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OVENBIRD NEST SITE SELECTION WITHIN A LARGE CONTIGUOUS FOREST IN EASTERN PENNSYLVANIA: MICROHABITAT CHARACTERISTICS AND NESTING DENSITY[1]

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ABSTRACT

Since 1982, Ovenbird breeding populations have been monitored on two forest plots within a contiguous forest of greater than 10,000 ha at Hawk Mountain Sanctuary in southeastern Pennsylvania. On these two plots, Owl's Head and River of Rocks, the number of Ovenbird territories remained stable and increased between 1982 and 2001, respectively, with an increase of greater than 20% between 1991 and 1999. On a third plot where surveys began later, the numbers of territories declined from 7.9 per 10-ha to 1.2 per 10-ha between 1991 and 1999 (Goodrich, unpubl. data). In this study, we evaluate if Ovenbirds select sites with certain vegetation and microhabitat characteristics for their nest sites and if that may explain nest selection and the differences in territory density found within this eastern Pennsylvania contiguous forest. We examined the microhabitat and vegetative characteristics of 11 Ovenbird nests from the two long-term study plots, Owl's Head and River of Rocks, together with 11 nearby random points within these plots (random-linked), and 12 random points within the the less dense Visitor Center plot. We compared habitat variables using multiple ANOVA's and least square means test. Significant variables were placed in a model to predict nest occurrence and the best predictive model comparing Visitor Center to nest sites and random-linked to nest sites was selected using AIC values. Nest site areas had a significantly greater percentage of vegetation cover, number of plant stems, and number of plant species than did either the random-linked or Visitor Center plots. The best models to predict nest occurrence included percent vegetation cover within higher density areas (i.e., Owls Head and River of Rock's plots) and number of stems when comparing nests to lower density sites on the Visitor Center plot. Litter depth also was an important predictor of nest occurrence within nesting areas with nest sites. Our results suggest that microhabitat and vegetation characteristics can vary significantly within a contiguous forest and these differences influence Ovenbird nesting densities. Microhabitat differences within the Visitor Center site (e.g. percent cover, number of species) may be mediated in part by higher frequency of white-tailed deer, greater abundance of invasive species, or other factors associated with its location near a forest opening. Disturbance factors that limit ground cover vegetation extent and diversity may limit the distribution of this forest-interior nesting species even within large forest blocks.
[J PA Acad Sci 83(1): 3–9, 2009]

INTRODUCTION

Ovenbirds (*Seiurus aurocapillus*) are neotropical migrant passerines that nest on the ground in small, dome-shaped nests in the interior of large forests. Robbins et al. (1989) found the species nesting in small forest fragments ranging from 100–850 ha as well as larger forests. Studies have shown that the breeding success of Ovenbirds is significantly lower in smaller forest fragments (Porneluzi et al. 1993, Robinson et al. 1995, Goodrich et al. *in prep*). Giocomo et al. (*in prep*) found that Ovenbird territory density is significantly lower in forest fragments less than 100 ha in size. Reasons for these differences may vary. In some cases it may result from increased nest predation by species utilizing the forest edge (Zegers et al. 2000). In other regions, the increased level of Brown-headed Cowbird parasitism (*Molothrus ater*) in fragments has been shown to cause forest bird declines (Robinson et al. 1995). Nesting territories in smaller fragments also may have reduced food supplies due to increased light reaching the forest floor (Burke and Nol 1998). Lower nesting densities of Ovenbirds may result if small forest fragments have inadequate habitat and food resources.

Long-term declines in Ovenbirds have been noted in a number of areas across their range, particularly in those areas most seriously affected by habitat fragmentation, such as Southern New England and the Cumberland Plateau (Sauer et al. 2003). Areas that still harbor abundant contiguous forest tracts such as Pennsylvania (Goodrich et al. 2002), are considered key regions for the long-term conservation of this and other forest-interior species.

However, contiguous forest tracts in Eastern North America also may vary in habitat quality and suitability for forest interior birds. Among the threats to birds in large forests in Pennsylvania are over-browsing by burgeoning white-tailed deer (*Odocoileus virginianus*) populations (DeGraaf et al.1991, Horsely et al. 2003), acid rain effects on vegetation health, soil ecology, and invertebrate population dynamics

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(Brotons et al. 1998, Hames et al. 2002), and habitat alteration through colonization by invasive species (Banko et al. 2002, Scheiman et al. 2003).

At Hawk Mountain Sanctuary, Berks County, Pennsylvania, within a greater than 10,000 ha tract of contiguous forest in the central Appalachians, nesting Ovenbirds have been monitored on two study plots, Owl's Head and River of Rocks, since 1982 (Porneluzi et al. 1993, Goodrich et al. 1998). The third plot, Visitor Center, was surveyed annually from 1991 through 1999.

Between 1991 and 1999, Ovenbirds averaged 6.3 ± 1.1 territories/10-ha and 5.4 ± 1.3 territories/10-ha on Owl's Head (OH) and River Rocks (ROR) plots and territory density increased non-significantly by 35% and 25% respectively (OH: $r = 0.23$, $df = 1$, $p = 0.50$; ROR: $r = 0.58$, $df = 1$, $p = 0.11$) (Goodrich et al. 1998, Barber and Goodrich, in prep.). In contrast, on the nearby Visitor Center plot adjacent to a 5 ha opening, the number of territories declined from an average of 7.7 territories/10-ha to only 1.12 territories/10-ha in 1999, a decline of 85% (Pearson correlation, $r = -0.89$, $p = 0.001$, $n = 9$). Nesting success on the Owls Head and River of Rocks plots has remained consistently high in the last 20 years, and significantly higher than nearby forest fragments suggesting that recruitment is not an issue within this forest landscape (Porneluzi et al. 1993, Goodrich et al. *in prep*). Ovenbird territory density has been shown to decline within forest adjacent to a clearcut during the three years after forest cutting (e.g., Wallendorf et al. 2006), however the Visitor Center opening was established in the mid-1970s, so decline in Ovenbird use in response to a new opening should have been detected earlier.

In this paper we examine if Ovenbirds select their nest sites within a contiguous forest based on microhabitat characteristics or if they place them at random, and if microhabitat differences may explain, in part, the significantly reduced densities of Ovenbirds observed in some areas. We investigate this question by quantifying the vegetative structure and other microhabitat characteristics near nest sites on the plots where densities increased, Owls Head and River of Rocks, and comparing them to random points paired with each nest site on the two sites where density increased and also with random points located on the nearby Visitor Center plot where nesting densities have declined.

METHODS

Study Area. The study was conducted at Hawk Mountain Sanctuary (HMS) in Berks County, Pennsylvania (40° 38'N and 75° 59'W). The 972 ha sanctuary is located within a larger >10,000 ha mixed deciduous forest on the Kittatinny Ridge of the central Appalachians in southeastern Pennsylvania. Our first plot, known as Owl's Head, is a 19.4 ha, 490 × 400 m rectangle on a ridge-top 408–448 m in elevation and dominated by oak-maple forest. The canopy is comprised mostly of chestnut oak (*Quercus prinus*) and red maple (*Acer rubrum*), while the understory is made up of black gum (*Nyssa sylvatica*) and sassafras (*Sassafras albidum*). The shrub and ground cover layer is composed of huckleberry (*Gaylussacia baccata*), sheep laurel (*Kalmia angustifolia*), lowbush blueberry (*Vaccinium pallidum*), teaberry (*Gaultheria procumbens*), and highbush blueberry (*Vaccinium angustifolium*). The second plot, River of Rocks, is a 16.9-ha, 430 × 400 m rectangle on an eastward facing rocky slope 265 to 347m in elevation. It is also dominated by chestnut oak and red maple, but red oak (*Quercus rubra*) and sweet birch (*Betula lenta*) make up a larger portion of the canopy than on Owl's Head (Steckel 1998). Black gum and sassafras still dominate the understory, although mountain laurel (*Kalmia latifolia*) is found in dense stands in certain areas on the plot. The shrub layer is largely similar to that found on Owl's Head (Goodrich et al. 1998). The Visitor Center plot is a 5-ha, L-shaped plot (each leg is 300 × 100 m) approximately 396 m in elevation. The vegetation is similar to that on the Owl's Head plot. However, Visitor Center is adjacent to the HMS Visitor Center and much of the plot lies within 100 m of a building, parking lot, or small clearing. This plot was smaller than the other two plots as it was designed to be adjacent to the opening. All three plots lie within 1 km of each other.

Survey and Nest Search Protocol. Beginning in early May 2003, both the Owl's Head and River of Rocks plots were surveyed almost daily as either part of a continuing Breeding Bird Census conducted annually since 1982 (Ralph et al. 1993), or a separate study of long-term Ovenbird nesting biology (e.g., Porneluzi et al. 1993). Surveys were conducted between dawn and 10 am EST on each plot by systematically walking 30 meter grid lines across each study site. During these surveys, all Ovenbirds sighted or heard were marked on plot maps using the spot-mapping technique and sightings of previously color-banded males were mapped along with any associated mate. All color-marked males were followed for 10 or more minutes each to detect behavior by male or female suggesting nesting activity. Any nests located during surveys were flagged so they could be relocated easily. The Visitor Center plot, which had been eliminated from the long-term study in 1999, was surveyed three times in 2003 for Ovenbird use during June and early July. Locations of singing or sighted birds were mapped and tallied following standard Breeding Bird Census instructions to determine the number of territories present on each plot (Ralph et al. 1993).

Vegetation Survey Protocol. Vegetation characteristics were measured at each of the nests in mid to late July 2003, after the nestlings had fledged. Sampling was conducted after fledging to avoid disturbing the nests. As many of the plant species found on the floor in this forest were woody perennials, we assumed that any relative differences among the sites found in July would be representative of differences present in early May when most of the birds return and select nest sites. Canopy cover, canopy species composition, light levels and other forest characteristics were not measured as our purpose was to compare the microhabitat at nest sites to other forest sites within the same forest at a finer scale.

A 1 m square frame was placed around the nests with the nest at the center and the four sides oriented in the cardinal directions. Within this square the litter depth, percent litter cover, percent bare ground, percent vegetation cover less than 1 m in height, and basal area were measured. All plant species within the 1 m plot and less than 1 m tall were identified, the number of stems counted, and the distance of the plot to the nearest tree in each of the cardinal directions measured and the tree species identified.

The percent nest concealment for each nest also was calculated by measuring the nest concealment from five different aspects: from 1 m away, at a height of 1 m, in each cardinal direction and also directly above the nest (Burke and Nol 1998). These five percentages were calculated as a proportion of 20 (i.e., 50% of 20 is 10) and then added together to reach a total percentage of 100. Slope, aspect, and distance to nearest edge for each nest were calculated by mapping GPS locations of the nests in ArcView 9.0, (ESRI 2003).

To compare habitat characteristics of nests to nearby locations within the study plot, vegetation also was measured at 11 random points placed at a randomly-selected angle at a distance of 30 m from each of the nests (hereafter referred to as random-linked sites). In addition, twelve random points were chosen on the Visitor Center plot by numbering the already marked 30 meter grid points for the plot and selecting random numbers to designate 12 randomly-selected grid points. Then, a 1 m plant survey site was placed in the center of the square to the northwest of this randomly selected grid point, to avoid placement along grid lines. For random points, the same vegetation and site characteristics were measured as for the nests with the exception of nest concealment, which was not calculated.

Statistical Analysis. Plots were placed into three separate groups: nest sites (pooling both River of Rocks and Owl's Head nests), random-linked sites 30 m away from nests, and random points in the lower-density plot, Visitor Center.

In order to initially assess the differences in habitat characteristics among the different groups, an ANOVA was conducted on each habitat variable measured. A least square means post-hoc test was conducted to determine which of the three groups differed from each other. The post-hoc test was conducted for both significant and insignificant ANOVA results to assess patterns among the three groups. Any variable showing significant variation among the three groups in the ANOVA or posthoc tests were then evaluated in a set of nine competing logistic regression models to predict nest occurrence in a used area (comparing random-linked points to nest sites) and to predict overall nest occurrence (by comparing Visitor Center points (unused) to nest sites). Only variables showing initial significance were included in models as per Burnham and Anderson (2002). The Akaike's Information Criterion, adjusted for small sample size (AICc), and Akaike weights (Burnham and Anderson 2002), were used to identify the most parsimonious model in each model set. The best model selected from each set was used to estimate probabilities of nest occurrence based on the habitat values.

RESULTS

Breeding Densities and Nest Sites. Territories were not checked on Visitor Center from 2000 to 2002, however in 2003 the density of Ovenbirds remained low in comparison to other study areas, e.g. there were 9.7 territories / 10 ha on the Owl's Head plot, 5.6 territories / 10 ha on the River of Rocks plot, and 2.2 territories / 10 ha on the Visitor Center plot. In 1999 territory density was similarly low on the Visitor Center as compared to the other two sites. Because the pattern of lower density in 2003 was similar to 1999 (1.1 territories/10 ha) we assumed the lower density was not an anomaly.

Eleven nests were located on the Owl's Head and River of Rocks plots (e.g., 72% of 2003 nesting pairs on the plots). Thus, vegetation cover and site characteristics were compared between 11 nests and 11 random-linked sites within the two higher density plots, Owls Head and River of Rocks, and 12 random sites within the lower density plot, Visitor Center.

Habitat Analyses. A total of 22 plant species were recorded in the 1 m^2 plots with 0 to 3 unknown species recorded per plot. The percentage of vegetation cover significantly differed among the three plots (Table 1) ($F = 5.432$, $df = 2$, $p = 0.009$). Percent cover around nests ranged from 10 to 100 percent with an average of 62% per nest (Table 1). Bonferroni post-hoc pair-wise comparisons

Table 1. Microhabitat measurements of Ovenbird nests and random points on Owl's Head, River of Rocks, and Visitor Center plots at Hawk Mountain Sanctuary, 2003 (mean, standard error) (** Denotes value significantly greater than other site values ($p < 0.05$)).

Sites	Distance to Edge (m)	Litter Depth (cm)	% Vegetation Cover**	Number of Stems**	Number of Blueberry (sp.) Stems	Number of Red Maple Stems	Number of Tree Seedlings	Number of Species**
Nests (n = 11)	51.27, 15.35	4.55, 0.47	62.7, 25.3	38.64, 4.88	19.27, 2.08	2.18, 0.60	5.18, 1.17	7.73, 0.78
Random-Linked Points (n = 11)	57.00, 10.65	3.18, 0.42	33.6, 9.7	32.46, 6.49	13.82, 2.80	7.09, 4.55	10.91, 5.06	6.91, 0.56
Random Points–*Visitor Center* (n = 12)	43.25, 10.51	3.54, 0.48	26.7, 26.4	22.5, 2.68	11.92, 2.81	4.00, 1.44	5.50, 1.57	5.58, 0.31

** Denotes significant difference found among the three plots at $p<0.05$ level .

Table 2. AIC Model selection results for comparing nest sites to unused sites in Visitor Center plot ($n = 23$).

MODEL	AICc	DIFF	WEIGHT
Number of stems	29.825	0.000	0.35470*
Percent vegetation	30.228	0.403	0.28997
Number of stems and percent vegetation	31.723	1.898	0.13731
Number of species	32.384	2.559	0.09867
Percent vegetation and litter depth	33.095	3.270	0.06915
Wood	35.931	6.106	0.01675
None	36.441	6.616	0.01298
Litter depth	36.772	6.947	0.01100
Four variables excluding litter depth	37.365	7.540	0.00818
All 5 variables	41.033	11.208	0.00131

*best model predicting nest location

revealed that vegetation cover was significantly higher at nest sites than at the random points in the Visitor Center plot (mean difference = 36.06%, $p = 0.011$, $df = 31$) and cover also was higher at nest sites compared to the random-linked sites (mean difference = 29.09%, $p = 0.057$, $df = 31$). However there was no significant difference between the random-linked and random Visitor Center sites (mean difference = 6.97%, $p = 1.0$). The average number of plant stems per plot varied significantly among the three samples ($r = 0.397$, $F = 2.894$, $p = 0.07$, $df = 34$; Table 1). Stem density at nest sites was higher than at Visitor Center points (Bonferroni pair-wise mean difference = 16.136, $df = 31$, $p = 0.07$), but was not greater than stem density at the random-linked sites (pair-wise mean difference = 6.182, $df = 31$, $p = 0.65$) (Table 1). The random-linked sites had more stems, but there was no significant difference between them and the Visitor Center sites ($p = 0.32$).

The average number of plant species per plot also varied significantly among the three sites ($r = 0.438$, $F = 3.678$, $p = 0.037$, $df = 31$) (Table 1). Post hoc Bonferroni pair-wise comparisons revealed that species diversity was greater at nest sites than at Visitor Center sites (mean difference = 2.144, $df = 31$, $p = 0.031$), but not at the random-linked sites ($p = 0.974$), and there was no significant difference between random-linked and Visitor Center sites ($p = 0.323$).

Litter depth, basal vegetation, and number of blueberry stems (*Vaccinium* sp.) were higher at nest sites compared to random points but the differences were not significant (Table 1). No other measurements exhibited significant differences between any of the sites ($p > 0.1$), including percent litter cover, distance to the nearest edge or trail, percent bare ground, basal area, the abundance of any of the individual species (e.g. red maple, mountain laurel, etc.), distance to nearest tree in the four cardinal directions, slope, and aspect. Bonferroni posthoc pair-wise comparisons were conducted on all insignificant habitat variables although none of the pair wise comparisons were significant ($p > 0.10$).

The average percent nest concealment for the 11 nests was 55% and did not differ between the two plots with nests (t-test, $p = 0.61$). Black gum was the most frequent tree on the three study plots comprising 42% of all trees, followed by chestnut oak with 26%, red maple with 17%, and red oak with 10%. There was no difference in the frequency of these trees among the three plot sites.

Comparison of Variables. The number of stems, number of species, percent vegetation cover, litter depth, and basal area, were included in our set of competing logistic regression models to determine which variable or combination of variables was the best predictor of Ovenbird nest presence. We evaluated litter depth as a predictor of Ovenbird nest sites because it was marginally significant and has been shown to be important in other studies of Ovenbird nest sites (Burke and Nol 1998). Because of the small sample size ($n = 34$ total points sampled), we compared nest sites to the random-linked and Visitor Center points separately.

When comparing nests and Visitor Center sites, the number of stems and percent vegetation cover were both important predictors of nest presence, with Akaike weights of 0.411 and 0.336 respectively (Table 2). Of the two, the number of stems seemed most important. The probability of a nest being present was modeled as Log (odds) = –4.4179 + 0.1500 * (number of stems) ($P < 0.05$) for both the intercept and the number of stems, (standard error of intercept = 2.1528, standard error of number of stems = 0.0738). According to this model, the probability of an Ovenbird nest being present on a plot with <15 stems was <11% (Figure 1). But the probability of a nest being present on a plot with >38 stems was >80%. The percent vegetation cover model was also useful in modeling nest presence with the equation: Log (odds) = –2.2266 + 0.4862*(percent vegetation cover) ($P < 0.05$ for both intercept and the percent cover, standard error of intercept = 0.9990, Standard error of % vegetation = 0.1948) (Figure 2).

For nest plots versus random-linked plots Akaike weights suggested that percent vegetation cover and litter depth were the two most important variables (0.3445 and 0.2417 Akaike weights respectively, Table 3). The best predictor model included only percent vegetation cover: Log (odds) = –1.7205 + 0.3588 *(percent vegetation) ($P < 0.08$ for the intercept and $P < 0.04$ for the percent vegetation; Standard error of intercept = 0.9554, standard error of percent vegetation = 0.1727). Using this equation, the probability of an Ovenbird nest being present on a plot increased with the percent vegetation cover. With <10 percent vegetation cover per m^2, there was <20% chance of a nest being present (Figure 2). With >90 percent vegetation cover, there was >80% chance that a nest was present (Table 2, Figure 2).

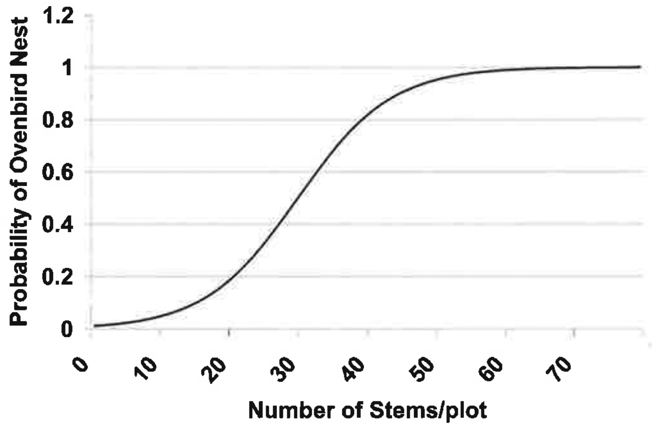

Figure 1. The probability of Ovenbird nest presence as function of the number of stems in a 1 m^2 plot when comparing nest sites to Visitor Center sites (Log (odds) = –4.4179 + 0.1500* (no. of stems)).

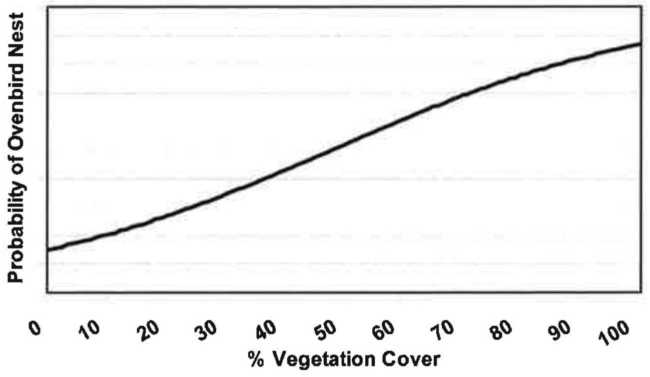

Figure 2. The probability of Ovenbird nest presence as function of percent vegetation cover in a 1 m^2 plot when comparing nest sites to random linked sites (Log (odds) = –2.2266 + 0.4862* (% vegetation)).

DISCUSSION

Our study suggests that the microhabitat within a contiguous forest can vary substantially and that variation influences nest site selection by Ovenbirds. We found that in the Visitor Center plot where Ovenbird density has declined, there were significantly fewer plant species, lower stem densities, and less vegetation cover overall as compared to nest sites. In addition, litter depth and number of blueberry stems were also lower than at the plots still occupied by Ovenbirds, although the difference was not significant. The best predictors of Ovenbird nest locations within the contiguous forest were vegetation cover and stem density.

The reasons causing the within-forest differences in vegetative structure are unknown. One possible explanation is the increased numbers of white-tailed deer and their concentration near openings in the contiguous forest, such as the Visitor Center area. Pennsylvania Game Commission (2001) data for the study area (e.g., Berks County) placed the density of white-tailed deer at >14.2 deer/km^2 for each year since 1982 and as high as 28.8 deer/km^2 during some years of the study period. The estimated regional deer population increased significantly during the study period suggesting deer browsing activity may have increased ($r = 0.474$, $n = 19$, $p = 0.041$) (Pennsylvania Game Commission 2001).

Deer densities of this level have been shown to cause changes in the ground cover and shrub vegetation. Declines in seedling numbers, stem density in most plants, and overall floral diversity have also been noted in areas of high deer density (e.g., Horsley et al. 2003). In addition, a forest health survey conducted at Hawk Mountain in 1998 reported heavy deer browse with little forest regeneration occurring, with greater impacts noted near openings (Steckel 1998).

Bird populations can be affected by higher deer densities, particularly those species nesting in the intermediate canopy (DeCalesta 1994). Although, DeCalesta and others have not found decreases in nesting populations of ground and canopy nesters linked to increases in deer, if deer occur at high levels for long periods they may significantly impact overall plant species diversity and stem density of shrub and herbaceous layers, causing effects such as those noted by

Table 3. AIC model selection results for comparing nest sites to random-linked points within the study plots ($n = 22$).

MODEL	AICc	DIFF	WEIGHT
Percent vegetation	32.495	0.000	0.34455*
Litter depth	33.204	0.709	0.24171
Percent vegetation and litter depth	34.402	1.907	0.13279
None	35.130	2.635	0.09227
Number of stems and percent vegetation	35.179	2.684	0.09004
Number of species	37.044	4.549	0.03544
Number of stems	37.204	4.709	0.03271
Wood	37.740	5.245	0.02502
Four variables excluding litter depth	41.059	8.564	0.00476
All five variables	44.895	12.400	0.00070

* best model predicting nest location

our results (Horsley et al. 2003). The Visitor Center plot is within 100 m of the Hawk Mountain Visitor Center and its parking facilities, while the other two plots are both > 1 km away from this opening, and deer may be more frequent in this area.

Another possible impact in the Visitor Center area of the forest is the invasion of non-native species along openings. Non-native plants, such as stilt grass (*Microstegium vimineum*), have begun to enter much of the forest interior along drainage swales adjacent to the Visitor Center and are altering the composition of the nearby forest ground cover (and its associated invertebrate populations). Non-native earthworms also have been invading the Hawk Mountain forest in recent years, particularly adjacent to disturbed areas (Maerz, J., pers. comm.). Recent research suggests that non-native earthworms may reduce the leaf litter mass which may affect both nest site suitability and prey availability as the worms appear to deplete the forest floor invertebrate population and reduce plant species richness (Holdsworth et al. 2007, Maerz, J., pers. comm.) Because Ovenbirds feed predominantly on forest floor invertebrates (Van Horn and Donovan 1994), non-native species that cause reduction in invertebrate densities could indirectly reduce the quality of nesting habitat available.

A final consideration is ground predators. Just as with deer, there may be more medium-sized and small mammals near the Visitor Center plot due to the plot's proximity to the HMS Visitor Center facilities, their openings, and their bird feeding stations. Studies on other ground-nesting birds have shown greater nest densities and greater nest survivorship in areas with lower small mammal numbers (Morton 2005, Schmidt et al. 2006).

Microhabitat differences appear to have important consequences for patterns of nest density in forest-nesting birds even within large areas of contiguous forest. Burke and Nol (1998) found that pairing success on small forest fragments was at times 0% while on the largest fragments it reached 100%. They attribute this drastic difference to the nest site microhabitat characteristics that females prefer, suggesting that females choose sites with deep litter and other characteristics that will increase their reproductive success. Coupled with our findings, this suggests that there may be certain microhabitat features that when absent may preclude nesting attempts. As suggested by Burke and Nol (1998), these characteristics may be indicative of habitat quality for invertebrate prey populations, but they may also be important for nest concealment and predator avoidance. In contrast, Van Horn and Donovan (1994) report little is known about nest site selection in Ovenbirds but they nest "in areas where the forest floor is open and shrubs are sparse"; they also note some nests are placed in "moderately dense herbaceous vegetation". Results of this study suggest Ovenbirds may prefer to place their nests in moderate dense cover and selection of sites in open areas may be a response to a lack of available cover or other aspects over-riding this preference such as litter depth.

This study highlights the need for a detailed understanding of the microhabitat characteristics needed for a healthy species population in conservation planning, not merely the overall habitat type or patch size most frequently used.

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LITERATURE CITED

Banko, P. C., P. T. Oboyski, J. W. Slotterback, S. J. Dougill, D. M. Goltz, L. Johnson, M. E. Laut, and T. C. Murray. 2002. Availability of food resources, distribution of invasive species, and conservation of a Hawaiian bird along a gradient of elevation. Journal of Biogeography 29: 789–808.

Barber, D. R., and L. J. Goodrich. *In prep.* Relative densities and population trends of forest nesting birds in Pennsylvania.

Brotons L., M. Magrans, L. Ferrus, and J. Nadal. 1998. Direct and indirect effects of pollution on the foraging behaviour of forest passerines during the breeding season. Canadian Journal of Zoology 76: 556–565.

Burke, D. M., and E. Nol. 1998. Influence of food abundance, nest-site habitat and forest fragmentation on breeding Ovenbirds. Auk 115: 96–104.

Burnham, K. P. and D. R. Anderson. 2002. Model selection and multimodel inference: A practical information-theoretic approach, 2nd edn. Springer-Verlag, New York.

DeCalesta, D. S. 1994. The effect of white-tailed deer on songbirds in managed forests in Pennsylvania. Journal of Wildlife Management. 58: 711–718.

DeGraaf, R. M., W. M. Healy, and R.T. Brooks. 1991. Effects of thinning and deer browsing on breeding birds in New-England oak woodlands. Forest Ecology and Management 41: 179–191.

ERSI (Environmental Systems Research, Inc.). 2003. ArcGIS 8.0. ESRI, Redlands, California, USA.

Giocomo, J. J., M. C. Brittingham, and L. J. Goodrich. *In prep.* Effects of internal openings on nest success of forest songbirds.

Goodrich, L. J., C. B. Viverette, S. E. Senner, and K. L. Bildstein. 1998. Long-term use of Breeding Bird Census plots to monitor populations of neotropical migrants breeding deciduous forests in eastern Pennsylvania, USA. Pages 149–165 In Forest biodiversity in North, Central and South America and the Caribbean: research and monitoring (F. Dallmeier and J. A. Comiskey, eds.). Man the Biosphere Series, Smithsonian. Vol. 21. Parthenon Publishing Group. Pp. 1–768.

Goodrich, L. J., M. Brittingham, C. B. Viverette, and J. C. Bednarz. *In prep.* Effects of forest fragmentation on long-term breeding success and return rates of Ovenbirds in eastern Pennsylvania.

Hames, R. S., K. V. Rosenberg, J. D. Lowe, S. E. Barker, and A. A. Dhondt. 2002. Adverse effects of acid rain on the distribution of the Wood Thrush *Hylocichla mustelina* in North America. Proceedings of the National Academy of Sciences of the United States of America 99: 11235–11240.

Holdsworth, A. R., L. E. Frelich, and P. B. Reich. 2007. Effects of earthworm invasion onplant species richness in northern hardwood forests. Conservation Biology 21: 997–1008.

Horsley, S. B., S. L. Stout, and D. S. DeCalesta. 2003. White-tailed deer impact on the vegetation dynamics of a northern hardwood forest. Ecological Applications 13: 98–118.

Morton, E. S. 2005. Predation and variation in breeding habitat use in the Ovenbird, with special reference to breeding habitat selection in northwestern Pennsylvania Wilson Bulletin 117:327–335.

Pennsylvania Game Commission. 2001. Pennsylvania Deer Statistics 1982–2000. Pennsylvania Game Commission, Harrisburg, Pennsylvania.

Porneluzi, P., J. C. Bednarz, L.J. Goodrich, N. Zawada, and J. Hoover. 1993. Reproductive performance of territorial Ovenbirds occupying forest fragments and a contiguous forest in Pennsylvania. Conservation Biology 7: 618–622.

Ralph, C.J., G.R. Geupel, P. Pyle, T.E. Martin, and D.R. DeSante. 1993. Handbook of field methods for monitoring landbirds. Gen. Tech. Rep. PSW-GTR-144. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 41 pp.

Robbins, C. S., D. K. Dawson, and A. Dowell. 1989. Habitat area requirements of breeding forest birds of the Middle Atlantic States. Wildlife Monographs No. 103.

Robinson, S. K., F. R. Thompson III, T. M. Donovan, D. R. Whitehead, and J. Faaborg. 1995. Regional forest fragmentation and the nesting success of migratory birds. Science 267: 1987–1990.

Sauer, J. R., J. E. Hines, and J. Fallon. 2003. The North American Breeding Bird Survey, Results and Analysis 1966–2002. Version 2003.1, U.S.G.S. Patuxent Wildlife Research Center, Laurel, Maryland.

Scheiman, D. M., E. K. Bollinger, and D. H. Johnson. 2003. Effects of leafy spurge infestation on grassland birds. Journal of Wildlife Management 67: 115–121.

Schmidt, K. A., R. S. Ostfeld, and K. N. Smyth. 2006. Spatial heterogeneity in predator activity, nest survivorship, and nest-site selection in two forest thrushes. Oecologia 148:22–29.

Steckel, D. 1998. Pennsylvania Forest Stewardship Plan for the Property of the Hawk Mountain Sanctuary Association. Natural Lands Trust, Inc. Media, Pennsylvania.

Van Horn, M. A., and T. M. Donovan. 1994. Ovenbird (*Seiurus aurocapillus*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/088.

Wallendorf, M. J., P. Porneluzi, W. Gram, R. Clawson, and J. Faaborg. 2006. Bird response to clear cutting in Missouri Ozark forests. J. of Wildlife Management 1899–1905.

Zegers, D. A., S. May, and L. J. Goodrich. 2000. Identification of nest predators at farm/forest edge and forest interior sites. Journal of Field Ornithology 71: 207–216.

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TARDIGRADES OF NORTH AMERICA: INFLUENCE OF SUBSTRATE ON HABITAT SELECTION[4]

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ABSTRACT

The patterns of habitat (moss or lichen) selection have been elusive for tardigrades. Samples of habitat were collected from ten different substrates (species of tree), the nematodes, rotifers, and tardigrades counted, and their distribution, density, and patterns of association analyzed in suburban Philadelphia. All three taxa were found more frequently than expected furthest from the roads while none showed a preference for height. Rotifers were positively associated with the moss habitat while nematodes and tardigrades were evenly distributed. All three taxa favored the Dogwood (*Cornus florida*) as a substrate while each taxon was negatively associated with other substrates (trees). This is the first report of tardigrades from Pennsylvania; 546 specimens from the following eight species are recorded: *Milnesium tardigradum*, *Macrobiotus areolatus*, *Macrobiotus harmsworthi*, *Macrobiotus hufelandi*, *Macrobiotus islandicus*, *Minibiotus intermedius*, *Ramazzottius oberhaeuseri*, and *Itaquascon* sp. The four most numerous species were each positively associated with different combinations of location, height, habitat, and substrate. Tardigrades were found more frequently than expected in habitats on angiosperm substrates. Evidence was found for association, positive or negative, between each substrate and at least one species of tardigrades. A range of pH values was identified among the different substrates. The tardigrades *Milnesium tardigradum* and *Ramazzottius oberhaeuseri* were associated with higher pH, while *Minibious intermedius* preferred the more acidic substrates, and *Macrobiotus hufelandi* was found over the widest range of pH. These patterns suggest the possibility for the development of micro-invertebrates as bio-indicators for habitat quality analysis.

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INTRODUCTION

The animals of the phylum Tardigrada remain a little known, little studied group (Kinchin, 1994). The ecological requirements of tardigrades are equally unknown, and although often abundant, the contribution of water bears to the biodiversity of the ecosystem is under documented. This lack of basic biological information may have excluded tardigrades from ecological and environmental studies.

Of the more than 700 described species of limno-terrestrial tardigrades only about 125 have been recorded from North America (McInnes, 1994). There are no records of tardigrades from Pennsylvania (Miller, 1997). Yet, in other regions they are often common in the aquatic habitat formed by water trapped by the leaves of mosses and the thalli of lichens.

Nelson (1975) stated that, "No correlation was noted between the various species of tardigrades and the species of moss. In general, tardigrades inhabited a variety of moss species." Ramazzotti & Maucci (1983) and Kathman & Cross (1991) both suggested that moss animals do not specialize in particular moss species. Meyer (2006a) was also not able to report a significant association between species of tardigrade and habitat in his extensive study in Florida.

In contrast, Kimmel and Meglitsch (1969) reported that tardigrades on Iowa trees had a relatively high frequency index for height, habitat, and substrate. Séméria (1982) found fewer species at urban sites than at suburban sites and suggested a link between air quality and tardigrade diversity. Miller et al. (1996) demonstrated that in the simpler ecosystem of Antarctica some relationships existed between habitats and species of tardigrades. Miller et al. (2001) again identified associations between species of tardigrades and their habitats.

Meininger et al. (1985) measured the air pollution around Cincinnati, Ohio and reported that air quality had a high correlation with lichens, humidity, pH, and tardigrade populations. In Alaska, Meininger and Spratt (1988) studied the impact of calcium carbonate dust from a road on the pH of the surrounding sphagnum moss. The pH of the moss declined and the composition of the tardigrade population changed with increased distance from the road.

Dastych (1988) reported that Polish tardigrade diversity changed with increasing acidity. Steiner (1994a) stated that tardigrades are affected by many interrelated biotic and abiotic factors, such as moisture, location, height, temperature, and substrate. He further observed that mosses from urban locations have significantly higher pH than do those from rural sites. Steiner (1995) concluded that abiotic factors are more important than the species of moss and that the acidic nature of the habitat may determine community structure, but conceded that, "knowledge about terrestrial invertebrates as indices of environmental quality is alarmingly poor."

Because two of the major tardigrade habitats (mosses and lichens) are found in abundance in Pennsylvania, this study was undertaken to confirm the presence of the phylum and establish an initial diversity for the state. In addition, the study afforded the opportunity to test the hypothesis that the substrate (species of trees) upon which the habitat (moss or lichen) is found does not influence the distribution, density, or diversity of micro-invertebrates, especially the tardigrade.

MATERIALS AND METHODS

The study area was the 40-acre campus of Chestnut Hill College in west suburban Philadelphia, PA (40° 05′ 11.61″ N, 75° 13′ 37.55″ W). The campus has over a thousand trees of 50 identified species (pers. comm. Ed Lafferty). A matrix of ten specimens of ten different trees was chosen as the experimental design.

Two samples were collected from each tree, one at the base and one two and a half meters up the trunk. A five centimeter-square sample of moss or lichen habitat was scraped from the substrate tree into a paper bag and labeled. Location was recorded with a Garmin GPS 12 and each tree digitally imaged for reference to the Master Landscaping Plan.

Each sample was soaked for 24 hours in a small dish of spring water. Three sub-samples were inspected at 30-power with a dissecting microscope and reflected light. Three phyla of animals (tardigrades, nematodes, and rotifers) were counted. The tardigrades were removed with an Irwin loop and mounted on slides in Hoyer's media under a glass cover slip (Miller, 1997). The tardigrades were identified to species using the keys in Ramazzotti & Maucci (1983) and Nelson (1991).

Distribution was assessed by the occurrence of the taxa in three zones (Figure 1). Zone A was near the roads that edged the campus. Zone B was the hill upon which most of the campus buildings were located. Zone C was the flood plain of the Wissahickon Creek. Density was recorded as the number of animals per sample. Diversity, the number of

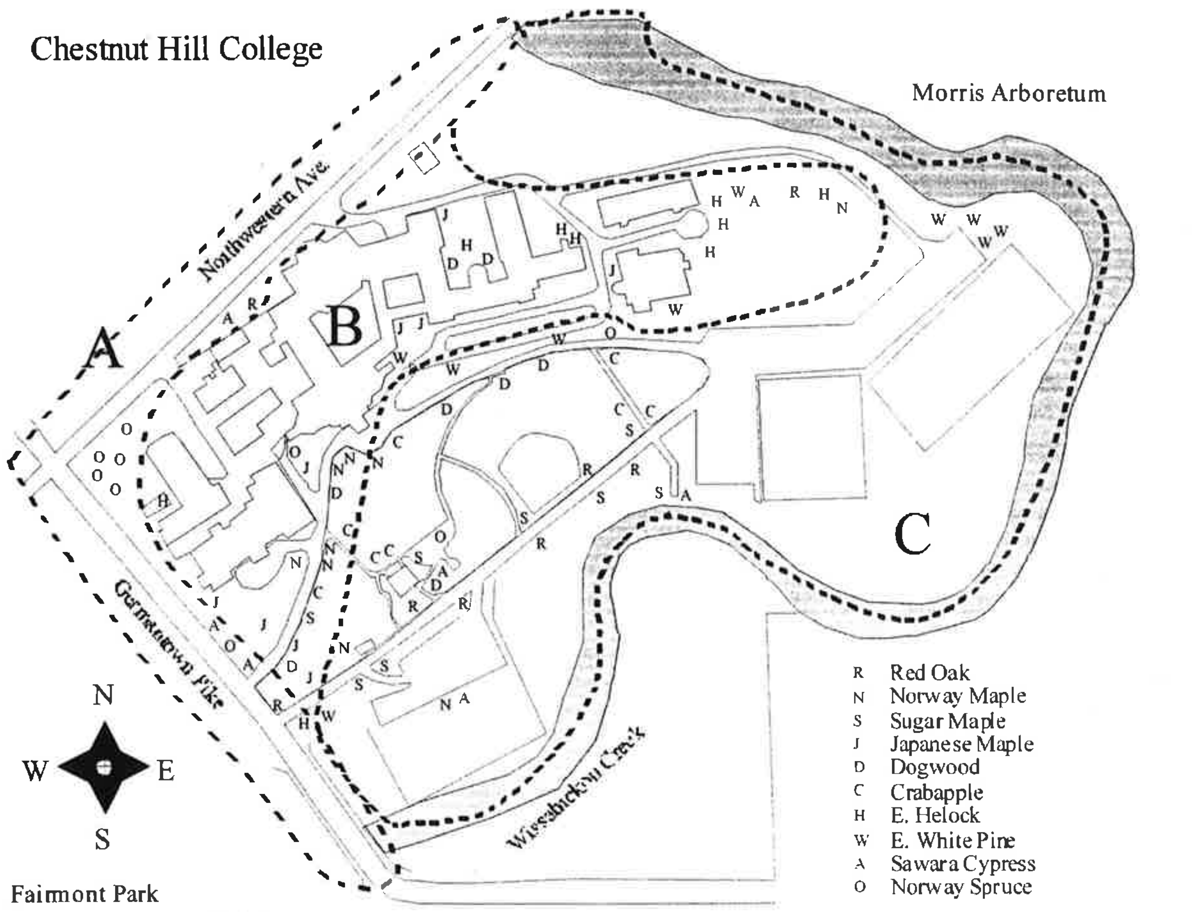

Figure 1. Chestnut Hill College Campus, Philadelphia, PA, USA; Large letters denote Zones; small letters denote tree species.

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Table 1. Associations of phyla to zone, height, habitat, & substrate.

			Nematode		Rotifera		Tardigrada	
	Totals	pH	Obs	Assoc	Obs	Assoc	Obs	Assoc
Individuals	5681		843		4292		546	
Samples	200		103		169		99	
Zone								
A: Road	22		88	x	808	+	33	x
B: Buildings	124		260	–	847	–	150	–
C: Lower	54		495	+	2367	+	363	+
Height								
Low	100		388	x	2642	x	306	x
High	100		455	x	1650	x	240	x
Habitat								
Moss	39		232	x	1661	+	106	x
Lichen	161		611	x	2631	–	440	x
Substrate								
Angiosperms								
Dogwood	*C. florida*	6.1	395	+	921	+	125	+
Sugar Maple	*A. saccharum*	5.8	28	–	492	x	99	+
Japanese Maple	*A. palmatum*	5.8	51	x	344	x	64	x
Norway Maple	*A. platanoides*	5.7	97	x	291	x	53	x
Crabapple	*Malus* sp.	5.6	70	x	191	x	43	x
Red Oak	*Q. rubrum*	5.3	26	–	420	x	43	x
Gymnosperms								
Norway Spruce	*P. abies*	5.2	30	–	577	x	4	–
E. Hemlock	*T. canadensis*	5.2	66	x	435	x	83	x
E. White Pine	*P. strobus*	4.6	11	–	135	–	28	x
Sawara Cypress	*C. pisifera*	4.3	69	x	486	x	4	–

x = Association as expected, based on $X^2 > 3.85$, P = 0.05, 1df.
+ = Association significantly greater than expected
– = Association significantly less than expected
o = Organism not present

species in a sample, was limited to tardigrades because rotifers and nematodes were not identified to species. Acidity (pH) of each sample was determined by colorimetric chemical reactions after treatment with pH determining reagents in a LaMotte Soil Testing Kit (Tucker, 1994).

Because of the small size of the study area, and the uniformity of the prevailing conditions, even distribution, diversity and density was expected. Microsoft Excel was used to calculate Chi-Square (X^2) (Fowler, Cohen, and Jarvis, 1998) for the difference between the observed and expected values. Chi-Square is a one-tailed test that ignores any other relationship except the magnitude of the difference. We coded the relationship with a plus (+) if the observed was significantly greater than the expected, with an "x" when no significant difference existed, with a minus (–) for the expected being significantly greater than the observed, and with an "o" to a set of conditions that did not occur.

RESULTS

The ten substrates were the gymnosperms Eastern Hemlock (*Tsuga Canadensis*), Eastern White Pine (*Pinus strobes*), Sawara Cypress (*Chamaecyparis pisifera*), and Norway Spruce (*Picea abies*) and the angiosperms Red Oak (*Quercus rubrum*), Norway Maple (*Acer platanoides*), Sugar Maple (*Acer saccharum*), Japanese Maple (*Acer palmatum*), Dogwood (*Cornus florida*), and Crabapple (*Malus* sp.) (Table 1). Two hundred habitat samples (161 lichen and 39 moss) were collected during the summer of 2001. The lichens were the greenish *Flavoparmelia* sp. and the grayish *Pseudoparmelia* sp.; the mosses were not identified.

The samples yielded 5,681 micro-invertebrates: 4,292 rotifers, 843 nematodes, and 546 tardigrades. Rotifers occurred in 169 samples, nematodes in 103 samples, and tardigrades in 99. The distribution by zone, height, habitat, and substrate is presented in Table 1.

Only rotifers occurred more frequently than expected in zone A. All three taxa occurred less frequently in zone B and more frequently in zone C. All three micro-invertebrates were represented as expected at both heights. Rotifers were more frequent in mosses and less frequent in lichens. Nematodes and tardigrades showed no preference for habitat (Table 1).

The four positive taxa-substrate associations were with angiosperms while five of seven negative associations were with gymnosperms. The Dogwood (*C. florida*) was the only substrate on which all three taxa occurred more frequently than expected. Tardigrades also favored the Sugar Maple (*A. saccharum*) as a substrate. The least favored substrates were

the Eastern White Pine (*P. strobus*) where both nematodes and rotifers were less numerous and Norway Spruce (*P. abies*) where nematodes and tardigrades were less numerous (Table 1).

Of the 546 tardigrades, 464 were in a life stage that could be identified to species. Eight species from two orders and five genera were identified as follows: 171 *Milnesium tardigradum* Doyère, 1840, 22 *Macrobiotus areolatus* Murray, 1907, one *Macrobiotus harmsworthi* Murray, 1907, 128 *Macrobiotus hufelandi* Schultze, 1834, nine *Macrobiotus islandicus* Richters, 1904, 56 *Minibiotus intermedius* (Plate, 1889), 74 *Ramazzottius oberhaeuseri* (Doyère, 1840), and three *Itaquascon* sp.

Tardigrade species richness was eight and the Simpson's Index of Diversity was 0.75. The maximum diversity was six species on *A. platanoides* while two substrates (*A. saccharum* and *Q. rubrum*) each housed five species. *Picea abies* had the lowest diversity with only a single species. The observed diversity on gymnosperm substrates ranged from one to three species whereas angiosperm substrates ranged from three to six species (Table 2).

Tardigrade density ranged from zero to 55 animals in a single sample. The average sample density ranged from 0.20 on *P. abies* and *C. pisitera* substrates to 6.25 for the *C. florida* substrate. Angiosperms exhibited greater tardigrade density than all but one of the gymnosperms (*T. canadensis*). Average density for angiosperms was double that of gymnosperms (Table 2).

Patterns of association were calculated for the four most frequently occurring species (Table 3). The occurrence data for the four infrequently occurring tardigrades was set aside because expected values did not meet the X^2 minimum of five. The four abundant species favored Zone C, furthest from the road. Three species occurred lower on the trees in contrast to the phylar pattern of more even occurrence, and *Macrobiotus hufelandi* and *Minibiotus intermedius* favored lichens while *R. oberhaeuseri* favored moss (Table 3).

Milnesium tardigradum and *R. oberhaeuseri* occurred on substrates with higher pH (lower acidity). *Minibiotus intermedius* was found more frequently in substrates with lower pH (higher acidity). *Macrobiotus hufelandi* was found over the widest range of pH values (Table 3).

DISCUSSION

The study confirmed the presence of phylum Tardigrada in Pennsylvania. This first record adds a new phylum and eight species to the biodiversity list for the state.

The large number of micro-invertebrates present and their broad dispersal throughout the small study area demonstrated that their ability to colonize a local habitat was not a limitation and the expectation of even distribution, diversity, and density was validated. Thus, we concluded that observed differences were an expressed result of conditions.

The distributional patterns suggest each phylum has different requirements. The positive association for all three phyla for zone C, furthest from the road, suggests that each taxon may be sensitive to the air quality as suggested by Steiner (1994a, 1994b, 1994c, 1995), Sémméa (1982), and Hohl et al. (2001). The uniformly negative association with zone B suggests that buildings affect the quality of the habitat.

None of the taxa showed a preference for height. It was observed that the sampling height was a vertical part of the substrate and may be an expression of habitat rather than taxa selection.

All phyla were represented on all substrates but not uniformly. Gymnosperms were less desirable than expected whereas few angiosperms were uninhabited (Table 1). All three phyla found the conditions provided by the habitats on Dogwood (*C. florida*) substrate with its higher pH to be acceptable, whereas two of the taxa found the Eastern White Pine (*P. strobus*) with its higher acidity (lower pH) to be the least favorable. Tardigrades found Sugar Maple (*A. saccharum*) to be a favorable substrate but nematodes did not (Table 1). These different results suggest that the substrate contributes to the chemistry of the interstitial habitat used by these taxa.

More than half of the tardigrade associations measured expressed significant shifts from the expected values of our

Table 2. Substrate profile in pH, count, density and diversity.

Substrate		pH			Count of tardigrades	Density per sample	Diversity per substrate
		Max	Mean	Min			
Angiosperms							
Dogwood	*C. florida*	6.58	6.13	5.74	125	6.25	4
Sugar Maple	*A. saccharum*	5.99	5.78	5.53	99	4.95	5
Japanese Maple	*A. palmatum*	6.64	5.76	5.29	64	3.2	3
Norway Maple	*A. platanoides*	6.39	5.72	4.99	53	2.65	6
Crabapple	*Malus* sp.	6.42	5.64	4.82	43	2.15	4
Red Oak	*Q. rubrum*	5.90	5.21	4.83	43	2.15	5
Gymnosperms							
Norway Spruce	*P. abies*	5.76	5.18	4.37	4	0.2	1
E. Hemlock	*T. canadensis*	5.58	5.12	4.37	83	4.15	3
E. White Pine	*P. strobus*	5.70	4.62	3.97	28	1.4	2
Sawara Cypress	*C. pisifera*	5.31	4.34	3.72	4	0.2	2

Table 3. Associations of phyla to zone, height, habitat, & substrate.

	Totals	pH	*Milnesium tardigradum*		*Ramazzouttius oberhaeuseri*		*Macrobiotus hufelandi*		*Minibiotus intermedius*	
Individuals	429		171		74		128		56	
Samples										
Zone										
A: Road	22		10	x	2	–	7	x	11	+
B: Buildings	124		92	x	10	–	25	–	0	o
C: Lower	54		69	+	62	+	96	+	45	+
Height										
Low	100		117	+	38	x	86	+	36	+
High	100		54	–	36	x	42	–	20	–
Habitat										
Moss	39		35	x	1	–	14	+	29	+
Lichen	161		136	x	73	+	114	x	27	–
Substrate										
Angiosperms										
Dogwood	*C. florida*	6.1	76	+	0	o	34	+	1	x
Sugar Maple	*A. saccharum*	5.8	23	x	41	+	9	x	3	x
Japanese Maple	*A. palmatum*	5.8	32	x	14	+	3	–	0	o
Norway Maple	*A. platanoides*	5.7	25	x	7	x	1	–	0	o
Crabapple	*Malus* sp.	5.6	8	–	7	x	22	x	3	x
Red Oak	*Q. rubrum*	5.3	3	–	4	x	14	x	0	o
Gymnosperms										
Norway Spruce	*P. abies*	5.2	4	–	0	o	0	o	0	o
E. Hemlock	*T. canadensis*	5.2	0	o	1	–	30	+	33	+
E. White Pine	*P. strobus*	4.6	0	o	0	o	14	x	13	+
Sawara Cypress	*C. pisifera*	4.3	0	o	0	o	1	–	3	x

x = Association as expected, based on $X^2 > 3.85$, P = 0.05, 1df.
+ = Association significantly greater than expected
– = Association significantly less than expected
o = Organism not present

hypothesis (Tables 1 and 3). This supports Nelson's (1975) suggestion that if relationships between tardigrades and their habitats exist, they are complex.

Assuming that air-borne chemical exposure is relatively uniform over this small area, the differences in pH of the habitat must result from the washing and dissolving of the habitat and substrate materials. It follows then that if the animals have a set of conditions that they tolerate, their presence or absence is an expression of those conditions. Steiner (1995) reported that habitat acidity increased with higher SO_2 levels and observed that tardigrade diversity decreased with the lower pH values. While he did not give specific pH values, he did say, "the acidic nature of the habitat may have determined the community structure."

In his studies of tardigrades in Poland, Dastych (1988) classified substrates as "carbonate" (alkaline, limestone, or higher pH) and "non-carbonate" (acidic, granites, or lower pH) and used the frequency of occurrence of tardigrades to characterize selection of habitat by each species. He showed that *Milnesium tardigradum* and *R. oberhaeuseri* favored higher pH substrates, *Minibiotus intermedius* favored lower pH substrates and *Macrobiotus hufelandi* to be a generalist found about equally on all substrates. Our results are consistent with Dastych's observations (Table 3).

Nelson (1975) measured elevation, exposure, height, and species of moss on Beech trees on Roan Mountain in Tennessee. She found *Milnesium tardigradum* at higher locations on the trees. Kimmel and Meglitsch (1969) found *M. tardigradum* at heights up to three meters but in greater abundance at lower levels. In our study, *M. tardigradum* favored the lower sites.

Our study had four species of tardigrade in common with Kimmel and Meglitsch (1969) (*Macrobiotus hufelandi*, *M. aerolatus*, *M. islandicus* and *Milnesium tardigradum*) but the substrate and habitat species were not the same. The two studies did share two substrates (*Acer* and *Quercus*) at the generic level. In both studies, *Macrobiotus* occurred on the widest range of substrates but was negatively associated with the *Acer* substrate. In Pennsylvania *Macrobiotus* occurred as expected on the *Quercus* substrate but in Iowa they occurred more than expected. In contrast, *Milnesium* occurred as expected on the *Acer* substrate in Pennsylvania but not in Iowa while the reverse was true for the *Quercus* substrate. Kimmel and Meglitsch (1969) concluded that differences in tardigrade population densities were related to height, species interactions, habitat and substrate. We concur.

Our hypothesis that the substrate upon which the habitat is found has no significant influence on the distribution, density, or diversity of the tardigrades is rejected. Significant evidence was found both for positive and negative associations between each substrate and at least one tardigrade species. It is clear that these are complex relationships.

Steiner (1994b) suggested that micro-invertebrates would be "a convenient biological system for indicating levels of air pollution." Our results also point to the possible use of micro-invertebrates, especially tardigrades, in the moss/lichen habitats as indicators of local environmental conditions.

Yet, Miller et al. (1994) reported tardigrade distribution within a moss sample to be complex with both density and diversity being unevenly distributed both horizontally and vertically. Nelson and Adkins (2001) observed differences within samples of the same moss and suggest tardigrades may migrate within the habitat. Meyer (2006) looked at sampling repeatability within a tardigrade population in Arkansas and reported great variation. These observations point to the need for statistically sound sampling designs to assess micro-fauna populations before they can be held up as Steiner's (1994b) "...indicators of air pollution".

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LITERATURE CITED

Dastych, H. 1988. Tardigrada of Poland. Monografie Fauny Polski, Polska Akademia Nauk Zaklad Zoologii Systematycznej Doswiadczalnej, 1: 1–255.

Fowler, J., Cohen, L., and Jarvis, P. 1998. Practical Statistics for Field Biology. John Wiley & Sons, Ltd. West Sussex, England. Pp. 111–112.

Hoffmann, I., 1987. Habitat preference of the most frequent moss-living Tardigrada in the area of Griessen (Hessen). Pages 211–216 in Bertolani, R. (ed.) Biology of Tardigrades: Selected Symposia and Monographs, U.Z.I. Vol. 2 Mucchi, Modena.

Hohl, A. H., Miller, W. R., and Nelson, D. R. 2001. The Distribution of Tardigrades Upwind and Downwind of a Missouri Coal-Burning Power Plant. Zoologischer Anzeiger 240(3–4): 395–402.

Kathmann, R. D. and Cross, S. F. 1991. Ecological Distribution of Moss-Dwelling Tardigrades on Vancouver Island, British Columbia, Canada. Canadian Journal of Zoology 69: 122–129.

Kimmel, R. G. and Meglitsch, P. A. 1969. Notes on Iowa Tardigrades. Proceedings of Iowa Academy of Science. 76: 454–462.

Kinchin, I. M. 1994. The Biology of Tardigrades. Portland Press, London, pp. 186.

McInnes, S. J. 1994. Zoogeographic Distribution of Terrestrial/Freshwater Tardigrades from Current Literature. Journal of Natural History 28: 257–352.

Meininger, C. A. and Spratt, P. A. 1988. Variations in tardigrade assemblages in dust-impacted Arctic mosses. Arctic Alpine Research, 20: 23–30.

Meininger, C. A., Ueta, G. W. and Snider, J. A. 1985. Variation in epiphytic microcommunities (tardigrade-lichen-bryophyte assemblages) of the Cincinnati, Ohio area. Urban Ecology, 9: 45–61.

Meyer, H. A. 2006a. Small-scale spatial distribution variability in terrestrial tardigrade populations. Hydrobiologica, 558: 133–139.

Meyer, H. A. 2006a. Interspecific association and substrate specificity in tardigrades from Florida, southeastern United States. Hydrobiologia, 588: 129–132.

Meyer, H. A., and Hinton, J. G. 2007. Limno-terrestrial Tardigrada of the Nearctic Realm. Journal of Limnology, 66 (Suppl.1): 97–103.

Miller, W. R. 1997. Tardigrades: Bears of the Moss. The Kansas School Naturalist 43(3): 1–16.

Miller, W. R., Miller, J. D. and Heatwole, H. F. 1996. Tardigrades of the Australian Antarctic Territories: The Windmill Islands, East Antarctica. Zoological Journal of the Linnaean Society 116: 175–184.

Miller, W. R., Horning, D. S. and Heatwole, H. F. 2001. Tardigrades of the Australian Antarctic: Macquarie Island, Sub-Antarctica. Zoologischer Anzeiger 240(3–4): 475–492.

Miller, W. R., Miller, J. D., and Heatwole, H. F. 1994. Tardigrades of the Australian Antarctic Territories: Assessing Diversity within a Sample. Memoirs of the Queensland Museum, 36(1): 137–145.

Nelson, D. R. 1975. Ecological Distribution of Tardigrades on Roan Mountain, Tennessee-North Carolina. IN: International Symposium on Tardigrades, 1974. Robert P. Higgins (ed.). Memorie dell'Istituto Italiano di Idrobiologia 32 suppl. 225–276.

Nelson, D. R. 1991. Tardigrada. IN: Ecology and Classification of North American Freshwater Invertebrates. Throp, J. H. and Crovich, A. P. (eds), San Diego Academy Press. pp. 501–521.

Nelson, D. R. and Adkins, R. G. 2001. Distribution of Tardigrades within a Moss Cushion: Do Tardigrades Migrate in Response to Changing Moisture Conditions? Zoologischer Anzeiger, 240(3–4): 493–500.

Peluffo, M. C. M., Peluffo, J. C., Rocha, A. M., and Doma, I. L. 2006. Tardigrade distribution in a medium-sized city of central Argentina. Hydrobiologica, 558: 141–150.

Ramazzotti, G. and Maucci, W. 1983. Il Phylum Tardigrada. Memorie dell'Istituto Italiano di Idrobiologia 41: 1–1011.

Steiner, W. A. 1994a. The Influence of Air Pollution on Moss-Dwelling Animals: 1. Methodology and composition of flora and fauna. Revue Suisse de Zoologie 101(2): 533–556.

Steiner, W. A. 1994b. The Influence of Air Pollution on Moss-Dwelling Animals: 2. Aquatic Fauna with Emphasis on Nematoda and Tardigrada. Revue Suisse de Zoologie 101(3): 699–724.

Steiner, W. A. 1994c. The Influence of Air Pollution on Moss-Dwelling Animals: 4. Seasonal and Long-term Fluctuations of Rotifer, Nematode and Tardigrade Populations. Revue Suisse de Zoologie 101(4): 1017–1031.

Steiner, W. A. 1995. The Influence of Air Pollution on Moss-Dwelling Animals: 5. Fumigation with SO_2 and exposure experiments. Revue Suisse de Zoologie 102(1): 13–40.

Séméria, Y. 1982. Researches sur la faune urbaine et semi-urbaine des tardigrades muscicoles et lichénicoles. II. L'éspace sub-urbain: Les hauteurs orientales de Nice-Ville. Bulletin de la Société Linnéenne de Lyon. 51: 315–328.

Tucker, M. R. 1994. LaMontte Soil Handbook. LaMontte Company, Chestertown, MD. Pp. 81.

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SUMMER BATS OF POTTER AND McKEAN COUNTIES, PENNSYLVANIA AND ADJACENT CATTARAUGUS COUNTY, NEW YORK[1]

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ABSTRACT

Five species of bats (n = 666) were caught: 47 big brown bats (*Eptesicus fuscus*), 20 red bats (*Lasiurus borealis*), 4 hoary bats (*Lasiurus cinereus*), 382 little brown myotis (*Myotis lucifugus*), and 213 northern myotis (*Myotis septentrionalis*). Catch was 12.1 bats/net site ($SD = 16.0$) and 2.9 bats/net night ($SD = 2.4$). At least one bat was captured at every net site, but at three sites only a single bat was caught. The greatest catch per site was 87, 67, and 34 (2 sites) bats. Species richness was highest at two sites where five species were caught; 2.2±1.1 species were caught per site and MacArthur's diversity index was 2.29. Evidence of reproduction was obtained for all species. Significantly more little brown myotis were caught late in the evening ($X^2 = 10.28$; $P = 0.036$), while the greatest catch of northern myotis was early in the evening ($X^2 = 32.05$; $P < 0.001$). More big brown bats ($X^2 = 57.28$; $P < 0.001$), little brown myotis ($X^2 = 382.27$; $P < 0.001$), and northern myotis ($X^2 = 20.60$; $P < 0.001$) were caught late than early, in the season. Little brown myotis were most frequently captured in riparian habitat ($\chi^2 = 45.79$, $P < 0.001$) while northern myotis were caught more often in uplands ($\chi^2 = 22.53$, $P < 0.001$). Similarities and differences in species diversity, relative abundance, reproductive condition and relative abundance of the sexes, periods of night time and seasonal activity, and use of habitat between this and other studies indicate that there are many aspects of the ecology of these species that we have yet to understand.

[J PA Acad Sci 83(1): 17–23, 2009]

INTRODUCTION

Eleven species of bats occur in Pennsylvania (Doutt et al. 1977; Merritt 1987; Whitaker and Hamilton 1998): Little brown myotis (*Myotis lucifugus*), northern myotis, (*Myotis septentrionalis*), Indiana bat, (*Myotis sodalis*), small-footed myotis (*Myotis leibii*), big brown bat (*Eptesicus fuscus*), evening bat (*Nycticeius humeralis*), eastern pipistrelle (*Pipistrellus subflavus*), eastern red bat (*Lasiurus borealis*), hoary bat (*Lasiurus cinereus*), Seminole bat (*Lasiurus seminolus*) and silver-haired bat (*Lasionycteris noctivagans*). The Seminole bat and evening bat are not known from north-central Pennsylvania, including the project area. Although all these species are widespread in the eastern United States, relatively little information is available about their distribution and abundance in Pennsylvania.

The purpose of this paper is to provide documentation of species of bats caught in northern Potter and McKean counties, Pennsylvania and adjacent Cattaraugus County, New York. Their relative abundance, evidence of reproduction and relative abundance of the sexes, periods of night time activity, relative abundance through the summer season, and habitat use were recorded. As identified by Yahner (2003), it is hoped that these data will contribute to understanding of the abundance and distribution of these species and development of sound conservation strategies for bats in Pennsylvania. These data are also compared to recent similar studies within forests of the eastern United States, including Ravenna Training and Logistics Site in north-central Ohio (Brack and Duffey 2006), Camp Dawson Collective Training Area in northern West Virginia (Brack et al. 2005), Crane Division, Naval Surface Warfare Center and Hoosier Nation Forest in south-central Indiana (Brack and Whitker 2004; Brack et al. 2004), and Ft. Leavenworth, in extreme eastern Kansas (Brack et al. 2007). Because numerous references will be made to these studies, they will for brevity be referred to hereafter as Ravenna, Camp Dawson, Crane, HNF, and Ft. Leavenworth.

MATERIALS AND METHODS

Study Area.—Studies were completed in northern Potter and McKean counties, Pennsylvania and in adjacent Cattaraugus County, New York during summer 2005 (Fig. 1). Most work was in the Glaciated High Plateau, although a small amount was in the Deep Valleys Section, also in the Appalachian Plateau Physiographic Province (PDCNR 2000). The Appalachian Plateau covers over one-half of Pennsylvania and is characterized by steep slopes interspersed with gently sloping plateau remnants, and numerous streams. The Glaciated High Plateau Section consists of broad to narrow, rounded to relatively flat, elongate uplands separated from the Glaciated Low Plateau Section by a steep-sloped, well defined escarpment (PDCNR 2000).

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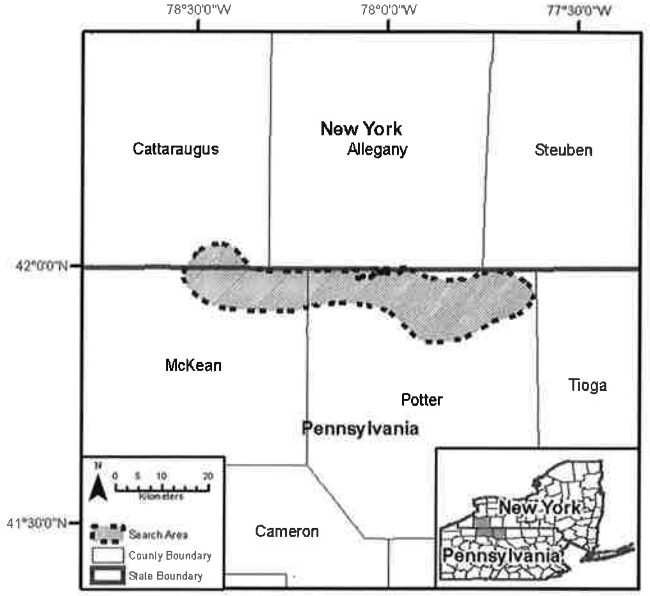

Figure 1. Location of project site in Potter and McKean counties, Pennsylvania and adjacent Cattaraugus County, New York.

Local relief is low to high and underlying rocks are sandstone, siltstone, shale, and conglomerate. The Deep Valleys Section has deep, steep-sloped valleys separated by narrow, flat to sloping uplands (PDCNR 2000). Relief between valleys and peaks can be > 300 m. The slope in most valleys is fairly uniform, but some have a large-scale, stair-step appearance from differential erosion of layers of sandstones and shales.

Braun (1950) described the forest association in the project area as the Allegheny Section of the Northern Appalachian Highland Division of the Hemlock-White Pine-Northern Hardwoods Region. Most of the project area lies within the unglaciated portion of the Allegheny, although the eastern side crosses into glaciated areas. Braun (1950) considered the natural forests of these glaciated and unglaciated areas as quite similar, with hemlock (*Tsuga canadensis*), beech (*Fagus grandifolia*), and sugar maple (*Acer saccharum*) as the most common canopy species, followed by black cherry (*Prunus serotina*), sweet and yellow birch (*Betula lenta* and *B. lutea*), red maple (*A. rubrum*), and white ash (*Fraxinus Americana*). Following Braun (1950), Fike (1999) described a similar Hemlock (White Pine) Northern Hardwood forest association. However, Braun (1950) found forests in uplands so modified by man that it rarely bore any resemblance to the original cover type. An unquantified assessment of dominant species (listing up to 3) was made at each net site: 14 sites did not have any of the three species listed by Braun (1950) as the most common canopy species, 21 sites had one, 19 had two, and only 1 site had all three.

Capture Methods.—Upland woods and wooded streams were identified on topographic maps for placement of mist net sites. Sites were placed no closer to one another than 1 km. Nets were placed in upland corridors (typically trails and infrequently used roads) and over streams used as flyways and travel corridors by bats (Brown and Brack 2003). Netting was conducted 15 May–12 August 2005 at 55 net sites. Netting effort included 220 complete and 18 partial net nights. A complete night of netting was considered to last for 5 hours beginning at dusk and typically ending about 0200 h. Sites were typically netted for 2 nights with 2 net sets, although netting was suspended during adverse weather (temperatures below 10°C, wind, or precipitation) and resulted in data collected during 18 partial nights of netting (0.5–2.25 hr) on 17, 18, and 20–24 May and 3 and 9 June. Net sets were 6–15 m long and 2–3 nets (5.2–7.8 m) high. Captured bats were identified to species and sex, reproductive condition, age, mass, and length of right forearm, and the time and location of capture (net site and net set) were recorded.

Data Analysis.—Chi-square analysis was used to compare (1) evenness of catch across species; (2) catch of adult males versus reproductive females; (3) catch across 5 hourly intervals of nightly capture adjusted to seasonal changes in timing of daylight; (4) catch across the season by dividing the study period (15 May–15 August) into three equal periods, weighted by level of netting effort (for all bats and for adults only); and (5) catch in riparian, bottomland, and upland habitat, weighted by level of effort in each. Dusk, when nets were opened, corresponded roughly to midway between sunset and civil twilight. Twilight is defined as when the sun is 6 degrees below the horizon, illumination is sufficient for objects to be distinguished, and the brightest stars are visible.

A species diversity index (SDI) was calculated: SDI = $1/\sum P_i^2$ (MacArthur 1972), where P_i is the proportion of bats belonging to species i in each sample. Capture was also assessed by catch per net night, per net site, species per site (i.e., species richness), and number of sites that caught bats.

RESULTS

Five species, 666 individuals, were represented in the sample (Table 1): 47 big brown bats, 20 eastern red bats, 4 hoary bats, 382 little brown myotis, and 213 northern myotis. Seventeen bats identified to species escaped before gender and morphometric data could be collected. The mean rate of capture was 12.1 bats/net site (*SD* = 16.0) and 2.9 bats/net night (*SD* = 4.9). At least one bat was captured at every net site, but only one bat was caught at three sites, whereas the greatest number of bats captured at a site was 87, 67, and 34 (2 sites).

Species richness was highest at two sites where five species were caught; 2.2±1.1 species were caught per net site. MacArthur's species diversity index was 2.29. The little brown myotis was the most commonly captured species (57% of catch), whereas the northern myotis was caught at the most sites (82% of sites; Table 2). The little brown myotis was caught at 73% of sites sampled. Chi-square analysis confirmed that species were not evenly represented in the sample ($\chi^2 = 789.84$, $P < 0.001$).

Table 1. Captures of adult males, pregnant (P), lactating (L), post-lactating (PL) females, and juvenile (Juv) bats. Bats identified to species but which escaped before sex and morphometric data were collected are noted. A Chi-square test of equality of catch by adult males and reproductive females is provided by species.

Species	Male	P	L	PL	NR	Juv	Escape	Total	χ^2	*P*-value
Big brown	10	2	1	8	4	21	1	47	0.05	0.827
Red	13	0	0	0	1	4	2	20	13.00	0.000
Hoary	0	0	0	1	0	3	0	4		
Little brown	140	12	3	52	31	138	6	382	25.74	0.000
Northern	130	16	0	18	28	13	8	213	56.20	0.000
Total	293	30	4	79	64	179	17	666	95.99	0.000

Table 2. Number and percent of 55 net sites where bats were caught, capture during each of five 1-hour periods (T1–T5) of netting beginning at dusk, and Chi-square analysis of the evenness of catch across the five periods.

	No./% Sites	T1	T2	T3	T4	T5	χ^2	*P*-value
Big brown	17/31%	8	13	13	10	3	7.36	0.118
Red	11/20%	4	5	2	2	7		
Hoary	3/6%	2	0	1	0	1		
Little brown	40/73%	66	78	61	80	97	10.28	0.036
Northern	45/82%	70	47	32	22	37	32.05	0.000
Total	55/100%	150	143	109	114	145	11.10	0.026

Evidence of reproduction, juveniles or pregnant, lactating, or post-lactating females, was obtained for all five species captured. Notably, no reproductive female red bats were caught, although juveniles were captured. Chi-square tests indicated that the catch of adult male eastern red bats, little brown myotis, northern myotis, and all species combined, was greater than the catch of reproductive females (Table 1). Capture of at least three reproductive individuals (females and juveniles) indicated that maternity colonies of big brown bats were near 5 sites, of little brown myotis were near 17 sites, and of northern myotis near 8 sites. Little brown myotis were most frequently captured in riparian habitat ($\chi^2 = 45.79$, $P < 0.001$) while northern myotis were caught disproportionately often in uplands ($\chi^2 = 22.53$, $P < 0.001$).

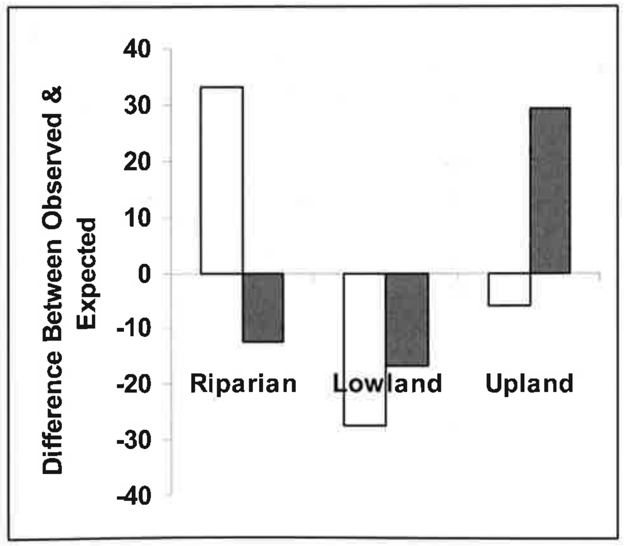

Figure 2. Differences between observed and expected numbers of captures, based on Chi-square analysis, of little brown myotis (open bars) and northern myotis (cross-hatched bars) at riparian, lowland, and upland net sites. Chi-square analysis was weighted by level of netting effort in each habitat.

The rate of capture for over 5 hours of sampling differed significantly for the little brown myotis, northern myotis, and for all species combined (Table 2). Disproportionately, more little brown myotis were caught late in the evening, while the greatest catch of northern myotis was early in the evening (Fig. 2). Seasonal differences also occurred, with more big brown bats, little brown myotis, northern myotis, and all species combined caught later, than early, in the season (Table 3).

DISCUSSION

Although nine species of bats are considered resident in northwestern and central Pennsylvania and southeastern New York (Richmond and Rosland 1949; Roslund 1951; Doutt et al. 1977; Merritt 1987; Whitaker and Hamilton 1998), only five were caught. However, the remaining four species are rare or uncommon. No federally endangered Indiana bats were caught. Silver-haired bats are most likely

Table 3. Catch during 15 May–14 June, 15 June–15 July, and 16 July–15 August, including all bats and adults only, for species with a sufficiently large catch to test with Chi-square analysis. Catch was weighted by level of effort in each period.

	All Bats		Adults Only	
Species	χ^2	*P*-value	χ^2	*P*-value
Big brown	57.28	0.000	55.37	0.000
Little brown	382.27	0.000	153.89	0.000
Northern	20.60	0.000	12.22	0.002
Total	399.89	0.000	173.94	0.000

to be caught as migrants, during spring and autumn. Published records of the eastern small-footed myotis are largely from winter hibernacula surveys and predominantly from south of the project area in more mountainous terrain (Doutt et al. 1977; Merritt 1987). In summer the species apparently roosts in vertical cracks of exposed cliff faces (Craig Stihler, unpublished data). Neither Roslund (1951) nor Richmond and Rosland (1949) reported the species from northcentral or northwestern Pennsylvania, respectively. In contrast, although we did not catch any eastern pipistrelles, Merritt (1987) considered the species common across the state, and both Roslund (1951) and Richmond and Rosland (1949) reported specimens from northcentral and northwestern Pennsylvania.

During summer studies at the entrance to Aitkin Cave, in Mifflin County to the southeast, Hall and Brenner (1968) also caught five species of bats, but in much different proportions: 1,060 little brown myotis, 173 northern myotis, 3 small-footed myotis, 17 eastern pipistrelle, and 7 big brown bats. However, use of caves in summer by bats may vary dramatically from use of woodlands. For example, bats may use caves for night roost between foraging bouts. Whitaker and Brack (2002) found that male, but not female, Indiana bats were often found in summer at caves that serve as winter hibernacula.

In comparison to other studies in wooded habitats of the eastern United States, the rate of bat capture in this study was greater, but the diversity (MacArthur 1972) less, being similar to Ft. Leavenworth, Kansas (Table 4) (Brack et al. 2007).

Big brown bat.—The big brown bat was the third most common of the five species captured. The capture of big brown bats was similar across the five hourly capture periods. In contrast, capture was greater early in the evening for studies at Ravenna, northern Indiana (Brack 1985), and southcentral Michigan (Brack et al. 1984), when insects are most abundant (Brack and LaVal 1985). In the present study, the catch of big brown bats, considering adults and juveniles together and adults alone, was greater late in the season. Similarly, at Ravenna more adult big brown bats were caught late in the season. Comparable numbers of males and reproductive females were caught, although captures of reproductive females and juveniles were concentrated in five areas, indicating maternity colonies were nearby. The capture of adult males appeared to be more dispersed. Brack et al. (2002) found that females were more common than males at lower elevations in Pennsylvania, and on HNF, males were more common than females.

The big brown bat is often considered a generalist in the type of habitats frequented (Duchamp et al. 2004), which may help explain its wide geographic distribution and capture at many project locations. However, capture was disproportionately high at riparian capture sites, as they were on HNF and Ft. Leavenworth. This species often eats heavily-chitinized insects, as identified in Pennsylvania (Agosta 2003), Ohio (Brack and Finni 1987), and Indiana (Whitaker 1995; Brack and Whitaker 2004). Insects eaten often include forest pests such as the Asiatic oak weevils (*Cyrtepistomus castaneus*), and agricultural pests such as the spotted cucumber beetles (*Diabrotica undecimpunctata*) (Whitaker 1995; Brack and Whitaker 2004).

Eastern Red bat.—The eastern red bat is a common summer resident of much of the eastern United States, including Pennsylvania, and uses a variety of woodland habitats. Red bats feed on a variety of insects, but moths often form much of the diet (Brack 1985; Brack and Finni 1987; Whitaker 1972; Whitaker et al. 1997), reflective of the woodland habitats they occupy. In the present study, it was caught at 20% of sample sites. In contrast, in southcentral Pennsylvania's Ridge and Valley Region, which is less wooded and more agricultural, Hart et al. (1993) caught red bats at 48.5% of sites netted and echolocation calls were detected at 53.8% of sample sites. The red bat is a seasonal migrant, and is likely absent during winter months (Whitaker and Hamilton 1998; Walters et al. 2006).

The catch of adult eastern male red bats was greater than the catch of reproductive females, similar to Camp Dawson, but in contrast to HNF. Differences in sex ratios of red bats have been attributed to migratory patterns (LaVal and LaVal 1979), but in West Virginia, Brack et al. (2002) found an inverse relationship between reproductive females and elevation; higher elevations are cooler, wetter, and have more variable temperatures. Ford et al. (2001), looking at museum specimens, found that male eastern red bats dominated in the Appalachian Highlands where mean monthly temperature in June fell below 28.5°C.

The catch of eastern red bats was insufficient to test for evenness of catch over the evening sample period, but at Ravenna, Clermont County, Ohio (Brack and Finni 1987), Crane, and southern Michigan (Brack et al. 1984), the catch of eastern red bats was not concentrated in any portion of the night.

Table 4. Capture success during the present study compared to similar studies in woodland habitats in the eastern and midwestern United States.

	Bats/Net night	Bats/Net site	Species Diversity Index*	Source
Potter & McKean Co., PA	2.9	12.1	2.3	
Ravenna, OH	2.4	9.7	2.9	Brack and Duffy 2006
Camp Dawson, WV	1.4	6.1	4.0	Brack et al. 2005
Crane, IN	1.8	5.6	4.4	Brack and Whitaker 2004
HNF, IN	2.1		4.3	Brack et al. 2004
Ft. Leavenworth, KS	2.9	9.4	1.6	Brack et al. 2007

* SDI = $1/\sum P_i^2$ (MacArthur 1972)

Hoary bat.—This summer woodland resident is not considered common anywhere in Pennsylvania (Richmond and Rosland 1949; Roslund 1951; Doutt et al. 1977; Merritt 1987), or elsewhere throughout its very wide geographic distribution (Whitaker and Hamilton 1998). Only four individuals, three of them juveniles, were caught in the present study, providing evidence of reproduction in the project area. This bat was caught at 6% of sites. Similarly, Hart et al. (1993) in southcentral Pennsylvania, caught hoary bats at 6.1% of sites they netted, but echolocation calls were detected at 38.5% of survey sites, which may indicate the species is not readily captured using typically-employed techniques.

The hoary bat is a seasonal migrant, and is likely absent during winter months (Whitaker and Hamilton 1998). Early studies considered the hoary bat a moth specialist (Black 1972), although this was not the case in Clermont County, Ohio (Brack and Finni 1987), Crane, or in other portions of Indiana (Brack 1985), which may reflect the wide distribution of the species and use of a variety of habitats.

Little brown myotis.—Although the little brown myotis is one of the most widespread species in North America, its abundance varies considerably from locality to locality. In this study, it was the most frequently caught species, but was not caught at the most sites, which may be related to multiple captures near large maternity colonies this species often forms. Captures of reproductive females and juveniles were more clumped than were captures of adult males, but more adult males than reproductive females were captured. However, a great many non-reproductive females were caught late in the summer, which may reflect an inability to accurately identify late-season post-reproductive females, especially individuals who birthed earlier or who lost young. Alternatively, numerous non-reproductive females might be present if females did not breed their first year, although Humphrey and Cope (1976) indicated that in Kentucky and Indiana, females did breed their first season. If non-reproductive females are included, the difference between males (n = 140) and females (n = 98) remains significant (χ^2 = 7.41, P = 0.006). Brack et al. (2002) found that reproductive females were less common than males at higher elevations in Pennsylvania, Virginia, and West Virginia. During summer, higher latitudes and elevations typically are cooler and wetter, and temperatures at higher elevations are more variable, adding significantly to the cost of reproduction. On Crane, the catch of adult males was greater than that of reproductive females, although no such disparity was apparent at nearby HNF or at Ravenna.

Adult little brown myotis and combined adult and juvenile little brown myotis were caught more frequently late in the season, which has implications when sampling for rare or uncommon species, such as the endangered congenera Indiana bat. At Ravenna, capture of little brown myotis did not vary across the season. Catch was also greater late in the evening, which was again in contrast to Ravenna.

The little brown myotis is sometime considered more common along streams and near bodies of water, and in this study was caught disproportionately often in riparian habitat, similar to HNF. Although the little brown myotis exhibits a great deal of variation in its diet, it often feeds on aquatic insects, reflecting use of this habitat. It is loosely described as a dipteran-lepidopteran-coleopteran feeder (Belwood and Fenton 1976; Buchler 1976; Anthony and Kunz 1977; Brack and Whitaker 2004). Characteristics of the echolocation call (Broders et al. 2004) and wing morphology (Arita and Fenton 1997) both indicate that this species of *Myotis* is more adapted to feeding in a less cluttered environment, such as over water, than are the closely related northern myotis and Indian bat.

Northern myotis.—The northern myotis is a common component of the woodland chiropterafauna of much of eastern North America. Summer maternity colonies are usually under sloughing bark or in cracks of trees (Lacki and Schwierjohann 2001). Although similar numbers of reproductive females and males were caught on Ravenna, Camp Dawson, and HNF, in the present study, the catch of adult males was greater than that of reproductive females. Males (n = 130) were also more common (χ^2 = 24.08, P = 0.000) than all females (n = 62). In some portions of its range, females are more common at higher elevations (Brack et al. 2002), and females were more common on Crane. In summer, disparity in numbers of adult males versus adult females for many woodland species of bats may arise because maternity colonies may be located in different habitats or geographic areas (Brack and Whitaker 2002; Cryan 2003). During autumn swarming, numbers of males and females may vary over time and is likely related to synchrony of mating and timing for entering into winter hibernation (LaVal and LaVal 1980; Brack et al. 2005).

In this study, northern myotis were caught more often in early evening, late in the season, and in upland habitat. In Missouri and Indiana, the northern myotis was active throughout the night and was more abundant at non-riparian sites (Brack and Whitaker 2001). Similarly, on Camp Dawson, the northern myotis was more commonly caught early in the evening and at upland sites, and capture was greatest at upland sites on HNF. Use of terrestrial-based habitat is reflected in the diet. In Missouri and Indiana, lepidopterans were most important in the diet, followed by coleopterans, trichopterans, and dipterans (Brack and Whitaker 2001). Spiders, probably consumed while gleaning, were the second most important food in the diet on Crane, and may be taken from the ground (Kirkland 1997).

Many similarities and differences in species diversity, relative abundance, reproduction and relative abundance of the sexes, periods of night time and seasonal activity, and use of habitat were found when comparing this investigation to studies in other wooded areas of the eastern United States. It is apparent that there are many things we still do not know about how these species live and interact, or about the plasticity of their ecology across the wide ranges they inhabit.

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LITERATURE CITED

Agosta, S. J. 2003. Diet of the big brown bat, Eptesicus fuscus, from Pennsylvania and western Maryland. Northeastern Naturalist 10:89–104.

Anthony, E. L. P. and T. H. Kunz. 1977. Feeding strategies of the little brown bat, *Myotis lucifugus*, in southern New Hampshire. Ecology 58:775–786.

Arita, H. T. and M. B. Fenton. 1997. Flight and echolocation in the ecology and evolution of bats. Trends Ecol. Evol. 12:53–58.

Belwood, J. J. and M. B. Fenton. 1976. Variation in the diet of *Myotis lucifugus* (Chiroptera: Vespertilionidae). Can. J. Zool. 54:1674–1678.

Black, H. L. 1972. Differential exploitation of moths by the bats *Eptesicus fuscus* and *Lasiurus cinereus.* J. Mamm. 53:598–601.

Brack, V. Jr. 1985. The foraging ecology of some bats in Indiana. Proc. Indiana Acad. Sci. 94:231–237.

Brack, V. Jr. and J. Duffey. 2006. Bats of Ravenna Training and Logistics Site, Portage and Trumbull counties, Ohio. Ohio J. Sci. 106:186–190.

Brack, V. Jr. and G. R. Finni. 1987. Mammals of southern Clermont County, Ohio, with notes on the food habits of four species of bats. Ohio J. Sci. 87:130–133.

Brack, V. Jr., J. D. Kiser Jr., J. Schwierjohann, and L. B. Williams. 2005. Bats of Camp Dawson, West Virginia: relative abundance, habitat use, and periods of activity. Proc. West Virginia Acad. Sci.77:1–6.

Brack, V. Jr. and R. K. LaVal. 1985. Food habits of the Indiana bat in Missouri. J. Mamm. 66:308–315.

Brack, V. Jr., R. J. Reynolds, W. Orndoroff, J. Zokaites, and C. Zokaites. 2005. Bats of Skydusky Hollow, Bland County, Virginia. Virginia J. Sci. 56:93–106.

Brack, V. Jr., L. Robbins and C. R. Davis. 2007. Bats of Fort Leavenworth Military Reservation and nearby areas of eastern Kansas and western Missouri. Transaction Kansas Acad. Sci. 110:73–82.

Brack, V. Jr., C. W. Stihler, R. J. Reynolds, C. Butchkoski and C. S. Hobson. 2002. Effects of climate and elevation on distribution and abundance in the Midwestern United States. Pp. 28–36, in The Indiana Bat: Biology and Management of an Endangered Species (A. Kurta, and J. Kennedy, eds.). Bat Conservation International. Austin, TX, 253 pp.

Brack, V. Jr., S. Taylor and V. R. Holmes. 1984. Bat captures and niche partitioning along select portions of three rivers in southern Michigan. Michigan Academician 16:391–399.

Brack, V. Jr. and J. O. Whitaker Jr. 2001. Foods of the northern myotis, *Myotis septentrionalis*, from Missouri and Indian, with notes on foraging. Acta Chiropterologica 3:203–210.

Brack, V. Jr. and J. O. Whitaker Jr. 2004. Bats of the Naval Surface Warfare Center at Crane, Indiana. Proc. Indiana Acad. Sci. 113:66–75.

Brack, V. Jr., J. O. Whitaker Jr. and S. E. Pruitt. 2004. Bats of Hoosier National Forest. Proc. Indiana Acad. Sci. 113:76–86.

Braun, E. L. 1950. Deciduous forests of eastern North America. The Blackburn Press (reprinted 2001), Caldwell, NJ, 596 pp.

Broders, H. G., C. S. Findlay and L. Zheng. 2004. Effects of clutter on echolocation call structure of Myotis septentrionalis and M. lucifugus. J. Mamm. 85:273–281.

Brown, R. J. and V. Brack Jr. 2003. An unusually productive net site over an upland road used as a travel corridor. Bat Res. News 44:187–188.

Buchler, E. R. 1976. Prey selection by *Myotis lucifugus* (Chiroptera: Vespertilionidae). Amer. Midl. Nat. 110:619–628.

Cryan, P. M. 2003. Seasonal distribution of migratory tree bats (*Lasiurus* and *Lasionycteris*) in North America. J. Mamm. 84: 579–593.

Doutt, J. K., C. A. Heppenstall and J. E. Guilday. 1977. Mammals of Pennsylvania, 9th edition. Pennsylvania Game Commission. Harrisburg, PA, 288 pp.

Duchamp, J. E., D. W. Sparks and J. O. Whitaker, Jr. 2004. Foraging-habitat selection by bats at an urban–rural interface: comparison between a successful and a less successful species. Can. J. Zool., 82:1157–1162.

Fike, J. 1999. Terrestrial & palustrine plant communities of Pennsylvania. Pennsylvania Natural Diversity Inventory, Department of Conservation and Natural Resources, Harrisburg, PA, 79 pp.

Ford, W. M., M. A. Menzel and J. A. Menzel. 2001. Influence of summer temperature on sex ratios in eastern red bats (*Lasiurus borealis*). Amer. Midl. Nat. 147:179–184.

Hall, J. S. and F. J. Brenner. 1968. Summer netting of bats at a cave in Pennsylvania. J. Mamm. 49:779–781.

Hart, J. A., G. L. Kirkland Jr. and S. C. Grossman. 1993. Relative abundance and habitat use by tree bats, *Lasiurus* spp., in southcentral Pennsylvania. Can. Field-Nat. 107: 208–212.

Humphrey, S. R. and J. B. Cope. 1976. Population Ecology of the little brown bat, *Myotis lucifugus*, in Indiana and North-central Kentucky. 1976. American Soc. Mammalogists Spec. Pub. 4:1–81.

Kirkland, G. L., Jr. 1997. Possible ground-foraging by the northern long-eared bat, *Myotis septentrionalis*. Bat Research News 38:90.

Lacki, M. J., and J. H. Schwierjohann. 2001. Day-roost characteristics of northern bats in mixed mesophytic forest. J. Wildl. Manag. 65:482–488.

LaVal, R. K., and M. L. LaVal. 1979. Notes on reproduction, behavior, and abundance of the red bat *Lasiurus borealis*. J. Mamm. 60:209–212.

LaVal, R. K., and M. L. LaVal. 1980. Ecological studies and management of Missouri bats, with species. Missouri Dept. Conserv. Terr. Series 8:1–53.

MacArthur, R. H. 1972. Geographical ecology. Harper and Row. New York, NY, 269 pp.

Merritt, J. F. 1987. Guide to the mammals of Pennsylvania. University of Pittsburgh Press. Pittsburgh, PA, 387 pp.

PDCNR (Pennsylvania Department of Conservation and Natural Resources). 2000. Physiographic Provinces of Pennsylvania [Online]. Available at: http//www.dcnr.state.pa.us/topogep (Accessed 20 September 2005).

Richmond, N. D. and H. R. Rosland. 1949. Mammal survey of northwestern Pennsylvania. Pennsylvania Game Commission. Harrisburg, PA, 67 pp.

Roslund, H. R. 1951. Mammal survey of northcentral Pennsylvania. Pennsylvania Game Commission. Harrisburg, PA, 55 pp.

Walters, B. L., D. W. Sparks, J. O. Whitaker Jr. and C. M. Ritzi. 2006. Timing of migration by eastern red bats (*Lasiurus borealis*) through central Indiana. Acta Chiropterologica 8:259–263.

Whitaker, J. O. Jr. 1972. Food habits of bats from Indiana. Can. J. Zool. 50:877–883.

Whitaker, J. O. Jr. 1995. Food of the big brown bat *Eptesicus fuscus* from maternity colonies in Indiana and Illinois. Amer. Midl. Nat. 134:346–360.

Whitaker, J. O., Jr., and V. Brack Jr. 2002. *Myotis sodalis* in Indiana. Pages 53–59 In The Indiana bat: Biology and Management of an Endangered Species (A. Kurta and J. Kennedy, eds.). Bat Conservation International, Austin, Texas, 239 pp.

Whitaker, J. O. Jr. and W. J. Hamilton Jr. 1998. Mammals of the eastern United States. Cornell University Press. Ithaca, NY, 583 pp.

Whitaker, J. O. Jr., R. K. Rose and T. M. Padgett. 1997. Food of the red bat, *Lasiurus borealis*, in winter in the Great Dismal Swamp, North Carolina and Virginia. Amer. Midl. Nat. 137:408–411.

Yahner, R. H. 2003. Terrestrial vertebrates in Pennsylvania: status and conservation in a changing landscape. Northeast Naturalist 10:343–360.

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EVALUATING THE USE OF FAIRMOUNT DAM FISH PASSAGE FACILITY WITH APPLICATION TO ANADROMOUS FISH RESTORATION IN THE SCHUYLKILL RIVER, PENNSYLVANIA[1]

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ABSTRACT

Many anadromous fish stocks throughout Atlantic slope drainages have been decimated because of the construction of dams. Prior to the creation of the Fairmount Dam in 1820, migratory species, such as American shad (*Alosa sapidissima*), striped bass (*Morone saxatilis*) and river herring (alewife, *Alosa pseudoharengus* and blueback herring, *A. aestivalis*) enjoyed unimpeded movement throughout the Schuylkill River drainage as far upstream as Pottsville, Pennsylvania (160 rkm). In 1979, a vertical slot fish passage facility was constructed on the west side of Fairmount Dam. However, very few anadromous species were utilizing the passage and by 1984 fish restoration activities were diverted to other drainages within the Delaware River basin. Between 2002 and 2006 the Philadelphia Water Department directed its monitoring efforts above and below the Fairmount Dam fishway. In 2004, 6,438 fish of 23 species ascended the Fairmount Dam fishway, including 91 American shad, 161 striped bass, and 2 river herring. A total of 8,017 fishes representing 25 species were counted passing through the fishway in 2005, including 41 American shad, 127 striped bass, and 5 river herring. In 2006, a total of 16,850 fishes representing 26 species were counted passing through the fishway including 345 American shad, 9 hickory shad, 61 striped bass, and 7 river herring. Electrofishing sampling results between 2004 and 2006 showed *A. sapidissima*, *A. aestivalis* and *A. pseudoharengus* were the dominant species below Fairmount Dam during spring, with peak assemblage contributions in 2006. The interannual trend in relative abundance of American shad below Fairmount Dam increased, as did overall shad passage trends in the fishway. Results also suggest that photoperiod may play a critical roll in movement through the fish passage facility, although additional physiochemical signals can not be ruled out at this time. With expected rehabilitation efforts on the Fairmount Dam fishway to begin in 2008, this study as well as future monitoring activities will be important components in measuring the efficacy of anadromous fish restoration activities within the Schuylkill River watershed.

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INTRODUCTION

Pennsylvania has a rich history of substantial spring runs of anadromous fishes. Nowhere was this more apparent than in the Philadelphia region, where centuries of annual American shad (*Alosa sapidissima*) migrations helped shape the natural, cultural and economic heritage of the area (Hallock 1894). The Schuylkill River, the largest tributary to the Delaware River, supported large numbers of American shad until the construction of dams in the early 1800's. Historical records indicate that shad and river herring (alewife *Alosa pseudoharengus* and blueback herring *A. aestivalis*) ascended the Schuylkill River as far upstream as Pottsville (160 rkm), but have not done so since 1820, when Fairmount Dam was built (Mulfinger and Kaufmann 1981). The dam served as a physical barrier to migratory fishes, completely blocking upstream movement and access to critical spawning grounds. In the years to follow, eight more dams were erected and unregulated industrial pollution into the Schuylkill River resulted in the demise of anadromous fishes in the Schuylkill River.

For more than 150 years, American shad appeared to have been extirpated from the Schuylkill drainage (Sykes and Lehman 1957). However, in the 1970's, Pennsylvania Fish and Boat Commission (PFBC) biologists documented the presence of American shad in the tidal reach of the Schuylkill River below Fairmount Dam. Subsequent surveys by PFBC revealed that river water quality and habitat in the Schuylkill River could again support a substantial population of American shad as well as other anadromous fishes, provided that fish passage was created at the Fairmount Dam (Mulfinger and Kaufmann 1981). In 1979, with funding from the City of Philadelphia, United States Fish and Wildlife Service (USFWS), and PAFBC, a vertical slot fish passage facility was constructed on the west side of Fairmount Dam. During the first few years of operation, Fairmount Dam fishway was heavily used by resident fish populations; however, very few American shad or river herring were successfully ascending the fishway (Mulfinger and Kaufmann 1981). Since none of the upstream dams were passable and few anadromous fishes were passing at Fairmount, the fishway was no longer actively maintained or monitored, and by 1984 restoration efforts refocused on the Lehigh River, an upstream tributary to the Delaware River. No fish counts were conducted from 1984 to 2004, until the Philadelphia Water Department (PWD) took responsibility for maintenance and operation of the fishway and developed a digital video monitoring system to record fish passage. An underwater viewing room and window allow direct observation of fishes swimming through the fishway.

The primary means for evaluating fish passage and anadromous fish restoration efforts is recorded video of fish moving past the viewing window. The recorded video allows frame-by-frame analysis to identify and enumerate species ascending and descending the fishway. These quantitative data of diversity and abundance of fish are compared to river electrofishing data in order to determine passage utilization. Monitoring fish passage will allow us to establish the size of the American shad run and compare those numbers to the upstream passage facilities and other fishways on the Delaware River. The U.S. Fish and Wildlife Service has estimated that the Schuylkill River has adequate habitat to support 700,000 to 800,000 American shad and that 200,000 to 250,000 American shad per year may utilize Fairmount fishway during upstream migration (USFWS 1999). The only way to verify the utilization and efficiency is by video recording actual fish passage at the viewing window.

As the most downstream passageway, the Fairmount Dam fishway is especially critical to the overall success of restoring migratory fish runs in the Schuylkill River watershed. American shad annually migrate from mixed stock assemblages in the open oceans to their natal freshwater streams and rivers to spawn (Talbot and Sykes 1958; Walburg 1960; Carscadden and Leggett 1975; Glebe and Leggett 1981). Shad fidelity to their spawning river is thought to be high, and spawning populations are genetically distinct (Bentzen et al. 1989; Nolan et al. 1991; Epifanio et al. 1995). Therefore, all planned upstream fish passage projects will be affected by the success or failure of the Fairmount Dam fishway at passing migratory species during spawning runs. Moreover, successful colonization and gene flow (i.e., genetic transference) of resident species is highly contingent upon minimizing the effects of fish barriers on movement (Albanese et al. 2004). Resident fish species within the Schuylkill drainage should benefit from the enhanced potential to reach suitable spawning and nursery habitat, and from a larger forage base provided by juvenile anadromous species.

This study describes the temporal variation of migratory and resident fish assemblages of the tidal Schuylkill River and their utilization of the Fairmount Fishway during the spring migratory period. We report on the abundance and interannual variation of fishes in the tidal Schuylkill River during spring migration, as well as temporal variability of fish passage utilization. In order to evaluate the progress of anadromous fish restoration, we examine the relationship between relative abundance downstream of Fairmount Dam and annual fish passage counts at the fishway.

MATERIALS AND METHODS

Site Description and History

The Schuylkill River, the largest tributary of the Delaware River Basin, is located in Southeastern Pennsylvania and is approximately 198 km in length from its headwaters in Pottsville, Schuylkill County to its confluence with the Delaware River in Philadelphia, Pennsylvania (Figure 1). Fairmount Dam is positioned 13.6 km upstream from the Delaware confluence and represents the boundary between tidal and non-tidal influences on the Schuylkill River. The Fairmount Dam Fishway is situated within the City of Philadelphia on the western bank of the Schuylkill River in Fairmount Park, Philadelphia (Figure 2).

A municipally-owned facility, the Fairmount Dam is 304.8 m in length with a crest elevation of approximately 3.2 m. Completed in 1821, the Fairmount Dam provided a source of drinking water as well as a pumping system for the distribution of water throughout the city of Philadelphia. However, this structure also prevented passage of fish from 1818 until 1979. Initiated in 1977 and completed in 1979, the Fairmount Dam Fishway provided a means of upstream dispersal of resident and migratory fishes. However, due to design and maintenance limitations, the function and efficiency of the Fairmount Dam Fishway has been an area of concern among fisheries biologists. Recently, the Philadelphia Water Department and the United States Army Corps of Engineers (USACE) have partnered in the restoration effort of the fishway with construction anticipated to begin in spring 2008.

Monitoring Techniques

Tidal Fish Assessments

Temporal variation of resident and migratory fish assemblages inhabiting the tidal portions of the Schuylkill River were assessed through standardized electrofishing techniques (Moulton et al. 2002). Electrofishing surveys were conducted three to four times per month from April 1st to July 1st, between 2002 and 2006. A Smith-Root gas-powered pulsator (GPP) portable electrofisher with two anode booms and adjustable umbrella arrays were mounted to a 17 ft aluminum flat bottom boat (model Grumman). Power to the GPP was supplied by a Honda gas generator and electrical current was regulated by a foot control switch.

Due to the unique physical and hydrologic conditions found directly below the Fairmount Dam, slight modifications in boat handling and collection techniques were applied. To ensure safe boat operation and maximize capture efficiency, surveys were conducted in an upstream fashion during low tide. Four fixed stations between the Fairmount Dam and Spring Garden Street Bridge were standardized based on sampling time (i.e., Catch Per Unit Effort) (Figure 3).

Fish were temporarily stunned by administering 2–4 amps direct current (DC) at a frequency of 60 pulse/sec.

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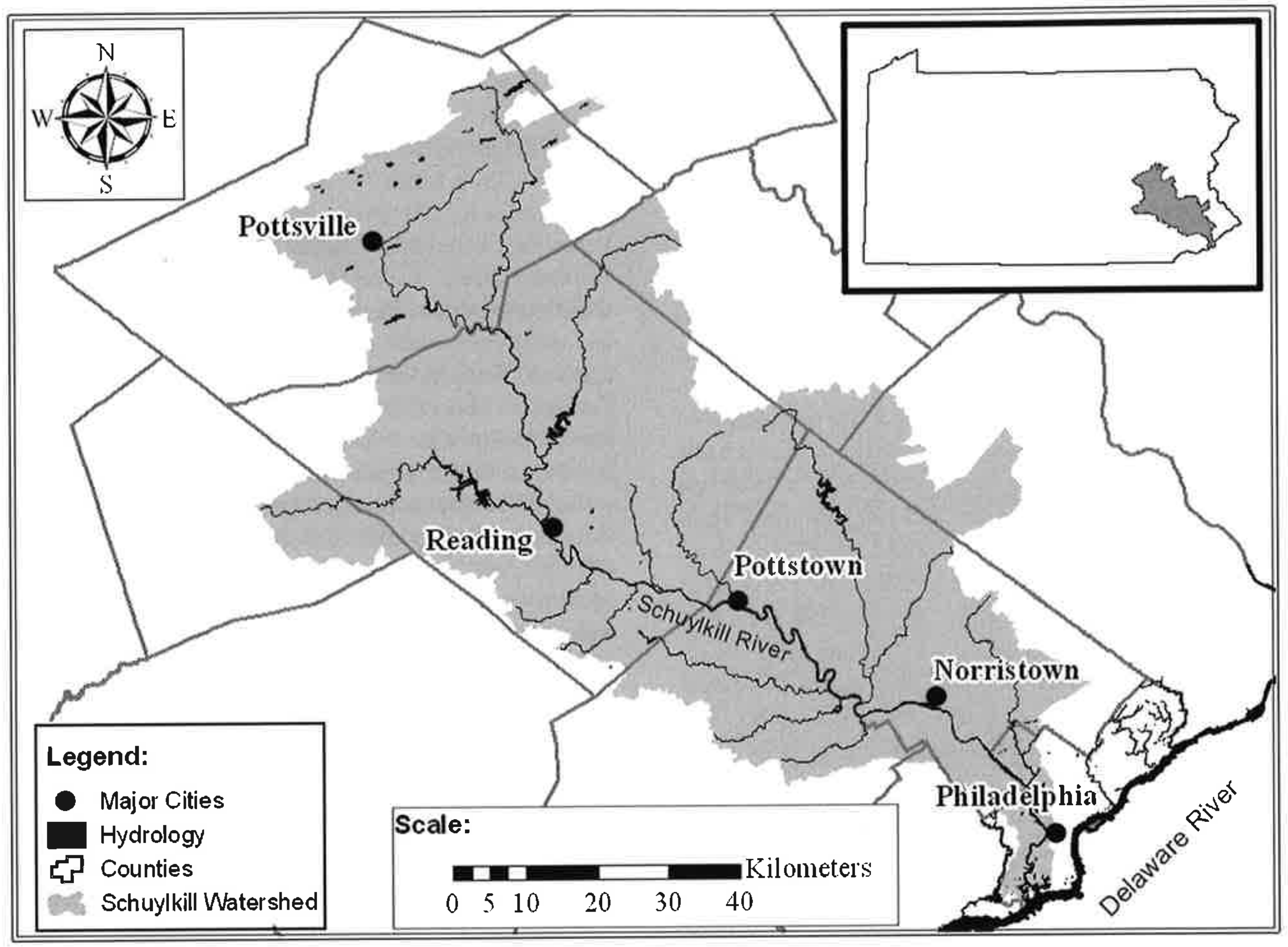

Figure 1. Regional map of the Schuylkill River Watershed located in Southeastern Pennsylvania.

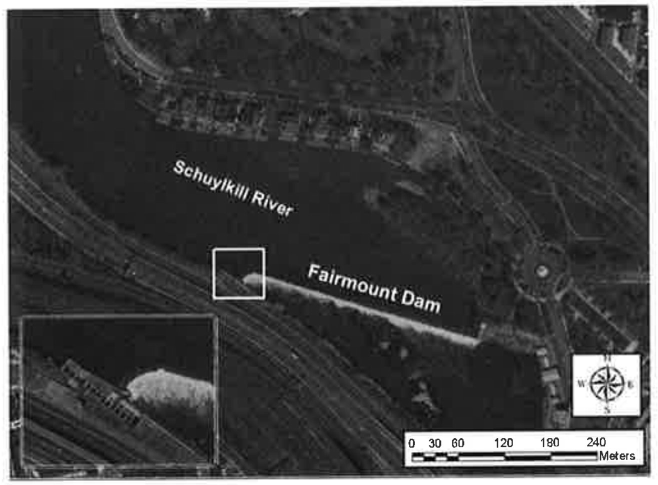

Figure 2. Aerial view of Fairmount Dam and vertical slot fishway (left insert) located on the west bank of the Schuylkill River at river km 13.6, Philadelphia, Pennsylvania.

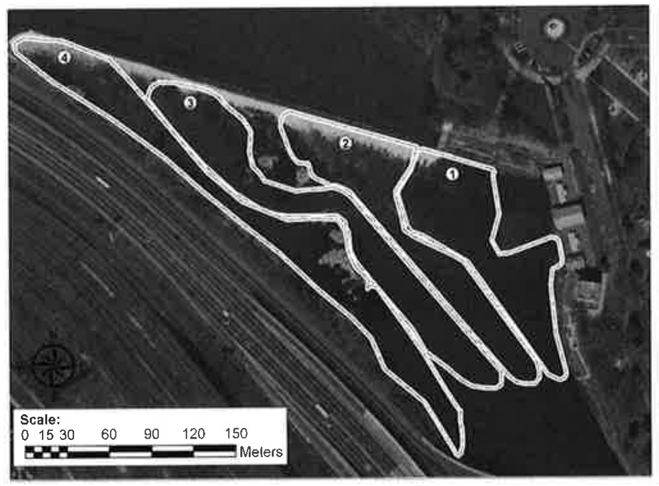

Figure 3. Aerial view of electrofishing stations on the Schuylkill River at Fairmount Dam. Each polygon represents separate sampling locations.

Fish were collected using non-conductive fiberglass nets (ca. 1/2" aperture), placed in a 380 liter aerated tank, and observed for any signs of mortality. Upon completion of a single pass, fish were identified to species, total length (cm) was measured, and fish were subsequently released downstream. Because sampling efficiency was not consistently effective for young-of-the-year (YOY) fish, all individuals less than 20 mm were not included in the sample results. Moreover, to reduce mortality, American shad (*Alosa sapidissima*) and hickory shad (*Alosa mediocris*) were minimally handled through immediate identification in the water or after netting, and placement downstream of the electrofishing boat.

Video Monitoring

A video monitoring program was established in 2003 to assess fish passage at the Fairmount fishway and determine temporal variability of fish assemblages inhabiting the lower Schuylkill River. Video monitoring protocols remained consistent over the three-year period and required continuous operation of the camera system (i.e., 24 h) from April 1 until July 1. The monitoring program utilized an IQeye™ digital video camera (San Clemente, CA) and OnSSI™ surveillance recording system (Suffern, NY) software to capture images of all fishes swimming past an underwater viewing window. The network-based digital video management system contains motion detection functions which only recorded when an object passed in front of the viewing window. All fish captured on video were identified to species, time stamped (i.e., h:m:s) and dispersal direction (i.e., upstream vs. downstream) was recorded.

Analyses

Assessments below the Fairmount Fishway focused on interannual variations in fish assemblages inhabiting the tidal Schuylkill River during the spring migration period (i.e., April 1st–July 1st). Total number of species captured during electrofishing surveys was used as a richness index for each year. Diversity was calculated using the Shannon-Wiener Index (*H'*), a metric that is not highly affected by sample size and that considers the relative abundance of each species to determine the diversity value (Magurran, 2004). *H'* was calculated using the following equation:

$$H' = -\sum p_i \ln p_i, \quad (1)$$

where $p_i = n_i/N$.
The evenness index (E) was derived from the Shannon-Weiner Index (*H'*) and was calculated using the following equation:

$$E = H'/\ln S \quad (2)$$

where S = total number of species.

In addition to interannual fish assemblage comparisons, temporal variation of *A. sapidissima* and *A. mediocris* during migration were also measured in terms of relative abundance (Equation 3).

$$\textbf{Catch Per Unit Effort (CPUE)=}$$
$$\textbf{No. of individuals captured x min}^{-1} \quad (3)$$

Diurnal patterns of fish passage usage by migratory species (*A. sapidissima*, *A. mediocris*, *A. aestivalis*, *A. pseudoharengus* and *Morone saxatilis*) were also measured between 2004–2006. Six daily periods were defined as follows: 1 (00:00 h to 3:59 h); 2 (04:00 h to 07:59 h); 3 (08:00 h to 11:59 h); 4 (12:00 h to 15:59 h); 5 (16:00 h to 19:59 h), and 6 (20:00 h to 23:59 h).

RESULTS

Tidal Fish Assessments

Table 1 summarizes fish collection results during electrofishing surveys from 2002 to 2006. In 2002, a total of 1728 fish representing 23 species were collected during spring sampling events (Table 2). Species diversity was greatest in 2002 (*H' = 2.38*) and a more evenly distributed fish assemblage (E = 0.68) was represented when compared to all of the sampling years (i.e., 2003–2006). Gizzard shad (*Dorosoma cepedianum*), quillback (*Carpoides cyprinus*) and common carp (*Cyprinus carpio*) were dominant contributors to community structure during this period (24.6%, 11.8% and 10.9% contribution, respectfully). Migratory species, such as *A. sapidissima*, represented only 3.6% of the fish assemblage while striped bass (*Morone saxatilis*) contributed approximately 9.6% of the total community structure. Resident sunfish species (*Lepomis auritus*, *L. gibbosus* and *L. macrochirus*) and channel catfish (*Ictalurus punctatus*) were also significant contributors to fish assemblage structure below the Fairmount Dam (9.1% and 8.3%, respectfully).

Sampling results in 2003 revealed that *D. cepedianum* and *C. cyprinus* were again significant contributors to the fish community structure (29.0% and 13.5%, respectfully). However, alosine species (*A. sapidissima*, *A. aestivalis* and *A. pseudoharengus*) comprised a majority of the fish assemblage, representing 42.3% of the community structure between 5/1/03 and 7/1/03. Similarly, sampling results between 2004 and 2006 showed *A. sapidissima*, *A. aestivalis* and *A. pseudoharengus* were the dominant species below Fairmount Dam during spring, with peak assemblage contributions in 2006 (62.7%). The marked increase in migratory species during the five-year study, however, must not overshadow the substantial decrease in certain resident populations or the presence of invasive predatory species in the tidal portions of the Schuylkill River. During 2002, sunfish species (*L. auritus*, *L. macrochirus*, and *L. gibbosus*) represented 9.1% of the fish community; however, sampling results during 2003–2006 revealed a substantial decrease in the presence of all sunfish species, with only a mean percent contribution of 0.2% ± 0.1%. Moreover, electrofishing surveys in 2006 demonstrated the presence of flathead catfish (*Pylodictis olivaris*) in tidal portion of the Schuylkill River. Although the current numbers of *P. olivaris* may not indicate an immediate threat to resident and migratory species, their presence does warrant continued monitoring to ascertain their effects on fish community structure in the Schuylkill drainage (Brown et al. 2005).

Table. 1. Fish collection counts by species below the Fairmount Dam, Schuylkill River, during spring monitoring, 2002–2006.
**Alosa sp.* include both *A. aestivalis* and *A. pseudoharengus*. ***Lepomis sp.* include all sunfish that were not identified to species.

Species		**2002**		**2003**		**2004**		**2005**		**2006**	
Scientifc Name	**Common Name**	**Number (n)**	**Percent Contribution (%)**	**Number (n)**	**Percent Contribution (%)**	**Number (n)**	**Percent Contribution (%)**	**Number (n)**	**Percent Contribution (%)**	**Number (n)**	**Percent Contribution (%)**
Alosa mediocris	hickory shad	0	0.0	0	0.0	4	0.2	120	4.2	51	1.0
Alosa sapidissima	American shad	63	3.6	535	32.0	470	26.6	1047	36.2	1950	38.0
*Alosa. sp**	herring*	97	5.6	173	10.3	261	14.8	12	0.4	1215	23.7
Ambloplites rupestris	rock bass	0	0.0	1	0.1	0	0.0	1	0.0	0	0.0
Anchoa mitchilli	bay anchovy	3	0.2	0	0.0	0	0.0	0	0.0	1	0.0
Anguilla rostrata	American eel	35	2.0	26	1.6	39	2.2	65	2.2	40	0.8
Catostomus commersoni	white sucker	107	6.2	44	2.6	56	3.2	193	6.7	67	1.3
Carassius auratus	goldfish	1	0.1	0	0.0	0	0.0	0	0.0	0	0.0
Carpiodes cyprinus	quillback	204	11.8	226	13.5	145	8.2	310	10.7	337	6.6
Cyprinella spiloptera	spotfin shiner	0	0.0	0	0.0	0	0.0	0	0.0	5	0.1
Cyprinus carpio	common carp	189	10.9	26	1.6	221	12.5	237	8.2	306	6.0
Dorosoma cepedianum	gizzard shad	425	24.6	485	29.0	387	21.9	275	9.5	592	11.5
Esox lucius x Esox masquinongy	tiger muskellunge	0	0.0	0	0.0	1	0.1	0	0.0	1	0.0
Hybognathus regius	eastern silvery minnow	13	0.8	0	0.0	0	0.0	0	0.0	0	0.0
Ictalurus punctatus	channel catfish	146	8.4	48	2.9	37	2.1	134	4.6	178	3.5
Lepomis auritus	redbreast sunfish	3	0.2	3	0.2	6	0.3	1	0.0	3	0.1
Lepomis gibbosus	pumpkinseed sunfish	4	0.2	5	0.3	7	0.4	4	0.1	1	0.0
Lepomis macrochirus	bluegill sunfish	6	0.3	3	0.2	3	0.2	4	0.1	11	0.2
*Lepomis sp***	Lepomis sp**	144	8.3	0	0.0	1	0.1	5	0.2	13	0.3
Menidia beryllina	inland silverside	1	0.1	0	0.0	0	0.0	0	0.0	0	0.0
Micropterus dolomieui	smallmouth bass	74	4.3	19	1.1	7	0.4	15	0.5	67	1.3
Micropterus salmoides	largemouth bass	21	1.2	28	1.7	5	0.3	16	0.6	37	0.7
Morone americana	white perch	8	0.5	2	0.1	0	0.0	197	6.8	42	0.8
Morone saxatilis	striped bass	166	9.6	40	2.4	102	5.8	153	5.3	127	2.5
Morone saxatilis x Morone chrysops	hybrid striped bass	0	0.0	0	0.0	1	0.1	14	0.5	4	0.1
Notropis amoenus	comely shiner	0	0.0	0	0.0	0	0.0	0	0.0	1	0.0
Notropis hudsonius	spottail shiner	0	0.0	0	0.0	0	0.0	2	0.1	1	0.0
Oncorhynchus mykiss	rainbow trout	0	0.0	0	0.0	0	0.0	1	0.0	0	0.0
Perca flavesins	yellow perch	7	0.4	3	0.2	3	0.2	14	0.5	22	0.4
Pomoxis nigromaculatus	black crappie	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Pylodictis olivaris	flathead catfish	0	0.0	0	0.0	0	0.0	0	0.0	3	0.1
Salmo trutta	brown trout	3	0.2	1	0.1	1	0.1	1	0.0	0	0.0
Sander vitreus	walleye	8	0.5	6	0.4	7	0.4	69	2.4	58	1.1
	Total (N)	1728		1674		1764		2890		5133	

Table 2. Fish community metrics for electrofishing surveys below Fairmount Dam during spring migration (2002–2006).

Metrics	**Year**				
	2002	**2003**	**2004**	**2005**	**2006**
Total (N)	1728	1674	1764	2890	5133
Species Richness	23	19	21	24	26
Shannon Index (H')	2.39	1.85	2.03	2.18	1.92
Evenness (E)	0.68	0.53	0.58	0.62	0.55

Video Monitoring Assessments

Table 3 summarizes the fish passage results from 2004 to 2006. In 2004, there were 6,438 fish of 23 species that ascended Fairmount fishway. Anadromous fishes utilized the fishway and accounted for 3.9% of the total spring passage through the fishway, including 91 American shad, 161 striped bass, and 2 river herring. American shad were observed passing by the viewing window from April 24 to June 25; striped bass were observed from April 26 to June 30; and river herring were observed from May 2 to May 15. Whereas the presence of hickory shad (*Alosa mediocris*), another anadromous species, was documented in the Schuylkill River below Fairmount Dam by electrofishing surveys, *A. mediocris* was not observed ascending the fishway in 2004. Channel catfish and quillback were the numerically dominant species and accounted for 56.3% of total spring fish passage. White suckers (*Catostomus commersoni*), common carp, and gizzard shad were also abundant in the fishway during the spring migration.

A total of 8,017 fish representing 25 species passed through the fishway in 2005, a 20% increase in fish passage by both resident and migratory species compared to 2004. Anadromous fishes accounted for 2.2% of total spring fish passage including 41 American shad, 127 striped bass, and 5 river herring. Despite the increase in total fish passage during 2005, there were decreases in numbers of two anadromous species

Table 3. Fish passage counts by species at the Fairmount Dam Fishway, Schuylkill River, Pennsylvania, during spring monitoring. Species status codes are as follows: NA = native anadromous; NC = native catadromous; NR = native resident; IR = introduced resident; and I = introduced.

Scientific Name	**Common Name**	**Status**	**2004^a Number Passed**	**2005^b Number Passed**	**2006^c Number Passed**
Alosa mediocris	hickory shad	NA	0	0	9
Alosa sapidissima	American shad	NA	91	41	345
Ameiurus catus	white catfish	NR	6	1	6
Ameiurus spp.	bullhead catfish	NR	0	0	2
Ambloplites rupestris	rock bass	IR	0	1	0
Anguilla rostrata	American eel	NC	32	70	34
Catostomus commersoni	white sucker	NR	731	1767	2887
Carpiodes cyprinus	quillback	NR	1807	2042	2631
Ctenopharyngodon idella	grass carp	I	2	0	1
Cyprinella analostana	satinfin shiner	NR	0	2	0
Cyprinus carpio	common carp	IR	401	1197	2215
Dorosoma cepedianum	gizzard shad	NR	691	553	2899
Ictalurus punctatus	channel catfish	IR	1816	1663	3421
Lepomis auritus	redbreast sunfish	NR	13	3	4
Lepomis gibbosus	pumpkinseed sunfish	NR	0	7	1
Lepomis macrochirus	bluegill sunfish	IR	22	147	276
Lepomis species	unknown sunfish		72	10	2
Micropterus dolomieui	smallmouth bass	IR	143	124	1225
Micropterus salmoides	largemouth bass	IR	11	10	42
Morone americana	white perch	NR	55	105	112
Morone saxatilis	striped bass	NA	161	127	61
Morone saxatilis x Morone chrysops	hybrid striped bass	IR	20	16	48
Oncorhynchus mykiss	rainbow trout	I	7	13	16
Pylodictis olivaris	flathead catfish	IR	68	43	466
Alosa aestivalis or pseudoharengus	River Herring	NA	2	5	7
hybrid trout	hybrid trout	I	0	8	40
Salmo trutta	brown trout	I	4	7	5
Sander vitreus	walleye	IR	57	33	84
	unknown		172	14	11
	unknown catfish		12	0	0
	unknown minnow		3	7	0
	unknown shad		32	0	0
	unknown trout		7	1	0
TOTAL			6438	8017	16850

[a] Power outages to the viewing room and video monitoring system resulted in 362 hours of lost video data.
[b] Power outages and data corruption of digital video files resulted in 337 hours of lost video data.
[c] Severe river flooding forced us to evacuate all video monitoring equipment from the viewing room and resulted in 168 hours of lost video data.

(*A. sapidissima* and *M. saxatilis*). The increase in total fish passage in 2005 was mainly from increased abundance of *C. commersoni*, *C. cyprinus*, *C. carpio*, and *Morone americana.*

Through video surveillance in 2005, American shad were observed passing by the viewing window from April 18 to June 28; striped bass were documented from May 11 to June 30; and river herring were observed from April 8 to June 18. River herring were the only anadromous fishes to increase in abundance from 2004 to 2005. Five resident species (*C. cyprinus*, *C. commersoni*, *D. cepedianum*, *I. punctatus*, and *C. carpio*) constituted 90.1% of fish passage during the spring migration. Moreover, there were several species documented in 2005 that were not represented in 2004, such as rock bass (*Ambloplites rupestris*), satinfin shiner (*Cyprinella analostana*), and pumpkinseed sunfish (*L. gibbosus*).

In 2006, a total of 16,850 fish representing 26 species were counted passing through the fishway, a two-fold increase in fish passage numbers when compared to 2005. Also, American shad passage increased 279.1 % from 2004 to 2006 and 741.5% from 2005 to 2006. Anadromous fishes accounted for 2.5% of total spring fish passage including 345 American shad, 9 hickory shad, 61 striped bass, and 7 river herring. *A. sapidissima* were observed passing by the viewing window from April 11 to June 6; *M. saxatilis* were documented from May 14 to June 24; *A. aestivalis* and *A. pseudoharengus* were counted from May 2 to June 20. In addition, 9 hickory shad passed through Fairmount fishway during a three day period (i.e., May 3 to May 6). This is the first confirmed passage of hickory shad, an endangered species in Pennsylvania, above Fairmount Dam in recorded history for the Schuylkill River. There is no reference to hickory shad in early historical fisheries accounts for the Delaware Estuary in Pennsylvania (Majumdar et al. 1986).

Similar to the previous years, *C. commersoni*, *C. cyprinus*, *C. carpio*, *D. cepedianum*, and *I. punctatus* were extremely abundant in the fishway, accounting for 83.4% of total fish passage in 2006. New records of fish passage were also documented for hickory shad and bullhead catfish (*Ameiurus sp.*) while previous recordings of rock bass and satinfin shiner (*C. analostana*) were not observed in 2006.

During the 2004–2006 migratory periods, channel catfish (n = 6,900) and quillback (n = 6,480) were the numerically dominant species. White sucker, common carp, and gizzard shad were also relatively abundant compared to other species (Table 2). American shad, smallmouth bass (*Micropterus dolomieui*), flathead catfish, bluegill (*L. macrochirus*), and gizzard shad numbers increased dramatically from 2004 to 2006, while most species displayed relatively minor interannual fluctuations. It should be noted that redbreast sunfish (*Lepomis auritus*) and striped bass numbers decreased during the study period.

Diurnal Passage

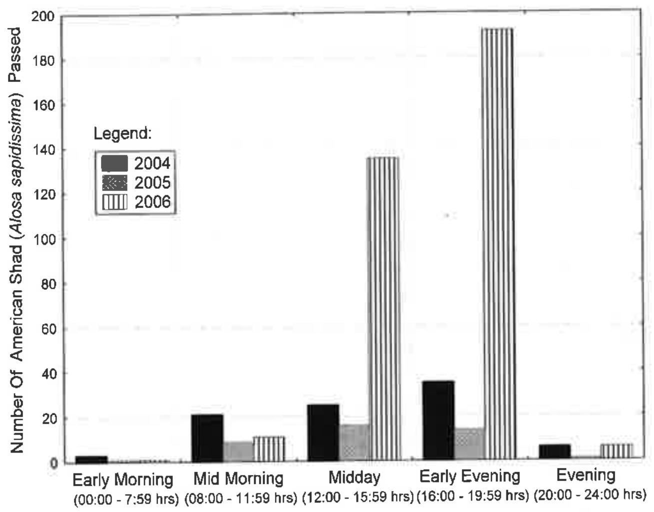

Figure 4. Diurnal pattern of passage for American shad (*A. sapidissima*) at Fairmount Dam fishway (2004–2006).

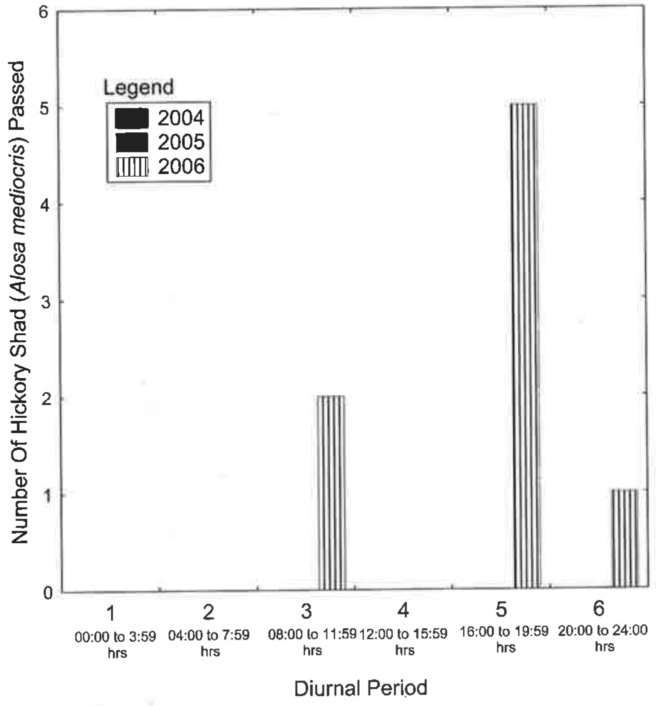

Figure 5. Diurnal pattern of passage for hickory shad (*A. mediocris*) at Fairmount Dam fishway (2004–2006).

Based on diurnal passage studies of anadromous species from 2004–2006 (Figures 4 to 7), peak passage generally occurred during periods 4 and 5, which corresponds to late morning through early evening. American shad passage was documented during each diurnal period; however, peak passage occurred from 16:00 hrs to 19:59 hrs, with a secondary peak from 12:00 hrs to 15:59 hrs (Figure 4). Hickory shad only passed during periods 3, 5, and 6, with peak passage also from 16:00 hrs to 19:59 hrs (Figure 5). Striped bass displayed a complex passage pattern, utilizing the fishway at all hours of the day, but mostly passing during the daylight hours. Peak passage for *M. saxatilis* occurred from 16:00 hrs to 19:59 hrs (Figure 6). River herring preferred utilizing the fishway during low-light hours more than any other anadromous species, with a majority of passage occurring during diurnal periods 1 and 5 (Figure 7).

Catch Per Unit Effort (CPUE)

Relative abundance of anadromous species for the tidal Schuylkill River below Fairmount Dam was collected from 2002 to 2006 (Figure 8). Catch per unit effort (CPUE) was used as an index of population (i.e., relative abundance) and expressed in the number of fish collected per minute of electrofishing. This means of normalizing data allows for interannual evaluation in trends of relative abundance as well as comparing data with state and federal fisheries agencies and among other river systems.

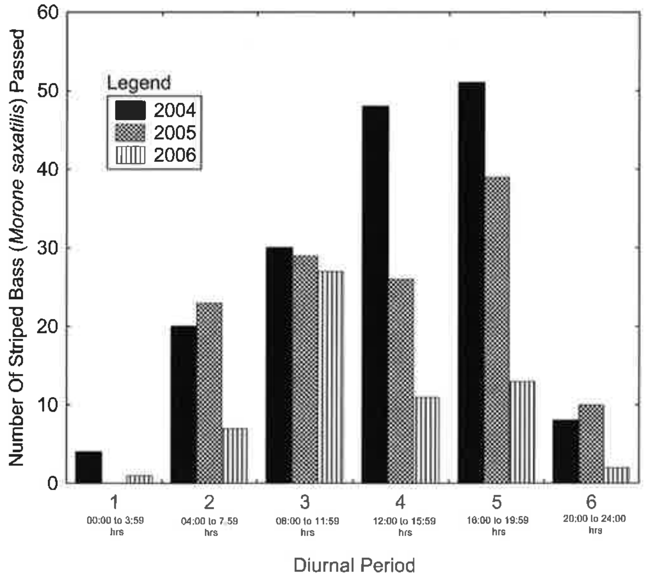

Figure 6. Diurnal pattern of passage for striped bass (*Morone saxatilis*) at Fairmount Dam fishway (2004–2006).

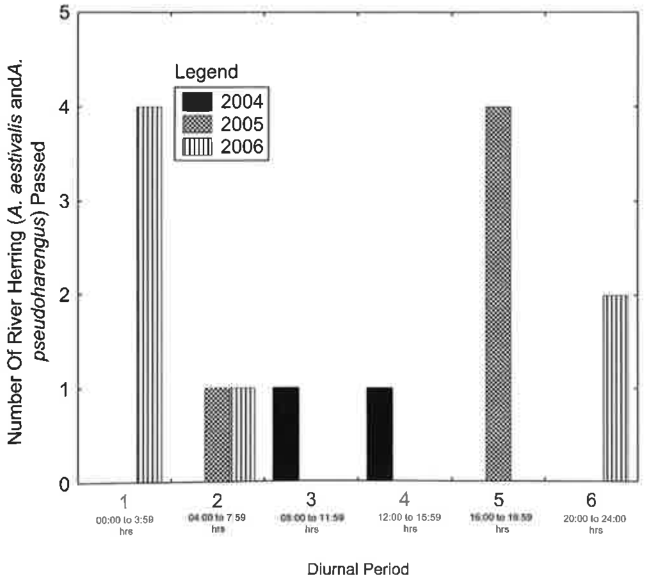

Figure 7. Diurnal pattern of passage for river herring (*Alosa aestivalis* and *A. pseudoharengus*) at Fairmount Dam fishway (2004–2006).

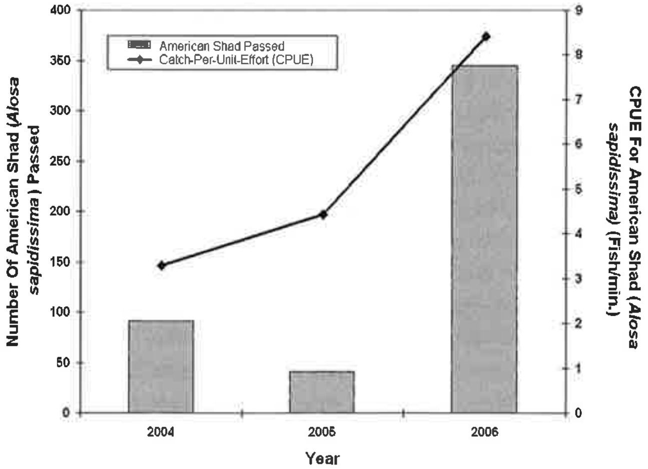

Figure 8. Interannual trends of adult American shad (*Alosa sapidissima*) in relative abundance (CPUE) below Fairmount Dam and fish passage (2004–2006).

During the study period, the increasing trend in relative abundance of American shad below Fairmount Dam was correlated with the general increasing trend in American shad passage at the fishway. CPUE for *A. sapidissima* increased from 3.29 in 2004 to 8.42 in 2006 (Figure 8). Similar trends in passage of *A. sapidissima* were also observed, with 91 American shad (*A. sapidissima*) passing through the ladder in 2004 and 345 passing in 2006. The decrease in American shad passage from 2004 to 2005 was most likely due to lost video data rather than an actual decrease in fish passage. Power outages to viewing room and video monitoring system resulted in 362 hours of lost video data in 2004, 337 hours in 2005 and 168 hours in 2006. While the number of hours lost in 2004 was greater than in 2005, video data corruption in 2005 occurred at expected peak passage times (i.e., mid-May) for American shad. The loss of video from these critical days in 2005 suggests that actual passage numbers of *A. sapidissima* were higher than recorded.

DISCUSSION

The tidal reach of the Schuylkill River serves as a vital conduit for resident and migratory fish species within the Delaware River basin. Nowhere is this more evident than at the Fairmount Dam fishway. The Fairmount Dam fishway acts as a gateway to the rest of the Schuylkill River, allowing upstream dispersal of both migratory and resident fishes. Without access to critical spawning habitat above the dam, the long-term sustainability of migratory fish populations within the Schuylkill Drainage may not be feasible. Based on this study, it is evident that the Schuylkill River supports a relatively diverse fish assemblage composed of various native anadromous, catadromous, and resident fishes, as well as introduced species, several of which have become established. More importantly, video surveillance has revealed that both resident and migratory species readily ascend the Fairmount Dam fishway. Weaver et al. (2003) showed similar results in their study of the James River, implying that resident species ascending the fishway may result in additional ecological benefits to the river and its tributaries.

During our three-year study, a total of twenty-six species of fish, as well as several hybrid species, were documented using the fishway during spring migrations. Anadromous fishes, such as American shad, hickory shad, striped bass, and river herring, frequently utilized the fishway for passage above the dam, and the presence of juvenile alewife upstream of the fishway in 2005–2006 suggests that quality spawning and nursery habitats still exist above Fairmount Dam. Moreover, fish passage counts for adult American shad show a discernable increase during the three-year period and although the numbers are significantly lower than historical records, fish surveys below Fairmount Dam indicate increasing trends in fish density during spring migrations.

Analysis of diurnal passage patterns revealed that the majority of anadromous species utilized the fishway during daylight periods (i.e., 12:00 and 19:59 hours), with some species specific variation. These findings corroborate with those of Weaver et al. (2003) at a James River vertical slot fishway in Virginia and Arnold (2000) at two Lehigh River vertical slot fishways in Pennsylvania. Our findings suggest that photoperiod may be one of the primary factors triggering upstream dispersal of migratory fish through the Fairmount Dam fishway; however, additional studies on physicochemical variables (e.g., temperature) and biotic interactions (e.g., predation) may need to be addressed before a definitive conclusion can be made.

This study represents the first detailed examination of fish community structure and fish ladder utilization by resident and anadromous species in the lower Schuylkill River Drainage in approximately twenty years. More specifically, Mulfinger and Kauffmann (1981) showed that annual American shad counts did not exceed twenty-two (n=22), while the current study documented a maximum of 345 American shad in 2006. Moreover, only one striped bass was observed passing through the fishway from 1979 to1984; whereas, 349 striped bass passed between 2004 to 2006. During this period, significant improvements in water quality have been made, while ecosystem-based restoration strategies, including dam removals and fish passage restorations, within the Schuylkill River basin have only recently been addressed. Currently, the Philadelphia Water Department and the United States Army Corps of Engineers have joined resources to restore the Fairmount Dam fishway, with construction efforts planned to commence in 2008. The Pennsylvania Fish and Boat Commission have also begun to refocus their efforts of American shad restoration by strengthening their shad fry stocking program in the Schuylkill River. In addition, there are several proposed plans for either fish passage facilities or dam removals for the remaining barriers on the Schuylkill River, with an ultimate goal of providing 160 kilometers of vital upstream habitat for resident and migratory species.

While the current restoration strategies along the Schuylkill River continuum may have a synergistic effect on the success of resident and migratory fishes, it is imperative that emphasis be placed on the largest, and perhaps, most important fishway. The fish passage facility at Fairmount Dam must be redesigned and built to optimize fish passage, otherwise precious resources and current restocking programs will have been wasted (Weaver et al., 2003). Preliminary results from our study indicate that proper operation, maintenance, and monitoring of the fishway may have a critical role in reestablishing anadromous fish populations throughout the Schuylkill River watershed. Although the total number of anadromous fish passed between 2004–2006 is relatively low, this interannual trend will serve as a baseline for pre-restoration efforts and will allow scientists to gauge the success of this fishway and future ecosystem-based activities within the Schuylkill River drainage.

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LITERATURE CITED

Albanese, B., P. L. Angermeier, and S. Dorai-Raj. 2004. Ecological correlates of fish movement in a network of Virginia Streams. Canadian Journal of Fisheries and Aquatic Sciences 61: 857–869.

Arnold, D. A. 2000. Lehigh River American shad: the first six years. Pennsylvania Angler and Boater 69(3):18–20.

Bentzen, P., G. G. Brown, and W. C. Leggett. 1989. Mitochondrial DNA polymorphism, population structure, and life history variation in American shad (*Alosa sapidissima*). Canadian Journal of Fisheries and Aquatic Sciences 46:1446–1454.

Brown, J. J., J. A. Perillo, T. J. Kwak and R. J. Horwitz. 2005. Implications of *Pylodictis olivaris* (flathead catfish) introduction into the Delaware and Susquehanna drainages. Northeastern Naturalist 12(4): 473–484.

Carscadden, J. E., and W. C. Leggett. 1975. Life history variation in population of American shad, *Alosa sapidissima*, spawning in tributaries of the St. John River, New Brunswick. Journal of Fish Biology 7:595–609.

Epifanio, J. M., P. E. Smouse, C. J. Kobak, and B. L. Brown. 1995. Measuring mitochondrial DNA divergence among populations of American shad (*Alosa sapidissima*): how much variation is enough for mixed-stock analysis? Canadian Journal of Fisheries and Aquatic Sciences 52:1688–1702.

Glebe, B. D., and W. C. Leggett. 1981. Latitudinal differences in energy allocation and use during the freshwater migrations of American shad (*Alosa sapidissima*) and their life history consequences. Canadian Journal of Fisheries and Aquatic Sciences 38:806–819.

Hallock, C. 1894. When Shad were a Penny A-Piece. Transactions of the American Fisheries Society: Vol. 23, No. 1 pp. 18–21

Magurran, A. E. 2004. Measuring biological diversity. Oxford: Blackwell Science.

Majumdar, S. K., F. J. Brenner, and A. F. Rhoads, editors. 1986. Endangered and Threatened Species Programs in Pennsylvania and other States: Causes, Issues and Management. The Pennsylvania Academy of Science, pp. 518.

Moulton, S. R., J. G. Kennen, R. M. Goldstein, and J. A. Hambrook. 2002. Revised protocols for sampling algal, invertebrate, and fish communities as part of the National Water-Quality Assessment Program. U.S. Geological Survey Report 02-150.

Mulfinger, R. M., and M. Kaufmann. 1981. Fish passage at the Fairmount fishway in 1979 and 1980 with implications for the Schuylkill River fisheries through future fishway construction. Pages 101–124 in Proceeding of The Schuylkill River Symposium, The Academy of Natural Sciences of Philadelphia. September 24 and 25, 1980.

Sykes, J. E., and B. A. Lehman. 1957. Past and present Delaware River shad fishery and considerations for its future. U.S. Fish and Wildlife Service. Res. Rep. No. 46. 25 pp.

Talbot, G. B., and J. E. Sykes. 1958. Atlantic coast migrations of American shad. U.S. Fish and Wildlife Service Fishery Bulletin 58:473–490.

United States Fish and Wildlife Service. 1999. Restoring anadromous fishes to the Schuylkill River basin. Fact Sheet.

Walburg, C. H. 1960. Abundance and life history of shad, St. John's River, Florida. U.S. Fish and Wildlife Service Fishery Bulletin 177:487–501.

Weaver, L. A., M. T. Fisher, B. T. Bosher, M. L. Claud, and L. J. Koth. 2003. Boshers Dam vertical slot fishway: a useful tool to evaluate American shad recovery efforts in the upper James River. American Fisheries Society Symposium 35:323–329.

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IDENTIFICATION OF *STAPHYLOCOCCUS* SPP. AND AEROBIC GRAM-NEGATIVE BACTERIA FROM THE CLOACAE OF MIGRATORY SHOREBIRDS (FAMILY *SCOLOPACIDAE*) FROM DELAWARE BAY, NEW JERSEY[1]

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ABSTRACT

A survey was conducted of the bacterial flora of migratory shorebirds from Delaware Bay, NJ. Fifty-four birds were sampled on 18 May, 2004 at Fortescue Beach, NJ and 37 birds were sampled on 20 May, 2004 at Reed's Beach, NJ. The sampled shore birds included 38 red knots (*Calidris canatus*), 16 dunlins (*Calidris alpina*), 9 ruddy turnstones (*Arenaria interpres*), 18 semipalmated sandpipers (*Calidris pusilla*), and 10 sanderlings (*Calidris alba*). Twenty-four different bacterial species were identified, 15 were identified to species and 9 were identified to genus. Organisms isolated included *Vibrio fluvialis*, *Staphylococcus aureus*, *Staphylococcus warneri*, *Staphylococcus sciuri*, *Staphylococcus xylosus*, *Staphylococcus hominus*, *Micrococcus* spp., *Escherichia coli*, *Enterobacter sakazakii*, *Enterobacter cloacae*, *Serratia liquifaciens*, and *Pseudomonas* spp. A total of 19 different bacteria were isolated from red knots, 11 from dunlins, 7 from ruddy turnstones, 10 from semipalmated sandpipers, and 6 from sanderlings.

[J PA Acad Sci 83(1): 34–37, 2009]

INTRODUCTION

The Delaware Bay is one of the largest gatherings of migratory shorebirds on the East Coast and is the second largest gathering in North America (Clark et al. 1993). The Delaware Bay stopover is an important staging area for shorebirds migrating from wintering sites in and around South America to Arctic and sub arctic breeding areas (Botten et al. 1994). Delaware Bay is located along the east coast, at the southern border of New Jersey and the northern border of Delaware (38°47'N to 39°20'N and 74°50'W to 75°30'W) (Clark et al. 1993). The migrating shorebirds arrive at the Delaware Bay from mid-May through the beginning of June and spend 10–14 days feeding mostly on horseshoe crab (*Limulus polyphemus*) eggs (Myers, 1983; Clark et al. 1993; Botten et al. 1994). The species of shorebirds at the Delaware Bay stopover include the red knot (*Calidris canutus*), which is listed as a bird of conservation concern by the US Fish and Wildlife Service (Andres, 2003).

Resident intestinal bacteria prevent potentially harmful environmental bacteria from colonizing. A dynamic balance exists between the intestinal flora, host physiology, and diet that directly influence the stability of the gut ecosystem. Identifying the normal flora of these species shorebirds is an important step in the investigation of the epidemiology of bacterial diseases within this group and related groups of birds. During their annual migrations, shorebirds can cover more then 15,000 miles and congregate in vast numbers (Andres, 2003). Migratory bird species have been shown to act as reservoirs and aide in the dispersal of a wide range of bacterial species (Hubalek, 2004). Migrating birds may play a role in the dispersal of pathogens such as *Staphylococcus aureus* and *Salmonella* spp. (Wood and Trust, 1972; Palmgren et al. 1997). Palmgren et al. (1997) reported *Salmonella typhimurium* in species of migrating gulls and *Staphylococcus aureus* was isolated from the feces of sea gulls (Wood and Trust, 1972). Numerous migratory bird species have been known to carry *Escherichia coli* including numerous antibiotic resistant strains (Kanai et al. 1981; Wallace et al. 1997). The objective of this study was to isolate and identify *Staphylococcus* spp. and aerobic Gram-negative bacteria from the cloacae of migratory birds (Family Scolopacidae) at the New Jersey side of the Delaware Bay stopover.

METHODS

Shorebirds were sampled on 18 May, 2004 at Fortescue Beach, NJ (39°14'16.29"N, 75°10'20.26"W) and 20 May, 2004 at Reed's Beach, NJ (39° 7'1.15"N, 74°53'29.44"W). The birds were captured by rocket net by personnel from the New Jersey Division of Fish and Wildlife Endangered and Nongame Species Program. Each bird was weighed and banded. The cloacae of the birds were sampled using a sterile swab (Fisher Scientific, USA). The swabs were placed into vials of tryptic soy broth (TSB). The vials of TSB were transported back to the laboratory at 4°C to reduce bacterial growth. The bird species sampled were red knots (*Calidris canatus*), dunlins (*Calidris alpina*), ruddy turnstones (*Arenaria interpres*), semipalmated sandpipers (*Calidris pusilla*), and sanderlings (*Calidris alba*).

The swabs were incubated in TSB for 24 hrs at 37°C within 20 hours of sampling. After incubation, the samples were plated onto selective media and incubated for 24 hrs at 37°C. *Staphylococcus* spp and *Micrococcus* spp. were isolated by growth on Mannitol Salt agar (MS) and identified using the API Staph system (bioMerieux Vitek, Inc. Durham, NC). Gram-negative bacteria were isolated using MacConkey's agar and identified using the API 20E (bioMerieux Vitek, Inc., Durham, NC).

RESULTS AND DISCUSSION

A total of 91 birds were sampled with 54 birds at Fortescue Beach and 37 birds at Reed's Beach, including 38 red knots, 18 semipalmated sandpipers, 16 dunlins, 10 sanderlings, and 9 ruddy turnstones.

Twenty-four species of bacteria were identified. Fifteen were identified to species and 9 were identified to genus. The number of isolates and prevalences of bacterial species isolated from the migrating birds are listed in Table 1. The most prevalent bacterial species were *Pseudomonas* spp (42%), *Micrococcus* spp (23%), *Staphylococcus sciuri* (19%), *Staphylococcus warneri* (14%), *Staphylococcus aureus* (13%), *Enterobacter cloacae* (12%), and *Escherichia coli* (11%). The following bacterial species were isolated only once: *Alcaligenes* spp., *Citrobacter freundi*, *Enterobacter sakazakii*, *Kluyvera* spp, *Salmonella* spp., *Serratia* spp., *Staphylococcus epidermidis*, *Staphylococcus hominis*, and *Pseudomonas* spp.

Enterobacter cloacae, fluorescent *Pseudomonas* spp., *Pseudomonas* spp., *Micrococcus* spp., and *S. aureus* were isolated from all five migratory bird species. The remaining bacterial species were isolated from one or more of the five bird species (Table 1). *Escherichia coli* was only isolated from the red knots and the dunlins (Table 1). *Staphylococcus sciuri* was isolated from all bird species except the sanderlings (Table 1). A total of 19 different bacteria were isolated from red knots, 11 from dunlins, 7 from ruddy turnstones, 10 from semipalmated sandpipers, and 6 from sanderlings.

All of the shorebirds sampled in this study appeared healthy at the time of collection. The shorebirds at the Delaware Bay stopover had already traveled on average 5,000 miles. The bacterial species identified during this study may represent some of the bacterial flora commonly occurring in the intestines of birds of the Family *Scolopacidae*.

Many of the bacterial species isolated during this study have been isolated from other bird species. Seagulls have been shown to act as carriers of *Salmonella* spp. (Fenlon, 1981; Quessy and Messier, 1992). Bacteria isolated from the gastrointestinal tract of other wild bird species included *Escherichia coli*, *Pseudomonas* spp. and *Staphylococcus*

Table 1: *Staphylococcus* spp. and aerobic Gram-negative bacteria identified from cloacal swabs of migratory shorebirds (Family *Scolopacidae*) from Fortescue Beach and Reed's Beach along Delaware Bay, NJ on May 18 and 20, 2004. The numbers in parentheses indicate the percentage of isolates identified.

	Number of Bacterial Isolates in Each Bird Species					
Bacterial Species	Red Knot (N = 38)	Dunlin (N = 16)	Ruddy Turnstone (N = 9)	Semipalmated Sandpiper (N = 18)	Sanderling (N = 10)	Total (N = 91)
Alcaligenes spp.	1 (3)	0	0	0	0	1 (1)
Chromobacterium spp.	1 (3)	1 (6)	0	0	1 (10)	3 (3)
Citrobacter freundi	1 (3)	0	0	0	0	1 (1)
Enterobacter cloacae	2 (5)	1 (6)	3 (33)	3 (17)	2 (20)	11 (12)
Enterobacter sakazakii	0	0	0	1 (6)	0	1 (1)
Escherichia coli	7 (18)	3 (19)	0	0	0	10 (11)
Fluorescent *Pseudomonas* spp.	1 (3)	1 (6)	2 (22)	2 (11)	2 (20)	8 (9)
Klebsiella spp.	1 (3)	0	0	0	0	1 (1)
Kluyvera spp.	1 (3)	0	0	0	0	1 (1)
Micrococcus luteus	1 (3)	0	0	0	0	1 (1)
Micrococcus spp.	12 (32)	4 (25)	1 (11)	3 (17)	1 (10)	21 (23)
Pseudomonas aurigenosa	0	1 (6)	0	0	0	1 (1)
Pseudomonas luteola	1 (3)	0	0	0	0	1 (1)
Pseudomonas putrefaciens	0	1 (6)	0	0	0	1 (1)
Pseudomonas spp.	14 (37)	6 (38)	5 (56)	8 (44)	5 (50)	38 (42)
Salmonella spp.	1 (3)	0	0	0	0	1 (1)
Serratia liquefaciens	1 (3)	0	0	1 (6)	0	2 (2)
Serratia spp.	1 (3)	0	0	0	0	1 (1)
Staphylococcus aureus	3 (8)	1 (6)	2 (22)	1 (6)	5 (50)	12 (13)
Staphylococcus epidermidis	1 (3)	0	0	0	0	1 (1)
Staphylococcus hominis	0	0	0	1 (6)	0	1 (1)
Staphylococcus sciuri	8 (21)	3 (19)	1 (11)	5 (28)	0	17 (19)
Staphylococcus warneri	5(13)	5 (31)	0	3 (17)	0	13 (14)
Staphylococcus xylosus	0	0	2 (22)	0	0	2 (2)

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spp. (Brittingham et al., 1988). Fecal surveys of flaconiformes and strigiformes identified a variety of bacterial species including *Alcaligenes* spp., *Citrobacter freundi*, *Enterobacter cloacae*, *E. coli*, *Klebsiella* spp., *Kluyvera* spp., *Pseudomonas aurigenosa*, *Serratia liquefaciens*, and *Serratia* spp. (Bangert et al., 1988). *Micrococcus luteus*, *Staphylococcus epidermidis*, and other species of *Micrococcus* and *Staphylococcus* were isolated from the intestinal tract of juvenile greater flamingos (Rollin and Baylet, 1983). *Staphylococcus sciuri*, *Staphylococcus warneri*, and *Staphylococcus xylosus* have been isolated from the conjunctiva and nasal cavity of several species of captive bustards (Silvanose et al., 2001). To our knowledge, *Chromobacterium* spp., *Enterobacter sakazakii*, and *Staphylococcus hominis* have not been previously isolated from other bird species. They have been isolated in the digestive tract of other animals such as Komodo dragons (Montgomery et al., 2002).

Some variations were observed in the flora isolated from each species of shorebird. Red knots had the most diverse bacterial flora (19 species) followed by dunlins (11 species), semipalmated sandpipers (10 species), and ruddy turnstones (7 species), with sanderlings (6 species) having the lowest number of isolated bacterial species. The differences in the number of bacterial isolates may be due to the variation in the number of each species of shorebird sampled during the study. The shorebirds share a common food source while at Delaware Bay but their over-wintering location varies by species. The red knots over winter in Argentina (Andres, 2003), dunlins winter along the Gulf of Mexico and parts of Mexico (Warnock and Gill, 1996), semipalmated sandpipers winter along the Caribbean and the Atlantic coast of South America (Harrington and Morrison, 1979), ruddy turnstones winter on Pacific Islands and the Pacific coast of North America (Andres, 2003) and sanderlings wintering grounds are widespread along the shoreline of every continent except Antarctica (Andres, 2003). The differences in flora could be related to this difference in over-wintering location and food habits during that period. Further research would be necessary to better understand these differences and potential changes that occur in the normal intestinal flora during the course of migration. *Enterobacter cloacae*, *Pseudomonas* spp., *Micrococcus* spp., and *S. aureus* were isolated from all species of shorebird in this study and could be considered part of the normal flora of these shorebirds. *Escherichia coli* and *S. sciuri* were isolated from some of the shorebird species. The bacteria isolated only once during the study (*Alcaligenes* spp., *C. freundi*, *E. sakazakii*, *Kluyvera* spp., *Salmonella* spp., *Serratia* spp., *S. epidermidis*, *S. hominis*, and multiple species of *Pseudomonas*) may be considered transient species of intestinal flora or opportunistic colonization due to fatigue or reduced immune function.

Many of the species identified in this study are known to be pathogenic in humans and animals (*Serratia* spp., *Staphylococcus aureus*, *Staphylococcus sciuri*, *Salmonella* spp., and *Pseudomonas* spp). Shorebirds congregate in vast numbers, which allows for horizontal transfer of bacteria. Hubalek (2004) reported that the stress of the migration may also cause an increase in the shedding rate of bacteria. The potential for extensive spread of these bacterial pathogens is enhanced by the large area traveled during the migrations of the shorebird hosts.

The shorebirds of Delaware Bay have a very diverse cloacal bacterial flora with 6 different groups of *Staphylococcus* spp. and 18 Gram negative rod species being identified within this study. This study is a start towards understanding the normal flora of shorebirds of the family *Scolopacidae*. These birds can act as carriers for bacteria that are pathogenic to members of *Scolopacidae*, other wildlife species and humans.

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LITERATURE CITED

Andres, B. A. 2003. Delaware Bay shorebird-horseshoe crab assessment report and peer review. U.S. Fish and Wildlife Service Shorebird Technical Committee Peer Review Panel.

Bangert, R. L., A. C. S. Ward, E. H. Stauber, B. R. Cho, and P. R. Widders. 1988. A survey of aerobic bacteria in the feces of captive raptors. Avian Dis. 32: 53–62.

Botton, M. L., R. E. Loveland, and T. R. Jacobsen. 1994. Site selection by migratory shorebirds in Delaware Bay, and its relationship to beach characteristics and abundance of horseshoe crab (*Limulus polyphemus*). The Auk 111: 605–616.

Brittingham, M. C., S. . Temple, and R. M. Duncan. 1988. A survey of the prevalence of selected bacteria in wild birds. J. Wildlife Dis. 24: 299–307.

Clark, K. E., L. J. Niles, and J. Burger. 1993. Abundance and distribution of migrant shorebirds in Delaware Bay. The Condor 95: 694–705.

Fenlon, D. R. 1981. Seagulls (*Larus* spp.) as vectors of salmonellae: an investigation into the range of serotypes and numbers of salmonellae in gull feces. J. Hyg. 86: 195–202.

Harrington, B. A. and R. I. G. Morrison. 1979. Semiplamated sandpiper migration in North America. Stud. Avian Bio. 2: 83–100.

Hubalek, Z. 2004. An annotated checklist of pathogenic microorganisms associated with migratory birds. J. Wildlife Dis. 40: 639–59.

Kanai, H., H. Hashimoto, and S. Mitsuitashi. 1981. Drug-resistance and conjugative R plasmids in *Escherichia coli* strains isolated from wild birds (Japanese tree sparrows, green pheasants and bamboo partridges). Jpn. Poultry Sci. 51: 805–808.

Montgomery, J. M., D. Gillespie, P. Sastrawan, T. M. Fredeking, and G. L. Stewart. 2002. Aerobic salivary bacteria in wild and captive komodo dragons. J. Wildlife Dis. 38: 545–551.

Myers, J. P. 1983. Conservation of migrating shorebirds: staging areas, geographic bottlenecks and regional movements. American Birds 37: 23–25.

Palmgren, H., M. Sellin, S. Bergstrom, and B. Olsen. 1997. Enteropathogenic bacteria in migrating birds arriving in Sweden. Scan. J. Infect. Dis. 29: 565–568.

Quessy, S., and S. Messier. 1992. Prevalence of *Salmonella* spp., *Campylobacter* spp. and *Listeria* spp. in ring-billed gulls (*Larus delawarensis*). J. Wildlife Dis. 28: 526–531.

Rollin, P. E., and R. Baylet. 1983. Intestinal microflora of young greater flamingos (*Phoenicopterus rubber roseus Pallas*) in the Camargue. J. Wildlife Dis. 19: 61–62.

Silvanose, C. D., T. A. Bailey, J. L. Naldo, and J. C. Howlett. 2001. Bacterial flora of the conjunctiva and nasal cavity in normal and diseased captive bustards. Avian Dis. 45: 447–451.

Wallace, J. S., T. Cheasty, and K. Jones. 1997. Isolation of Vero cytotoxin-producing *Escherichia coli* 0157:H7 from wild birds. J. App. Micro. 82: 399–404.

Warnock, N., and R. E. Gill Jr. 1996. Dunlin (*Calidris alpina*) in The Birds of North America, No. 203. Academy of Natural Sciences, Philadelphia, and The American Ornithologists' Union, Washington, D. C.

Wood, A. J., and T. J. Trust. 1972. Some qualitative and quantitive aspects of the intestinal microflora of the glancons-winged gull (*Lurus glaucescens*). Can. J. Micro. 18: 1577–1583.

Journal of the Pennsylvania Academy of Science 83(1): 38–41, 2009

MICROANATOMY OF GASTRO-INTESTINAL TRACT OF *MASTACEMBELUS ARMATUS* (LACEPEDE): A SCANNING ELECTRON MICROSCOPY STUDY[1]

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ABSTRACT

***Mastacembelus armatus* (Lacepede) have short and nearly straight gastro-intestinal tracts with loops at both ends of the stomach. It begins with the mouth and ends with the anus. The topological specialization of the internal surface of the gastrointestinal tract (oesophagus, stomach, intestine and rectum), including the buccopharynx has been investigated using a scanning electron microscope. It has been found that the floor of the buccopharynx has few taste buds and it mainly serves as a passage of respiratory water current. The main feature of the oesophagus is the presence of microridges cells and test buds. The stomach is provided with numerous folds to increase digestive surface area and is differentiated clearly into anterior cardiac and posterior pyloric stomach. The intestine is provided with zig-zag folds and maximum secretion of mucin. The internal surface of the rectum is made up of numerous irregular loop-like mucosal folds and is differentiated into anterior and posterior parts.**

[J PA Acad Sci 83(1): 38–41, 2009]

INTRODUCTION

Morphology, histology and histochemistry of the alimentary canals of teleostean fishes have received considerable attention (Chakrabarti and Sinha, 1957; Jaish, 1968; Srivastava, 1968; Sinha, 1981; Moitra, 1984; Kumar & Bohra, 2003). However, there is only limited information available on the topological characteristics of the internal surface of the gastro-intestinal tracts of teleosts (Ezeasor and Scokoe, 1980; Sinha, 1981; Moitra, 1984; Sinha and Chakrabarti, 1986a and 1986b; Choudhary, 1992).

Mastacembelus armatus (Lacepede) is one of the common eel shaped and physoclistic fish found in the muddy bottoms of Asian fresh waters. It belongs to the order *Mastacembeleformes* and family Mastacembelidae. Generally, its total length ranges between 17.8-49.0 cm and is locally called 'Baam' due to their large eel shaped body (Srivastava, 1968). The present study was therefore undertaken to elucidate the topological characteristics of the buccopharynx and gastrointestinal tract of *M. armatus* utilizing a scanning election microscope (SEM).

MATERIALS AND METHODS

Living specimens of adult *M. armatus* were collected from the eutrophic swamps and Dhars of the Kosi region, especially from Katihar and Purnea districts of North Bihar and were anaesthetized in MS 222. The Buccopharynx and gastro-intestinal tract were removed immediately after dissection and the food particles and mucus were washed out thoroughly with distilled water. The tissue of each specific regions were preserved in various concentrations of formalin, then transferred to a mixture of absolute alcohol and acetone of different concentrations, and were finally preserved in anhydrous acetone at room temperature.

The tissues were critically point dried using dry ice. The dried materials were then gold coated and studied under a Philips PSEM 500 Scanning Electron Microscope.

RESULTS

M. armatus is a carnivorous fish with a small and straight gut with single loops at both ends of the stomach. It begins at the mouth and ends at the anus (Figure 1). It is differentiated into the following distinct regions with their unique topological features of internal surface.

1. Buccopharynx

The surface of the buccopharynx is rough and consists of vascular and non-vascular areas. Few mucin droplets can also be seen scattered variably (Figure 2a).

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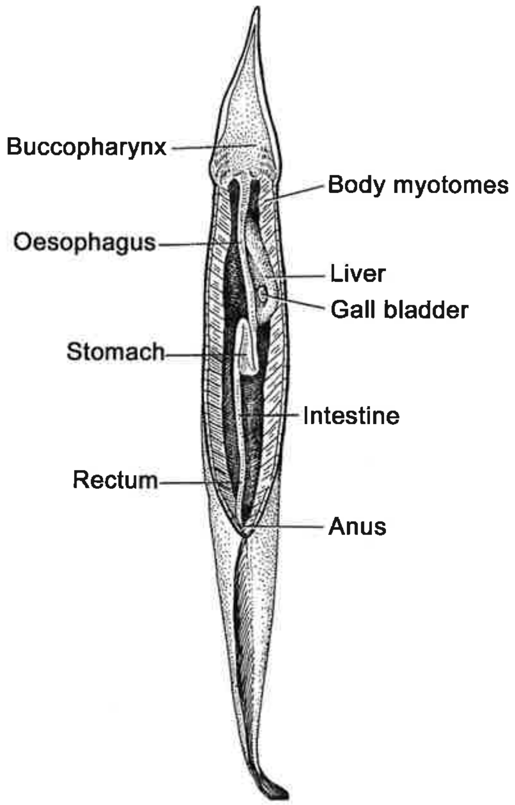

Figure 1. Gastro-intestinal tract of *Mastacembelus armatus* (Lecepede) [x.1/2 Nat. Size].

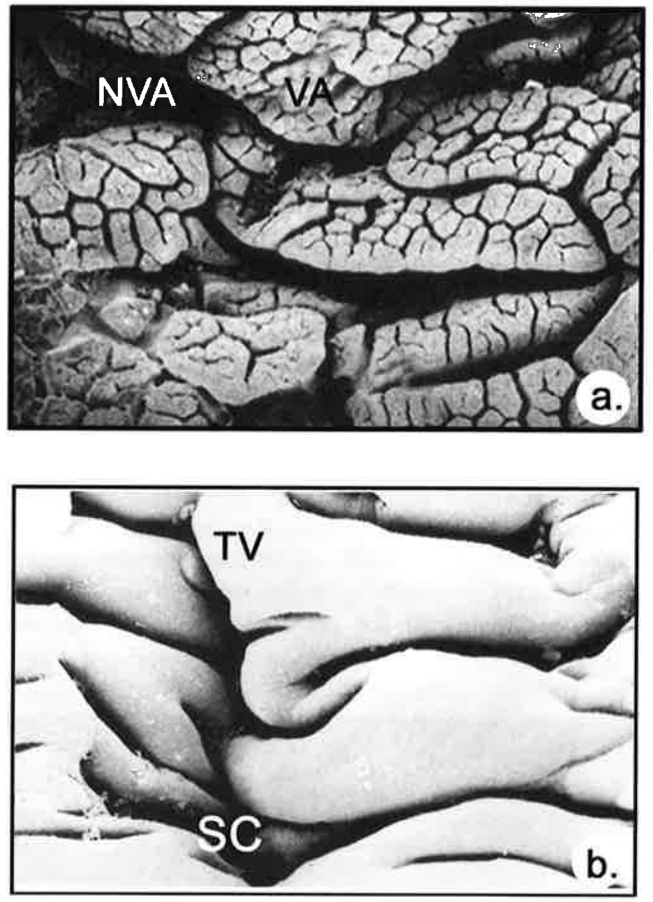

Figure 2a. SEM photograph of Buccopharynx of *Mastacembelus armatus* (Lacepede) showing vascular areas (VA) and non-vascular areas (NVA), respectively, x35. 2b. SEM photograph of Oesophagus of *M. armatus* showing vertically arranged transverse folds (TV) and shallow cavity (SC), respectively, x75.

2. Oesophagus

The entire inner surface of the oesophagus is arranged into folds. The folds are vertically arranged. Higher magnification of these folds revealed their surface to be sculptured by the microridged individual epithelial cells. Many mucous gland openings are detected (Figures 2b & 3a).

3. Stomach

The stomach consists of a large longitudinal fold along with small vertical interconnecting folds. These folds are covered with several hundreds of epithelial cell units and join one another encircling the pits of the gastric glands. The shapes and sizes of the folds and the pits of these glands are irregular. The epithelial cells are continued inside the pits. Mucin droplets are also observed here and seen sporadically (Figure 3b).

4. Intestine

The inner wall of the intestine exhibits zig-zag mucosal folds which may be recognized as primary mucosal folds. The adjacent primary mucosal folds roughly run parallel with each other throughout the entire length, thus forming a single continuous, but relatively shallow cavity. The primary mucosal folds are provided with few secondary ones. Various mucous gland openings are also observed infrequently. The surface is covered by mucus in such a way that it is difficult to recognize the epithelial cell boundaries (Figure 4a).

5. Rectum

The surface of the rectum exhibits highly irregular mucosal folds enclosing shallow cavities. In high magnification it was observed that the mucosal folds of the rectum were provided with ridges and numerous minute circular openings. The secreted mucin covers the circular openings/pores. The circular openings present in the rectum were larger in diameter, yet secreted mucin droplets were found to cover less openings. Microridges were of the same pattern as observed in oesophagus (Figures 4b, 5a & 5b).

DISCUSSION

M. armatus is a carnivorous fish for which the value of the Relative Length of Gut (RLG) is less than one. Its alimentary canal shows various degrees of differentiation of its internal mucosal topography. The internal mucosal architectural pattern was examined using a scanning electron microscope. It was revealed that structurally, the gastro-intestinal tract could be divided into buccopharynx, oesophagus, stomach, intestine and rectum.

The floor of the buccopharynx has numerous respiratory islets but few taste buds. The paucity of taste buds in the buccopharynx was observed earlier by Moitra (1984), and Choudhary (1992) in the buccopharynces of *Clarias batrachus* (Linn) and *Heteropneustes fossilis* (Bloch). The buccopharynx seems to be a passage of respiratory water current, while the presence of taste buds is evidently related to the selection of food. The mucus covering the surface aids the passage of food, and the microridged surface of the buccopharynx epithelium helps in fixing the mucus.

Under low magnifications, oesophageal surface also shows microridged cells. In some instances, the mucus glands openings are seen to be covered by the mucin.

The entire stomach is arranged into folds, which increases the digestive surface area. The mucosal folds of the stomach are vertically arranged and covered with numerous columnar epithelial cells. These folds join one another encircling the gastric gland pits. Scattered mucin droplets are also seen adhering to certain epithelial cells. Similar observations have been made by Sis et al. (1979), Ezeasor and Strokoe (1980), and Choudhary (1992) in teleosts in SEM studies. However, it has been found that the shapes and sizes of the folds and pits are dissimilar in different species.

The mucosal folds of the intestine are interconnected with each other, forming a complex zig-zag pattern. The columnar epithelial cells exhibit shallow irregular depressions and mucin droplets of varying shapes and sizes.

Highly irregular mucosal folds in the forms of loops were also observed in the rectum.

LITERATURE CITED

Chakrabarti, P. and Sinha, G. M. (1957). Mucosal surface of the alimentary canal in *Mystus vittatus* (Bloch): A Scanning Electron Microscopic Study, *Pro. Indian Nat. Sci. Scad.* B53 No. 4 PP. 317–322.

Choudhary, S. (1992). Scanning Electron Microscopic Study of the Gut Epithelium of *Heteropneustes fosslis* (Bloch). *J. Freshwater Bio.* 4 (1): 53–59.

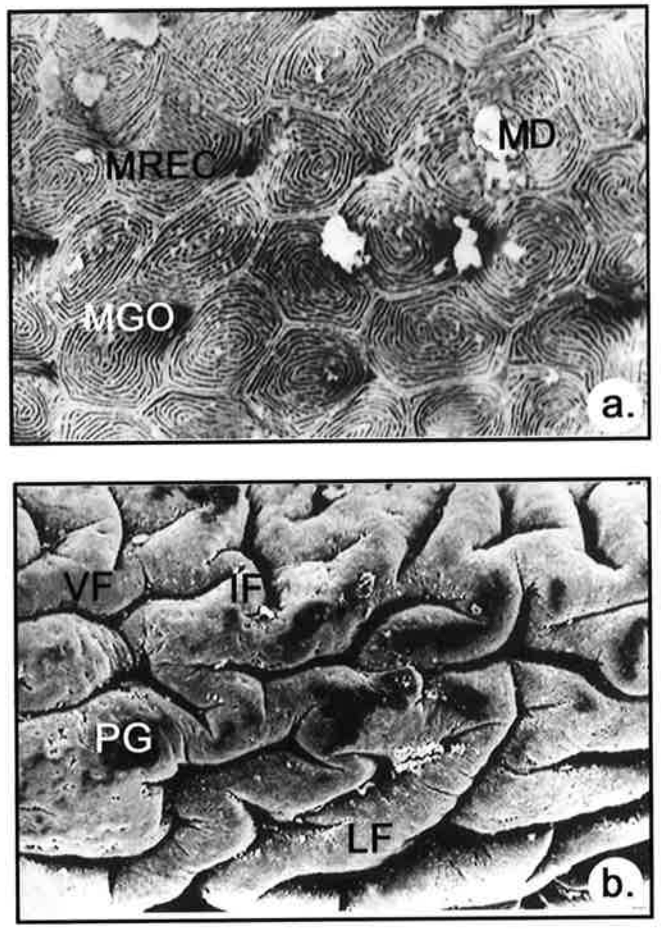

Figure 3a. SEM photograph of Oesophagus of *M. armatus* showing microridge of epithelial cell (MREC), opening of mucous gland (OMG) and mucous droplets (MD), x 2,000. 3b. SEM photograph of stomach of *M. armatus* showing longitudinal folds (LF), vertical folds (VF), interconnecting folds (IF), and pits of gastric glands (PG), x150.

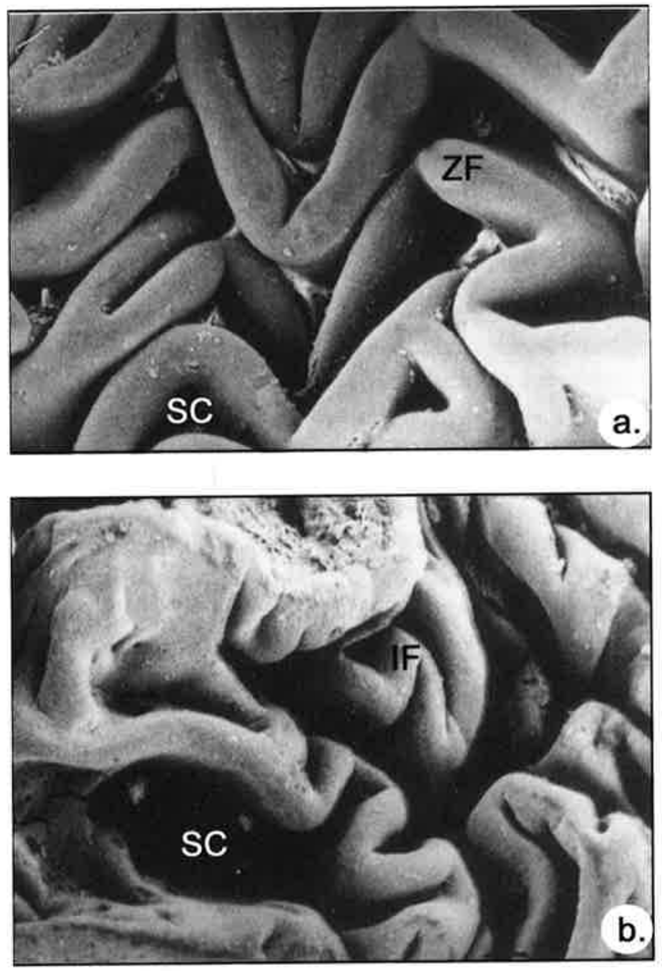

Figure 4a. SEM photograph of intestine of *M. armatus* showing zig-zag folds (ZF) and shallow cavity (SC), respectively x100. 4b. SEM photograph of rectum of *M. armatus* showing irregular folds (IRF) and shallow cavity (SC), respectively x200.

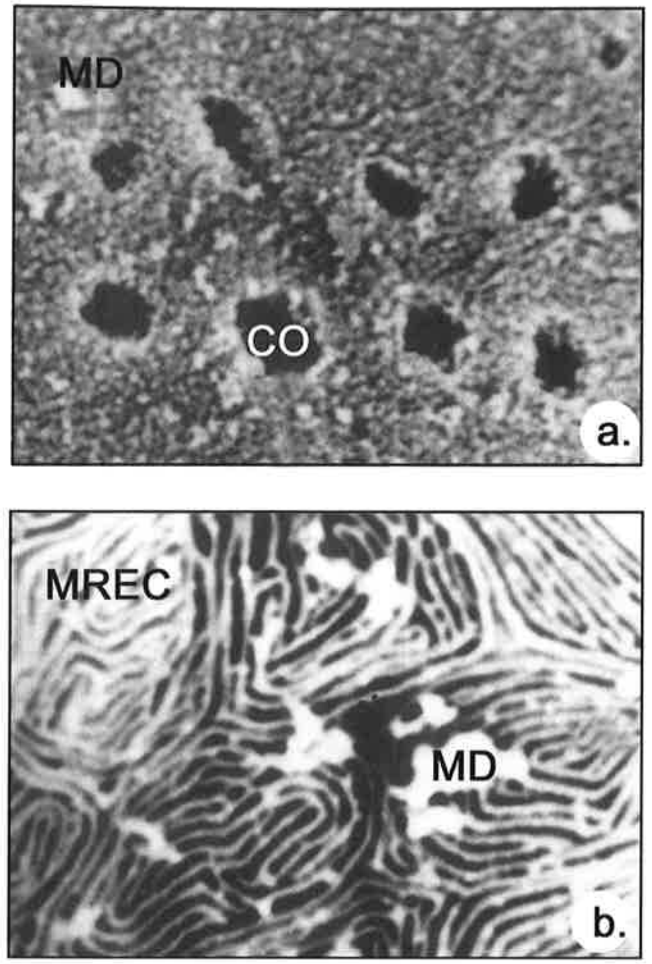

Figure 5a. SEM photograph of rectum of *M. armatus* showing many circular openings (CO) and few number of mucous droplets (MD), x2,000. 5b. SEM photograph of rectum of *M. armatus* showing microridge of epithelial cell (MREC) and mucous droplets (MD), x5,000.

Ezeasor, Daniel, N., and Scokoe, W. M. (1980). Scanning Electron Microscopic Study of the Gut mucosa of the rainbow trout *Salmo gairdneri* (Richardson). *J. Fish Biol.* 17: 529–539.

Jaish, S. C. (1968). Functional Anatomy of the Digestive Organs of Freshwater Fish, *Xenentodon cancial* (Ham.) (Beloniformes, Belonidae). *Ichthyologica*, Vol. VII (I): 1–8.

Kumar, A. and Bohra, C. (2003). Impact of ecodegradation on eco-morphology and gut anatomy of certain stream fishes of Santal Pargana (Jharkhand), India. Indian J. Environ. & Ecoplan. 10: 85–90.

Moitra, A. (1984). Structure of the alimentary canal and metabolism in relation in nutrition in certain air-breathing fish, Ph.D. Thesis, T.M.B.Univ., Bhagalpur, India.

Sinha, G. M. (1981). Scanning electron microscopy of the intestine in an Indian fresh water carp, *Cirrhinus mrigala* (Hamilton). *Inland Fish Soc. India* 13: 51–56.

Sinha, G. M. and Chakrabarti, P. (1986a). On the topological characteristics of the mucosal surface in buccopharynx and intestine of an Indian freshwater major carp, *Catla catla* (Ham.). A light and scanning electron microscopic study. *Zoo. Jh. Anat.* 113: 375–389.

Sinha, G. M. and Chakrabarti, P. (1986b). Scanning electron microscopic studies on the mucosa of the digestive tract in *Mystus aor* (Ham.) *Proc. Indian Nath, Sci. Acad.* 52: 267–273.

Sis, R. F., Ives, Jones, D. M., Lewis, D. H., and Haensly, W. E. (1979). The microanatomy of the oesophagus, stomach and intestine of channel catfish *Ictalurul punctatus. J. Fish. Biol.* 14: 179–186.

Srivastava, G. J. (1968). Fishes of U.P. and Bihar, Vishwavidyalaya Prakashan, Varanasi, India.

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RESEARCH NOTE

EXTENSIONS OF THE KNOWN RANGES OF *PERCINA SHUMARDI* GIRARD AND THREE SPECIES OF *ETHEOSTOMA* (SUBGENUS *NOTHONOTUS*) IN PENNSYLVANIA[1]

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ABSTRACT

We used Missouri benthic trawls to sample benthic fish assemblages of the Ohio River within Pennsylvania during the summer and autumn of 2007. As part of our survey, we established range extensions for four species of darters (Percidae: Etheostomatini). These included the River Darter, *Percina shumardi* Girard, which is a new species record for Pennsylvania, although it is common in lower reaches of the Ohio River. We also extended the ranges of Bluebreast Darter, *Etheostoma camurum* (Cope), Spotted Darter, *Etheostoma maculatum* Kirtland, and Tippecanoe Darter, *Etheostoma tippecanoe* Jordan and Evermann, into the Ohio River. These latter three species are classified as threatened within Pennsylvania. The expansion of the known ranges of these fishes may be due to water quality improvement in the Ohio River, or may be the result of more efficient sampling techniques. Further sampling is warranted to elucidate their full ranges within Pennsylvania.

[J PA Acad Sci 83(1): 42–44, 2009]

INTRODUCTION

Over the past several years while conducting mussel surveys, we have noted the abundance of many species of darters (Percidae: Etheostomatini) in the deep pools and runs of large rivers. These habitats are difficult to sample for small fishes; thus they have been underrepresented in ichthyological surveys. The development of the Missouri benthic trawl (Herzog et al. 2005) for sampling small benthic fishes has greatly improved the effectiveness of our sampling large riverine habitats; hence, our knowledge of the distribution and abundance of these species has increased. As a result of utilizing these sampling techniques, we extended the known ranges of the River Darter, *Percina shumardi* Girard, and three species of *Etheostoma* (subgenus *Nothonotus*) in Pennsylvania.

METHODS AND MATERIALS

We sampled the Ohio River in Pennsylvania at regular 1.0 km intervals from its formation at the confluence of the Allegheny and Monongahela rivers in Pittsburgh to the Ohio and West Virginia border (Fig. 1) in August 2007. We sampled the tailwaters of the Montgomery Dam (New Cumberland Pool) and the Dashields Dam (Montgomery Pool) in October 2007. Sampling was conducted using a Missouri benthic trawl according to the sampling protocols established by Herzog et al. (2005). Trawls were conducted in the central channel as well as near-shore, at depths ranging between 1. 5–6. 7 m. All fishes were identified in the field, with voucher specimens retained for laboratory verification.

RESULTS AND DISCUSSION

We captured a total of 35 River Darters, *Percina shumardi* (Fig. 2), from the Ohio River. We collected four individuals in the New Cumberland Pool of the Ohio River; and two individuals each at two sites located approximately 7 km and 11 km upstream from the Ohio/West Virginia border, respectively (PSU 4477, Fig. 1). Further targeted sampling revealed that their range within Pennsylvania extends at least 34 km upstream on the Ohio River to the Dashields Dam (PSU 4459, 4460, 4476).

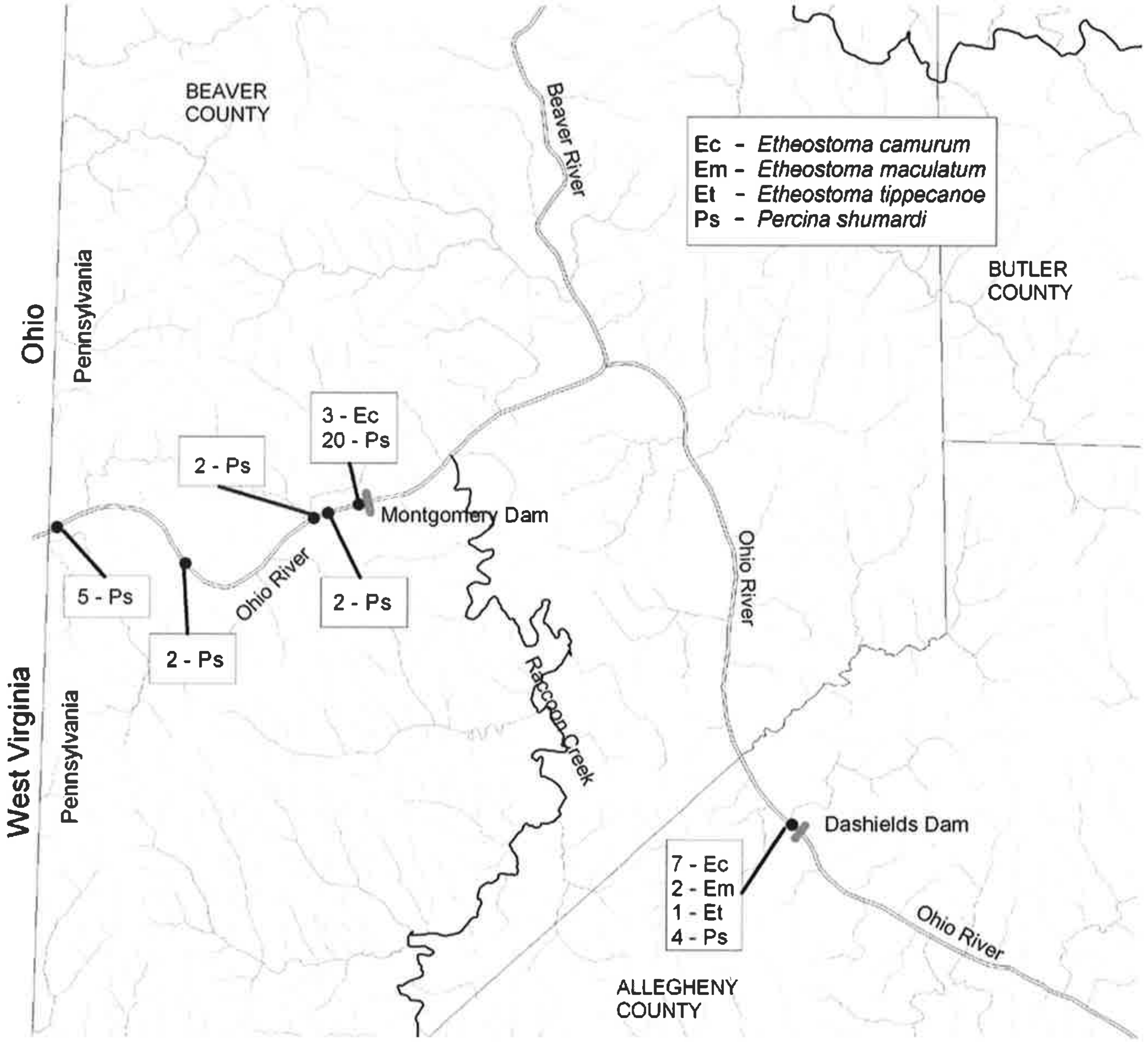

Figure 1. Map showing capture data for rare darter species caught during benthic trawl sampling of the Ohio River.

The River Darter is distributed throughout the Mississippi River drainage, and is locally abundant in the Ohio River into West Virginia and Ohio, as well as being the most common darter collected from the Mississippi River (Kuehne and Barbour 1983, Page 1983). While River Darters have never been collected from Pennsylvania prior to this study, Cooper (1983) suggested that they may be a future migrant into Pennsylvania as water quality improved. Although River Darters have been thought to be invertebrate-generalist feeders (Trautman 1981, Page 1983), it has been determined that they may also specialize in feeding on snails, similar to other species of *Percina*, subgenus *Imostoma* (Haag and Warren Jr. 2006).

River Darter habitat consists primarily of large rivers with gravel/cobble/boulder substrates and with moderate to fast currents (Scott and Crossman 1973, Trautman 1981, Cooper 1983, Page 1983), with younger individuals inhabiting shallower water. Specimens have been collected, however, from areas which are too turbid for many other darter species (Scott and Crossman 1973, Trautman 1981, Kuehne and Barbour 1983), and also from streams (Haag and Warren Jr. 2006); thus, these range extensions for *P. shumardi* within Pennsylvania may underestimate their true distribution within the state.

We collected three Bluebreast Darters, *Etheostoma camurum* (Cope), from Montgomery Dam tailwaters (New Cumberland Pool, PSU 4459). Seven Bluebreast Darters, five Spotted Darters, *Etheostoma maculatum* Kirtland, and one Tippecanoe Darter, *Etheostoma tippecanoe* Jordan and Evermann, were collected from the Dashields Dam tailwaters (Montgomery Pool, PSU 4476). These dams are located approximately 13 km and 34 km from the Ohio/West Virginia border, respectively (Figure 1).

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Figure 2. River Darter (*Percina shumardi*), New Cumberland Pool, Ohio River, Beaver County, PA . 7 October 2007 . Photo: R.W. Criswell.

These three species are presently classified as threatened within Pennsylvania by the Pennsylvania Fish and Boat Commission (2007). The Tippecanoe Darter has heretofore been reported only from the Allegheny River system. The Bluebreast Darter and Spotted Darter were collected from the Allegheny and Mahoning rivers, but have been extirpated from the latter (Bean 1892, Cooper 1983). The closest records downstream of the state line for the Bluebreast Darter and Tippecanoe Darter are from the lower Muskingum River, but they probably occurred in the unimpounded Ohio River as well (Trautman 1981). The nearest downstream records of the Spotted Darter include the middle sections of the Elk River in West Virginia (Stauffer Jr. et al. 1995) and Muskingum and Scioto rivers in Ohio (Trautman 1981), but there are none from the mainstem Ohio River. Water quality in the Ohio River has been improving over the last 50 years, with marked improvement since the Clean Water Act was implemented in 1972, and is closely correlated with marked improvements in fish diversity and assemblages from 1957–2001 (Thomas et al. 2005). Our recent records, facilitated by the use of benthic trawls as a novel sampling gear, therefore most likely represent an expansion of the Allegheny River populations of all three species as a result of improved water quality.

Additional sampling is warranted to elucidate the full range of these species throughout the Ohio River drainage in Pennsylvania, including both the Allegheny and Monongahela rivers. It is likely that further sampling using benthic trawls will yield more new species records for Pennsylvania and document additional range extensions.

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LITERATURE CITED

Bean, T. H. 1892. The fishes of Pennsylvania. Rep. State Comm. Fish. Pa., 1889–1891. 149 pp.

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

Haag, W. R. & M. L. Warren Jr. 2006. Seasonal feeding specialization on snails by River Darters (*Percina shumardi*) with a review of snail feeding by other darter species. Copeia: 604–612.

Herzog, D. P., V. A. Barko, J. S. Scheibe, R. A. Hrabik & D. E. Ostendorf. 2005. Efficacy of a benthic trawl for sampling small-bodied fishes in large river systems. North American Journal of Fisheries Management 25: 594–603.

Kuehne, R. A. & R. W. Barbour. 1983. The American darters. The University Press of Kentucky, Lexington, KY. 177 pp.

Page, L. M. 1983. Handbook of darters. TFH Publications, Neptune City, NJ. 271 pp.

Pennsylvania Fish and Boat Commission. 2007. Threatened Species Title 58 Pennsylvania Code, Section 75. 2.

Scott, W. B. & E. J. Crossman. 1973. Freshwater fishes of Canada. Galt House Publications Ltd., Oakville ON, Canada. 966 pp.

Stauffer Jr, J. R., J. M. Boltz & L. R. White. 1995. The fishes of West Virginia. Academy of Natural Sciences of Philadelphia, Philadelphia, PA. 389 pp.

Thomas, J. A., E. B. Emery & F. H. McCormick. 2005. Detection of temporal trends in Ohio River fish assemblages based on lockchamber surveys (1957–2001). pp. 431–449. In: J. N. Rinne, R. M. Hughes & R. Calamusso (eds.) American Fisheries Society Symposium 45: Historical changes in large river fish assemblages of the Americas, American Fisheries Society, Bethesda, MD.

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