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Chapter 9

Effects of Stream Acidification on the Breeding Biology of an Obligate Riparian Songbird, the Louisiana Waterthrush (*Seiurus motacilla*)

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ABSTRACT

I compared territory density, pairing success, productivity, and philopatry of Louisiana Waterthrushes (*Seiurus motacilla*) occupying unpolluted and acidified forested headwater habitats in the mountains of southwestern Pennsylvania. Streams impacted by acid mine drainage and/or acid deposition were characterized by reduced abundance, biomass, and/or diversity of aquatic macroinvertebrates, the principal prey of waterthrushes, compared to unpolluted streams. The average number of waterthrush territories (1.5 vs. 2.7 per kilometer) and nesting pairs (1.1 vs. 2.3 per kilometer) was lower on acidified streams; nesting success and return rates did not differ between stream categories. Waterthrushes occupying acidified streams included novel food items in their diet, e.g., immature terrestrial salamanders, and foraged at peripheral, unpolluted aquatic sites within the watersheds much more often compared to waterthrushes on unpolluted streams. Although the impact of acid pollution on macroinvertebrates clearly affects the breeding density of waterthrushes, this effect apparently is mitigated by shifts in the species' foraging ecology to take advantage of available foraging opportunities in impacted watersheds. Consequently, waterthrushes nesting along acidified streams are within the carrying capacity of those environments (i.e., they are not food-limited) and, therefore, are no less productive or site-faithful than waterthrushes nesting at much higher densities along unpolluted streams.

INTRODUCTION

The Louisiana Waterthrush (*Seiurus motacilla*; LOWA), although superficially thrush-like in its appearance and terrestrial habit, actually is an atypical wood warbler (Aves: Parulinae), most species of which are small, brightly colored, and arboreal. It is a locally common breeding bird in Pennsylvania, especially along medium- to high-gradient headwater streams draining forested ridges in the southern half of the state (Gross, 1992) (Fig. 1).

The LOWA is the only obligate headwater riparian songbird in the eastern U.S. The ecology of the species is closely tied to resources available to it in this specialized habitat, not only on the breeding grounds, but also in migration and on its neotropical wintering grounds (Lack, 1976; Rappole and Warner, 1981). Its diet is comprised predominantly of immature and adult aquatic macroinvertebrates found in and alongside these streams (Eaton, 1958; Craig, 1984, 1987); its nest typically is built in a cavity in an eroded section of stream bank (Bent, 1953) (Fig. 2).

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Figure 1. Typical forested headwater habitat for Louisiana waterthrushes in the mountains of southwestern Pennsylvania. Photo by R. S. Mulvihill.

Figure 2. A color-banded Louisiana waterthrush feeding young at its nest in a stream bank on Powdermill Run. Photo by C. R. Wood.

The waterthrush's dependency on aquatic prey makes it potentially susceptible to stream acidification, which typically reduces the abundance, biomass, and/or diversity of benthic macroinvertebrates (Kimmel et al., 1985; Sharpe et al., 1987; Madarish, 1997). Variation in these macroinvertebrate community parameters could affect LOWAs in the following ways: 1) loss of diversity likely would limit the microhabitat, diel, and/or seasonal availability of prey; 2) reduced abundance could lead to decreased foraging success rates and increased size of foraging search areas per unit time; and 3) in the absence of any compensating factors, decreased aquatic biomass ultimately might limit the carrying capacity of the environment for waterthrushes.

The hypothesis that acidified headwater streams constitute lower quality habitat for LOWAs, compared to unpolluted streams, therefore, carries with it several testable predictions: 1) fewer waterthrushes will establish territories along acidified streams (i.e., territories will be larger and/or disjunct; 2) pairing success will be lower for males holding territories on acidified streams; 3) nesting success of waterthrushes will be lower on acidified streams due to effects of food limitation on nesting female (i.e., nutritional constraints on egg production limiting clutch sizes and/or renesting frequency) or nestling waterthrushes; 4) waterthrushes on acidic streams will have lower foraging success rates and larger foraging search areas per unit time, include more non-aquatic prey in their diet, and/or use peripheral aquatic sites for foraging more often.

A strong relationship between stream acidity, macroinvertebrate availability, and the distribution and abundance of Dippers (*Cinclus cinclus*), another obligate riparian songbird, has been observed throughout Great Britain (Ormerod et al., 1985, 1986; Vickery, 1991). Demonstrable and predictable responses of LOWAs to stream acidification, if found, would support use of the waterthrush as a sort of "canary-in-a-cage," or bioindicator, for assessing the ecological condition of acid-impacted headwater streams in Pennsylvania (Mulvihill, 1997).

This study began in 1996 at Powdermill Nature Reserve, a 2,200-acre field biological station of Carnegie Museum of Natural History. At the Reserve, differences in stream quality between unpolluted Powdermill Run and acidified Laurel Run adjacent to it provided an excellent opportunity to assess possible effects of stream acidification on the breeding biology and foraging ecology of LOWAs. Data collected in 1996-1997 describe differences in the availability of stream macroinvertebrates, waterthrush breeding densities, foraging behavior, and reproductive success between Powdermill Run and Laurel Run before any mitigation of abandoned mine drainage (AMD) impacts. Two primary sources of AMD on Laurel Run were treated in fall 1997 through reclamation projects sponsored by PA DEP, the Loyalhanna Watershed Association, and the Western Pennsylvania Coalition for Abandoned Mine Reclamation (Gangewere, 1998); thus, data from 1998 potentially reflected early ecological responses in Laurel Run following these remediation efforts. The study at Powdermill was funded partially in 1997 and 1998 through grants from the Wild Resource Conservation Fund.

Additional data in 1998 concerning the ecological relationship between stream acidification and waterthrushes were collected during the first year of a three-year, EPA-funded study with colleagues Dr. Rob Brooks, from Penn State University, and Dr. Terry Master, from East Stroudsburg University. This cross-regional assessment of bioindicators of the ecological condition of 21 headwater streams in the state included three additional acidified and reference headwater streams in southwestern Pennsylvania.

METHODS

Study Areas

The eight forested headwater (first and second order) streams included in the present study are located in Westmoreland, Fayette, and Somerset counties in the Laurel Highland region of southwestern Pennsylvania. Four of these represent acidified streams: Linn Run, Laurel Run, Gary's Run, and Jonathan Run. Based on water chemistry (Table 1) and known surrounding land use, the dominant source of acidification is acid deposition for Linn Run and Gary's Run and acid mine drainage for Laurel Run and Jonathan Run. The other four headwaters served as so-called "reference" streams, having no known significant anthropogenic impacts: Camp Run, Powdermill Run, Roaring Run, and Blackberry Run. In general, acidified and associated reference streams were in close geographical proximity to one another (Figure 3). Study areas constituted 2-3 km reaches of these streams, flagged at 50-m intervals. Monitoring of Powdermill and Laurel Run began in April 1996; monitoring of the other study sites began in April 1998.

Table 1. Base flow water quality data for acidified streams in the study.

Stream/reach		*pH*	*Tot. Acid.*[a]	*Tot. Alkal.*[a]	*Al*[b]	*Fe*[b]	*Mn*[b]	*Sulfate*[b]	*Spec. Cond.*[c]
Linn Run	/lower	5.2	5	2	0.4	0.07	0.11	9	29
	/middle	4.7	8	1	0.5	0.14	0.08	8	32
	/upper	6.1	3	3	0.3	0.14	0.05	7	25
Gary's Run	/lower	5.5	4	2	0.2	<0.05	0.06	8	27
	/middle	5.3	4	2	0.3	0.06	0.10	8	27
	/upper	4.8	6	1	0.4	0.07	0.11	8	32
Laurel Run	/lower	5.8	<10	4.9	1.9	1.33	0.20	26.4	180
	/middle	3.3	141	0	18.9	3.38	4.68	211.1	610
	/upper	4.4	<10	0	0.9	0.33	2.25	44.5	190
Jonathan Run	/lower	4.7	14	0.8	2.6	0.74	0.88	45	139
	/middle	4.5	15	1	1.8	0.26	0.97	51	161
	/upper	4.5	21	0.8	3.3	0.45	1.9	78	207

[a] mg/l as $CaCO_3$
[b] mg/l
[c] specific conductance, micromhos/cm

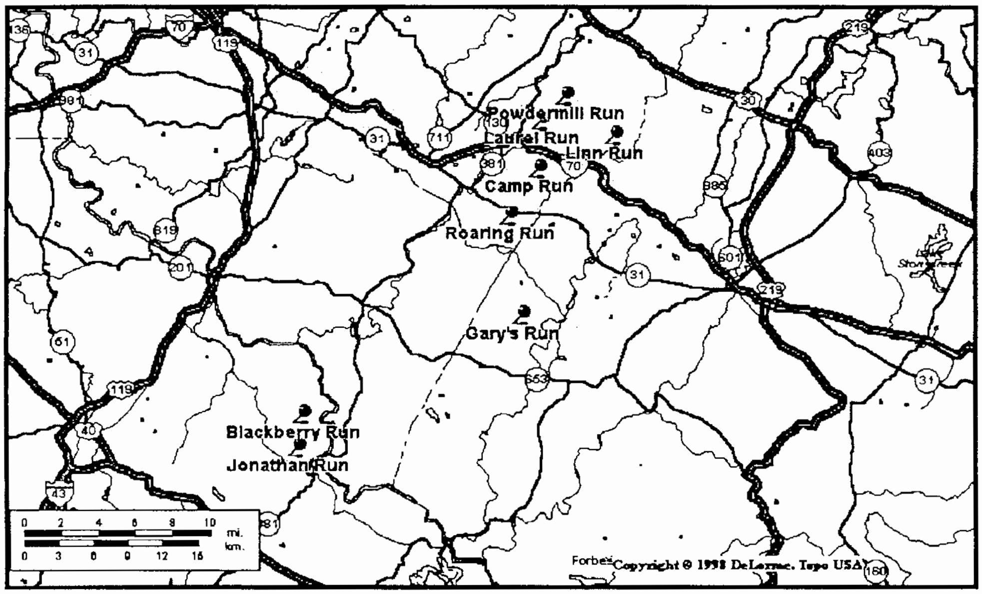

Figure 3. Location of acidified and unpolluted headwater streams included in this study.

Macroinvertebrate and Water Sampling

Macroinvertebrate samples were collected monthly (April-August) in Powdermill Run and Laurel Run in 1997, and again in Laurel Run in 1998, subsequent to the installation of two passive treatment systems to mitigate the impacts of AMD. Surber and Coarse Particulate Organic Matter (CPOM, i.e., natural submerged leaf pack) samples were collected from five stratified random stations each month, for a total of ten samples per stream per month. Additional CPOM samples were taken at selected tributaries on Laurel Run. At the other study sites, Surber and CPOM samples were collected once in mid-June at each of five stratified random sampling stations, for a total of ten samples per stream. Organisms in each macroinvertebrate sample were identified to the lowest practical taxonomic level (typically to genus) and counted by taxon. Total dry weight of macroinvertebrates was measured for each sample, and the dry weight of CPOM material was also measured for each CPOM sample. Biomass density was calculated as mg macroinvertebrate dry weight per m^2 for Surber samples and per mg CPOM material for CPOM samples. For the purposes of this paper, only data from Powdermill Run and Laurel Run in 1997, Laurel Run in April 1998, and Linn Run in June 1998 were available. Water samples were collected during base flow conditions from lower, middle, and upper reaches of the study areas; samples were processed by Geochemical Testing (Somerset, PA). Water quality data for Laurel Run are taken from results of a stream quality survey and mine drainage assessment by the Office of Surface Mining (OSM, 1995).

Monitoring Louisiana Waterthrushes

Territories and nesting

Study areas were visited almost daily from early April through July, the period of time when Louisiana Waterthrushes (i.e., LOWAs) are present on their southwestern Pennsylvania breeding grounds (Leberman, 1976). Waterthrushes on each study area were banded with a unique combination of three or four leg bands, including a numbered U.S. Fish and Wildlife Service band and two or three colored celluloid bands. Territorial males were usually caught after being lured into a mist net with tape playback of the species' territorial advertising song; females, and any males not caught with song recordings, were caught in nets placed at least 10m upstream or downstream of their nests. Territories were delimited by repeated observation of color-banded birds. The number of territories within each study area was rounded off to the nearest half territory. Paired status of territorial males was determined based on behavioral cues (i.e., cessation of regular territorial "advertising" song; Eaton, 1958) and/or observed association with a female waterthrush or an active nest.

An attempt was made to locate every nest of waterthrushes in each study area and to determine nesting outcomes. Nests were monitored every two or three days until young fledged or the attempt failed. Nestling waterthrushes were banded at 7-9 days old; they fledged at 10 days. Protracted nest watches were made for nests at Powdermill Run and Laurel Run to determine the length of attentive and inattentive periods for incubating female LOWAs and to determine nestling provisioning rates. These data have not yet been analyzed. However, details of some observations made during these nest watches which relate to possible differences in the foraging behavior of LOWAs in these two streams are discussed (see below).

Foraging ecology

Quantitative data on foraging were collected opportunistically. Actively foraging birds were observed for a period of 2-5 minutes and all foraging maneuvers were dictated into microcassette recorders. At the end of the observation, the area searched by the bird and the habitat composition of the search area were noted. In addition, we surveyed the study areas both systematically and opportunistically for concentrations of splay left by foraging waterthrushes on exposed rocks and logs in the stream channel. Because only waterthrushes consistently foraged within the stream channel on our study sites, the vast majority of observed splay could be confidently attributed to this species; furthermore, the appearance of waterthrush splay was distinctive with respect to size, shape, and consistency. We used this method for assessing degree of waterthrush use of mainstem vs. peripheral aquatic foraging habitats. In general, full quantitative analyses of foraging and splay data was not possible for this paper; results are mostly qualitative and, therefore, should be considered provisional.

RESULTS AND DISCUSSION

Macroinvertebrate Data

Data from 1997 confirmed that the aquatic macroinvertebrate community in Laurel Run is characterized by lower taxonomic richness, abundance, and biomass compared to Powdermill Run (Table 2). In particular, the community is dominated by a few acid-tolerant taxa, specifically *Leuctra* and *Amphinemura* stoneflies, and contains few or none of the most acid-intolerant forms (e.g., Ephemeroptera and some Trichoptera taxa) (Figure 4). This shift in community pattern has been documented elsewhere in the region (Kimmel et al., 1985; Sharpe et al., 1987; Madarish, 1997) and in the U.K, where its impacts on the Dipper have been well-studied (Ormerod et al., 1985; Ormerod and Tyler, 1991; Vickery, 1991). Data for Laurel Run in 1998, following installation of passive treatment systems for acid discharges into the stream, showed an increase in the total number of taxa and individuals. The increase in taxa, however, was mostly for Chironomidae; the increase in number of individuals was mostly for the two acid-tolerant Plecopteran taxa. This suggests that the passive treatment systems installed on Laurel Run in the fall of 1997 had not had a significant impact on the macroinvertebrate community by early in the following spring. For the purposes of comparing LOWA population data, therefore (see below), I provisionally considered Laurel Run to still be in the acidified category in 1998.

Although most data collected from the other study streams in 1998 have not yet been analyzed, data for Linn Run indicate that the macroinvertebrate community of headwater streams impacted by episodic acid deposition are affected similarly—i.e., loss of most acid-intolerant taxa, Ephemeroptera, and dominance of acid-tolerant Plecopterans (Fig. 5). Data from Linn Run suggest that the abundance and, presumably, biomass of macroinvertebrates in acidified streams can sometimes be comparable to levels seen in unimpacted streams. Importantly, however, this comparison is based on June samples collected in different years.

Table 2. Comparison of taxonomic richness and mean (± s.d.) per sample number of individuals and biomass density of aquatic macroinvertebrates in unpolluted Powdermill Run and acidified Laurel Run in 1997.

Stream	*No. Taxa*		*Surbers (n=25)*		*CPOMS (n=25)*	
Dates	*Total*	*E, P, T*[a]	*No. Indivs.*	*Dry Wt.*[b]	*No. Indivs.*	*Dry Wt.*[c]
Powdermill Run			111.2	847	108.4	800
4/97-8/97	82	10, 12, 13	(66.5)	(401.4)	(71.9)	(351.7)
Laurel Run			42.7	515	62.8	340
4/97-8/97	58	2, 7, 7	(37.3)	(222.0)	(56.2)	(120.5)

[a] E=Ephemeroptera; P=Plecoptera; T=Trichoptera
[b] biomass density expressed as mg/m^2
[c] biomass density expressed as mg/100 g dried CPOM

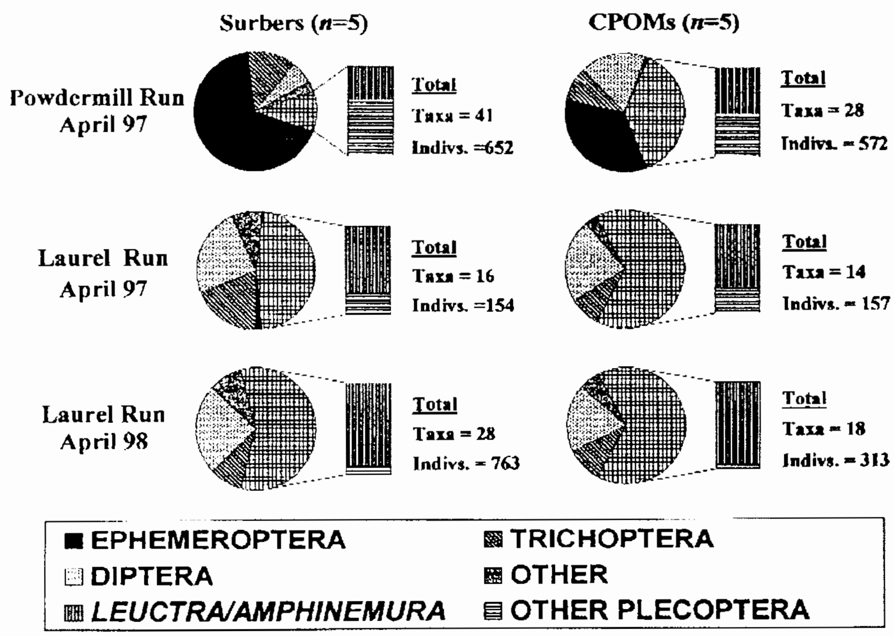

Figure 4. Percent composition of benthic macroinvertebrate taxa in April samples collected from Powdermill Run in 1997 and Laurel Run before (1997) and after (1998) installation of passive treatment systems for acid mine discharges.

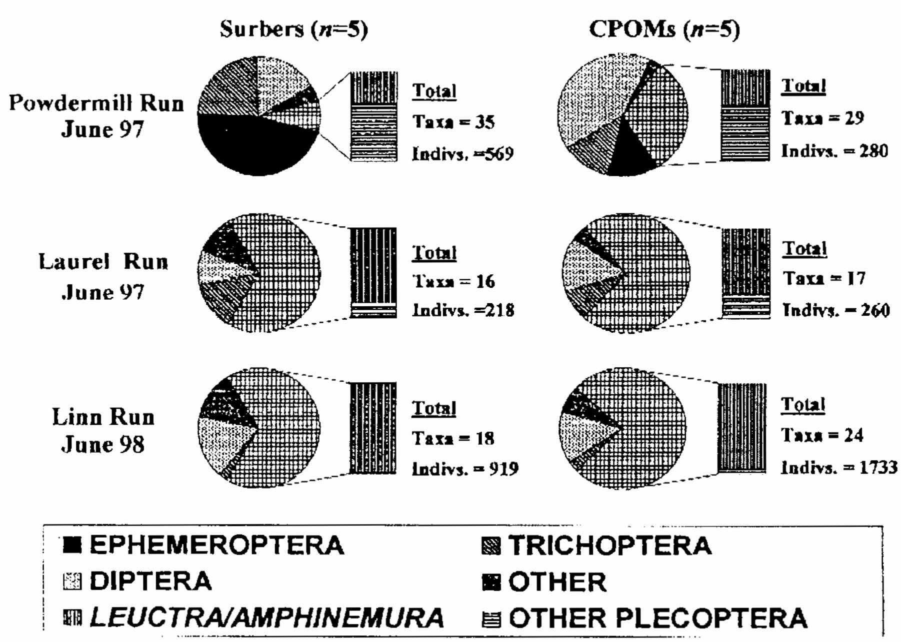

Figure 5. Comparison of percent composition of benthic macroinvertebrate taxa in June samples collected from a reference stream (Powdermill Run), an acid mine drainage impacted stream (Laurel Run), and an acid deposition impacted stream (Linn Run).

LOWA Breeding Densities

On average, there were more waterthrush territories (5.4 vs. 3.0) on reference streams compared to acidified streams (Table 3). The number of territories on the reference streams gives an average territory length of 370 m, which reflects near-maximum observed population densities for the species on its breeding grounds (Robinson, 1995; Terranova and Master, 1995; pers. obs.). Number of territories on reference streams exceeded the number on all acidified streams except Jonathan Run. The comparatively large number of territories on Jonathan Run probably can be attributed to extensive peripheral aquatic resources in that watershed (see Foraging below).

There was a higher percentage of nesting pairs (85%) on reference streams than on acidified streams (77%) (Table 3). Males on all but one reference stream attracted mates, whereas males on all but one acidified stream failed to attract a mate. The number of nesting pairs was lower on all acidified streams compared to all reference streams except Blackberry Run; the difference was particularly striking between full 3-km study reaches of Powdermill Run, where there have been no fewer than nine nests in any year of the study, and Laurel Run, where there have been no more than three (Fig. 6). Although apparently very suitable as habitat for LOWAs (*sensu* Prosser and Brooks, 1998), Blackberry Run was characterized by very low water flow and volume compared to other reference streams, nearly drying up at times when other streams still had substantial surface flow. For this reason, although Blackberry Run will continue to be monitored for the study, a substitute reference stream will be sought in 1999.

Table 3. Comparison of stream pH, number of LOWA territories, and number of nesting LOWA pairs for 2-km reaches of acidified and reference streams in 1998; data for Laurel Run and Powdermill Run are the average of three years, 1996-1998.

Category	*Stream Name*	*pH*	*No. Territories*	*No. Nesting Prs.*
Acidified	Laurel Run	4.7	3	2.3
	Linn Run	5.3	3.5	3
	Gary's Run	5.2	1	1
	Jonathan Run	4.6	4.5	3
Average		4.9	3	2.3
Reference	Powdermill Run	7.2	6	6
	Camp Run	7.4	4.5	4.5
	Roaring Run	7.3	6	6
	Blackberry Run	7.3	5	2
Average		7.3	5.4	4.6

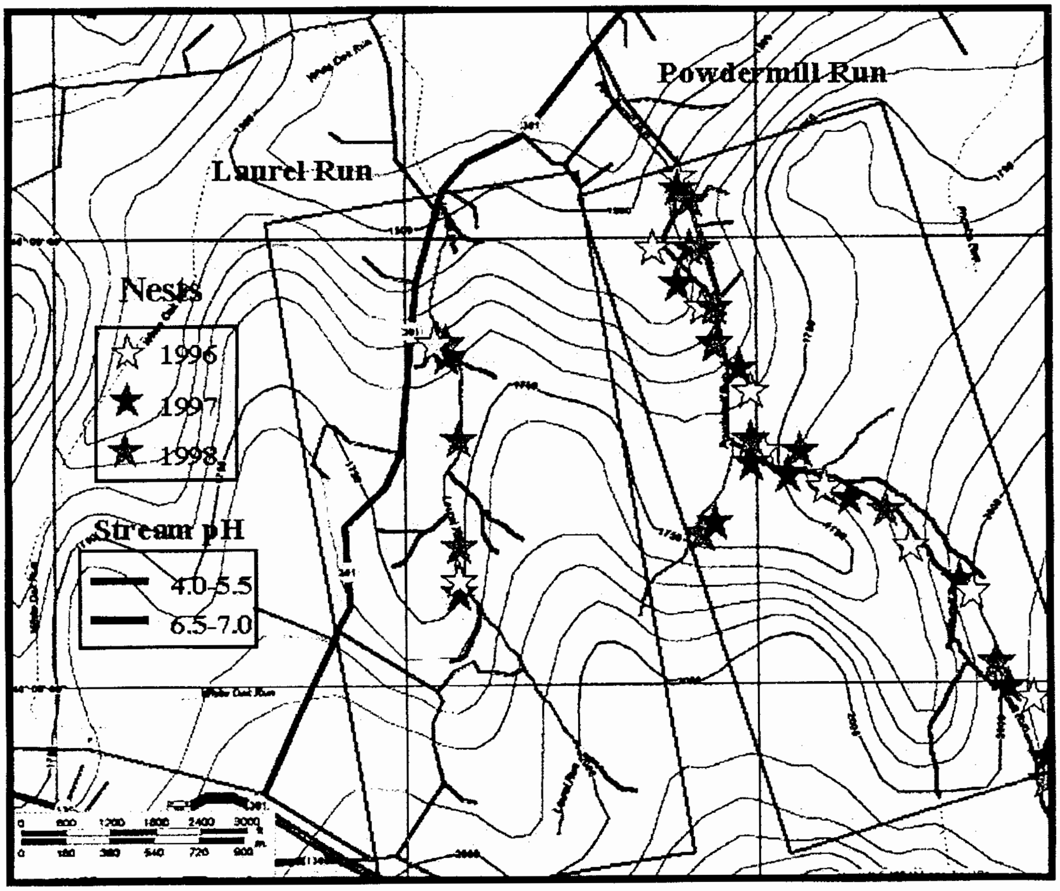

Figure 6. Locations of Louisiana waterthrush nests, 1996-1998, along equivalent 3-km reaches of acidified Laurel Run and unpolluted Powdermill Run.

Reduced territory density, increased territory size, and gaps between territories also have been observed for Dippers on acidified streams in Great Britain (Ormerod et al., 1985; Vickery, 1991), and this has been attributed to decreased quantity and/or quality of prey in acidified streams. Energy-rich invertebrate taxa known to be preferred by Dippers, especially for feeding their young, were among the least acid-tolerant taxa in these studies (e.g., Ephemeroptera and some Trichoptera; Ormerod, 1985; Breitenmoser-Würsten, 1997). It stands to reason that the comparatively high caloric density of these taxa makes them important to waterthrushes, as well, and that their scarcity in the macroinvertebrate community of acidified streams is the primary cause of reduced waterthrush densities there. Data on prey selection by waterthrushes, however, are much more scanty than for the Dipper (Eaton, 1958; Craig, 1984, 1987) and too few to support this conclusion.

LOWA Nesting Success

Although total waterthrush productivity per reach was higher for reference vs. acidified streams, average number of young fledged per successful nest was equal between stream categories, and nesting success rates were actually higher for the acidified streams (Table 4). These data suggest that waterthrushes nesting on acidified streams are finding sufficient food resources for egg production and nestling provisioning. The larger territory size for waterthrushes on acidified streams (up to three times as large as territories on reference streams) undoubtedly compensated for the comparatively depauperate macroinvertebrate communities there. In addition, waterthrushes on acidified streams modified their foraging ecology to utilize supplemental food resources within their territories (see below). Lower rates of nest loss (i.e., predation) in acidified streams may be due to the greater dispersion of nests in these sites (Martin, 1993); also, these sites may, in fact, support smaller populations of nest-predators, such as raccoons, that also rely, to some degree, on aquatic prey.

Table 4. Comparison of LOWA nesting success rates and productivity for two-kilometer reaches of acidified and reference streams in southwestern Pennsylvania in 1998.

Category	*Stream Name*	*Successful Nests*	*Failed Nests*	*Percent Successful*	*Avg. No. Fledged*
Acidified	Laurel Run	3	0	100	4.3
	Linn Run	3	0	100	4.5
	Gary's Run	1	0	100	3.0
	Jonathan Run	3	0	100	4.3
Subtotals		10	0	100	4.0
Reference	Powdermill Run	6	2	75	3.2
	Camp Run	4	2	67	4.3
	Roaring Run	6	3	67	3.2
	Blackberry Run	2	0	100	5.0
Subtotals		18	7	72	3.9

LOWA Foraging Ecology

Most information concerning possible differences in waterthrush foraging ecology between acidified and reference streams comes from the observation of birds on Powdermill Run and Laurel Run; only a few data were collected from the other study sites in 1998. LOWAs on Laurel Run rarely foraged in the main stream; instead, they foraged predominantly on selected small tributaries. The first indication that these peripheral sites were important to LOWAs came from the observation of large concentrations of splay, or droppings, visible on rocks and logs in certain tributaries, in contrast to little or no splay evidence in the main stream. In Powdermill Run, large splay accumulations could be found both on the main stem and on many of the tributaries. Invariably, the Laurel Run tributaries used by LOWAs were found to be characterized by good water quality; in fact, LOWA use of tributaries in Laurel Run coincided perfectly with water quality data collected earlier (OSM, 1995), i.e., the LOWAs used only those tributaries with circumneutral pH. Furthermore, LOWA territories on Laurel Run were more or less centered on these tributaries, and all Laurel Run nests were built within 100m of one of the peripheral sites with good water quality (see Fig. 6). Average macroinvertebrate biomass density for CPOM samples from these tributaries (avg. 870 mg per 100g CPOM material; n=10) was more than twice that found in Laurel Run's main stem and comparable to Powdermill Run (see Table 2). Similar water quality data for peripheral sites on the other three acidified streams studied in 1998 were not collected. However, it is worth noting that the one large (ca. 1000 m) territory and associated nest on Gary's Run coincided with a segment of that stream, near its mouth, that was found in an earlier study to be at the upper end (pH 5.1-6.0) of a pH gradient for that stream (Madarish, 1997); furthermore, the birds also included a portion of an adjoining, circumneutral stream in their territory.

Data on the diet of LOWAs is difficult to collect by direct observation, making a quantitative assessment of the importance of terrestrial prey in the diet of LOWAs in Laurel Run and other acidified streams impossible. However, LOWAs in Laurel Run were observed many times feeding immature terrestrial salamanders to their nestlings. There were a few scattered observations of this behavior at LOWA nests in Powdermill Run, but, despite the much smaller number of nests under observation, the behavior was observed more than five times as often in Laurel Run. Interestingly, before this study, the species had never been recorded feeding on salamanders (Robinson, 1995), although it has been known to take small anurans on its tropical wintering grounds (Eaton, 1958). There were additional observations of LOWAs on Laurel Run feeding caterpillars, millipedes, and other terrestrial invertebrates to their nestlings, and the possibility that LOWAs nesting along acidified streams supplement their diet with terrestrial prey more often that LOWAs occupying unpolluted streams needs to be studied further.

CONCLUSIONS

Although not all of the data from this study have been analyzed and additional data are needed to address some remaining questions, results to date provide a fairly clear picture of the effects of stream acidification on the breeding biology of the Louisiana Waterthrush in Pennsylvania. It is apparent that a reduction in aquatic macroinvertebrate abundance, biomass, and/or diversity in acidified headwaters affects the density of breeding waterthrushes. This effect, however, can be partially mitigated by shifts in the bird's foraging ecology to take advantage of any available alternative foraging opportunities (e.g., novel food items and peripheral aquatic habitats). Thus, while reduced LOWA density compared to reference conditions seems to be indicative of an overall reduction in water quality in acidified headwater ecosystems, the exact locations being used by LOWAs can possibly be used to identify areas of good water quality within these impacted watersheds. The utility of LOWAs as bioindicators will be greatly enhanced if a simple means, such as splay surveys, can be used both to assess overall LOWA densities and to target areas being used by LOWAs within headwaters. Developing such a means is one of the goals of this ongoing study.

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