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Adult Trichoptera of the Devil Track River Watershed, Cook County, Minnesota and Their Role in Biomonitoring.

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ADULT TRICHOPTERA OF THE DEVIL TRACK RIVER WATERSHED, COOK COUNTY, MINNESOTA AND THEIR ROLE IN BIOMONITORING.

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ABSTRACT

Thirty two light trap collections of 7,797 adult Trichoptera made from 1990–1992, show that the Devil Track River Watershed in northeast Minnesota includes at least 16 families, 41 genera, and 101 species of caddisflies including three new state records: *Agyrpnia colorata*, *Agrypnia obsoleta,* and *Polycentropus glacialis*. The greatest number of species were represented by the families Limnephilidae (21), Leptoceridae (19), Hydroptilidae (13), Polycentropodidae (12), Phrygaenidae (10), and Hydropsychidae (9). Twenty two species were collected at all sites and 46 at one or two sites. The greatest number of species (81) was collected from the Devil Track River and Devil Track Lake with fewer (64 and 40) from two sites on Junco Creek. Most species are widely distributed and inhabit cool streams and lakes throughout eastern and northern North America. The high species diversity at all sites and the low number of tolerant species indicate that water quality within the watershed is good to excellent. However, increased water temperature, acidity, and/or organic enrichment could adversely affect at least one third of the Trichoptera species inhabiting the Devil Track River Watershed.

Based on an analysis of sediment cores from the profundal region of seven lakes in Minnesota and Wisconsin, including Thrush Lake which lies just west of the Devil Track River Watershed, Swain et al. (1992) concluded that the atmospheric deposition rate of mercury has increased by a factor of 3.7 during the past 140 years. High mercury levels reported in the common loon (Ensor et al. 1992), as well as northern pike, walleye (Swain and Helwig, 1989) and lake trout caused The Minnesota State of Health to issue an advisory in 1989 to limit consumption of fish from several northeastern Minnesota lakes. The Minnesota Pollution Control Agency concluded that mercury concentrations in northeastern Minnesota lake sediments have increased 2-5 percent per year and that mercury contamination in food chains, including fish, is due to air pollution (Minnesota Pollution Control Agency, News Release, 23 January 1990; Swain and Helwig 1989).

Four of the ten precipitation monitoring sites in 1991 and three of twelve through September, 1992 exceeded the Minnesota wet sulfate deposition standard (11 kg/ha.) (Orr et al. 1992). The Minnesota Pollution Control Agency estimates that, over a period of time, up to 2,200 lakes and 600,000 ha of forests in Minnesota could be damaged by precipitation with a pH of 4.7 or less. During the second quarter of 1992, the average precipitation pH at ten Minnesota

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monitoring sites ranged from 4.6 to 5.2. For this period, the mean quarterly pH at two sites near the Devil Track River Watershed, Cascade and Hovland, was 4.4 and 4.5, respectively (Minnesota Pollution Control Agency, News Release for 17 August 1992). Results of these and other studies (Burton et al. 1985, Simpson et al. 1985, Smith et al. 1990) show the need to monitor not only birds and fish but also macroinvertebrates which inhabit watersheds that are highly susceptible to acid precipitation, heavy metals and climate change (Johnson et al. 1993).

The present study was undertaken to survey the Trichoptera (caddisflies) of the Devil Track River (DTR) watershed, an area of approximately 145 km^2 located mostly within the Superior National Forest of Cook County, Minnesota. Trichoptera were chosen because caddisflies are generally susceptible to environmental pollutants (Moore et al. 1991, Norris and Georges 1993, Usis and Foote 1991) and are important components of benthic macroinvertebrate communities. Caddisflies contribute to the secondary productivity, energy budgets and decomposition processes of streams, rivers and lakes (Benke and Wallace 1980, Benke et al. 1984, Cudney and Wallace 1980, Hynes 1970, Mackay and Kersey 1985, Parker and Voshell 1983, Waters 1979, Wiggins and Mackay 1978) and wetlands (Garono and MacLean 1988, MacLean and MacLean 1984, Usis and MacLean 1986a,b; Flannagan and Macdonald 1987). Adults were surveyed because, while specific identifications are possible for about one-third of larval Trichoptera in North America (Schefter and Wiggins 1986, Schuster and Etnier 1978, Schmude and Hilsenhoff 1986, Wiggins 1977), the taxonomy of adults is much better known (Wiggins, 1978). Faunistic and taxonomic studies by Etnier (1965), Hilsenhoff (1981), and Lager et al. (1979) have provided important data on the Trichoptera fauna of the Great Lakes region.

The primary objective of this study was to obtain a list of adult Trichoptera that currently inhabit the Devil Track River Watershed and based on their published tolerances to acidity, organic pollution and water temperature, identify species that are potentially environmentally threatened. A secondary objective was to provide data on species abundance, sex ratios, and community characteristics that might be useful in interpreting any short or long term changes in biodiversity, of caddisflies or other aquatic insects, due to the effects of acid rain, heavy metal contamination or climate change (Allan and Flecker 1993). A better understanding of community structure and environmental conditions will of course depend on quantitative surveys (Norris and Georges 1993, Resh 1979) of immature aquatic insects and water quality data.

The Devil Track River Watershed

The largest body of water within the DTR watershed (Fig. 1) is Devil Track Lake which lies in an east-west direction and covers approximately 1080 ha (9.0 × 1.2 km) and reaches a depth of 18 m. The only inlets into the lake are Junco Creek which originates approximately 12 km to the North and flows into the northwest end of the lake and an unnamed stream that enters the lake along its north shore. For much of its distance, Junco Creek flows through small ponds, lakes, and wetlands. Water from a number of small lakes in the northern portion of the watershed flows into a small unnamed stream which empties into Junco Creek 1 km. north of Junco Lake.

The Devil Track River flows out of a small bay at the east end of the lake. A small dam at the outlet regulates the level of the lake and the flow of water into the river. The Devil Track River flows east through several beaver ponds

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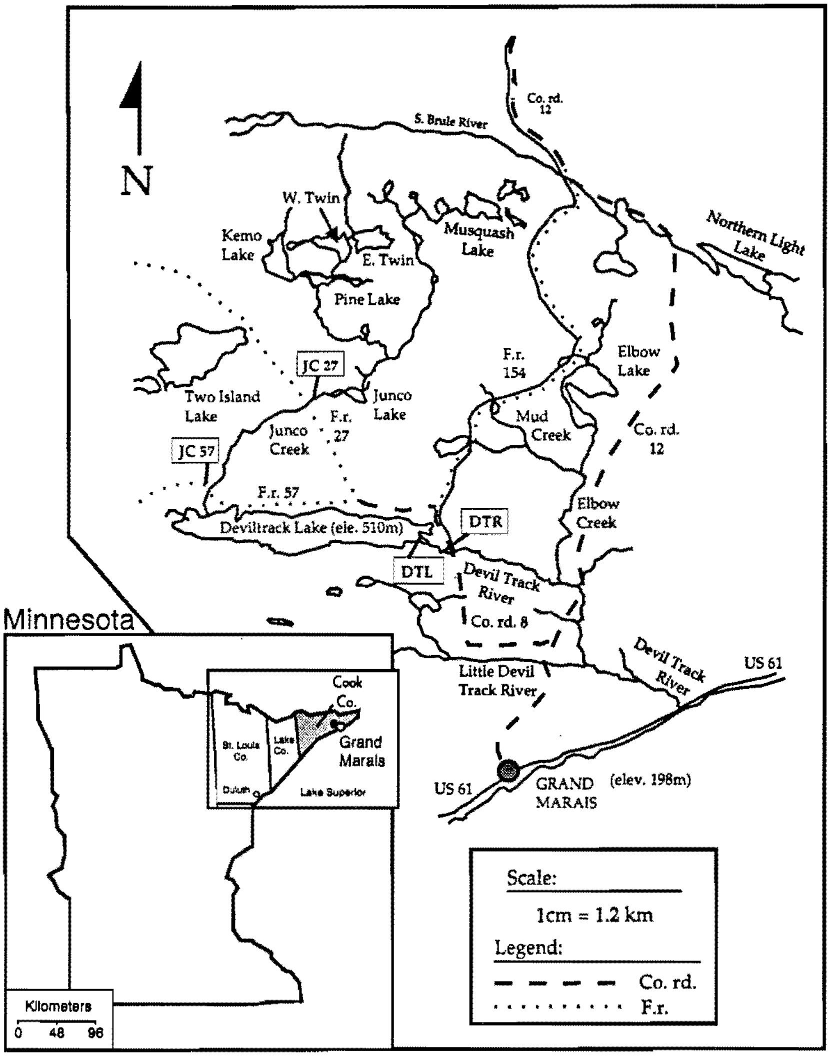

Figure 1. Location of the Devil Track River Watershed, Cook County, Minnesota. Only the major lakes, rivers, creeks, roads and collecting sites are shown. Two Island Lake, the South Brule River and Northern Light Lake lie outside of the watershed. Collection sites were: DTR = Devil Track River, DTL = Devil Track Lake, JC27 = Junco Creek 27, JC57 = Junco Creek 57.

and is crossed by County Rd. 8 approximately 750 m east of the lake. Elbow Creek flows south from Elbow Lake, the second largest body of water in the watershed, for 4.7 km before entering the Devil Track River. East of County Rd. 8, the river turns sharply southward and 2.5 km downstream enters the Devil Track Gorge. Water from wetlands and several small lakes south of Devil Track Lake are drained by the Little Devil Track River which flows east for 8 km where it enters the larger river near the head of the gorge. The river descends more than 210 m through the steep walled gorge for approximately 3.0 km until it enters Lake Superior 4.0 km east of Grand Marais, Minnesota.

Cabins and homes occur along the north shore and the eastern third of the south shore. A small airport, located for many years along the north shore of Devil Track Lake, has been relocated just north of County Rd. 8. Much of the watershed supports a dense white pine–northern hardwoods forest, including white and jack pine, balsam fir, white spruce, paper birch and quaking aspen. Black spruce and tamarrack occur in bogs and poorly drained areas. Much of the watershed was extensively logged during the early 1900s when nearly all the white pine was cut. Relatively few primitive forest roads, logging roads, and snowmobile trails penetrate the watershed.

The Devil Track River Watershed, like many in northeastern North America, is characterized by small amounts of exchangeable basic cations (e.g. $Ca^{++}$and Mg^{++}), greatly limiting the capacity to buffer inputs of acidic anions (e.g. SO_4^{--} and NO_3^-) (Driscoll and Newton 1985). Surface waters deficient in natural buffering capacity are thus susceptible to atmospheric deposition of acidic anions and acid shock during spring melt. In addition, H^+, Al, and trace metals are often released from the soil into surface waters (Driscoll and Newton, 1985, Smith et al. 1990). Based on field and laboratory analyses done by the Minnesota Department of Natural Resources, Division of Fisheries (Table 1), pH values for the Devil Track River (n = 23) in the 1980s ranged from 6.45 to 7.27. Values ranged from 6.78 to 7.50 for Devil Track Lake (n = 6) and 6.16 to 7.03 for Junco Creek (n = 6). Total alkalinity values ranged from 4.8 ppm for Junco Creek to 21.4 ppm for the Devil Track River.

MATERIALS AND METHODS

A total of thirty two light trap collections of adult Trichoptera was made by means of portable 8 w blacklight traps at four sites. Traps were operated for 4 to 5 hr beginning shortly after sundown. Locations and collection dates were: (1) the Devil Track River (DTR) ca 650 m downstream from where it flows out of the lake: 16, 26 August 1990, 16, 24 June, 5 July, 4 September 1991, 30 July, 6 August 1992; (2) the east end of Devil Track Lake (DTL): 14, 23, 26 August 1990, 16, 24 June, 5 July 1991, 5 September 1991, 29 July, 6, 16 August 1992; (3) Junco Creek (JC27) where it flows beneath Forest Rd. 27: 17, 27 June, 9 July 1991, 26 July, 8, 15, 19 August 1992; and (4) Junco Creek (JC57) where it flows below Forest Rd. 57, shortly before the stream enters Devil Track Lake: 17, 27 June, 7 July 1991; 26 July, 8, 15, 19 August 1992. Voucher specimens are currently housed in The Youngstown State University insect collection.

Simpson's index of diversity ($D = N(N-1)/S\, n_i\, (n_i - 1)$, where N is the total number and n the number of species i collected) and Sorenson's community coefficient ($S = 2C/n_{ij} + n_{ik}$, where C is the fewer number of individuals n of species i collected at sites j and k) were calculated for each site. Tolerances of caddisfly species to acidity, organic enrichment and temperature were based on values compiled by Harris and Lawrence (1978) and Hilsenhoff (1987). Biotic indices (BI) were based on the number of adult caddisflies collected only

Table 1. pH and total alkalinity for selected sites within the Devil Track River Watershed. Data provided by The Minnesota Department of Natural Resources, Division of Fisheries. Single values were recorded as the low for that date.

		pH		alkalinity[a]	
Site	Date	low	high	low	high
Devil Track River km from mouth					
0.00	1941	7.60	—	37.5	—
n.r.	03/82	6.85	7.27	23.5	27.0
n.r.	04/82	6.45	7.00	8.0	17.5
n.r.	05/82	6.80	—	2.9	—
n.r	06/82	7.02	—	16.6	—
0.25	10/86	6.91	—	21.4	—
12.00	10/86	6.89	—	14.9	—
Devil Track Lake	07/52	7.00	—	n.r.	—
	07/77	7.50	—	20.5	—
	08/83	7.24	—	14.1	—
	07/86	7.38	—	13.4	—
	07/87	6.78	—	12.1	—
	08/90	6.99	—	15.5	—
Junco Creek					
0.3 - 16.0 km from	07/86	6.16	7.03	4.8	25.6
Olson Creek	08/86	6.91	—	12.4	—

[a]alkalinity values recorded as mg/l for 1941 and 1982. Values for all other years are ppm.

for those species whose tolerance values (T.V.s: 0–10, where 0 = the most intolerant, 10 = the most tolerant) are known (Hilsenhoff 1982, 1987, 1988). Species were assigned to larval functional categories according to Anderson and Wallace (1984) and Cummins et al. (1984). Trichoptera nomenclature was based on Morse (1993 and per. com.).

RESULTS

Values of Simpson's diversity index (D) were 4.15 for DTL, 8.15 for DTR, 8.53 for JC27 and 11.33 for JC57 (Table 2). Even though both the DTR and DTL sites had the same number of species (81), diversity at the lake was only half that of the river site. The relatively low value for Devil Track Lake was no doubt due to the large number (1388) of *Nyctiophylax affinis* (Banks) collected at this site. Sorensen's community coefficient was highest for DTR and DTL (0.841) and lowest for JC57 with all other sites. Collectors and shredders were especially numerous at the river and lake sites with fewer numbers of piercers, predators and scrapers present at all sites.

Results of this survey demonstrate that the DTR supports at least 16 families, 41 genera and 101 species of Trichoptera (Table 3). Included in this list

Table 2. Community characterists of adult Trichoptera collected by light traps from 1990–1992 at four sites located within The Devil Track River Watershed, Cook County, Minnesota.

	Survey Site			
	DTR	DTL	JC27	JC57
No. of species	81	81	64	40
No. of individuals	2788	2908	1615	486
Simpson's index of diversity (D)	8.15	4.15	8.53	11.33
Sorensen's Community Coefficient (S)				
DTR	1.000	0.841	0.731	0.590
DTL		1.000	0.694	0.532
JC27			1.000	0.590
JC57				1.000

are three new state records: *Agyrpnia colorata* Hagen, *Agrypnia obsoleta* (Hagen), and *Polycentropus glacialis* (Ross). The greatest number of species were represented by the families Limnephilidae (21), Leptoceridae (19), Hydroptilidae (13), Polycentropodidae (12), Phrygaenidae (10) and Hydropsychidae (9). Ten additional families had three or fewer species. Caddisflies that emerged prior to the onset of light-trapping in mid June (e.g. possibly some *Banksiola* species) would not have been collected.

Species present at all sites were: *Anabolia bimaculata* (Walker), *Banksiola crotchi* Banks, *Ceraclea transversa* (Hagen), *C. diluta* (Hagen), *Ceratopsyche slossonae* (Banks), *C. sparna* (Ross), *Cheumatopsyche pettiti* (Banks), *Chimarra obscura*, *Hydatophylax argus* (Harris), *Hydropsyche bettini* Ross, *Hydroptila hamata* Morton, *Lepidostoma togatum* (Hagen), *Limnephilus indivisus* Walker, *N. affinis*, *Platycentropus radiatus* (Say), *Polycentropus cinereus* Hagen, *Polycentropus confusus* Hagen, *Polycentropus remotus* Banks, *Ptilostomis ocellifera* (Walker), *Ptilostomis semifasciata* (Say), *Pycnopsyche guttifer* (Walker) and *Pycnopsyche lepida* (Hagen). Except for *Oxyethira rivicola* Blickle & Morse, common or abundant hydroptilid species were collected only from the river and lake. Forty species were collected at only one or two sites. Only one species, *N. affinis*, was represented by more than 1,000; three between 400–500; six between 200–399; seven between 100–199; 13 between 50–99; and 72 by fewer than fifty individuals.

Females outnumbered males overall (F:M = 1.33) and >2:1 in the following common or abundant species: *Ceraclea ancylus* (Vorhies), *C. sparna*, *Chimarra feria* Hagen, *H. bettini*, *Ithytrichia clavata* Morton, *Oecetis ochracea* Curtis, *O. rivicola* (no males recorded), *P. confusus* and *Psychomyia flavida* Hagen (no males recorded). Interestingly, while the sex ratio for *C. feria* was heavily in favor of females, the M:F ratio for *C. obscura* was nearly 1.0. Males greatly outnumbered females (M:F > 2:1) for only *A. bimaculata*, *Ceraclea cancellata* (Betten), *Ceraclea tarsipunctata* (Vorhies), *Mayatrichia ayama* Mosley, *Oecetis persimilis* (Banks) and *P. guttifer*. However, the numbers of each species collected by light traps and the resulting sex ratios may have

Table 3. Species of Trichoptera collected by light traps operated at four sites within the Devil Track River Watershed, Cook County, Minnesota from 1990 –1992. Included are species reported pH and temperature ranges, tolerance values (T.V.s), numbers collected and sex ratios. The sites were The Devil Track River (DTR), Devil Track Lake (DTL), Junco Creek at Forest Rd. 27 (JC27) and Junco Creek at Forest Rd. 57 (JC57).

	environmental tolerances and no. of Adult Caddisflies at site								
Taxon	pH[a]	Tem.[b]	T.V.[c]	DTR	DTL	JC27	JC57	Total	F:M[d]
Philopotamidae									
Chimarra feria Ross	n.r.	n.r.	1	424	1	1	0	426	13:1
Chimarra obscura (Walk.)	5.9-8.9	E,M,O,S	4	306	16	128	1	451	0.9:1
Dolophilodes distinctus (Walk.)	5.9-8.0	M,O,S	0	1	0	2	43	46	5.6:1
Psychomyiidae									
Psychomyia flavida Hagen	6.0-8.7	M,O	2	0	5	3	75	83	all F
Polycentropodidae									
Neureclipsis crepuscularis (Walk.)	n.r.	n.r.	7	13	3	0	0	16	8.0:1
Neureclipsis valida (Walk.)	n.r.	n.r.	5	1	11	2	0	14	3.6:1
Nyctiophylax affinis (Banks)	n.r.	n.r.	5	115	1388	195	27	1725	0.8:1
Phylocentropus placidus (Banks)	6.0-6.8	n.r.	5	5	15	0	5	25	2.1:1
Polycentropus aureolus (Banks)	n.r.	n.r.	6	1	1	2	0	4	all M
Polycentropus cinereus Hagen	4.6-8.8	M,O,S	6	61	127	1	4	193	1.6:1
Polycentropus confusus Hagen	n.r.	n.r	6	53	107	7	33	200	2.3:1
Polycentropus crassicornis Walk.	n.r.	n.r.	6	0	0	1	0	1	all M

Table 3. Continued

	environmental tolerances and no. of Adult Caddisflies at site								
Taxon	pH[a]	Tem.[b]	T.V.[c]	DTR	DTL	JC27	JC57	Total	F:M[d]
Polycentropodidae (Cont.)									
Polycentropus flavus (Banks)	n.r.	n.r.	6	12	9	6	0	27	4.4:1
Polycentropus glacialis (Ross)	n.r.	n.r.	6	0	8	0	0	8	7.0:1
Polycentropus interruptus (Banks)	n.r.	n.r.	6	5	4	1	0	10	all M
Polycentropus remotus Banks	n.r.	n.r.	6	8	13	1	7	29	13.5:1
Hydropsychidae									
Ceratopsyche morosa (Hagen)	6.2-8.5	M,O,S	2	10	34	0	2	46	3.6:1
Ceratopsyche alternans (Walker)	7.7-8.5	M,O	3	9	14	0	0	23	3.6:1
Ceratopsyche slossonae (Banks)	4.6-8.2	M	4	290	33	11	17	351	1.5:1
Ceratopsyche sparna (Ross)	4.6-7.0	M,O,S	1	157	57	6	99	319	4.1:1
Cheumatopsyche aphanta Ross	8.0	n.r.	5	18	3	1	0	22	1.2:1
Cheumatopsyche pettiti (Banks)	5.9-8.2	M,O,S	5	219	46	44	1	310	0.7:1
Cheumatopsyche speciosa (Banks)	n.r.	n.r.	5	2	0	1	0	3	all F
Hydropsyche betteni Ross	5.9-8.5	M,O,S	6	20	14	69	22	125	41:1
Hydropsyche dicantha Ross	n.r.	n.r.	2	0	0	77	2	79	6.2:1

Rhyacophilidae									
Rhyacophila fuscula (Walk.)	3.8-9.1	M,O,S	0	0	0	0	10	10	0.1:1
Glossosomatidae									
Agapetes illini Ross	8.0-8.7	M	0	1	0	0	12	13	0.9:1
Glossosoma nigrior Banks	6.0-8.2	M,O,S	0	1	0	0	7	8	1.7:1
Hydroptilidae									
Hydroptila albicornis Hagen	n.r.	n.r.	6	0	0	0	3	3	all F
Hydroptila amonea Ross	n.r.	n.r.	6	0	1	6	2	9	8:1
Hydroptila consimilus Morton	6.8-9.1	M,O	6	3	9	0	0	12	all F
Hydroptila hamata Morton	6.0-8.2	M,O,S	6	4	13	1	1	19	3.8:1
Hydroptila salmo Ross	n.r.	n.r.	6	0	2	0	0	2	all M
Hydroptila scolops Ross	n.r.	n.r.	6	6	14	0	0	20	1.2:1
Hydroptila waubesiana Betten	6.8-7.2	M	6	0	64	0	0	64	all F
Hydroptila wyomia Denning	n.r.	n.r.	6	0	0	1	0	1	all M
Ithytrichia clavata Morton	n.r.	n.r.	n.r.	51	5	0	0	56	3:1
Mayatrichia ayama Mosely	<7.0-8.4	M,O	n.r.	166	24	2	0	192	0.1:1
Neotrichia okopa Ross	n.r.	n.r.	n.r.	21	6	0	0	27	1.7:1
Oxyethira michiganensis Mosely	n.r.	n.r.	3	2	1	1	0	4	all F
Oxyethira rivicola Blickle & Morse	n.r.	n.r.	3	2	0	76	19	97	all F
Phrygaenidae									
Agrypnia colorata Hagen	7.5-8.2	O	7	2	0	0	0	2	all M
Agrypnia obsoleta (Hagen)	n.r.	n.r.	7	1	3	0	0	4	all M

Table 3. Continued

Taxon	pH[a]	Tem.[b]	T.V.[c]	DTR	DTL	JC27	JC57	Total	F:M[d]
	environmental tolerances and no. of Adult Caddisflies at site								
Phrygaenidae (Cont.)									
Agrypnia improba (Hagen)	6.8-9.6	O	7	14	14	3	0	31	0.5:1
Agrypnia Macdunnoughi (Milne)	n.r.	n.r.	7	5	6	1	0	12	0.7:1
Agrypnia vestita (Walk.)	n.r.	n.r.	7	7	15	3	0	25	1.8:1
Banksiola crotchi Banks	n.r.	n.r.	n.r.	24	61	8	7	100	1:1
Hagenella canadensis (Banks)	n.r.	n.r.	n.r.	0	1	1	0	2	all M
Phryganea cinerea Walk.	n.r.	n.r.	8	1	2	6	0	9	0.1:1
Ptilostomis ocellifera (Walk.)	7>8.5	M,O,S	5	45	14	15	4	78	1.2:1
Ptilostomis semifasciata (Say)	n.r.	n.r.	5	12	31	4	7	54	0.7:1
Brachycentridae									
Micrasema wataga Ross	n.r.	n.r.	2	2	0	2	1	5	1.5:1
Lepidostomatidae									
Lepidostoma bryanti (Banks)	n.r.	n.r.	1	2	1	0	0	3	0.5:1
Lepidostoma sackeni (Banks)	n.r.	n.r.	1	4	4	0	0	8	0.3:1
Lepidostoma togatum (Hagen)	n.r.	n.r.	n.r.	1	2	22	7	32	9.7:1
Limnephilidae									
Anabolia bimaculata (Walk.)	5.9-8.4	M,O	2	32	44	8	6	90	0.2:1
Anabolia consocia (Walk.)	7.0-8.2	M,O,S	3	38	21	2	0	61	0.6:1
Arctopora pulchella (Banks)	n.r.	n.r.	n.r.	0	1	0	0	1	all M

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Asynarchus montanus (Banks)	n.r.	n.r.	n.r.	10	7	0	1	18	0.6:1
Asynarchus mutatus (Hagen)	n.r.	n.r.	n.r.	0	1	0	0	1	all M
Hydatophylax argus (Harris)	7.0-8.2	n.r.	2	1	4	1	7	13	12:1
Ironoquia punctatissima (Walk.)	6.2-9.4	M,O,S	3	2	0	0	0	2	all F
Limnephilus indivisus Walk.	7.0-8.2	M,O,S	3	2	1	1	1	5	0.6:1
Limnephilus moestus Banks	n.r.	n.r.	3	4	6	2	0	12	0.7:1
Limnephilus ornatus Banks	n.r.	n.r.	3	10	2	0	0	12	1.8:1
Limnephilus rhombicus (L.)	7.3-8.5	M,O	3	3	0	0	0	3	all F
Limnephilus sericeus (Say)	n.r.	n.r.	3	10	12	0	2	24	0.4:1
Limnephilus sublunatus Provancher	n.r.	n.r.	n.r.	0	2	1	0	3	1.0:1
Limnephilus submonilifer Walk.	8.4-8.5	M	3	1	3	0	0	4	3:1
Platycentropus amicus (Hagen)	n.r.	n.r.	4	1	0	0	0	1	all M
Platycentropus radiatus (Say)	7.0-8.2	M,O,S	4	6	14	2	4	26	3.3:1
Pycnopsyche aglona Ross	n.r.	n.r.	4	0	0	16	0	16	all F
Pycnopsyche guttifer (Walk.)	4.6-8.3	M,O,S	4	70	29	15	14	128	0.6:1
Pycnopsyche lepida (Hagen)	6.3-8.2	M,O,S	4	28	6	13	8	55	all F
Pycnopsyche limbata (McLachlan)	n.r.	n.r.	4	0	0	1	7	8	0.3:1
Pycnopsyche subfasciata (Say)	6.5-7.3	M,O,S	4	5	1	0	4	10	0.6:1

Table 3. Continued

Taxon	environmental tolerances and no. of Adult Caddisflies at site								
	pH[a]	Tem.[b]	T.V.[c]	DTR	DTL	JC27	JC57	Total	F:M[d]
Odontoceridae									
Psilotreta sp.	~ 7.0	M,O,S	n.r.	0	1	0	0	1	all F
Sericostomatidae									
Agarodes distinctus Ulmer	n.r.	n.r.	3	25	2	0	0	27	2.0:1
Molannidae									
Molanna blenda Sibley	5.4-6.9	M,O,S	6	4	8	0	3	15	0.1:1
Molanna tryphena Betten	6.1-7.0	M,O	6	0	0	1	0	1	all M
Molanna uniophila Vorhies	n.r.	n.r.	6	1	11	0	4	16	0.3:1
Heliopsychidae									
Heliopsyche borealis (Hagen)	6.5-8.5	M,O	3	4	5	1	0	10	all M
Leptoceridae									
Ceraclea alagma Ross	n.r.	n.r.	3	3	5	1	0	9	all M
Ceraclea ancylus (Vorhies)	7.9	M	3	112	197	38	0	347	5.9:1
Ceraclea annulicornis (Stephens)	n.r.	n.r.	3	2	0	1	0	3	0.5:1
Ceraclea cancellata (Betten)	n.r.	n.r.	3	6	11	61	0	78	0.3:1
Ceraclea diluta (Hagen)	n.r.	n.r.	3	34	41	404	5	484	1.1:1
Ceraclea resurgens (Walk.)	n.r.	n.r.	3	9	0	2	0	11	0.1:1
Ceraclea tarsipunctata (Vorhies)	7.5-8.2	M,O	3	0	0	248	0	248	0.4:1
Ceraclea transversa (Hagen)	n.r.	n.r.	3	117	79	10	2	208	0.9;1

Mystacides sepulchralis (Walk.)	6.5-8.8	M,O	4	1	2	0	0	3	0.5:1
Oecetis cinerascens (Hagen)	n.r.	n.r.	8	8	8	0	0	16	0.6:1
Oecetis inconspicua (Walk.)	5.9-8.8	M,O,S	8	22	115	44	0	181	1.0:1
Oecetis ochracea Curtis	n.r.	n.r.	8	29	25	23	0	77	all F
Oecetis persimilis (Banks)	n.r.	n.r.	8	67	4	3	0	74	0.3:1
Trianodes abus Milne	n.r.	n.r.	6	0	3	0	0	3	0.5:1
Trianodes dipsius Ross	n.r.	n.r.	6	2	2	1	0	5	all F
Trianodes flavescens Banks	n.r.	n.r.	6	4	22	2	0	28	13:1
Trianodes injustus (Hagen)	n.r.	n.r.	6	0	1	0	0	1	all M
Trianodes marginatus Sibley	n.r.	n.r.	6	5	6	2	0	13	0.6:1
Trianodes tardus Milne	n.r.	n.r.	6	3	4	0	0	7	all F
Totals:: Families: 16				13	14	12	13		
Genera: 41				36	34	29	25		
Species: 101				81	81	64	40		
No. 7797				2788	2908	1615	486	7797	

[a]Range of reported pH values and tolerances:: acidobionic < 5.0; acidophilic < 7.0; alkaliphilous ~ 7.0; alkalibionic > 8.5, n..r.. not recorded (Harris and Lawrence, 1978).
[b]Temperature tolerances:: S, stenothermal (< or 5C); O, oligothermal (0-15 C); M, mesothermal (15-30); euthermal (> 30 C), n..r.. not recorded (Harris and Lawrence, 1978)..
[c]T.V., Tolerance Vlaues:: 0-1, very intolerant; 2-4, intolerant; 5-7, moderately tolerant; 8-10, very tolerant (Hilsenhoff, 1987).
[d]F:M, ratio of female to male adult caddisflies.

been biased due to the collection method since not all caddisflies are attracted to light. This may explain the few number of Brachycentridae collected.

The largest number of caddisfly species (81) and individuals (2908 and 2788) were collected at the Devil Track River (DTR) and Devil Track Lake (DTL) sites respectively (Table 3). Considerably fewer species (64 and 40) and individuals (1615 and 486) were collected at the two Junco Creek sites (JC27 and JC57). Collections in 1992 were generally much smaller than other years due to below normal temperatures (nightime temperatures were often below 10°C).

Based on published tolerances to reduced dissolved oxygen, organic enrichment (Harris and Lawrence, 1978 and Hilsenhoff 1987), water temperature and pH, all sites included both tolerant and intolerant species (Table 3). The greatest number of species were moderately tolerant (T.Vs = 5–7), while relatively few were either intolerant (T.V.s = 0–4) or very tolerant (T.V.s = 8–10). Intolerant species were: *A. illini*, *Ceratopsyche morosa* (Hagen), *C. sparna*, *C. feria*, *Dolophilodes distinctus* (Walker), *Glossosoma nigrior* Banks, *H. argus*, *H. dicantha*, *Lepidostoma bryanti* (Banks), *Lepidostoma sackeni* (Banks), *L. togatum*, *Micrasema wataga* Ross, *P. flavida* and *Rhyacophila fuscula* (Walker). Species recorded to be the most tolerant to one or more of the conditions listed above were: *A. colorata*, *A. obsoleta*, *A. improba* (Hagen), *A. macDunnoughi* (Milne), *A. vestita* (Walker), *Neureclipsis crepuscularis* (Walker), *N. Valida* (Walker), *Oecetis cinerascens* (Hagen), *O. inconspicua* (Walker), *O. ochracea* (Curtis), *O. persimilis*, and *Phryganea cinerea* Walker.

Many species have been reported from a very wide range of water temperatures (0°–30° C). Two of the most abundant species, *C. feria* and *C. obscura*, can tolerate water temperatures above 30°C. *Agrypnia improba*, *A. colorata*, and *C. tarsipunctata* have been reported from a narrower range of cool water temperatures (0°–15° C). The range of pH tolerated by most species has been reported to be < 5.5 (acidobionic) to >7.0 (alkaliphilous). *Agrypnia improba*, *C. tarsipunctata*, *Ceratopsyche alternans* (Walker), *Limnephilus submonilifer* Walker, and *P. ocellifera* reportedly have a narrow pH range of 7.0 > 8.5 (alkaliphilous to alkalibionic). The pH of the Devil Track River, was lower (6.45-7.27) than previously reported for *A. colorata* and *Agapetes illini* Ross (Table 3). Biotic Index (BI) values (Table 4) calculated from species abundances and published tolerance values showed water quality to be either good or excellent for the four Devil Track River Watershed sites. The inclusion of primarily lentic species, e.g. phrygaenids, was not thought to bias the BI calcutions at these well aerated sites due to stream flow or wave action.

DISCUSSION

The large number of Trichoptera species reported in this study demonstrates that The Devil Track River Watershed supports a large and diverse aquatic fauna. The actual number of Trichoptera species that inhabit the watershed is no doubt greater than that reported here. For example, the presence of species found only at the Junco Creek 57 site suggests that additional species may inhabit the small lakes and streams in the northern portion of the watershed, the Devil Track River Gorge, and numerous bogs and wetlands that typically support a characteristic caddisfly fauna (Garrono and MacLean 1988). Unfortunately, light trap data provide only an indirect means of evaluating the Trichoptera community and their aquatic microhabitats. However, it is reasonable to assume that the diversity reported here is typical of Trichoptera and other aquatic insects that inhabit the watersheds of the vast and relatively unpolluted region of northeastern Minnesota and adjacent Ontario.

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Table 4. Biotic Index values of four sites within the Devil Track River Watershed, Cook County, Minnesota based on light trap collections of adult Trichoptera

Devil Track River	Devil Track Lake	Junco Creek F. R. 27	Junco Creek F. R. 57
3.68	4.83	3.95	2.92
Very Good	Good	Very Good	Excellent

Most caddisfly species that populate the Devil Track River Watershed, inhabit cool streams and lakes throughout the Deciduous Forest Biome of eastern North America (Holzenthal and Monson (per. com.), Nimmo, 1986, Ross, 1944). Ranges of *A. colorata A. obsoleta, A. improba, A. macDunnoughi*, *A. montanus* (Banks), *Asynarchus mutatus* (Hagen), *Hagnella canadensis* (Banks), *H. argus* and *Limnephilus sublunatus* Provancher, extend throughout the Boreal Forest Biome to the north and west (Marshall and Larson, 1982, Nimmo, 1971, 1986). No species was endemic or considered to be threatened or endangered (Holzenthal and Monson (per. com.). The caddisfly fauna of the heavily shaded JC57 site was the least similar with the other sites. The relatively warm JC27 site showed a greater similarity with the Devil Track river and lake (S= 0.73 & 0.69) than with the other Junco Creek site (JC57, S=0.59). This relatively low faunal similarity was due to the presence of cool water intolerant species at JC57 that were absent from the other sites. Not surprisingly, the Devil Track River and Devil Track Lake showed the closest faunal similarity (S=0.84).

Much remains to be learned about tolerances of many species of Trichoptera and other aquatic insects to heavy metals, low pH, organic pollution and warm water (Johnson et al. 1993, Lehmkuhl 1979, Moore et al. 1991, Mance 1987). Literature summarized by Jonhson et al. (1993) indicates that many Trichoptera taxa tolerate pH values < 4.7, but fewer (e.g. *Anabolia* and *Hydropsyche* spp.) tolerate reduced oxygen concentrations due to organic enrichment. However, predictions based on generalizations may be incorrect as tolerances to low pH, heavy metals and other environmental factors depend on life history traits such as larval size (instar), growth rate, voltinism, phenology and reproductive behavior (Lehmkuhl, 1979).

Community level effects would include secondary production, changes at the functional group level (e.g. collectors, grazers, piercers, predators and shredders) (Johnson et al. 1993) and decomposition rates (Kimmel et al. 1985, Mackay and Kersey, 1985). Smith et al. (1990) found that stream pH was positively correlated with mayfly density and richness and, while total invertebrate density was not affected, collector-gatherer richness, and scraper density and richness were positively correlated with stream acidity. Mackay and Kersey (1985), Kimmel et al. (1985), and Simpson et al. (1985) found markedly fewer benthic macroinvertebrates in acidic streams, and decreased decomposition rates of leaf litter as well. A similar response of filter feeding Trichoptera (collectors) to increased acidity would have a major impact on the structure of the benthic macroinvertebrate community of the Devil Track River.

Trichoptera are not as sensitive to low pH as Ephemeroptera (Johnson et al. 1993, Mackay and Kersey 1985, Smith et al. 1990), however, increased acidity and heavy metals would surely affect many caddisfly species (Johnson et al. 1993, Moore et al. 1991) and functional groups, e.g. hydropsychid and polycentropodid collectors. Values of pH, often reported from field observations carried out under "normal" conditions, may be of limited use when determining tolerances to acidity. For example, references given in Johnson et al. (1993, Table 4.1) record tolerances for *Agrypnia* and *Limnephilus* species to be less than 4.7. However, older references in Harris and Lawrence (1978) record *A. improba* and *L. submonilifer*, as well as *C. tarsipunctata*, *C. alternans* and *P. ocellifera*, from slightly to quite basic habitats (pH 7.0 > 8.5). Limnephilids and other shredders may be more tolerant of low pH and heavy metals than most other benthic macroinvertebrates (Mackay and Kersey 1985, Moore et al. 1991). Armitage and Tennessen (1984) concluded that short-term increases in acidity and aluminum concentration did not adversely affect the diversity and density of caddisflies inhabiting a North Carolina soft water stream. While species such as *Frenesia difficilis* (Walker) and *R. fuscula* may survive in acidic streams (pH < 5.0, Mackay and Kersey 1985, Simpson et al. 1985), exposure to low pH over long periods would surely affect the life cycles of many species of caddisflies and other aquatic insects (Johnson et al. 1993). Smith et al. (1990) reported that *Glossosoma*, *Pycnopsyche* and *Trianodes* were absent from the most acidic sites and together with *Hydropsyche*, might be good indicators of acidic conditions. While insects are in general more tolerant to increasing heavy metal concentrations than Crustacea and gastropods (Mance 1987), caddisflies exhibit most of the characteristics of "ideal" sentinel organisms (Hellawell 1986, Johnson et al. 1993, Norris and Georges 1993).

Based on tolerance values (Hilsenhoff 1987), species that could be adversely affected by increased organic pollution (Table 5) include six net-spinning caddisflies, *C. sparna*, *C. morosa*, *Chimarra feria*, *D. distinctus*, *H. dicantha* and *P. flavida*; two grazers, *A. illini* and *G. nigrior*; three case-building species, *H. argus*, *L. bryanti* and *L. sackeni*; and a predator *R. fuscula*. The number of species affected would no doubt be higher as little is known about tolerance values for most species of caddisflies. Populations of more tolerant species such as *A. obsoleta*, *A. improba*, *A. macDunnoughi*, *A. vestita*, *N. crepuscularis*, *N. validus*, *O. cinerascens*, *O. inconspicua*, *O. ochracea* and *O. persimilis* that inhabit the slower portions of The Devil Track River, Junco Creek and Devil Track Lake could increase as a result of organic enrichment or reduced oxygen levels.

While many caddisfly species recorded from The Devil Track River Watershed inhabit a wide range of temperatures, it is interesting that two of the most abundant species, *C. feria* and *C. obscura* can tolerate warm water, i.e. >30°C. Because of insufficient data on thermal tolerances, the actual number of species that would be affected by rising water temperatures is no doubt higher. Increased water temperatures would directly affect the life cycles of aquatic insects (Lehmukuhl 1979, Waters 1979) and indirectly affect their food quality, growth rates, and size (Anderson and Cummins 1979). Higher water temperatures and extended developmental seasons could, because of faster larval growth, result in a second generation for some hydropsychid caddisflies (Mackay 1979) or prevent diapause and thus disrupt the life cycles of cool water species (Lehmukuhl 1979). While tolerant species might not be adversely affected by increased water temperatures, cool water species such as *A. illini*, *Agrypnia colorata*, *A. improba*, *G. nigrior*, *Psilotreta* sp. and *R. fuscula* (Table 5) could become locally extinct.

The high species diversity, the presence of intolerant species at all sites and the relatively low Biotic Index values indicated that water quality was good to excellent throughout the watershed. However, increased levels of organic pollution and/or decreased levels of dissolved oxygen could stress small populations of intolerant species. At the same time populations of more tolerant species would likely increase. Both changes could greatly affect commu-

Table 5. Trichoptera of the Devil Track River Watershed, Cook County, Minnesota potentially threatened by increased acidity, heavy metals, organic pollution and/or water temperatures. Potentially threatened species of *Agrypnia*, *Ceraclea*, *Lepidostoma*, *Psilotreta*, and *Pycnopsyche* are presented in the Discussion.

	Reported Tolerance Ranges for Environmental Factor			
Family / Genus	acidity[a]	heavy metals	organic pollution[b]	water temp[c].°C
Philopotamidae				
Chimarra (2 spp.)	5.9		4	< 5 -> 30
Dolophilodes distinctus	5.9		0	< 5 - 30
Psychomyiidae				
Psychomyia flavida	6.0 - 8.7		2	0 - 30
Hydropsychidae	d			
Ceratopsyche (4 spp.)	4.6 - 8.5	d	1,2,3	< 5 - 30
Hydropsyche dicantha	n.r.	d	2	n.r.
Rhyacophilidae				
Rhyacophila fuscula	3.8 - 9.1		0	< 5 - 30
Glossosomatidae				
Agapetes illini	8.0 - 8.7		0	15 - 30
Glossosoma nigrior	6.0 - 8.2		0	< 5 - 30
Phrygaenidae				
Agrypnia (2 spp.)	6.8 - 9.6		0	< or = 5
Ptilostomis ocellifera	7.0 > 8.5		5	< 5 - 30
Brachycentridae		d		
Micrasema wataga	n.r.		2	n.r.
Lepidostomatidae				
Lepidostoma (3 spp.)	n.r.		1	n.r.
Limnephilidae				
Hydatophylax argus	7.0 - 8.2		2	n.r.
Limnephilus submonilifer	8.4 - 8.5 ?	d	3	15 - 30
Pycnopsyche (5 spp.)	4.5 - 8.3		4	< 5 - 30
Odontoceridae				
Psilotreta (1 sp.)	7.0		0	< 5 - 30
Leptoceridae				
Ceraclea (2 spp.)	7.5 - 8.2		3	0 - 30

[a] pH ranges: < 5.5 - Acidobionic, < 7.0 - Acidophilic, 7.0 - 8.0 - Alkaliphilous, > 8.5 - Alkalibionic (Harris and Lawrence 1978).
[b] Tolerance Value ranges: 0 - 3, intolerant; 4 - 6, moderately tolerant; 7 - 10, tolerant. (Hilsenhoff 1987).
[c] Temperature tolerances: < or = 5, Stenothermal; 0 - 15, Oligothermal; 15 - 30, Mesothermal; > 30, Euthermal (Harris and Lawrence 1978).
[d] Moore et al. (1991)

nity structure and food chains. Therefore biomonitoring of benthic macroinvertebrates, including Trichoptera, by traditional or automated methods (Johnson et al. 1993, Morgan et al. 1987) is essential in order to evaluate the status of environmentally threatened watersheds.

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