Ecological Consequences of Sediment Input to a Mountain Stream Insect Community: A Self-Mitigating System?

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ABSTRACT

The Cheyenne Stage II Diversion Project began in 1983 in an effort to collect 23,000 acre-feet of water annually from 30 tributary streams of the North Fork of the Little Snake River (NFLSR). As a consequence of the Diversion Project, Green Timber Creek (a steep, rough, regulated tributary of the NFLSR) received 1,500 m^3 of a broad-sized range of sediment in May, 1988. Both Green Timber Creek and the NFLSR support the largest known, essentially pure population of the endangered Colorado River cutthroat trout, *Oncorhynchus clarki pleuriticus* Cope. Because the primary food source for the cutthroat trout is aquatic insects, a study was conducted to assess the impact of sediment deposition on the aquatic insect community. Our 1989 study found that the addition of the sediment had a minimal impact on the abundance and diversity of aquatic insects. These results were similar to a more extended study conducted on the impact of sediment deposition in the NFLSR. The apparent lack of significant impact may be a result of: (1) rapid recolonization, (2) exposure of the embedded substrate by high, spring flow rates, (3) continuous transportation of finer sediments from the drainage, and (4) effective utilization of large, sediment particles by the aquatic community.

The increasing importance of water in the semi-arid west has accelerated anthropogenic alterations in the flow regimes of water systems. As an increasing number of streams are being regulated, an understanding of the responses of biotic communities to perturbation is important not only in assessing human-induced changes, but such knowledge may also provide insight to the structure and function of natural systems (Cline et al. 1982). Of primary concern in the regulation of high mountain stream systems is the introduction of sediments into the system, especially during the construction period.

During the early 1960's, the city of Cheyenne, Wyoming constructed a transbasin diversion system through the Continental Divide to transport water from the North Fork of the Little Snake River Drainage (western slope) to the Encampment River Drainage (eastern slope). This development project (Stage I) was expanded in 1983 (Stage II) to collect 23,000 acre-feet of water annually from the North Fork and thirty of its tributaries.

The North Fork and its tributaries support the largest, essentially pure population of the Colorado River cutthroat trout, <u>Oncorhynchus clarki pleuriticus</u> Cope (Binns, 1977). This species is classified as "Endangered" (Utah), "Threatened", (Colorado), and "Sensitive" (Wyoming), and has been listed in the "Special Concern" category of the American Fisheries Society (Binns 1977).

On May 27 and 28, 1988, a manhole on the pipeline surcharged and overflowed, depositing ca. 1,500 m^3 of a broad size range of sediment (sand to rubble, 0.125-200 mm) into Henry and Green Timber Creeks (Noe 1989). Green Timber Creek is a major tributary of the

North Fork of the Little Snake River and supports a population of the Colorado River cutthroat trout. The objective of this research was to determine the impact of sediment on the aquatic insects in Green Timber Creek, which are an important food source for the cutthroat trout.

Description of Study Area

Green Timber Creek is a high gradient, regulated headwater stream originating at an elevation of 2850 m a.s.l. in the Sierra Madre of the Medicine Bow National Forest, Wyoming (Figure 1). Located on the west side of the Continental Divide, Green Timber Creek flows westwardly through stands of subalpine fir (*Abies lasiocarpa*) and englemann spruce (*Picea engelmannii*), and through mountain meadows to the confluence of the North Fork of the Little Snake River, approximately 4.0 km downstream from the headwaters. Sediment entered Green Timber Creek at the Henry Creek confluence and was deposited in Green Timber Creek for approximately 1.5 km, extending to the North Fork of the Little Snake River confluence. The city of Cheyenne, Wyoming is required to release normally diverted water down Green Timber Creek for routine channel flushing and maintenance during normal operating conditions. These flow recommendations, developed by Wesche et al. (1977) call for a three day annual release of 3.96 m^3s^{-1} (14 cfs) during the spring runoff period and a maintenance flow of 0.28 m^3s^{-1} (1 cfs). Due to the damage to the regulatory structures, and to reduce the volume of sediment being transported down the Green Timber Creek drainage, there was no flushing flow in 1988 and 1989.

Methods

The study consisted of one unimpacted site above and three impacted sites below the Henry Creek confluence and two unimpacted sites on the North Fork of the Little Snake River (Figure 1). At each site, six aquatic insect samples were collected using two surber samplers (0.728 and 0.350 mm mesh) which enclosed 0.1 m^2 of substrate, monthly from June to September, 1989. Taking three samples with each mesh size increased sampling efficiency (Peckarsky 1984).

Green Timber Creek Sites 1 (above the impact), and 3 (0.5 km below the impact) had aquatic insects samples taken in September 1984, September 1985, and September 1988 by the United States Forest Service as part of their Cheyenne Stage II monitoring program (Mangum 1984, 1985, 1988). Green Timber Creek Site 2 (immediately below the impact) was added by the U.S. Forest Service in 1988 as an additional station to monitor the effects of the sediment input. Green Timber Site 4 was included in 1989 to assess the impact the sediment spill had on Green Timber Creek at the confluence of the North Fork of the Little Snake River.

The North Fork of the Little Snake River Sites 1 and 2 were used as unimpacted sites because of baseline data were available from previous collections taken in 1985, 1986, and 1987 (DeBrey and Lockwood 1990). Also, these sites reflected the substrate, water velocity and grade of the impacted stations on Green Timber Creek below the sediment input more accurately than the upper reaches of

Green Timber Creek, due to a sharp increase in channel grade upstream from Green Timber Creek Site 1.

Samples were immediately preserved in 70 percent ethanol. In the laboratory, the insects were picked from the debris under a binocular dissecting microscope and identified. The Shannon (base 10) index of diversity, Shannon index of evenness, taxonomic richness (total number of taxa), and abundance (total number of individuals per unit area) were computed using Ecological Measures software (Kotila, 1986). To assure consistency and interpretability of the indices, values were computed at the family level, which was the most specific taxonomic level common to all identifications. In addition, ecological indices were calculated for the lowest taxonomic levels (species, genus or family); these values are meaningful within this study but can not be accurately interpreted in context of other published values. Means of the ecological indices were calculated for the combined impacted and unimpacted sites.

Statistical analyses consisted of chi-square tests of differences in the frequency of aquatic orders between impacted and unimpacted sites in 1989, and analysis of variance (with rank conversions to alleviate problems of non-normal distributions of ecological indices) of differences in ecological indices between impacted and unimpacted sites in 1989. In all tests, differences were considered significant at $P<0.05$. Because long-term data sets were collected on only one impacted and one unimpacted site, statistical analysis was inappropriate. However, these data sets appear to be the only temporally extensive information on aquatic community dynamics of a sediment-impacted stream system. Few long-term data sets exist for mountain stream systems, and having a sediment spill occur on a portion of such a system is a unique and fortuitous event. As such, there is considerable value in qualified, descriptive assessment of the data.

Results

Aquatic Insect Composition

In 1989, Ephemeroptera (Baetidae, Heptageniidae), Plecoptera (Nemouridae), Trichoptera (Rhyacophilidae) and Diptera (Chironomidae) accounted for the majority of aquatic insect abundance, although Coleoptera was well represented by the family Elmidae (Table 1, Appendix 1). There were no significant differences between impacted and unimpacted sites with regard to the frequency of the aquatic orders. However, there were clear temporal trends in both the unimpacted and impacted sites. In unimpacted sites, percent composition of Ephemeroptera declined from June through September, Plecoptera increased from June through September, and Trichoptera, Diptera and Coleoptera remained relatively constant. The impacted areas differed from the unimpacted in that the relative frequency of Trichoptera increased and Plecoptera remained relatively constant, from June through September.

During 1989, diversity and evenness increased in both the impacted and unimpacted sites from June through August with a slight decrease in September (Tables 2 and 3). In June, these indices were significantly greater in impacted sites than in unimpacted sites. Richness (Tables 2 and 3) in the impacted sites increased from June/July through August/September. Richness in the unimpacted area remained virtually constant throughout the season. Abundance (Tables 2 and 3) increased 75% from June through July in the impacted sites, then decreased sharply in August and recovered in September. Abundance in the unimpacted sites continuously declined throughout the study. In August and September, abundance was significantly greater in impacted sites than in unimpacted sites. For all months, the impacted areas had higher values for diversity, richness, evenness and abundance than the unimpacted sites (except evenness in August).

Long-term Effects

Comparison of ecological parameters (based only on collections taken in September) of the unimpacted and impacted sites on Green Timber Creek for the years 1984, 1985, 1988, and 1989 revealed differences in community dynamics (Table 4). Diversity in Green Timber Creek Site 1 (unimpacted) generally decreased from 1984 through 1989. Richness increased from 1984 to 1985 but declined from 1985 to 1989. Evenness decreased from 1984 through 1988 and increased substantially in 1989. From 1988 to 1989 diversity and evenness increased slightly in Site 2 (impacted); however, richness decreased during this time. Diversity at Site 3 (impacted) decreased from 1984 through 1988 but increased markedly in 1989. Richness increased from 1984 to 1985 and remained constant through 1989.

Changes in the community structure also differed between impacted and unimpacted sites on Green Timber Creek, although similar trends were found in several orders (Table 5). From 1984 through 1989, the unimpacted reach (Site 1) had a 2.5-fold increase in Ephemeroptera, a 1.4-fold increase in Plecoptera, a 3.0-fold decrease in Trichoptera, a 3.7-fold decrease in Coleoptera, and essentially no change in Diptera. In the impacted reach (Site 3) there was also an increase (2.7-fold) in Ephemeroptera and a decrease (4.0-fold) in Coleoptera. However, there was essentially no change in Plecoptera or Trichoptera, and Diptera decreased by 1.7-fold.

From 1988 to 1989, the unimpacted reach (Site 1) had slight increases in Plecoptera, Trichoptera and Coleoptera, a 1.5-fold increase in Ephemeroptera and a 1.8-fold decline in Diptera. During this period, the impacted reaches (Sites 2 and 3) had an average increase of 1.5- to 2.8-fold in all orders, except Diptera which experienced a 3.8-fold decrease.

Discussion

Diversity and evenness showed a clear decline from 1984-1985 to 1988 and a recovery in 1989 in both the impacted and unimpacted sites. However, recovery in the impacted sites was much more pronounced and actually exceeded the 1984-1985 levels. There may be several reasons to explain this recovery pattern.

First, given the length of time between initial impact (May 1988) and the first aquatic community collection (September 1988), recolonization may have occurred. Gore (1979) found Baetidae recolonizing a newly formed stream 14 hours after water was released into the channel. Shaw and Minshall (1980) reported colonization of artificial substrate with 1 day. Allan (1975) found that Baetis bicaudatis Dodds rapidly colonized introduced substrate in high mountain streams and noted that there was rapid recolonization among most Ephemeroptera and slow recolonization among most Trichoptera. Green Timber Creek and its tributaries upstream of Henry Creek confluence were unimpacted which could have allowed for rapid recolonization by drift (Townsend and Hildrew 1976).

A second explanation for recovery was suggested by Lenat et al. (1981), who proposed that insects utilize islands of reduced habitat. Although there was a decrease in the biological indices in 1988, there apparently was not a complete removal of the aquatic insects in Green Timber Creek. Those substrates not embedded in the finer sediment were able to support the reduced insect fauna and this would have allowed for emergence and upstream flight. Muller (1982) proposed the term "colonization cycle" for downstream drift and compensatory upstream flight by adult females, including movements into seasonably favorable habitats. Indeed, Resh et al. (1981) showed that adult oviposition was responsible for recolonization of a caddisfly population in a California spring following complete elimination and subsequent recovery of the habitat.

A final explanation of the recovery can be derived from Thienemann's (1954 in Hynes 1970) principle, which suggests that the greater the diversity of conditions in a locality, the more diverse the biotic community. The sudden addition of a broad size range of sediment into Green Timber Creek probably had an immediate detrimental effect on the aquatic fauna. However, in a short period of time, the aquatic insects were able to utilize the more diverse habitat, created by the deposition of a broad size range of sediment. These findings substantiate the findings of Pennak and Van Gerpen (1947), Ward (1975), and DeBrey and Lockwood (1990) which show a progressive increase in abundance from a sand to a rubble substrate then a decrease in total numbers when substrate size increases to bedrock. Minshall (1984) suggested that total abundance increases with heterogeneous substrate (gravel and rubble) as compared to a homogeneous substrate (sand and bedrock). Also, the shift in percent composition in Sites 2 and 3 from sand tolerant Chironomids to sand intolerant Ephemeroptera, Trichoptera and Plecoptera indicates that the finer sediments were being transported downstream. Wesche et al. (1988) concluded that moderate to high gradient mountain stream channels located in the forest snowpack zone may be maintained with reduced streamflow regimes. Wesche (1990) found that flows of less than 0.28 m^3s^{-1} (1 cfs, the required maintenance flow for Green Timber Creek) would transport sediment up to 2.0 mm in diameter.

Barton (1977), Cline et al. (1982), and DeBrey and Lockwood (1990) have found no substantial long-term impacts to the aquatic macroinvertebrates with the addition of sediment due to construction activities. These findings are substantiated by this study. We surmise that the reason there were no demonstrable long-term impacts to the aquatic insects of Green Timber Creek includes: (1) the presence of substrates that were not completely embedded and were able to serve as islands for the aquatic community, (2) upstream flight by females, (3) the presence of unimpacted upstream reaches that allowed for rapid recolonization, (4) high spring flows which remove finer sediment exposing the more utilized substrates, and (5) continuous transport of finer sediments downstream.

Literature Cited

Allan, D. J. 1975. The distributional ecology and diversity of benthic insects in Cement Creek, Colorado. Ecology 56:1040-1053.

Barton, B. A. 1977. Short term effects of highway construction on the limnology of a small stream in southern Ontario. Freshwater Biology 7:99-108.

Binns, N. A. 1977. Present status of indigenous populations of cutthroat trout (Salmon clark) in southwest Wyoming, Fisheries Technical Bull. No. 2, Wyoming Game and Fish Department, Cheyenne, Wyoming.

Cline, L. D., Short, R. A., and Ward, J. V. 1982. The influence of highway construction on the macroinvertebrates and epilithic algae of high mountain stream. Hydrobiologia 96:149-159.

DeBrey, L. D. and Lockwood, J. A. 1990. Effects of sediment and flow regime on the aquatic insects of a high mountain stream. Regulated Rivers. In press.

Hynes, H. B. N. 1970. The Ecology of Running Waters. University of Toronto Press, Toronto.

Gore, J. A. 1979. Patterns of initial benthic recolonization of a reclaimed coal strip-mined river channel. Canadian Journal of Zoology 57:2429-2439.

Kotila, P. M. 1986. Ecological Measures, Software Package, Natural Science Division, Franklin Pierce College, Rindge, New Hampshire.

Lenat, D.R., Penrose, D. L., and Eagleson, K. W. 1981. Variable effects of sediment addition on stream benthos. Hydrobiologia 79:187-194.

Mangum, F. A. 1984. Aquatic ecosystem inventory macroinvertebrate analysis. Green Timber Creek, Medicine Bow National Forest. USDA - Forest Service Intermountain Region, Provo, Utah.

1985. Aquatic ecosystem inventory macroinvertebrate analysis. Green Timber Creek, Medicine Bow National Forest. USDA - Forest Service Intermountain Region, Provo, Utah.

1988. Aquatic ecosystem inventory macroinvertebrate analysis. Green Timber Creek, Medicine Bow National Forest. USDA - Forest Service Intermountain Region, Provo, Utah.

Minshall, G. W. 1984. Aquatic insect-substratum relationships. In V. H. Resh and D. M. Rosenberg [eds.], The Ecology of Aquatic Insects. Praeger, New York. 358-400.

Muller, K. 1982. The colonization cycle of freshwater insects. Oecologia (Berlin) 52:202-207.

Noe, H. 1989. Review, design and construction services: fish habitat restoration on Green Timber Creek. Cheyenne Water and Sewer Departments, Board of Public Utilities, Request for Proposals, 17 pp.

Peckarsky, B. L. 1984. Sampling the stream benthos, p. 131-160. In J. A. Downing and R. H. Rigler [ed.] A manual on methods for the assessment of secondary productivity in fresh waters. IPB Handb. No. 17. 2nd ed. Blackwell Scientific Publications, Oxford.

Pennak, R. W., and Van Gerpen, E. D. 1947. Bottom fauna production and physical nature of the substrate in a northern Colorado stream. Ecology 28:42-48.

Resh, V. H. 1982. Age structure alteration in a caddisfly population after habitat loss and recovery. Oikos 38:280-284.

Shaw, D. W., and Minshall G. W. 1980. Colonization of an introduced substrate by stream macroinvertebrates. Oikos 34:259-271.

Townsend, C. R., and Hildrew, A. G. 1976. Field experiments on the drifting, colonization, and continuous redistribution of stream benthos. Journal of Animal Ecology 45:759-772.

Ward, J. V. 1975. Bottom fauna-substrate relationships in a Northern Colorado trout stream: 1945 and 1974. Ecology 56: 1429-1434.

Wesche, T. A. 1990. Sediment transport relations and channel maintenance implications for Big Sandstone Creek. Wyoming Water Research Center report to the Wyoming Water Development Commission. Laramie, Wyoming. 44p.

Wesche, T. A. Skinner, Q. D., Hasfurther, V. R. and Wolff, S. W. 1988. Stream channel response to flow depletion. Wyoming Water Research Center report to the Wyoming Water Development Commission. Laramie, Wyoming. 16p.

Wesche, T. A., Reiser, D. W., Wichers, W., and Wichers, D., 1977. Fishery resources and instream flow recommendations for streams to be impacted by Cheyenne's proposed Phase II development, Water Resources Research Institute Report to Wyoming Game and Fish Department, Laramie, Wyoming. 62p.

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Table 1. Percent composition by order and family for Green Timber Creek and the North Fork of the Little Snake River, 1989.

Site/Order	Month: June	July	August	September
Unimpacted/				
Ephemeroptera	41	28	31	20
Baetidae	33	6	8	3
Heptageniidae	5	16	13	13
Ephemerellidae	2	6	5	2
Plecoptera	12	20	25	30
Nemouridae	6	6	11	7
Chloroperlidae	4	13	12	18
Perlodidae	0	0	0	0
Trichoptera	10	12	20	13
Rhyacophilidae	7	10	12	10
Glossosomatidae	0	0	6	1
Hydropsychidae	0	0	0	1
Diptera	37	38	24	31
Chironomidae	33	26	20	24
Simuliidae	3	10	1	2
Coleoptera	1	2	6	6
Elmidae	1	2	6	6

Table 1. (continued)

Site/Order	Month June	July	August	September
Impacted/				
Ephemeroptera	48	41	31	35
Baetidae	21	4	12	17
Heptageniidae	24	28	9	11
Ephemerellidae	3	6	9	6
Plecoptera	14	26	10	20
Nemouridae	6	7	1	2
Chloroperlidae	7	17	7	9
Perlodidae	0	0	0	8
Trichoptera	7	13	26	16
Rhyacophiladae	5	7	12	8
Glossosomatidae	0	0	5	1
Hydropsychidae	0	0	5	4
Diptera	30	17	26	24
Chironomidae	20	12	19	20
Simuliidae	6	2	2	0
Coleoptera	1	2	6	5
Elmidae	1	2	6	5

Table 2. Ecological indices (Shannon-Weaver base 10 diversity and evenness and total species richness) and abundances (number per 0.1 m^2) for unimpacted, and impacted sites, Green Timber Creek and the North Fork of the Little Snake River, 1989 (family level).

	Month			
Site/Index	June	July	August	September
Unimpacted/				
Diversity	0.751	0.911	1.013	0.926
Evenness	0.636	0.788	0.831	0.782
Richness	15	14	15	15
Abundance	410	369	276	255
Impacted/				
Diversity	0.902	0.946	1.075	1.004
Evenness	0.758	0.791	0.818	0.793
Richness	16	16	20	19
Abundance	345	603	405	502

Table 3. Ecological indices (Shannon-Weaver base 10 diversity and evenness and total species richness) and abundances (number per 0.1 m^2) for unimpacted, and impacted sites, Green Timber Creek and the North Fork of the Little Snake River, 1989 (lowest taxonomic level).

	Sites					
Month/Indices	NF1	NF2	GT1	GT2	GT3	GT4
June/						
Diversity	0.730	0.871	0.837	1.035	1.035	0.899
Evenness	0.571	0.694	0.644	0.809	0.783	0.706
Richness	19	18	20	19	21	24
Abundance	375	181	401	231	159	352
July/						
Diversity	0.913	0.999	1.019	0.936	1.153	1.119
Evenness	0.796	0.796	0.812	0.720	0.872	0.875
Richness	14	18	18	20	21	19
Abundance	240	221	499	534	415	203
August/						
Diversity	1.013	1.069	1.161	1.144	1.205	1.093
Evenness	0.841	0.822	0.853	0.808	0.833	0.772
Richness	16	20	23	26	28	26
Abundance	140	318	201	335	596	352

Table 3. (continued)

Month/Indices	Sites NF1	NF2	GT1	GT2	GT3	GT4
September/						
Diversity	1.000	0.943	1.016	0.941	1.163	1.064
Evenness	0.796	0.783	0.768	0.750	0.822	0.771
Richness	18	16	21	18	26	24
Abundance	220	178	190	72	408	704

Table 4. Ecological indices (Shannon-Weaver base 10 diversity and evenness and total species richness) for unimpacted and impacted sites On Green Timber Creek, from 1984 to 1989.

Site/ Index	Year			
	1984	1985	1988	1989
Site 1/				
Diversity	1.058	0.969	0.878	0.941
Evenness	0.828	0.702	0.645	0.764
Richness	19	24	23	17
Site 2/				
Diversity	N/A	N/A	0.841	0.898
Evenness	N/A	N/A	0.657	0.764
Richness	N/A	N/A	19	15
Site 3/				
Diversity	1.017	0.863	0.680	1.112
Evenness	0.796	0.643	0.515	0.829
Richness	16	22	21	22

Table 5. Percent composition by order and family for Green Timber Creek sites 1 (unimpacted), 2 (impacted), and 3 (impacted), from 1984 through 1989.

Site/Order	Year			
	1984	1985	1988	1989
Site 1/				
Ephemeroptera	12	17	20	30
Plecoptera	26	49	31	35
Trichoptera	24	11	4	8
Diptera	27	22	42	24
Coleoptera	11	1	2	3
Site 2/				
Ephemeroptera	NA	NA	18	21
Plecoptera	NA	NA	36	52
Trichoptera	NA	NA	5	2
Diptera	NA	NA	41	16
Coleoptera	NA	NA	0	9
Site 3/				
Ephemeroptera	16	15	9	38
Plecoptera	29	39	16	26
Trichoptera	20	9	7	20
Diptera	19	36	63	11
Coleoptera	16	1	5	4

Appendix 1. List of aquatic insect fauna of Green Timber Creek - North Fork of the Little Snake River in 1989.

1. Order Ephemeroptera
    a. Family Baetidae
        1. *Baetis bicaudatis*
        2. *Baetis tricaudatis*
    b. Family Heptageniidae
        1. *Rithrogen* sp.
        2. *Cinygmula* sp.
        3. *Epeorus deceptivus*
        4. *Epeorus albertae*
    c. Family Ephemerellidae
        1. *Drunella doddsi*
        2. *Ephemerella coloradensis*
        3. *Ephemerella tibiali*
    d. Family Siphlonuridae
        1. *Ameletus* sp.
    e. Family Leptophlebiidae
        1. *Paraleptophlebia* sp.
2. Order Plecoptera
    a. Family Capniidae
    b. Family Nemouridae
        1. *Zapada* sp.
        2. *Podmosta* sp.
    c. Family Chloroperlidae
        1. *Alloperla* sp.

Appendix 1 (continued)

2. *Suwallia* sp.

d. Family Perlodidae

1. *Megarcys* sp.

2. *Skwala* sp.

e. Family Perlidae

1. *Acroneuria* abnormis

2. *Hesperoperla* *pacifica*

3. Order Trichoptera

a. Family Rhyacophilidae

1. *Rhyacophila* sp.

b. Family Glossosomatidae

1. *Glossosoma* sp.

2. *Anagapetus* sp.

c. Family Brachycentridae

1. *Brachycentrus* sp.

d. Family Hydropsychidae

1. *Arctopsyche* *grandis*

e. Family Hydroptilidae

1. *Hydroptila* sp.

f. Family Polycentropodidae

1. *Polycentropus* sp.

g. Family Limnephilidae

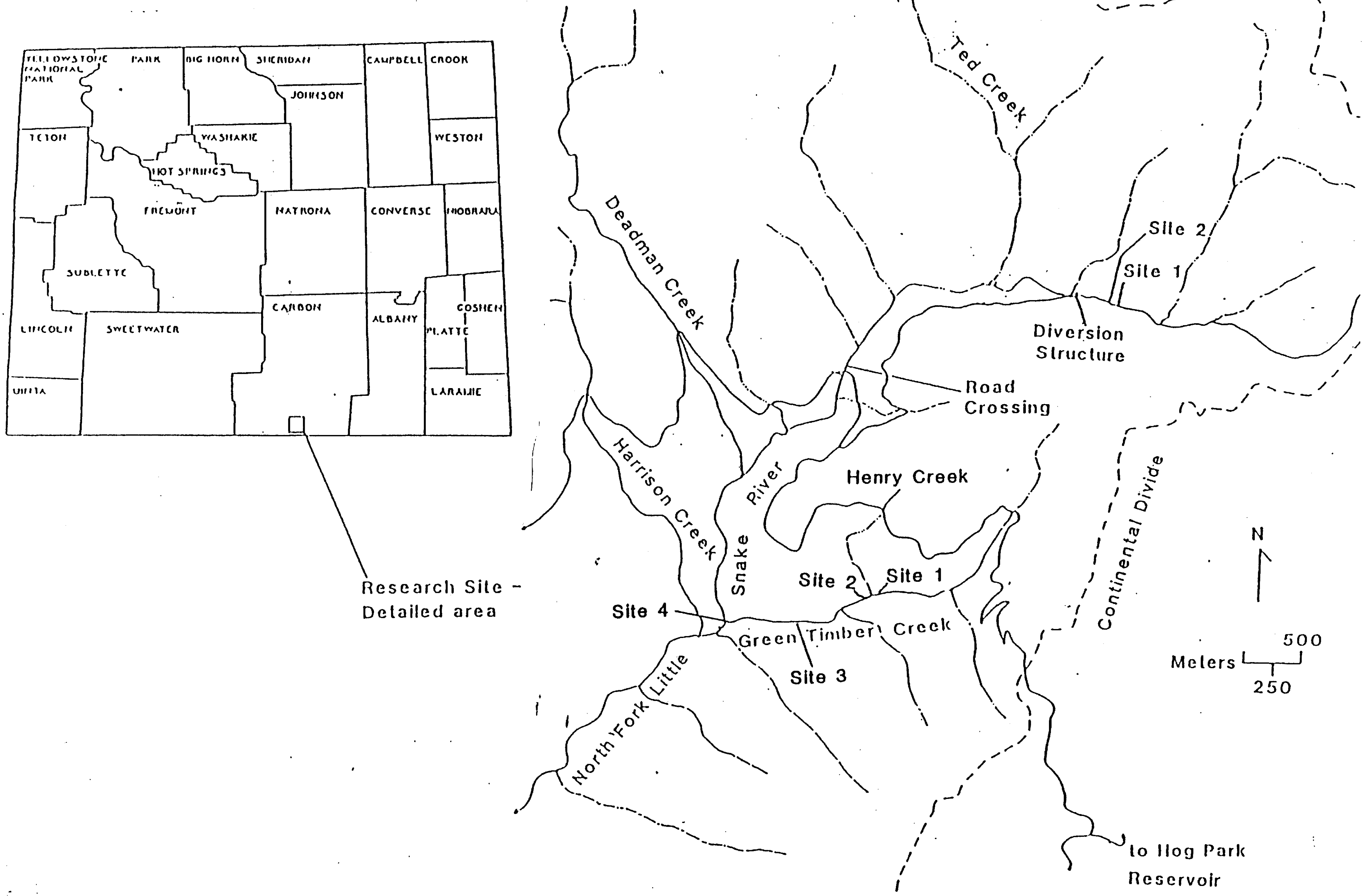
1. *Neothremma* sp.

2. *Dicosmoecus* sp.

Appendix 1 (continued)

4. Order Diptera
   a. Family Tipulidae
      1. _Dicronota_ sp.
      2. _Hexatoma_ sp.
   b. Family Ceratopogonidae
   c. Family Simuliidae
      1. _Prosimulium_ sp.
   d. Family Blephariceridae
      1. _Agathon_ sp.
   e. Family Dixidae
      1. _Dixa_ sp.
   f. Family Empididae
      1. _Clinocera_ sp.
   g. Family Chironomidae
5. Order Coleoptera
   a. Family Elmidae
      1. _Heterlimnius_ _corpulentus_

Figure 1


YELLOWSTONE NATIONAL PARK
PARK
BIG HORN
SHERIDAN
CAMPBELL
CROOK
JOHNSON
TETON
WASHAKIE
WESTON
HOT SPRINGS
FREMONT
NATRONA
CONVERSE
NIOBRARA
SUBLETTE
CARBON
ALBANY
GOSHEN
PLATTE
LINCOLN
SWEETWATER
UINTA
LARAMIE
Research Site - Detailed area
Ted Creek
Deadman Creek
Site 2
Site 1
Diversion Structure
Road Crossing
Harrison Creek
Snake River
Henry Creek
Continental Divide
N
Site 2
Site 1
Site 4
Green Timber Creek
Site 3
Meters
500
250
North Fork Little
to Hog Park Reservoir