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Water quality and benthic invertebrates in the Ensign Hollow watershed, southwestern Clayton County and southeastern Fayette County, Iowa, were monitored from 2000 to 2001. Measurements of physical and chemical parameters of water quality, as well as analysis of benthic invertebrates, all indicated that streams of the Ensign Hollow watershed were exposed to slight organic pollution. Furthermore, the greatest threat to this watershed appeared to be sedimentation introduced through runoff

INDEX DESCRIPTORS: Ensign Hollow, Ensign Creek, Hewett Creek, water quality, family biotic index.

The Ensign Hollow area is a 2,408 ha watershed located in southwestern Clayton County and southeastern Fayette County in northeast Iowa that includes the upper reaches of Hewett Creek and its tributary, Ensign Creek (Fig. 1). Ensign and Hewett creeks are both classified as Class B coldwater streams (Iowa Water Quality Standards 1990), meaning that because they are suitable for coldwater species, their water quality is to be protected for wildlife, fish, aquatic and semiaquatic life. In addition, both creeks have been designated as high quality streams because their exceptionally better water quality exceeds minimum guidelines for chemical constituents in Iowa surface waters (Iowa Water Quality Standards 1990).

Both Ensign Creek and Hewett Creek are managed by the Iowa Department of Natural Resources as catch and release areas for trout. While Hewett Creek is stocked, Ensign Creek is one of a handful of streams in the state of Iowa that supports a naturally reproducing population of rainbow trout. Trout numbers have increased dramatically since Ensign Hollow was protected as a catch and release area, from an estimated population of less than ten trout in 1990 to an estimated population of over 900 trout in 1999 (Palas 2001).

Approximately 65% of the watershed was planted in crops and 13 livestock enterprises were present (Palas 2001). According to a non-point pollution assessment report prepared by the state, sediment from soil erosion was the primary impairment of the streams in Ensign Hollow, followed by nutrients (nitrogen and phosphorus) and pesticides (Palas 2001).

The Ensign Creek watershed (287 ha) was the subject of a project from 1991–1994 termed Ensign Hollow I and sponsored by the Clayton and Fayette Soil and Water Conservation Districts. The goal of this project was to improve water quality by providing cost share funds to landowners to institute land use improvement practices (Palas 2001). A second project running from 1999 to 2002 (Ensign Hollow II) funded land improvement projects in the 2121 ha that made up the Hewett Creek watershed (Palas 2001).

As a component of the Ensign Hollow II project, the water quality of the Ensign Hollow watershed was examined by monitoring the following physical and chemical parameters: temperature, pH, specific conductance, turbidity, suspended solids, dissolved oxygen, ammonia, nitrate-nitrite, total nitrogen, reactive phosphorus and total phosphorus. In addition, benthic invertebrates were sampled for use as biological indicators of water quality. The data were used in this report to provide an assessment of the water quality in Ensign and Hewett Creeks.

METHODS

Ensign Hollow was monitored at riffles on Ensign Creek, Hewett Creek and approximately 2 km downstream of their confluence (Fig. 1). Beginning with September 2000 and ending with November 2001, each site was assessed monthly, with visits occurring within the first seven days of the month. Additional visits were made within 24 hours of certain significant rain events characterized by 1.5 cm of precipitation falling within a 24 hour period.

During each visit, temperature, pH, specific conductance and dissolved oxygen were measured using a Hydrolab minisonde multiprobe connected to a field laptop computer. A Hach 2100P turbidimeter was used to measure turbidity. Sixty ml of water were filtered through a 25 mm Nalgene SFCA syringe filter with a 0.45 μm pore size. This sample, which would be analyzed for ammonia and nitrate-nitrite, was preserved with one drop of 18 molar sulfuric acid and refrigerated. Another 60 ml, to be analyzed for reactive phosphorus, was filtered and frozen. Sixty ml of raw water, to be analyzed for total nitrogen and total phosphorus were preserved with one drop of 18 molar sulfuric acid and refrigerated. To determine suspended solids, from 250 to 500 ml of sample (depending on turbidity) were vacuum filtered through a pre-weighed 47 mm Gelman glass fiber filter which was then frozen. The following day the samples were shipped overnight on ice to the United States Geological Survey Environmental Management Technical Center's water quality lab in LaCrosse, Wisconsin for analysis.

Each site was sampled for benthic invertebrate populations in September and May using a kick net to collect aquatic arthropods from 5 m of riffle. All arthropods were identified (to genus whenever possible) and used to calculate the Family Biotic Index (Hilsenhoff 1988). This index is computed based on the number of individuals in each family and the tolerance value for that family (Hilsenhoff 1988). The tolerance value, which can range from zero to ten, refers to the ability of species in that family to tolerate polluted water, with zero being the least tolerant. For each site, September and May collections were combined and treated as one sample. The Family

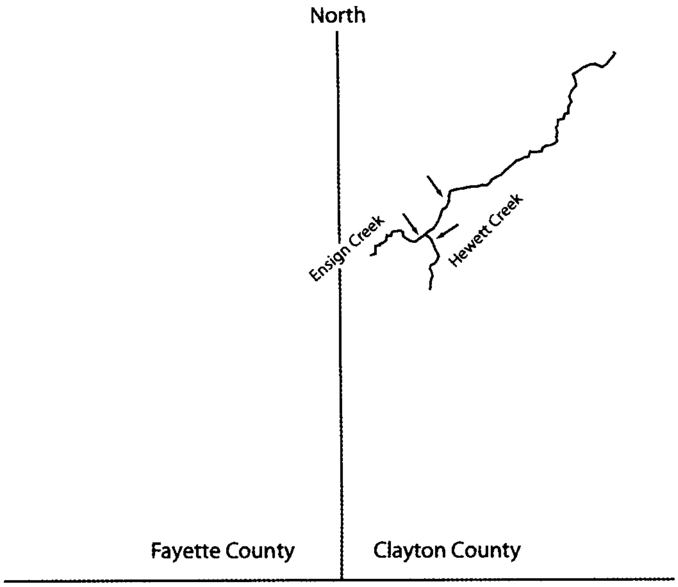

Fig. 1. Map of Ensign Hollow watershed indicating location of sampling sites (Scale: 1 cm = 2 km).

Biotic Index was calculated by multiplying the number of individuals in each family by the tolerance value for that family. These products were summed and divided by the total number of arthropods collected from the site. Families without a tolerance value were not included in the computations.

RESULTS AND DISCUSSION

Sixteen water samples were collected and analyzed from each of the three sites (Table 1). Twelve of these samples, referred to as non-rain events, represent typical monthly samples (Table 2), while four are associated with significant rain events (Table 3).

Temperature

Ensign Creek, which is primarily spring-fed, had the most consistent water temperatures (Table 1). Hewett Creek had a much greater range of fluctuation and occasionally approached 24°C, which has been shown to be lethal for trout (Black 1953, Hokansen et al. 1977, Jobling 1981, Bjornn and Reiser 1991). High temperatures were encountered with low flows in late summer (Table 2) and have been identified as preventing natural reproduction by trout in many Iowa streams (Harlan et al. 1987).

pH

pH levels, averaging around eight, did not vary among the three sites and were typical for limestone streams in northeast Iowa (Table 1). Weathering of limestone adds calcium carbonate to the water (hardness), elevating the pH above neutral. Rain events, which diluted the levels of calcium carbonate, produced a slight drop in pH (Table 3).

Specific Conductance

Conductivity, the ability of water to conduct an electrical current, is influenced by the presence of ions dissolved in the water. Northeast Iowa streams typically display high conductivities because of the dissolved limestone. Conductivity did not display much variation among the three sites, with averages ranging from 539 micro-

Table 1. Overall measurements of water quality from Ensign Hollow (mean with range below, n = 16).

Location	Temperature °C	pH	Conductivity µS/cm	Dissolved oxygen mg/L	Turbidity NTU	Ammonia mg/L	Nitrate-Nitrite mg/L	Total Nitrogen mg/L	Reactive Phosphorus mg/L	Total Phosphorus mg/L	Suspended Solids mg/L
Confluence	11.6	7.9	544	12.3	16	0.0929	7.037	7.221	0.019	0.091	15.65
	3.6–18.6	7.6–8.2	443–594	10.6–15.0	3–130	0.0190–0.3432	5.491–9.728	5.784–10.261	0.004–0.097	0.040–0.280	3.50–96.00
Ensign	11.6	8	539	11.6	18	0.0863	9.577	10.031	0.021	0.091	19.05
	6.3–17.2	7.7–8.3	435–585	10.1–14.4	3–143	0.0220–0.3010	7.608–14.539	8.490–13.991	0.006–0.077	0.019–0.339	5.20–89.40
Hewett	12.6	7.9	553	12.2	12	0.0573	4.717	4.983	0.019	0.083	10.85
	1.3–22.9	7.6–8.2	445–595	9.9–15.3	2–110	0.0117–0.2240	3.425–7.619	3.696–8.090	0.003–0.770	0.040–0.222	2.10–74.20

Table 2. Nonrain event measurements of water quality from Ensign Hollow (mean with range below, n = 12).

Location	Temperature °C	pH	Conductivity µS/cm	Dissolved oxygen mg/L	Turbidity NTU	Ammonia mg/L	Nitrate-Nitrite mg/L	Total Nitrogen mg/L	Reactive Phosphorus mg/L	Total Phosphorus mg/L	Suspended Solids mg/L
Confluence	11.7	8	558	12.8	5	0.0790	6.916	6.949	0.010	0.065	6.79
	3.6–18.6	7.8–8.2	496–594	10.8–15.0	3–9	0.0190–0.3432	5.491–9.521	5.784–8.308	0.004–0.020	0.040–0.116	3.50–11.00
Ensign	12	8	554	11.7	7	0.0756	9.333	9.628	0.012	0.058	11.15
	6.3–17.2	7.9–8.3	486–585	10.1–14.4	3–16	0.0220–0.3008	7.608–14.539	8.490–12.973	0.006–0.023	0.019–0.100	5.20–22.20
Hewett	12.7	8	561	12.9	3	0.0426	4.39	4.616	0.011	0.066	4.02
	1.3–22.9	7.6–8.2	505–595	10.7–15.3	2–5	0.0117–0.1310	3.425–5.486	3.696–5.617	0.003–0.021	0.040–0.186	2.10–6.30

Siemens/cm in Ensign Creek to 553 microSiemens/cm in Hewett Creek (Table 1). Not surprisingly, measurements below the confluence tended to fall somewhere in between those recorded for Ensign and Hewett. In general, rain events produced lower conductivity measurements (Table 3), with the dilution effects of rainwater more than compensating for the additional ions brought in by runoff.

Dissolved Oxygen

Dissolved oxygen is one of the most critical parameters of water quality impacting living organisms. Dissolved oxygen is influenced by temperature, as warmer water is unable to hold as much oxygen as colder water, and by turbulence, which mixes more air with the water. Dissolved oxygen levels at the three sites never dropped below 9.9 mg/L (Table 1), well above the minimum required by coldwater fish such as trout (Mills 1971). Dissolved oxygen did drop slightly as runoff diluted the highly oxygenated stream water (Table 3). Despite having cooler temperatures, Ensign Creek had slightly less dissolved oxygen than Hewett Creek, suggesting that pollution may be having more of an impact on this stream.

Turbidity

Turbidity levels were typically low at all three sites with average readings below 10 nephelometric turbidity units (NTU). However, rain events dramatically impacted turbidity, with readings rising to well over 100 NTU (Table 3). Invertebrates vary with respect to their ability to tolerate turbid conditions. Also, invertebrates vary with respect to their preference for silty or rocky substrates.

Sediment can bury and suffocate invertebrates and fish eggs. Clearly, runoff carrying sediment has the most negative impact on the watershed.

Nitrogen

Ammonia levels were within acceptable ranges for coldwater streams in Iowa (Iowa Water Quality Standards 1990), averaging less than 0.1 mg\L (Table 1). Average ammonia levels doubled following rain events but remained below acceptable maxima for coldwater streams (Table 3). Maximum or nearly maximum ammonia levels were also encountered in samples not associated with rain events (Table 2) but presumably were tied to fertilizer application. Ammonia levels were highest at the confluence, and levels were consistently higher in Ensign Creek compared to Hewett Creek.

Averages of combined nitrate and nitrite levels in Ensign Creek were twice that of Hewett Creek (9.5 mg\L versus 4.7 mg\L), and measurements at the confluence were intermediate (Tables 1 and 2). Levels rose slightly following significant rain events (Table 3). It is not unusual for the ground water that feeds springs in northeast Iowa to be contaminated with nitrate and nitrite. The high levels of nitrate and nitrite in Ensign Creek are probably due to the large springs at Ensign's origin.

Total nitrogen represents the sum of ammonia, nitrate, nitrite and organic nitrogen in the water. Because most of this nitrogen is contributed by nitrate and nitrite, Ensign Creek again had higher levels than the other two sites (Tables 1 and 2), and levels were typically higher following significant rain events (Table 3).

Phosphorus

Reactive phosphorus and total phosphorus levels tended to be low at all three sites, averaging around 0.01 mg\L and 0.06 mg\L, respectively (Table 2), although significant rain events quadrupled reactive phosphorus levels and doubled total phosphorus levels (Table 3).

Table 3. Rain event measurements of water quality from Ensign Hollow (mean with range below, n = 4).

Location	Temperature °C	pH	Conductivity µS/cm	Dissolved oxygen mg/L	Turbidity NTU	Ammonia mg/L	Nitrate-Nitrite mg/L	Total Nitrogen mg/L	Reactive Phosphorus mg/L	Total Phosphorus mg/L	Suspended Solids mg/L
Confluence	11.5	7.8	501	11.0	48	0.1313	7.368	7.968	0.046	0.164	48.10
	9.2–14.4	7.6–8.0	443–565	10.6–11.7	12–130	0.0380–0.3120	5.853–9.728	6.167–10.261	0.017–0.097	0.072–0.280	15.10–96.00
Ensign	10.4	7.9	491	11.3	52	0.1158	10.250	11.140	0.050	0.182	48.00
	9.0–11.7	7.7–8.0	435–565	10.8–12.1	12–143	0.0320–0.3010	8.350–13.110	8.760–13.990	0.013–0.077	0.067–0.339	24.40–89.40
Hewett	12.2	7.9	529	10.2	40	0.0978	5.616	5.994	0.041	0.130	35.90
	9.1–16.1	7.7–8.1	445–571	9.9–11.6	11–110	0.0410–0.2240	4.121–7.619	4.529–8.090	0.027–0.077	0.076–0.222	13.30–74.20

In undisturbed aquatic ecosystems, nitrogen and phosphorus are typically limiting nutrients. Their relative concentrations determine how much plant growth can occur. Overloading aquatic ecosystems with these nutrients produces plant blooms. Most of these plants are short-lived and upon dying are decomposed by bacteria, which greatly reduces dissolved oxygen levels. With their high levels of dissolved oxygen, the streams of Ensign Hollow do not show signs of nutrient overloading.

Suspended Solids

Suspended solids in samples from Ensign Creek on average were twice as high as samples from Hewett Creek, 19.05 mg\L versus 10.85 gm\L (Tables 1 and 2). At 15.65 mg\L, the average measurement at the confluence fell in the between the above two averages. Not surprisingly, the amount of suspended solids increased dramatically after a significant rain event. Maximum values of 74.20, 89.40 and 96 mg\L were recorded at Hewett, Ensign and the confluence, respectively. This provides further evidence that the primary threat to these streams is runoff-derived sediment.

Benthic Invertebrates

Overall, similar assemblages of benthic invertebrates were recovered from all three sites (Table 4). Samples were dominated by small minnow mayfly larvae (Family Baetidae). Other common components of the invertebrate assemblages included spotted sedge caddisfly larvae (Family Hydropsychidae) and blackfly larvae (Family Simulidae). Riffle beetles (Family Elmidae) were common in Hewett Creek and below the confluence. Scuds (Family Gammaridae) were restricted to the riffles sampled on Ensign Creek and below the confluence, where aquatic vegetation was present.

The Family Biotic Indices (FBI) were similar for all three sites (Table 5). Values for Ensign Creek and Hewett Creek were nearly identical, at 4.05 and 4.00, respectively. The index for the confluence, at 4.20, was slightly higher.

Using more than 2000 stream samples from across Wisconsin, Hilsenhoff (1988) developed a guide for evaluating water quality (specifically the relative amount of organic pollution) based on the FBI (Table 6). According to this guide, the benthic invertebrate surveys suggested that the water quality at all three sites is very good, with possible slight organic pollution.

The FBI has been used extensively in Wisconsin as an indicator of water quality (Hilsenhoff, 1988). The EPA has encouraged states to incorporate aquatic organisms into water quality monitoring (U.S. EPA 1990) based on the rationale that these organisms are sensitive to intermittent perturbations of water quality that could easily be missed by solely relying on periodic analysis of physical and chemical parameters of water quality. The state of Iowa is in the process of developing such biological criteria based on sampling fish and benthic invertebrates (Wilton 2000).These samples are analyzed using an index of biotic integrity (IBI) that represents the sum of 12 different measures, including species diversity, relative abundance of sensitive and tolerant organisms, and the proportion of individual organisms belonging to specific feeding and habitat groups. Indices are compared to reference sites, which are presumed to be streams least disturbed by human activity. Fish IBI scores are highest (best) in northeast Iowa streams. Benthic invertebrate IBI scores also tend to be higher in northeast Iowa streams, although the pattern is not as strong, suggesting that benthic invertebrates are more strongly influenced by local water quality conditions (Iowa Department of Natural Resources 2001).

The FBI has the advantages of providing a rapid assessment of water quality without requiring species-level identification of arthropods. However, it also has certain limitations (Hilsenhoff, 1988).

Table 4. Benthic invertebrate survey results.

Location / Date	Confluence 9/00	Confluence 5/01	Ensign 9/00	Ensign 5/01	Hewett 9/00	Hewett 5/01
Taxonomy (Tolerance Value)						
Family Hydropsychidae (4)						
Hydropsyche	48	42	18	25	32	18
Potamyia	4	12	—	—	—	—
Family Limnephilidae (4)						
Limnephilus	—	—	—	1	—	—
Family Phryganeidae (4)						
Ptilostomus	2	—	—	—	—	—
Family Baetidae (4)						
Baetis	81	>200	72	>200	9	>200
Family Ephemerellidae (1)						
Ephemerella	—	—	—	2	—	—
Family Heptageniidae (4)						
Stenonema	—	2	2	2	36	5
Family Ceratopogonidae (6)						
Subfamily Ceratopogoninae	—	1	—	—	—	2
Family Chironomidae (6)						
Subfamily Chironominae	—	—	—	—	—	2
Subfamily Tanypodinae	2	2	3	—	—	—
Family Simulidae (6)						
Simulium	48	—	16	—	8	1
Family Tipulidae (3)						
Antocha	—	3	2	2	2	3
Family Elmidae (4)						
Optioservus	15	19	—	—	25	—
Family Hydrophilidae						
Tropisternus	—	—	—	—	1	—
Family Corydalidae (0)						
Chauliodes	—	1	—	—	5	—
Family Sialidae (4)						
Sialis	—	—	—	—	1	—
Family Corixidae						
Trichocorixia	—	—	1	—	1	—
Family Gammaridae (4)						
Gammarus	14	6	83	37	—	—

Table 5. Comparison of sites based on benthic invertebrate sampling.

Site	Confluence	Ensign	Hewett
Number of taxa	13	10	12
Total number of individuals	504	465	349
Family biotic index	4.20	4.05	4.00

Although a single tolerance value is used for an entire family, in reality not all species within a family share the same level of tolerance for organic pollution. Thus, the tolerance value for the family is actually an average of all the tolerance values for individual species in that family. This can skew the results in two ways. In unpolluted streams, the FBI may suggest that the water quality is lower than it actually is, while in polluted streams the index may suggest higher than actual water quality.

In this study, the analysis of physical and chemical parameters of water quality supports the evaluation of water quality derived from the FBI. Clearly, the benthic invertebrate sampling and water quality data suggested that the water quality of Ensign Hollow was very

Table 6. Evaluation of water quality based on Family Biotic Index (FBI) index (from Hilsenhoff 1988).

Water Quality	FBI	Degree of Organic Pollution
Excellent	0.00–3.75	Organic pollution unlikely
Very good	3.76–4.25	Possible slight organic pollution
Good	4.26–5.00	Some organic pollution probable
Fair	5.01–5.75	Fairly substantial pollution likely
Fairly poor	5.76–6.50	Substantial pollution likely
Poor	6.51–7.25	Very substantial pollution likely
Very poor	7.26–10.0	Severe organic pollution likely

good. As with many Iowa streams, the greatest threat is sedimentation through runoff. Sedimentation fills in holes and spawning beds important to trout, and suffocates eggs and invertebrates that become buried. Sedimentation also influences benthic invertebrate populations that have specific substrate preferences. Finally sedimentation can impact water temperature, since muddy bottoms trap more solar radiation. Efforts to maintain or improve the water quality of Ensign Hollow should be devoted to reducing sedimentation by runoff.

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