Chapter 3: Influence of eastern hemlock (Tsuga canadensis) on fish community structure in small headwater streams of the Delaware Water Gap National Recreation Area.

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INTRODUCTION

This report summarizes findings of the USGS Biological Resources Division work on fish biodiversity in eastern hemlock (Tsuga canadensis) stands of the Delaware Water Gap National Recreation Area (DEWA). Parallel studies of macroinvertebrate biodiversity are reported elsewhere. This report addresses objective two (determine the contribution of hemlock stands to aquatic biodiversity in DEWA) of the Leetown Science Center study plan, entitled "Aquatic Biodiversity in Eastern Hemlock Forests."

METHODS

We initially planned to incorporate the blocked-pair design described in Chapter 1. However, a large fraction of the selected streams dried up during the summer fish sampling period (Table 1), and consequently our sampling was compromised and we were only able to employ the paired approach in our analysis for a subset of selected site pairs. Specifically, of the 28 stream reaches initially selected (Chapter 1), only 13 contained sufficient flow to support fish. Four streams were completely dry and seven were mostly dry (Table 1). Ultimately, we sampled the 24 stream reaches that contained water.

Electrofishing techniques were used to collect fish in single passes, downstream to upstream. Collected individuals were identified, measured to the nearest mm of total length, and released behind the advancing electroshocker. Species, functional, and tolerance diversities were calculated for each stream using the Shannon-Wiener diversity index, H. For functional and tolerance diversity analyses, fish species were assigned commonly accepted trophic levels (piscivore, insectivore, or omnivore) and tolerance levels (intolerant, tolerant, or other [either intermediate in tolerance or conflicting designations in the literature]) prior to index computation by stream sample. Using the stratified-pair design described in Chapter 1, diversity indices for each stream were subtracted from those of its pair (hardwood vs hemlock). The remaining 14 means were averaged and the result compared to zero. The null hypothesis of no significant difference in means was rejected if $p < 0.10$. Fisher's Exact Test was used on unstratified presence/absence data to test for species, functional, and tolerance associations among stand type, terrain type, and order. Proportions and frequencies were also calculated for the stand types (hardwood or hemlock), terrain types (bench, ravine, or slope), and stream orders (1st or 2nd).

Table 1. Extent of drying for the 28 streams sampled in DEWA. Wet=entire stream channel wetted; mostly wet=>50% of stream channel wetted; mostly dry=<50% of stream channel wetted; and dry=completely dry.

Site #	Stand#	Forest type	Terrain	Stream order	Extent of drying	Fish
042201	142	hardwood	ravine	2	wet	present
051101	243	hardwood	bench	1	mostly dry	present
072113	365	hemlock	ravine	1	wet	present
081102	529	hardwood	bench	1	dry	absent
083102	561	hardwood	slope	1	dry	absent
092112	485	hemlock	ravine	1	mostly dry	absent
102211	657	hemlock	ravine	2	wet	present
111113	822	hemlock	bench	1	wet	absent
152102	1020	hardwood	ravine	1	mostly dry	absent
152213	1059	hemlock	ravine	2	mostly wet	absent
162101	1202	hardwood	ravine	1	mostly dry	absent
172212	1191	hemlock	ravine	2	wet	present
182202	1327	hardwood	ravine	2	wet	present
191202	1335	hardwood	bench	2	wet	present
191211	1368	hemlock	bench	2	wet	present
192111	1449	hemlock	ravine	1	wet	present
222103	1784	hardwood	ravine	1	wet	present
232203	1850	hardwood	ravine	2	dry	absent
271103	1909	hardwood	bench	1	dry	absent
271111	1509	hemlock	bench	1	mostly dry	absent
271112	2037	hemlock	bench	1	wet	absent
273103	1614	hardwood	slope	1	mostly dry	absent
273111	1673	hemlock	slope	1	mostly wet	absent
273112	1653	hemlock	slope	1	mostly wet	absent
273113	1742	hemlock	slope	1	wet	present
283101	2204	hardwood	slope	1	mostly dry	absent
291201	2035	hardwood	bench	2	wet	present
291212	2107	hemlock	bench	2	wet	present

RESULTS AND DISCUSSION

Streams which dewatered or partially dewatered were not more likely to be found in a particular stand type (Fisher's Exact Test p=0.257). From the streams which were at least partially watered a total of 1,406 fish of 15 species and 7 families were collected. Eight of 13 species (62%) were found only in hardwood sites, while one of seven species (14%; golden shiner) was unique to hemlock stands. Among the six species found in both hardwood and hemlock stands, American eel and creek chub were found in greater proportion in hardwood than hemlock sites, though neither exceeded 8% in either stand type (Table 2). Brook trout and brown trout were three times and twice as prevalent in hemlock as hardwood stands, respectively (Table 2).

Table 2. Proportional sample representation for the six species found in both hardwood (490 fish) and hemlock (832 fish) stands.

	No. stands found in		No. fish found in		Proportion of sample	
Species	Hardwood	Hemlock	Hardwood	Hemlock	Hardwood	Hemlock
American eel	2	1	20	5	0.04	0.01
Brown trout	1	1	22	71	0.04	0.09
Brook trout	1	4	21	107	0.04	0.13
Blacknose dace	4	6	384	637	0.78	0.77
Creek chub	1	1	40	7	0.08	0.01
Pumpkinseed	3	3	3	5	0.01	0.01

When the data were differentiated by terrain type (regardless of stand type), brook trout were found to be the most ubiquitous species, found in bench, ravine, and slope habitats (Table 3). Species found only in benches were golden shiner and creek chub, while those found only in ravines were American eel, brown trout, cutlips minnow, common shiner, longnose dace, and fallfish. Slope habitats had no unique species. There were no unique species in first order streams, which harbored only four species: brook trout, blacknose dace, pumpkinseed, and bluegill.

From an individual stream perspective, with one exception, both hardwood and hemlock stream samples harbored only one to four species of fish. The exception was Shimers Brook, a 2nd-order ravine hardwood stream segment with 12 species, well outside the range for all other streams sampled. Shimers Brook was also the most taxonomically diverse stream, followed by Tumbling Water 2, a 2nd-order bench hemlock site, with four species among only 18 individual fish. Sufficient stream data were available to statistically compare the proportion (after arcsine transformation) of insectivores in samples where fish were present (hardwood versus hemlock). Insectivores were in significantly higher proportion in hardwood (0.90) than in hemlock (0.46) stands ($F_{1, 8} = 7.0$, $P = 0.03$). Likewise, hemlock stands had greater proportions of piscivores (0.85 versus 0.54), though not significantly different ($F_{1, 5} = 1.26$, $p = 0.62$). Neither the taxa richness metric nor the three diversity metrics showed a significant forest stand-type effect (Fig.1). When analyzed by pooled forest type without regard to other physiographic variables, we found species and tolerance diversities were similar for the two groups, though mean functional diversity for hemlock was numerically twice that of hardwood stands (Table 4). Similar analysis of pooled terrain types showed highest numerical diversities (functional and tolerance) in bench, followed by ravine, and lastly slope terrains, while stream orders showed much higher diversity in 2nd order (Table 4). Mean stream species diversity (H_s) was 0.10 (n = 14) for hardwood stands and 0.09 (n = 14) for hemlock stands ($F_{1, 26} = 0.00$, $p = 0.97$). Mean stream functional diversity (H_f) was 0.04 for hardwood stands and 0.07 for hemlock stands ($F_{1, 26} = 0.74$, $p = 0.40$). Tolerance diversity (H_t) was the same for hardwood ($0 = 0.07$) and hemlock ($0 = 0.08$) stands ($F_{1, 126} = 0.00$, $p = 0.99$). Using unstratified presence/absence data the only species to show a stand preference was bluegill (Table 3). Blacknose dace, insectivores, and other (tolerance) preferred bench and ravine over midslope terrain. American eel, blacknose dace, pumpkinseed, insectivores, omnivores, tolerant, intolerant, and other were found significantly more often in 2nd order than 1st order.

Table 3. Presence (x) of each species, trophic guild, and tolerance guild in each stand type, terrain type, and stream order with a statistical analysis of association (Fisher Exact Test) using presence/absence data. Abbreviations under trophic guild are omnivore (0), insectivore (I), and piscivore (P); those under tolerance are tolerant (T), intolerant (I), and other (O). In parentheses is the number of sample units for each physiographic variable. Asterisks indicate the class(es) statistically preferred by a species or group.

Species				Stand found in			Terrain type found in				Stream order found in		
Common name	Scientific name	guild	Tolerance	Hardwood	Hemlock	Fisher p value	Bench	Ravine	Slope	Fisher p value	1	2	Fisher p value
American eel	Anguilla rostrata	I	T	X	X	1.000		X		0.211		X*	0.037
Brown trout	Salmo trutta	P	I	X	X	1.000		X		0.492		X	0.119
Brook trout	Salvelinus fontinalis	P	I	X	X	0.336	X	X	X	1.000	X	X	1.000
Cutlips minnow	Exoglossum maxillingua	I	I	X		1.000		X		1.000		X	0.357
Common shiner	Luxilus comutus	O	O	X		1.000		X		1.000		X	0.357
Golden shiner	Notemigonus crysoleucas	O	T		X	1.000	X			0.571		X	0.357
Blacknose dace	Rhinichthys atratulus	I	O	X	X	1.000	X*	X*		0.097	X	X*	0.011
Longnose dace	Rhinichthys cataractae	I	I	X		1.000		X		1.000		X	0.357
Creek chub	Semotilus atromaculatus	O	T	X	X	1.000	X			0.159		X	0.119
Fallfish	Semotilus corporalis	O	T	X		1.000		X		1.000		X	0.357
White sucker	Catostomus commersoni	O	T	X		1.000		X		1.000		X	0.357

Table 3 (cont).

Species				Stand found in			Terrain type found in				Stream order found in		
Common name	Scientific name	guild	Tolerance	Hardwood	Hemlock	Fisher p value	Bench	Ravine	Slope	Fisher p value	1	2	Fisher p value
Margined madtom	Noturus insignis	I	I	X		1.000		X		1.000		X	0.357
Pumpkinseed	Lepomis gibbosus	I	I	X	X	1.000	X	X		0.432	X	X*	0.013
Bluegill	Lepomis macrochirus	I	T	X*		0.098	X	X		0.648	X	X	0.116
Tessellated darter	Etheostoma olmstedi	I	O	X		1.000		X		1.000		X	0.357
Insectivores				X	X	1.000	X*	X*		0.097	X	X*	0.011
Omnivores				X	X	1.000	X	X	X	0.579	X	X*	0.037
Piscivores				X	X	0.385	X	X	X	0.741	X	X	0.207
Tolerant				X	X	0.695	X	X		0.432	X	X*	0.013
Intolerant				X	X	0.648	X	X	X	0.682	X	X*	0.097
Other				X	X	1.000	X*	X*	X	0.097	X	X*	0.011

Table 4. Unstratified, summed, fish species richness (R), total individuals sampled (N), species diversity (Hs), functional diversity (Hf), and tolerance diversity (Ht) by forest stand type, terrain type, and stream order.

Physiographic variable	Variable types	R	N	H_s	H_f	H_t
Forest stand type	Hardwood	14	573	0.096	0.036	0.075
	Hemlock	7	832	0.089	0.071	0.075
Terrain type	Bench	6	237	0.118	0.071	0.100
	Ravine	13	1146	0.117	0.064	0.092
	Slope	1	23	0.000	0.000	0.000
Stream order	1	4	138	0.030	0.015	0.030
	2	15	1268	0.206	0.122	0.157

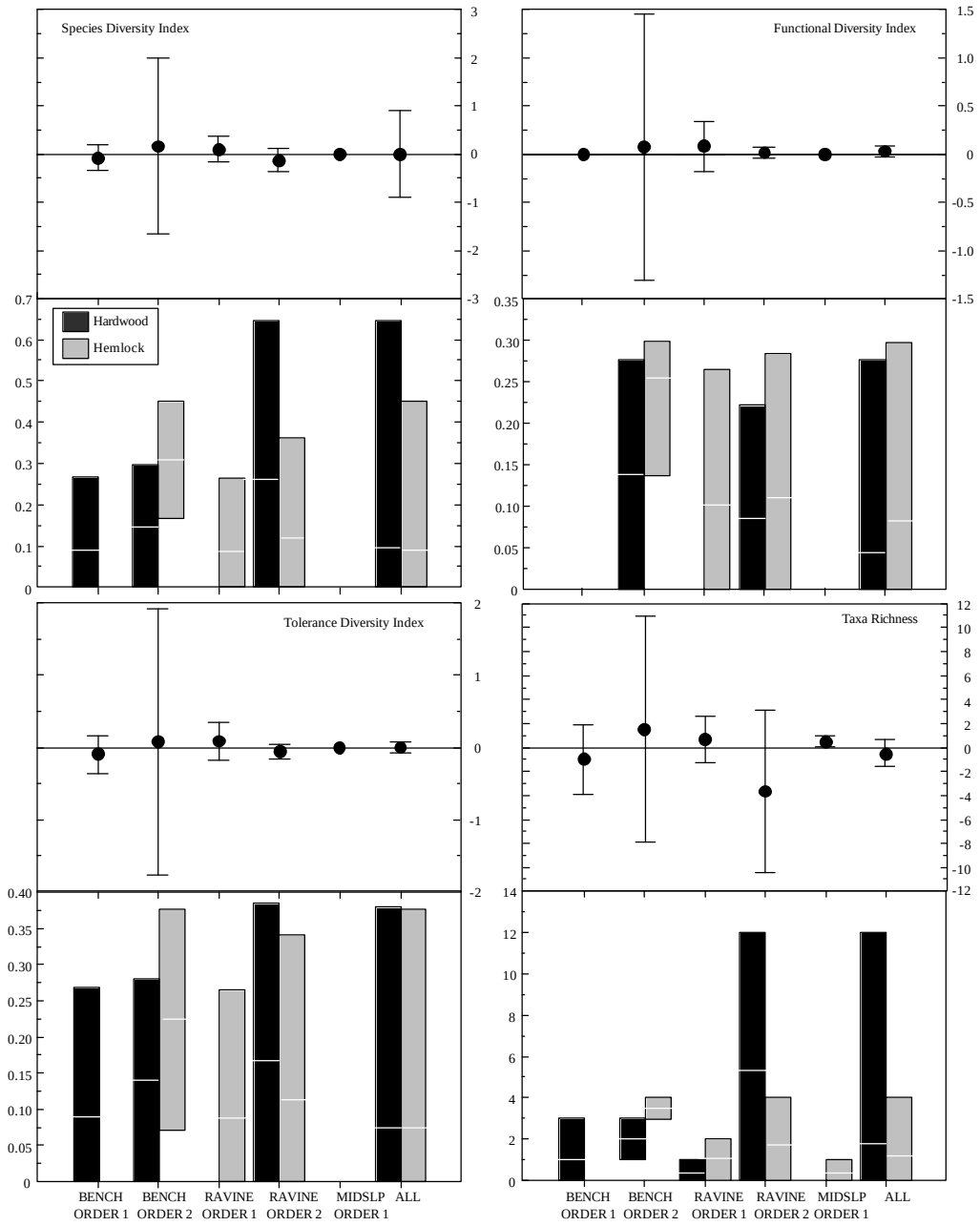

Figure 3-1. Comparison of four community metrics by stand type, terrain type, and stream order. Top graph shows mean differences for stratified pairs. Positive values indicate higher means for hemlock. Bottom panel shows range of values. White line is the mean.

CONCLUSIONS

Fish species associations and other ichthyofaunal qualities unique to hemlock stands were subtle. Both hemlock and hardwood streams typically supported 1 - 4 species of fish. The single golden shiner cannot be considered indicative of hemlock sites. However, brook trout proportions in hemlock were three times those in hardwood stands, and their presence in hemlock versus hardwood streams was four times that of brown trout. Hemlock streams did not differ significantly from hardwood streams in terms of species or tolerance diversity, but functional diversity was twice as high in hemlock as hardwood. Trophic structure was different between the two forest stand types, in that hemlock streams supported proportionally fewer insectivores and more piscivores than hardwood streams. Among terrain types, species found exclusively in or preferring benches were goldenshiner, creek chub, blacknose dace, and bluegill. Species found exclusively in ravines were American eel, brown trout, and four species of minnows. First order streams harbored only brook trout, blacknose dace, and sunfishes, which probably recruited from headwater ponds. Ravines thus appeared to represent for brook trout a transitional terrain, above which it either out-competed or otherwise did not have to compete with its sister salmonid, the brown trout.