15.3	5	16.1	57	6.4	17	1.7	57	6.4	17
Adams	14.6	6	18.5	33	6.0	13	2.7	33	5.3	10
Wayne	13.4	7	15.5	52	12.3	63	2.5	38	9.0	47
Bucks	12.9	8	24.4	3	4.7	2	6.8	4	5.5	12
Counties in Lowest Growth Group										
Allegheny	-7.8	60	21.6	8	6.7	19	6.1	5	7.2	23
Venango	-7.8	61	19.5	22	8.7	46	3.1	26	8.2	35
Fayette	-8.8	62	17.3	46	15.5	66	2.3	43	11.1	61
Beaver	-9.0	63	22.2	5	5.8	11	3.9	11	8.1	34
Elk	-9.0	64	19.4	23	6.4	17	3.3	20	6.7	19
Lawrence	-10.2	65	19.2	25	7.8	34	3.2	24	9.8	51
Cambria	-11.0	66	18.9	30	7.6	31	3.1	26	11.9	65
Cameron	-11.4	67	16.8	50	8.0	39	0.4	67	11.2	62
Pennsylvania	0.2	-	20.0	-	7.8	-	4.6	-	7.4	-

Source: Computed by author from data provided by the Bureau of the Census and the Pennsylvania State Data Center.
*Characteristics shown are for 1980.
**Families below poverty level and unemployment are ranked from lowest to highest.

clouded somewhat by the differences within the county growth groups. For example, two counties from each group—Chester and Bucks, Beaver and Allegheny—comprised the highest median-family-income category. The others are somewhat the same insofar as the groupings contain members from both high- and low-growth counties. Specifically, the remaining counties had medians which ranged from lows of $15,500 in Wayne County and $16,100 in Perry, to Lancaster's $20,600. Although there were fewer families below the poverty level and a greater number earning $50,000 or more annually in the high-growth group shown on Table 3, both groups of counties had one member with a larger percentage of families below the poverty level than the state's. In terms of families which earned $50,000 or more annually, Chester, Bucks, Allegheny and, to a lesser extent, Lancaster were among the leaders.

Like the income measures, unemployment shows some differences between the groups but each had counties which exceeded by far the state's percentage—Carbon, Cameron, Fayette, and Lawrence in the group that declined (Table 3), and Pike and Wayne from among the gainers. The point is that, in many of the socioeconomic characteristics shown, the existing differences between the groups are compromised by similarities across groups, as well. Thus, neither group of counties was homogeneous in the characteristics shown on Table 3.

COUNTIES IN WHICH DEATHS EXCEEDED BIRTHS

In order to explore further the associations between population change and demographic composition, a third group of counties was identified whose array of characteristics are, in part, more closely related to the expected conditions of population decline—those whose fertility was exceeded by mortality, producing negative reproductive change. Figure 2, a cartographic cross-classification table, portrays counties by net-migration and reproductive change, reducing each to gain or loss and creating four possible combinations. The counties in which both components produced gains (upper-left map in Figure 2) are less numerous than those shown in Figure 1 as increasing in population size. Those which lost via net-migration but gained through reproductive change (Figure 2, upper right) include all western and northern counties save those in the northeast. However, a most interesting pattern emerges when counties in which mortality exceeded fertility are considered—as the lower maps in Figure 2 show, there are seven such counties, six of which lost, as well, through net-migration (only Carbon gained more migrants than it lost). Moreover, all but Forest County are in or near the anthracite area of northeastern Pennsylvania.

Table 4 lists the counties which lost numbers of inhabitants through reproductive change and shows the detail of

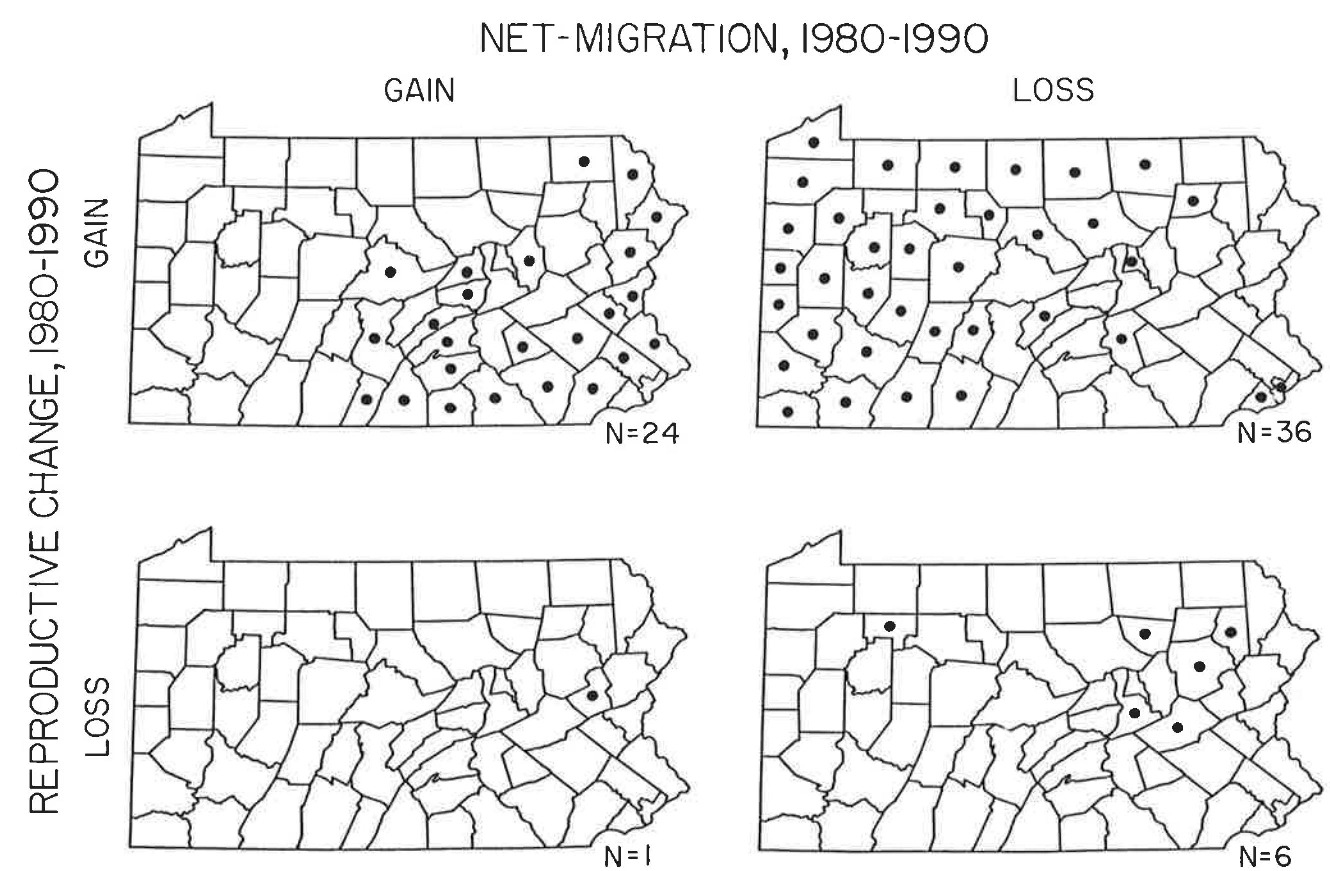

FIGURE 2. Cartographic cross-classification table of Net-migration and reproductive change in Pennsylvania by county, 1980-1990.

the components of change. Although loss through net-migration is not as great for these counties as those shown in the lower part of Table 1—indeed, Carbon's gain through net-migration ranked eighth in the state[4]—other components are quite distinctive given their low fertility and high mortality. The final column in Table 4, detailing median age, provides the probable cause for loss through reproductive change—the older populations of the anthracite area contribute to lower crude rates of fertility and higher crude rates of mortality.

The social, residential, and economic characteristics shown on Tables 2 and 3 for the high- and low-growth groups are shown on Table 5 for the third county group, as well. In some ways, the characteristics of the anthracite counties and Forest are more expressive of those in population decline than the eight counties which rank lowest in the category and are listed in Tables 2 and 3. Certainly median age (Table 4) and the several economic characteristics shown in Table 5 seem to associate well with population decline. However, there is no need to speculate since Table 6 lists for all three county groups, and all counties in Pennsylvania, the weighted means for each of the variables listed on Tables 4 and 5, permitting direct comparison. The low-growth group is shown with and without Allegheny because of the enormous influence exerted on the group's weighted means by that county's very large population. Comparing the low-growth group (without Allegheny) to those in which deaths exceeded births yields the following results: The (mostly) anthracite counties' populations are, on average, clearly older, less well educated and less rural. Moreover, family income lags and there are fewer wealthy families in the anthracite group. The low-growth

TABLE 4. Components of Population Change, 1980-1990, and Median Age[4]
Counties in which Deaths Exceeded Births

	Reproductive Change		Births		Deaths**		Net-Migration		Population Change		Median Age**	
	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank
Carbon	-0.3***	62	11.9	56	12.2	60	7.0	8	6.7	19	35.5	64
Northumberland	-0.3***	61	12.1	53	12.4	62	-3.4	35	-3.6	40	35.1	61
Lackawanna	-0.5	64	11.8	59	12.3	61	-3.3	34	-3.8	43	35.2	62
Sullivan	-2.3	67	10.3	67	12.6	65	-1.5	27	-3.9	44	32.7	45
Luzerne	-1.5	65	11.0***	64	12.5	63	-2.9	31	-4.4	45	36.0	65
Schuylkill	-2.0	66	11.0***	65	13.0	67	-3.0	32	-5.0	49	36.9	66
Forest	-0.4	63	10.8	66	11.2	54	-4.9	38	-5.3	51	35.4	63
Pennsylvania	3.3	-	13.6	-	10.3	-	3.1	-	0.2	-	32.1	-

Source: Computed by author from data provided by the Bureau of the Census, the Pennsylvania State Data Center, and the Pennsylvania Department of Health; the latter disclaims responsibility for any analyses, interpretations, or conclusions.
*Median age is for 1980.
**Deaths and median ages are ranked from lowest to highest.
***Although just one place is shown, decimals were carried out sufficiently to break ties in rank.

TABLE 5. Selected Social, Residential, and Economic Characteristics, 1980
Counties in which Deaths Exceeded Births

	% High School Graduates		Rural Population All		Rural Population Farm		Median Family Income		Families Below Poverty Level*		Family Income ≥ $50,000		Unemployment*	
	%	Rank	%	Rank	%	Rank	$ (000)	Rank	%	Rank	%	Rank	%	Rank
Carbon	57.4	63	42.5	49	0.7	54	17.8	38	7.6	31	1.7	57	7.8	25
Northumberland	57.6	61	49.0	42	2.4	30	15.9	58	8.1	41	1.5	60	8.7	44
Lackawanna	63.8	31	16.8	63	0.4	61	17.3	45	7.2	24	2.8	30	8.3	39
Sullivan	61.0	46	100.0	1	6.3	7	14.6	67	9.7	49	1.3	66	11.6	65
Luzerne	61.2	43	26.1	58	0.3	62	17.0	49	7.2	24	2.2	46	8.9	46
Schuylkill	56.3	64	52.1	39	1.3	45	16.2	54	7.7	32	1.8	54	8.3	39
Forest	59.1	52	100.0	1	2.6	27	15.5	63	8.6	45	1.5	60	9.4	49
Pennsylvania	64.7	-	30.7	-	1.3	-	20.0	-	7.8	-	4.6	-	7.4	-

Source: Computed by author with data from the Bureau of the Census.
*Families below poverty level and unemployment are ranked from lowest to highest.

counties, on the other hand, have more families in poverty and greater unemployment among its population 16 and older. Comparing all columns on Table 6, the two groups which lost inhabitants are quite distinct from both the high-growth group and all counties for most measures. The eight counties which led the state in growth are clearly higher—or lower, when appropriate—in all measures than the other groups shown.

CONCLUDING REMARKS

Although the change in population was slight statewide, counties varied considerably in their rates of change. Despite the fact that eastern Pennsylvania recorded all of the noteworthy gains at the county level in population and all but one county in western Pennsylvania suffered declines, the location of counties grouped by rates of change produced several clusters of significant growth. These were found in the northeast along the Delaware River, in suburban Philadelphia, and in east-central Pennsylvania. Moreover, the groups of counties selected for analysis on the basis of their noteworthy growth or decline in numbers of inhabitants, proved to be less than homogeneous as some of them related in unexpected ways to a series of demographic, residential, social, and economic characteristics. Indeed, a third group, counties that reported mortality in excess of fertility, associated with the range of social-economic and age variables in a manner more consistent with places in population decline. Further, all but one of this group were located together—in the anthracite area or nearby.

Finally, comparing this work with an earlier study, population change in the Commonwealth from 1960-1970 (Schnell 1974), is interesting for both its similarities as well as its differences. In the earlier study, rates of change among the leading counties ranged from about 21 to 35 percent, for example, much lower than for that group in this study. The statewide pattern of change in the 1960s also favored the southeast in terms of large gains, but the west was not so homogeneously in decline. In the earlier study, only Pike, with its aged population and almost equal rates of birth and death, varied from the growth model of youthful populations moving to areas where broadly based opportunities were expanding. This study features Pike (which, despite great relative growth since 1970, continues to differ from most counties) along with two of its neighbors that are quite similar in a variety of characteristics. Perhaps a major difference between the two studies is the absence of mortality exceeding fertility at the county level during the 1960 decade. This is not a mystery when one is reminded that the baby boom continued until the mid-sixties and that much has happened since then concerning the aging of the population, women's roles, and marriage and the family—fit subjects for future study.

ENDNOTES

1. Were one to use 1980 MSA boundaries, the collective gain of 49,484 inhabitants made between 1980 and 1990 would disappear, given that it is a small fraction of the more than 350,000 inhabitants added to Pennsylvania's metropolitan population by several additions to MSAs. The changes included the addition of Lebanon County to the Harrisburg MSA, Fayette to Pittsburgh, and Columbia and Wyoming to Scranton-Wilkes Barre. (Data are from the Pennsylvania State Data Center 1991 and the additions to MSAs are from an Office of Management and Budget release 1991.)
2. This discussion includes only the Pennsylvania sections of the state's MSAs, omitting four New Jersey counties from the totals reported in the 1980 and 1990 Censuses.
3. In specific terms, Pennsylvania gained just 17,748 persons from 1980-1990, the total increasing less than 0.2 percent from 11,863,895 to 11,881,643. In absolute terms, three counties stand alone in growth—Bucks with an increase of just under 62,000 (growing to more than 541,000 in 1990), Lancaster's more than 60,000 (to 422,822), and Chester's nearly 60,000 (to 376,396). At the other end of the growth range, Allegheny County lost more than 113 thousand (falling to 1,336,449 in 1990) and Philadelphia declined by more than 102 thousand (to 1,585,577). As in 1980, only Philadelphia and Allegheny exceeded one million inhabitants, and Bucks (with 541,174) joined Montgomery (678,111) and Delaware (547,651) as the only other counties in the Commonwealth with populations of more than a half-million. Otherwise Lancaster grew to exceed 400,000 and just five others had as many as 300,000—Berks, Chester, Luzerne, Westmoreland, and York. Thus, little changed among the most populous counties as all 11 remained atop the list in 1990.
4. Carbon County is part of the Allentown-Bethlehem MSA and, as such, could very well enjoy a reputation which no longer associated this county so strongly, or exclusively, with the anthracite area. In addition to its relationship with a growing MSA, Carbon County is located adjacent to the Pocono Plateau, a popular resort and retirement area in the Northeast. Indeed, on the matter of population change, ten of the eleven municipalities with significant relative gains were in the eastern and southern parts of Carbon County, the greatest gainers located adjacent to Monroe County, quite close to such popular resorts as Mt. Pocono. By contrast, the municipalities which lost population are located in the west and on or near the anthracite fields.

TABLE 6. Population Change, 1980-1990, and Selected Demographic, Social, Residential, and Economic Characteristics, 1980, for Groups of Selected Counties

	Weighted Means*				
	Counties in Highest Growth Group**	Counties in Lowest Growth Group**		Counties in which Deaths Exceeded Births	All Counties
		All Eight	Without Allegheny		
% Population Change	17.6	-8.2	-9.1	-3.5	0.2
Median Age (years)	30.4	33.1	32.3	35.8	32.1
% High School Graduates	69.2	66.7	62.2	60.4	64.7
% Rural Population	43.7	19.1	47.4	33.0	30.7
% Rural Farm Population	3.0	0.3	0.9	0.8	1.3
Median Family Income, $ (000)	22.5	20.7	19.1	16.9	20.0
% Families Below Poverty Level	5.5	7.4	8.8	7.4	7.8
% Families with Income ≥$50,000	6.3	5.1	3.1	2.2	4.6
% Unemployed	5.2	8.1	9.8	8.6	7.4

Source: Computed by author with data from Tables 2, 3, 4, and 5.
*The means were weighted by each county's population in 1990.
**For the members of each of these groups, see Table 1 and Table 4.

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RESEARCH NOTE

PISCIVORY BY THE CENTRAL STONEROLLER *CAMPOSTOMA ANOMALUM*[1]

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ABSTRACT

The central stoneroller (*Campostoma anomalum*) is thought to be herbivorous based on certain morphological characteristics and studies on its food habits. We report the first observation of piscivory in the species. Central stonerollers ate American shad (*Alosa sapidissima*) larvae under both field and laboratory conditions. These observations suggest that under certain conditions, the central stoneroller feeds opportunistically.
[J PA Acad Sci 66(2):90-91, 1992]

OBSERVATIONS

The central stoneroller (*Campostoma anomalum*) occurs in riffle habitats of lotic environments throughout much of the central and eastern United States (Burr, 1980). The species has a cartilaginous pad on the lower jaw and a unique elongate intestine that coils around the gas bladder (Kraatz, 1924), both of which are adaptations for herbivores (Burkhead, 1980). The central stoneroller feeds primarily on detritus, algae, zooplankton, and chironomids (Kraatz, 1923; McKee and Parker, 1982; Matthews *et al.*, 1987; McNeely, 1987), although Burkhead (1980) observed opportunistic feeding on earthworms and fish food by this species in aquaria. Food items are highly macerated in the intestine (Burkhead, 1980; Fowler and Taber, 1985).

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On 11 July 1989 we collected a 32 mm (TL) central stoneroller that had three larval American shad (*Alosa sapidissima*) in its stomach. The specimen was taken as part of an ongoing evaluation of fish predation on recently released American shad larvae in the Susquehanna River basin (Johnson and Dropkin, in press). The stoneroller was collected with a 7.6 x 1.2 m (4.8 mm mesh) seine at Montgomery Ferry (Perry County, Pennsylvania) on the Susquehanna River. About 45 minutes prior to collection, 1.5 million American shad larvae (8-16 mm) had been released at the site. To our knowledge, this is the first report of piscivory by this species.

For further examination of piscivory by the central stoneroller, we collected three individuals with a seine from Pine Creek (Tioga County, Pennsylvania) in the upper Susquehanna watershed. These fishes acclimated for 24 hours in two 20 l aquaria prior to feeding trials. The two fishes in one of the aquaria died from probable, though unobserved, aggressive interactions. One fish died overnight while the other stoneroller died from severe wounds about 8 hours later. Their wounds were indicative of an attack by another fish. After 24 hours the third stoneroller in the second aquarium actively fed on live American shad larvae. Nine attacks on shad were observed, six of which were successful.

Neither the field nor laboratory conditions under which we observed piscivory by the central stoneroller can be considered normal. While stonerollers are undoubtedly exposed to a variety of larval fishes in the wild, including American shad, densities of larvae at the stocking site were probably abnormally high. Furthermore, in the laboratory, no escape cover was provided nor was alternative food offered when larval shad were introduced into the aquaria after 24 hours. These observations support the view of Burkhead (1980) that, under certain conditions, the central stoneroller feeds opportunistically.

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RESEARCH NOTE

REDISCOVERY OF THE MUD SALAMANDER (*PSEUDOTRITON MONTANUS*, AMPHIBIA, PLETHODONTIDAE) IN PENNSYLVANIA, WITH RESTRICTION OF THE TYPE-LOCALITY[1]

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ABSTRACT

Collections of the Eastern Mud Salamander (*Pseudotriton m. montanus*) from Pennsylvania, the first since the species was described by Baird (1849), are reported. The type-locality of the species is restricted to the new site, in Caledonia State Park, Franklin County, which is the only precisely known locality for the species in Pennsylvania. [J PA Acad Sci 66(2):92-93, 1992]

INTRODUCTION

The Mud Salamander (*Pseudotriton montanus*) was described by Spencer Fullerton Baird (1849) from specimens collected during his residence (1836-1850) in Carlisle, Pennsylvania. The type-specimens are extant in the Smithsonian (United States National Museum 3839, *fide* Cochran, 1961; S. Gotte, pers. comm.). The species ranges from southern New Jersey to Louisiana in the Coastal Plain and Piedmont, and southern Ohio to western Kentucky west of the Appalachians. *Pseudotriton montanus* is similar in size and proportions to the frequently sympatric Red Salamander (*P. ruber*), but the distinguishing characters of pattern and iris color were thoroughly reviewed by Bishop (1943) and Mittleman and Gier (1948). The validity of the species is not in question.

Since 1849 the syntypes have been the only specimens of *P. montanus* collected in Pennsylvania. The type-locality given by Baird (1849) was "South Mountain, near Carlisle, Pennsylvania." It was not customary in the middle of the 19th Century to provide precise type-localities in species descriptions, if indeed precise collection site data existed. Generations of herpetologists have searched likely habitats on South Mountain for specimens of *P. montanus*, without success. Conant (1957) noted the exclusively Coastal Plain distribution of the species in the northern part of its range. He concluded that the species "may now have disappeared" from the type-locality near Carlisle. The most recent field guide to North American amphibians and reptiles (Conant and Collins, 1991) concludes that the type-locality is "an old isolated record" and that the species is "now probably extinct there."

RESULTS

In 1988 I received photographs of a specimen of *P. montanus* reported to have been collected in 1979 in Caledonia State Park, Franklin County, Pennsylvania. Unfortunately the specimen was not preserved, so the record could not be verified. In 1988 and 1989 field crews from Carnegie Museum of Natural History, working on a survey of the rare and endangered amphibians and reptiles of Pennsylvania, spent more than 30 man/days in unsuccessful searching for *P. montanus* in Caledonia State Park.

In June 1991, the collector of the 1979 specimen gave me another specimen of *P. montanus* which he had collected in Caledonia State Park, near the site of the 1979 collection. Given the precise locality data provided by the collector, a second specimen was found in August 1991, confirming the presence of a population of *P. montanus* in Caledonia State Park. These two specimens are preserved in Carnegie Museum of Natural History (CM). The voucher specimens are CM 122412 (adult female; snout-vent length 79.8 mm; total length 145 mm), and CM 122413 (transforming, sex not determined; snout-vent length 44.3 mm; total length 77 mm).

DISCUSSION

South Mountain, which is the northernmost extension of the Blue Ridge, is bounded on the west by the Great (= Shenandoah, in Virginia) Valley and on the east by the Piedmont. Drainage to the east and north is by streams tributary to the Susquehanna River. The western and southwestern slopes are drained by Conococheague and Antietam creeks, tributaries of the Potomac River. Most of South Mountain is wooded upland, which would not provide suitable habitat for *P. montanus*. Moreover, in upland habitats *P. montanus* may be excluded by competition with *P. ruber* (Dunn, 1926). There is no question that *P. ruber* is by far the most abundant and widespread species of *Pseudotriton* at the South Mountain sites we sampled.

Caledonia State Park is on the southwest side of South Mountain. It lies at the head of the valley of Conococheague Creek, a low-gradient stream that drains most of the southern part of the Great Valley in Pennsylvania and enters the Potomac River near Hagerstown, Maryland. Thus, a potential lowland dispersal corridor from the Coastal Plain for *P. montanus* could be available via the Potomac valley. Several aquatic plant species with primarily Coastal Plain distributions are also found on the southwestern slopes of South Mountain (A. Wilkinson, pers. comm.), and in the northern Shenandoah Valley (Harvill, 1972). Harvill (1972) has pointed out that some of these Coastal Plain disjuncts in the Shenandoah Valley date from interglacial or early post-glacial times. Whatever the time or route of dispersal, the Coastal Plain-Shendandoah Valley disjunction pattern characterizes a significant segment of the biota.

Conant (1957) reported a record of *P. montanus* from Catoctin Mountain, Frederick County, Maryland. Catoctin Mountain is part of the same northward extension of the Blue Ridge as South Mountain, and lies approximately 30 km (airline) south of the Caledonia State Park site. The scenario of westward dispersal via a Potomac Valley corridor could also explain the apparently isolated occurrence of *P. montanus* in the Catoctin Mountain area.

As Caledonia State Park, Franklin County, is the only site in Pennsylvania where *Pseudotriton montanus* is known to occur, I restrict the type-locality of the species to that site. The precise locality is recorded with the voucher specimens, but will not be published in order to discourage casual collecting or habitat destruction. The Pennsylvania Fish Commission will be requested to place *Pseudotriton montanus* on the official state list of endangered species of amphibians and reptiles.

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Credit for rediscovery of the Mud Salamander on South Mountain belongs to Troy Corman, who collected two of the three recent specimens. For assistance in the field I thank R.W. Van Devender and his students. Anthony Wilkinson, The Nature Conservancy, and Tom Rawinski, Virginia Natural Heritage Program, provided helpful information on plant distributions. Collecting permits were provided by the Pennsylvania Fish Commission and the Bureau of State Parks, Pennsylvania Department of Environmental Resources. Field work was supported by the Pennsylvania Wild Resource Conservation Fund. I thank Clark N. Shiffer and Frank Fehlbaum for assistance in obtaining this support.

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RESEARCH NOTE

BIBLIOGRAPHY OF PENNSYLVANIA HERPETOLOGY: 1987-1991[1]

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ABSTRACT

Scientific literature on Pennsylvania amphibians and reptiles published between 1987 and 1991 is listed and indexed by species.
[J PA Acad Sci 66(2):94-96, 1992]

INTRODUCTION

In "Amphibians and Reptiles in Pennsylvania" (Carnegie Museum of Natural History, Special Publication, No. 6, 1982) a bibliography of Pennsylvania herpetology, including literature published through the end of 1980 and some 1981 references, was published. That bibliography was updated through 1986 in a subsequent publication (McCoy, 1986, Proc. Pennsylvania Acad. Sci. 60:122-124). The literature on Pennsylvania herpetology that has appeared since 1986, through the end of 1991, is here listed and indexed by species.

The style of numbered references and species indices are the same as in the previous publications. Only the scientific literature was scanned for pertinent references. Papers in popular and ephemeral publications, including newspapers and regional society bulletins, are not listed. This compilation includes several references published before 1987 that were inadvertently omitted from the earlier lists.

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COMMENTARY

ABATEMENT CONTRACT SPECIFICATION DOCUMENTS: A DISCUSSION OF ISSUES[1]

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ABSTRACT

This paper discusses some common issues associated with abatement contract specifications. The issues discussed include quantity estimates, description of work, applicable regulatory standards, pre-bid conferences, and information transfer and documentation. Practical solutions are provided as a guide to specification writers.
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INTRODUCTION

Contract specifications and related documents generally describe specific work activities for a contractor, a planner/preparer (i.e. architect, engineer, industrial hygienist, or oversight company), and also set forth the owners' responsibilities and duties. This document is the instrument by which the owner provides to solicit prospective bids to obtain costs for particular construction activities, including abatement. Specifications are similarly used in "other" industries for describing a particular standard of work to be performed (e.g. description of machine standards or tolerance). This paper is limited to one type of activity in the construction industry, Abatement.

The term abatement, in this text, includes activities that involve remediation, removal or *in situ* treatment of asbestos containing materials (ACM), lead-based paint (LBP) or hazardous waste. Examples that are provided will focus on asbestos abatement. Activities involving these substances or materials are regulated by various local, state and federal agencies (Corbitt, 1990; Kending, 1990; Lange, 1991; Lange, et al. 1991; Kaiser, et al. 1992); the regulatory requirements are often incorporated, by reference, into the specifications which are part of the contract documents.

A specification can be organized in a number of formats. The most common format is described by the Construction Specification Institute guide "MASTERFORMAT". This guide provides "boiler plate" language for common construction activities (Construction Specification Institute, 1988). The National Institute of Building Science - NIBS, (1988) publishes a similar document for asbestos abatement (Asbestos Abatement and Management in Buildings: a model guide specification). These guidelines provide information on practical aspects of formulating specification sections.

Traditionally, contract specifications are divided into "up-front" contract documents (contract administration and implementation) and specification(s), also called technical specification(s) (work requirements and administrative/regulatory practices applicable to the actual abatement). The administrative, or up-front material, usually includes a form of advertisement (notice of bid), a form for proposal, a form for agreement, instruction to bidders, and general and special conditions which are commonly referred to as terms and conditions (Dunham and Young, 1975; NIBS, 1988). Collectively, this information contains the contract language for implementation, interpretation and evaluation of the specification and related contract documents.

The specification sections are usually categorized into divisions that contain one or more subsections. The common divisions used are; Division One - General and Administrative requirement and Division Two - Site Work Procedures. A detailed discussion of this format has been previously described (NIBS, 1988).

This paper discusses some of the issues or common problems of a specification(s) and related contract documents. These issues include quantity estimates, description of work, applicable regulatory standards, pre-bid conferences, information transfer and documentation following contract award. The term specification (contract document) in this paper will include "up-front" documents and technical specification sections.

DISCUSSION

Specifications must be prepared as a legal document that will stand challenge even in hindsight. Preparers of these documents often have limited formal training (US Environmental Protection Agency - EPA, 1987) and, in many cases,

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no practical "hands-on" experience preparing abatement documents. This is often observed in specifications that are developed for asbestos abatement projects at public schools. Therefore, specification writers must develop a thorough technical knowledge of the work practices included in the specifications that they prepare (Dunham and Young, 1975). The academic training of specification preparers is diverse, but usually involves one of the professional scientific or engineering disciplines (e.g. industrial hygiene). A common characteristic among many professional specification preparers is a period of practical training with an experienced writer. Brief training courses (e.g. project designer) (EPA, 1987) do not provide the "non-professional" with enough detailed information, or the professional with sufficient practical instruction. Although these training courses provide a good introduction and often provide unique insight, additional academic and practical training (e.g. seminars, refresher courses, etc.) beyond a brief course is necessary for a professional to adequately function in this area. The production of an ill-prepared document can result in abatement delays, expensive litigation and additional costs and responsibilities for a consulting company and the owner (Schaber and Rohwer, 1984; Feitshans, 1991).

Quantity Estimates

Most contract documents set forth an estimated quantity of material to be abated, usually listed, or described, or referenced to, in the "Form for Proposal". This quantity may be represented in square feet, linear feet, weight, cubic feet or yards, or other units of measure. The quantity is usually obtained from direct measurement, previous reports or abstracted from drawings. When stating a quantity of measurement in a specification, a value of error will exist, as with any measurement, called the "confidence interval". Construction specification documents have generally established ranges for quantity error values. The commonly published values (confidence interval) range from 5 to 25 percent (Merritt, 1976; US Army Corps of Engineers, 1988).

The quantity confidence interval or range can be considered from two perspectives, between or within the value. First, the range can be between plus or minus the percent value stated. For example, if the contractor bid on removal of 1,000 linear feet (ln. ft.) of a 4 inch diameter pipe having asbestos containing insulation and the quantity confidence interval is ten percent, the required removal quantity is between 900 and 1,000 linear feet. Second, the value could be within the range stated. Using the previous example, of a 1,000 ln. ft., a confidence interval value of ten percent would result in a quantity range of 950 to 1,050 linear feet. Any quantity below either of the ranges would require renegotiation of the contact cost, while values above would necessitate negotiation on the remaining quantity.

Most specifications require the contractor to provide unit costs for additional work, over and above the quantity listed. The contract document must clearly state which scenario (between or within) will be used to interpret quantity differences, and the method for adjusting the original amount. In some cases the quantity will be provided and the contractor will be paid on a unit price basis for quantities in the described range. Other methods for establishing costs for work performed, primarily applicable to the building construction industry, are described in Dunham and Young, (1975). Additions or deductions outside the range, as prevously discussed, would require renegotiation with the owner or its representative (Merrit, 1976; West Virginia Department of Highways, 1986; Pennsylvania Department of Environmental Resources, 1990). Specifications commonly suffer from two problems relating to quantity estimates. First, the specification quantity is different than the actual quantity because the physical measurement is inaccurate and/or additional material is identified during the abatement project. Second, quantity confidence intervals are not set forth in the specification, rather, the word approximate or estimate is used in association with listed quantity values. The word approximate is defined by the Random House dictionary as "being nearly as specified." This definition does not provide a clear insight as to the confidence interval that is being used. However, this definition infers a lower confidence value (five percent or less). The terms "approximate" and/or "estimate" must be clearly defined in the terms/definition section of the specification document (Association of Soil and Foundation Engineers', 1978). Without an adequate definition, it is reasonable to conclude that the contractor is only responsible for a lower bound value of the quantity.

Specification prepares can use various mechanisms to avoid these problems. Preparers can either require the contractor to bid on unit prices or use a lump sum bid contract with the contractor responsible for abatement/remediation in the areas/locations specified.

When the specification requires the contractor to bid on unit prices, with a stated quantity, the owner is not provided a not to exceed cost estimate. A cost estimate for unit prices will only be as accurate as the quantity estimate. Lump sum contracts can stipulate that the contractor be the responsible party for the quantity estimate, in general, and these contracts provide specification preparers with the most protection from erroneous estimates, except in the case of fraud. However, this practice alone does not provide the owner with an effective bidding tool. Rather, contractors will provide estimates to protect themselves from inaccuracies in their quantity estimate or substantially under bid the project and attempt to claim exorbitant change orders after the contract is awarded and the project is underway.

A combination lump sum bid and unit price contract can be used to provide a workable format that is equitable for both the bidder (contractor) and owner, and provide legal protection for a specification preparer. The form of proposal-price schedule can be modified to require a lump sum cost, but provide a removal quantity (Housing Authority of the County of Lawrence, 1991). This is accomplished by the specification representing "accurate and honest" measurements of the quantities, providing a "brief" description of the work location, and requesting unit price bids that will be totalled resulting in a lump sum base bid (Table 1). The contractor is required to verify the specification quantity estimates, and modify the estimates, if necessary, to provide unit prices that are totalled for a lump sum bid (not to exceed cost). A clear description of this bidding process and cost schedule must be incorporated into the general conditions (Form for Proposal) and price schedule (Table 1).

TABLE 1. Quantity and cost for abatement.#

Item Number	Description	Estimated Quantity*	Unit	Unit Bid Price	Total Bid Price
01000	General Requirements	1	Lump Sum	$______	$______
02081	Floor Tile and Mastic	2,000 ______	Sq. Ft.^	$______	$
	Thermal Pipe Insulation	1,000 ______	Ln. Ft.^	$______	$______
Total Base Bid +					$______

\# Failure to complete or clearly mark any blank space or line shall invalidate this bid. Alteration of the bid form other than filling in blank spaces shall invalidate the bid. A description of the work location, requirements and practices can be found in the specification. Regardless of the quantity listed, abatement shall include all work indicated or mentioned in the specification. Listed quantities are based and abstracted from the work to be performed.

* The contractor is responsible for verifying and, if necessary, determining quantities. The contractor may adjust the quantities in the blank space provided (below the listed quantity), however the award cost is based on the total base bid. If no adjustment is necessary, place a N/A in the blank space/line for changing the quantity.

^ Ln. Ft. - linear feet; Sq. Ft. - square feet.

\+ Represents a lump sum bid (a not to exceed cost) calculated from the total bid prices.

Description of Work

A description of the work to be performed and general location(s) must be provided. Failure to adequately provide this information may result in a request by the contractor for a change order. Descriptive information provided should include location(s) in the building or site, items or materials to be abated (e.g. asbestos containing floor tile and mastic), its general physical condition, content of the hazardous material (e.g. 2.5 mg/squared centimeter for lead-based paint) and the location(s) of abatement or activity (e.g. room 113 in building J). Consistency throughout the document is necessary. Conflicting, unspecific or ambiguous statements should be carefully avoided. Clear and concise work requirements will eliminate confusion and provide direction to the contractor.

Regulatory Requirements

Many specifications provide a statement that the contractor "shall comply with all applicable local, state and federal regulations." However, this language provides no insight to the type of regulations that are applicable as related to the work practices or abatement strategy. Considerable complexities, design changes and additional costs may be incurred by the owner for regulatory compliance by the contractor. This is most evident when the lesser known regulations are applied (e.g. local sanitary requirements for asbestos abatement). A list of applicable regulations in the specification provide the contractor with sufficient information for compliance criteria necessary for a bid estimate. A list is shown in Table 2 of regulations applicable to the state of Pennsylvania for asbestos abatement and hazardous waste operations.

TABLE 2. Regulatory requirements for asbestos abatement and hazardous waste operations in the state of Pennsylvania.

1. Occupational Safety and Health Administration (OSHA) Standards: Title 29 Code of Federal Regulations (CFR), 1910 - General Industry; 1926 - Construction Industry; including but not limited to: 1910.120 - Hazardous Waste Operations and Emergency Response; 1910.1000 - Air Contaminants; 1910.1001 - Asbestos, Tremolite, Anthophyllite, and Actinolite; 1910.1200 - Hazard Communication; 1910.134 - Respiratory Protection; 1926.58 - Asbestos, Tremolite, Anthophyllite, and Actinolite; as amended.
2. US Environmental Protection Agency (EPA) Standards: Title 40 CFR 61, subparts A and M - National Emission Standards for Hazardous Air Pollutants; as amended.
3. EPA Standards: Title 40 CFR 763, subpart E - Regulations on Asbestos Containing Materials, including appendices A, B, C, and D; subpart F - Regulations Identifying Friable Asbestos Containing Materials; subpart G - Regulations for Asbestos Abatement Projects; as amended.
4. US Department of Transportation (DOT) Standards: 49 CFR, subchapter C - hazardous Materials Regulations, sections 171 to 177, inclusive; as amended.
5. Clean Water Act. 33 U.S.C. §§ 1251 et. seq.; as amended.
6. Clean Air Act. 42 U.S.C. §§ 7401 et. seq.; as amended.
7. Toxic Substance and Control Act. 15 U.S.C. §§2601 et. seq.; as amended.
8. Resource Conservation and Recovery Act. 42 U.S.C. §§ 6901 et. seq.; as amended.
9. Comprehensive Environmental Response, Compensation and Liability Act. 42 U.S.C. §§ 9601 et. seq.; as amended.
10. Emergency Planning and Community Right to Know Act of 1986. 42 U.S.C. §§ 11001 et. seq.; as amended.
11. Environmental Quality Improvement Act of 1970. 42 U.S.C. §§ 4371 et. seq.; as amended.
12. Federal Water Pollution Control Act. 33 U.S.C. §§ 1251 et al.; as amended.
13. Noise Control Act of 1972. 42 U.S.C. §§ 4901 et. seq.; as amended.
14. Soil and Water Conservation Act of 1977. 16 U.S.C. §§ 1801 et. seq.; as amended.
15. Solid Waste Disposal Act. 16 U.S.C. §§ 2001 et. seq.; as amended.
16. Pennsylvania Code Title 25. Environmental Resources, subpart A. Preliminary Provisions, Article I. Statement of Policy, Chapter 16, Water Quality Toxics Management; including subchapters A and B; as amended.
17. Pennsylvania Code Title 25. Environmental Resources, subpart C. Protection of Natural Resources, Article I. Land Resources, Chapter 75. Solid Waste Management; including subchapters A, B and C; as amended.
18. Pennsylvania Code Title 25. Environmental Resources, subpart C. Protection of Natural Resources, Article I. Land Resources, Chapter 82. Conservation of Pennsylvania Native Wild Plants, subchapters A through G, inclusive; as amended.
19. Pennsylvania Code Title 25. Environmental Resources, subpart C.

Protection of Natural Resources, Article II. Water Resources, Chapter 91 General Provisions; as amended.

20. Pennsylvania Code Title 25. Environmental Resources, subpart C. Protection of Natural Resources, Article II. Water Resources, Chapter 92. National Pollutant Discharge Elimination System; as amended.
21. Pennsylvania Code Title 25. Environmental Resources, subpart C. Protection of Natural Resources, Article II. Water Resources, Chapter 93. Water Quality Standard; as amended.
22. Pennsylvania Code Title 25. Environmental Resources, subpart C. Protection of Natural Resources, Article II. Water Resources, Chapter 94. Municipal Wasteload Management, section 32. Public Health Hazard or Pollution; as amended.
23. Pennsylvania Code Title 25. Environmental Resources, subpart C. Protection of Natural Resources, Article II. Water Resources, Chapter 95. Waste Water Treatment Requirements; as amended.
24. Pennsylvania Code Title 25. Environmental Resources, subpart C. Protection of Natural Resources, Article II. Water Resources, Chapter 97. Industrial Wastes, all sections; as amended.
25. Pennsylvania Code Title 25. Environmental Resources, subpart C. Protection of Natural Resources, Article II. Water Resources, Chapter 101. Special Waste Water Pollution Regulations; as amended.
26. Pennsylvania Code Title 25. Environmental Resources, subpart C. Protection of Natural Resources, Article II. Water Resources, Chapter 102. Erosion Control; as amended.
27. Pennsylvania Code Title 25. Environmental Resources, subpart C. Protection of Natural Resources, Article III. Air Resources, Chapter 121. General Provisions; as amended.
28. Pennsylvania Code Title 25. Environmental Resources, subpart C. Protection of Natural Resources, Article III. Air Resources, Chapter 123. Standards for Contaminants, all sections; as amended.
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31. Pennsylvania Code Title 25. Environmental Resources, subpart C. Protection of Natural Resources, Article III. Air Resources, Chapter 137. Air Pollution Episodes; as amended.
32. Pennsylvania Code Title 25. Environmental Resources, subpart C. Protection of Natural Resources, Article III. Air Resources, Chapter 139. Sampling and Testing; as amended.
33. Pennsylvania Code Title 25. Environmental Resources, subpart D. Environmental Health and Safety, Article V. Radiological Health, Chapter 215. General Provisions; as amended.
34. Pennsylvania Code Title 25. Environmental Resources, subpart D. Environmental Health and Safety, Article V. Radiological Health, Chapter 217. Licensing of Radioactive Material; as amended.
35. Pennsylvania Code Title 25. Environmental Resources, subpart D. Environmental Health and Safety, Article VII. Hazardous Waste Management, Chapter 260. Definitions and Requests for Determination; as amended.
36. Pennsylvania Code Title 25. Environmental Resources, subpart D. Environmental Health and Safety, Article VII. Hazardous Waste Management, Chapter 261. Criteria, Identification and Listing of Hazardous Waste, subchapters A through E, inclusive; as amended.
37. Pennsylvania Code Title 25. Environmental Resources, subpart D. Environmental Health and Safety, Article VII. Hazardous Waste Management, Chapter 262. Generators of Hazardous Waste, subchapters A through F, inclusive; as amended.
38. Pennsylvania Code Title 25. Environmental Resources, subpart D. Environmental Health and Safety, Article VII. Hazardous Waste Management, Chapter 263. Transporters of Hazardous Waste, subchapters A through E, inclusive; as amended.
39. Pennsylvania Code Title 25. Environmental Resources, subpart D. Environmental Health and Safety, Article VII. Hazardous Waste Management, Chapter 264. New and Existing Hazardous Waste Management Facilities Applying for a Permit, subchapters A through O, inclusive; as amended.
40. Pennsylvania Code Title 25. Environmental Resources, subpart D. Environmental Health and Safety, Article VII. Hazardous Waste Management, Chapter 265. Interim Status Standards for Hazardous Waste Management Facilities and Permit Program for New and Existing Hazardous Waste Management Facilities, subchapters A through R, inclusive; as amended.
41. Pennsylvania Code Title 25. Environmental Resources, subpart D. Environmental Health and Safety, Article VII. Hazardous Waste Management, Chapter 267. Financial Responsibility Requirements for Hazardous Waste Storage, Treatment and Disposal Facilities, subchapters A through D, inclusive; as amended.
42. Pennsylvania Code Title 25. Environmental Resources, subpart D. Environmental Health and Safety, Article VII. Hazardous Waste Management, Chapter 269. Siting, subchapters A through C, inclusive; as amended.
43. Pennsylvania Code Title 25. Environmental Resources, subpart D. Environmental Health and Safety, Article VII. Hazardous Waste Management, Chapter 270. Permit Program, all subsection; as amended.
44. Pennsylvania Code Title 34. Labor and Industry, Part 1. Industrial Board, Chapter 6. Construction and Repairs, all sections; as amended.
45. Pennsylvania Code Title 34. Labor and Industry, Part 1. Industrial Board, Chapter 21. Ladders, all sections; as amended.
46. Pennsylvania Code Title 34. Labor and Industry, Part 1. Industrial Board, Chapter 25. Lifting and Carrying Apparatus, all sections; as amended.
47. Pennsylvania Code Title 34. Labor and Industry, Part 1. Industrial Board, Chapter 27. Lighting, all sections; as amended.
48. Pennsylvania Code Title 34. Labor and Industry, Part 1. Industrial Board, Chapter 39. Safety Standards, all sections; as amended.
49. Pennsylvania Code Title 34. Labor and Industry, Part 1. Industrial Board, Chapter 41. Sanitation, all sections; as amended.
50. Pennsylvania Code Title 34. Labor and Industry, Part XIII. Worker and Community Right to Know, Chapter 301. Jurisdiction, Definitions, Exemptions and Administration Matters, all sections; as amended.
51. Pennsylvania Code Title 34. Labor and Industry, Part XIII. Worker and Community Right to Know, Chapter 303. Preparation of Hazardous Substances and Environmental Hazard Survey Forms, all sections; as amended.
52. Pennsylvania Code Title 34. Labor and Industry, Part XIII. Worker and Community Right to Know, Chapter 305. Maintenance and Disclosure of Survey Forms and Lists, all sections; as amended.
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58. Pennsylvania Code Title 34. Labor and Industry, Part XIII. Worker and Community Right to Know, Chapter 323. Hazardous Substance List, all sections; as amended.
59. Pennsylvania Department of Labor and Industry: Asbestos Occupations Accreditation and Certification Act - No. 1990-194, as amended.
60. Pennsylvania, Commonwealth of. Clean Streams Law (P.L. 1987) Act 394; (35 P.S. 691.1 *et seq.*) as amended.
61. Pennsylvania, Commonwealth of. Solid Waste Management Act (P.L. 380, nos. 97); as amended.
62. Pennsylvania, Commonwealth of. Air Pollution Control Act, (P.L. 2119, nos. 787); as amended; including the Pennsylvania Clean Air Act, Senate bill 1650, Printer's No. 2435; as amended.

63. Pennsylvania, Commonwealth of. Hazardous Sites Cleanup Act (Act 1988-108) House Bill 1852; as amended.
64. Pennsylvania, Commonwealth of. Soil Conservation Law (P.L. 228, No. 74) (3 P.S. 255-1 et. seq.), as amended.
65. Pennsylvania, Commonwealth of. Wild Resource Conservation Act (P.L. 597, No. 170) (32 P.S. 5301 et. seq.), as amended.
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69. Allegheny County Health Department, Bureau of Air Pollution Control: Asbestos Abatement, Article XX, as amended.
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Pre-Bid Conferences

Contract documents/specification(s) are commonly not available to prospective abatement contractors until the time of the pre-bid conference. The contract documents should be available before the pre-bid conference to allow contractors to review the information and formulate questions. Discussions, questions, interpretation, and clarification of the specification are the primary reasons for the pre-bid conference, beside allowing contractors to examine the site (US Department of Housing and Urban Development - HUD, 1983).

A major problem during projects is misinterpretation of the specification relating to discussions held during the pre-bid conference. A method to avoid this controversy and later parole evidence issues (Schaber and Rohwer, 1984) is clear and careful record keeping of the pre-bid (also called pre-construction) conference. This is best accomplished by circulating pre-bid conference meeting minutes. These minutes must include the names of the contractors present, questions and answers, changes in the scope of work, and a clear description of any noted errors in the specification. Any additional relevant information affecting the bid estimate of quantity of the project should be included (HUD, 1983). The pre-bid meeting minutes are usually faxed, mailed (registered/certified) or required to be picked up at the office of the owner's representative or the owner.

Failure to provide adequate pre-bid meeting minutes may result in successful legal challenges over interpretation of the specification (Schaber and Rohwer, 1984). In addition to questions raised during the pre-bid meeting that are incorporated into minutes; any additions, changes or clarifications etc. added subsequent to the release of the specification and drawings, but before the bid date are incorporated into the bid document by addenda(um). All prospective contractors must receive a copy of each addenda, which may include meeting minutes, in sufficient time to review and modify their bid accordingly. The suggested length of time contractors should be provided for the bidding process, submittal of questions, and time to prepare their bid after receipt of all contract documents is shown in Table 3. To apply a firm legal status to pre-bid documents, they should be referenced in the specification and incorporated as part of the contract documents.

TABLE 3. Length of time for bidding projects under various conditions as related to the engineers' project cost estimate. +*#

Project Cost a	Total Bid Time b, c	Time allowed for submittal of questions	Time allowed by contractor to forward a bid after receipt of final documents
$25K or less	9 days	3 days	4 days
$25K to $50 K	10 days	3 days	5 days
$50K to $100K	12 days	4 days	5 days
$100K to $200K	17 days	6 days	8 days
$200K to $500K	21 days	7 days	10 days
$500K to $1M	25 days	8 days	12 days
$1M to $5M	30 days	10 days	15 days
$5M	43 days	15 days	20 days

\+ business day.

* additional time may be necessary if the bid process becomes complicated or requires on-site treatment of hazardous materials.

\# Pennsylvania state law may require public bids to be advertised three times, at least once a week for three consecutive weeks, which may require a total bid time of not less than 21 calender days for advertising, not including other necessary time (e.g. submittal).

a represents total estimated cost of the project.

b total bid time includes: time that the specification is available for review before the pre-bid meeting, time for submittal, and time after receipt of final and complete documents.

c total days include the day the specifications are available and the day bids are due.

Information Transfer and Documentation Following Contract Award

During abatement projects, as in other construction projects, a considerable volume of documents are generated and accumulated by the contractor, oversight company and owner. Most information is transmitted verbally from one party to another party which is commonly not documented or recorded. Depending on the size and complexity of the project the information transfer can be voluminous and often complicates the information flow and leads to confusion and inaccurate communication. Methods of handling the paperwork communication trail must be formulated for accurate and effective maintenance of documents.

One method of dealing with the issue and avoiding miscommunication, while providing all parties with accurate documentation, is weekly or biweekly project coordination meetings. During these project coordination meetings or project abatement conferences, an agenda should be agreed to, and information such as daily log sheets, or other pertinent information be exchanged. Meeting minutes should be discussed and reviewed by the respective parties and acknowledged by all participants in the meeting prior to adjournment. The meeting minutes may then be used as the opening agenda for the following meeting to resolve problems and ascertain progress on the job. Issuance and distribution of, or transfer of, related documents should also be noted in the meeting minutes. Important issues raised in the daily logs should be discussed and clarified. A timely information transfer program will provide adequate communication to all parties and raise important issues for discussion and ultimately a resolution of any problem encountered.

SUMMARY

This discussion raises important issues that can often create problems which may lead to a deteriorating scenario of construction abatement delays, additional costs and expensive litigation. Various methods to avoid and some recommendations as to prevention of the many problems are discussed. Not all possible scenarios have been presented, but general guidance is provided. This paper should assist specification preparers in avoiding some common pitfalls when preparing abatement documents and hopefully recognize and eliminate costly delays.

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