

**Assessment of the Aquatic Resources of  
Agate Fossil Beds National Monument**

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## 1.0 INTRODUCTION

Surveys of the biological conditions of U.S. streams have indicated that most are influenced by chemical, physical or flow alterations. As a consequence "natural" biological communities continue to be altered despite federal legislation mandating their protection. The National Park Service is concerned with the aquatic resources under their protection, and in particular, the long-term maintenance of the biotic integrity of these resources. A component of this is the ability to anticipate and predict possible future impacts to specific aquatic resources. Resource inventory and monitoring are essential elements in this process, since they provide the basis for verifying predicted impacts as well as assessing the pace and extent of any changes in the status of the resource.

This report provides an inventory of the aquatic macroinvertebrates of and baseline information about the aquatic ecosystem of the Niobrara River through Agate Fossil Beds National Monument (AFBNM), and outlines a program for monitoring the aquatic resources using biological criteria.

### 1.1 Biological Indicators

In their essay about science and management in the National Park Service, Davis et al. (1988) stated their "belief that long-term ecological information is essential for carrying out the mission of the National Park Service." They outlined the role of long-term ecological monitoring in Park organization and in assessing ecosystem health. Resource inventory specifies elements

of the landscape that are managed by the National Park Service. Hellawell (1978) provided a definition of "monitoring" and two terms which are often used interchangeably, "survey" and "surveillance:"

Survey: an exercise in which a set of standardised observations (or replicate samples) is taken from a station (or stations) within a short period of time to furnish qualitative or quantitative descriptive data.

Surveillance: a continued programme of surveys systematically undertaken to provide a series of observations in time.

Monitoring: surveillance undertaken to ensure that previously formulated standards are being met.

Surveillance is a tool with which managers observe and document changes over time. In a monitoring program the parameters monitored must be chosen to reflect ecosystem change so corrective action may be taken (Cairns 1990). One goal of long-term monitoring is to assess the natural variability of components of an ecosystem and distinguish this natural variability from anthropogenically caused changes (Likens 1985, Schindler 1987).

Karr et al. (1986) defined five classes of environmental factors that affect aquatic ecosystems: energy source, water quality, habitat quality, flow regime, and biotic interactions (Table 1-1). They stress that these classes are interrelated and the biological community may be altered by changes in any one of the factors. Therefore, the components and structure of the biological community reflect many environmental factors, making

Table 1-1. Environmental factors that affect aquatic biota  
(modified from Karr et al. 1986).

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1. Food (Energy) Source

- type, amount, and particle size of organic material entering a stream from the riparian zone versus primary production in the stream
- seasonal pattern of available energy

2. Water Quality

- temperature
- turbidity
- dissolved oxygen
- nutrients (primarily nitrogen and phosphorus)
- organic and inorganic chemicals, natural and synthetic
- heavy metals and toxic substances
- pH

3. Habitat Structure

- substrate type
- water depth and current velocity
- spawning, nursery, and hiding places
- diversity (pools, riffles, woody debris)
- basin size and shape

4. Flow Regime

- water volume
- temporal distribution of floods and low flows

5. Biotic Interactions

- competition
  - predation
  - disease
  - parasitism
-

biological monitoring a powerful tool. Additionally, the integration of many environmental factors suggests that approaches to water resource management problems be broad-based. Solutions that consider many aspects of the watershed, and manage the ultimate cause of a problem, are likely to be more effective and more economical than solutions which only consider proximate causes (Karr et al. 1986, Ohio Environmental Protection Agency 1988).

Stream biota reflect the chemical, physical, and biological conditions in which they evolved. Biological community changes, and therefore biological evaluation, reflect environmental conditions and anthropogenic impacts. Perhaps the earliest use of stream biota in describing changes in stream conditions was the "saprobien system" (Kolkwitz and Marsson 1908, 1909). This scheme divided a flowing water body into zones of various stages of recovery after introduction of point source organic enrichment and described the biotic community found in each of these zones (Hawkes 1979, Hellawell 1978, 1986). These zones were largely characterized by structural attributes of the benthic macroinvertebrate community.

Surveillance of aquatic and wetland habitat quality using macroinvertebrate species or communities as indicators of biotic integrity has become common practice. Macroinvertebrates are especially useful for this purpose because they are (a) common in most streams, (b) readily collected, (c) relatively easily identified, (d) not very mobile, and (e) generally have life cycles of a year or more. Benthic macroinvertebrates have been used to

assess water quality in a number of ways including toxicological assays, bioaccumulation, indicator species, and community measures (including biotic indices, diversity indices, similarity indices, description of community structure and function). All of these approaches have been used with some success, and likewise they each have limitations.

In their most basic form, laboratory toxicological assays expose organisms to concentrations of a toxicant and measure survival. This accounts for acute, or immediate, toxicity and tolerance of the organism. An assay is specific to the organisms and toxins or pollutants tested. This approach becomes more complex when chronic (delayed) effects, and additional stresses are considered.

A number of species have been used as "bioaccumulative" indicators. These indicator organisms accumulate polluting substances from their environment, and their tissues are analyzed for specific substances (Hellowell 1986).

The indicator species approach surveys the abundance of a population of a species that is sensitive or tolerant to a type of pollutant. This strategy is limited to the known stresses to which a species is sensitive. Sensitivity to a specific stress for a species may vary regionally or seasonally. Natural variation of populations, and species interactions complicate interpretation of data.

Biotic indices applied to invertebrate communities are an extension of the use of indicator organisms to a community

(Washington 1984). These indices assign a value related to pollution tolerance to each taxon, and through a mathematical formula calculate a score. The index may or may not account for absolute or relative abundances of organisms (Hellawell 1986). Like the indicator species concept, the effectiveness of a biotic index is considered limited to certain types of pollution and to specific geographical areas (Washington 1984). Some popular biotic indices include the Trent index (Woodiwiss 1960), Chandler Biotic Score (1970), and Hilsenhoff's biotic index (1982, 1987, 1988).

The two components of community structure that are used in calculation of diversity indices are species richness and species abundance (evenness). A specific index may consider one or both of these components. These indices must be interpreted with caution because they do not consider qualitative species composition, because moderate disturbance may increase diversity, and because many communities have naturally low diversity. Commonly used diversity indices include Shannon's  $H'$  (Shannon and Weaver 1949), Brillouin's  $H$  (1951), and Simpson's  $D$  (1949).

Similarity or comparison indices are mathematical measures of the similarity of two community structures. An impacted community is usually compared to a reference site upstream or in the same region. Species composition, abundance, or both may be measured. These indices, along with ordination techniques, have been extensively used in plant ecology (Washington 1984, Hellawell 1986). Popular similarity indices include Pinkham and Pearson's index (1976) and Jaccard's index (1912).

Components of community structure and function may be expected to change when environmental quality is impacted. Parameters such as species richness, density, biomass, production, and functional groups are commonly measured. Any or all of these components may change with a specific stress.

## 1.2 Scope of Study

The following report is the result of a two year project originally designed to be both scientific and advisory in nature. A comprehensive analysis of the ecological status of the Niobrara river in AFBNM is provided along with recommendations for long-term management and monitoring. Specific objectives include:

1. Description of the Niobrara River in AFBNM and the surrounding drainage basin including
  - a. selected water quality parameters
  - b. geomorphic setting
  - c. stream habitat features
  - d. inventory of aquatic macroinvertebrates.
2. Assessment of the current status of the Niobrara River in the AFBNM in terms of the composition of the macroinvertebrate assemblages.
3. Identification of areas of concern, and recommendation of management and long-term monitoring strategies.
4. Providing assistance in determining the role and effort of Park Service personnel in providing long-term monitoring information.

### 1.3 National Park Service Midwest Region

The detailed data collected at AFBNM is intended to serve as a general background from which to derive a more simple monitoring program at other parks with similar ecological conditions and management needs. Within the National Park Service Midwest Region, Agate Fossil Beds National Monument (Nebraska), Homestead National Monument of America (Nebraska), Pipestone National Monument (Minnesota), Herbert Hoover National Historic Site (Iowa), George Washington Carver National Monument (Missouri), and Wilson's Creek National Battlefield (Missouri) all have resource management responsibility with a first or second order stream that has a significant portions of the upstream watershed outside the boundary of the Park.

These six Parks are located in the plains region of North America. Streams within the plains region have similar features such as low gradient, presence of predominant silt or sand substrate, relatively high buffering capacity of the water, and a general similarity in the type and dynamics of the biological communities. Matthews (1988) provided a review of ecological characteristics of prairie stream systems. In order to facilitate understanding patterns and management of regional ecosystems, Omernick (1987) delineated ecoregions in the conterminous U.S. These ecoregions were based primarily on patterns of land form, general type of potential vegetation, soils and land use. The National Park Service units fall into one of the following ecoregion delineated by Omernick: Western High Plains (Agate),

Central Great Plains (Homestead), Northern Glaciated Plains (Pipestone), Western Corn Belt Plains (Herbert Hoover), Central Irregular Plains (George Washington Carver), Ozark Highlands (Wilson's Creek). Differences in land use around the Parks predicate to a large extent the generic environmental risk to aquatic resources that is expected within the more specific ecoregion (Gallant et al. 1989). Other specific environmental risks should be elaborated on an individual stream basis.

#### 1.4 Acknowledgements

The authors would like to thank the superintendent of Agate Fossil Beds National Monument, John B. Rapier III, and the staff of Agate Fossil Beds National Monument and Scotts Bluff National Monument for their cooperation, hospitality, and information throughout the study. Dr. Gustavo Diaz, National Park Service, Water Resources Division, Fort Collins, Colorado, assisted with the stream flow analysis. Dave Beeson identified and evaluated the qualitative periphyton samples. We also thank the Meade family for their kind hospitality and for access to their ranch throughout this study.



## 2.0 STUDY AREA

Agate Fossil Beds National Monument (AFBNM) was established in 1965 to protect concentrations of animal fossils in the 20 million year old sedimentary rock. The Niobrara River winds through the 1100 ha AFBNM west to east. The river originates near Lusk in eastern Wyoming. It flows approximately 612 km along the northern half of Nebraska and empties into the Missouri River near Niobrara, Nebraska, in Knox County at about 381 m above sea level. The entire river basin encompasses over 30,000 km<sup>2</sup> (11,870 mi<sup>2</sup>) (Nebraska Soil and Water Conservation Commission 1971). Above the U.S.G.S. gaging station near the western boundary of the AFBNM the Niobrara River drains approximately 2200 km<sup>2</sup> (840 mi<sup>2</sup>). The elevation at Park headquarters is about 1420 m.

The Arikaree Group of the High Plains aquifer system underlies the region. This aquifer system is below 85% of the State, and the Arikaree group is in the northern part of the panhandle. This group contains sand with sandy silt and concretions up to 150 m thick (USGS 1988). A test well was dug at the AFBNM on 24 July 1967 by Meder Smith, Inc. of Alliance Nebraska. The log of the test well indicated that the geology is dominated by sand and sandrock (Fig. 2-1). The sediments are moderately permeable and of tertiary age (Nebraska Soil and Water Conservation Commission 1971).

The lands bordering the Park and most land within the region are devoted to grazing, supporting various densities of livestock. In the surrounding area there is also dryland agriculture and some

Figure 2-1. Log of test well, drilled by Meder Smith, Inc.,  
24 July 1967, Agate Fossil Beds National Monument, Nebraska.



MEDER SMITH, Inc.

## MEDER SMITH, Inc.

WELLS ★ PUMPS ★ ACCESSORIES

1016 West Third P. O. Box 517 Phone 762-5791

Allamore, Nebraska 69301

July 24, 1967



### LOG OF AGATE FOSSIL BEDS TEST WELL

|     |     |                                                                                                                                |
|-----|-----|--------------------------------------------------------------------------------------------------------------------------------|
| 1   | 5   | Top soil & sand                                                                                                                |
| 5   | 10  | Sand                                                                                                                           |
| 10  | 15  | Loose rocks & sand                                                                                                             |
| 15  | 20  | Sand with some loose rocks                                                                                                     |
| 20  | 23  | Magnesia rock & sand                                                                                                           |
| 23  | 28  | Magnesia rock & sandrock with some fine sand                                                                                   |
| 28  | 35  | Sandrock & hard rock & fine sand                                                                                               |
| 35  | 36  | Soft sandrock & sand                                                                                                           |
| 36  | 42  | Hard rock with little layers of sand                                                                                           |
| 42  | 46  | Hard coarse & fine sand                                                                                                        |
| 46  | 47  | Soft & fine sand                                                                                                               |
| 47  | 48  | Hard rock & soft fine sand                                                                                                     |
| 48  | 54  | Hard & soft rock with intermittent 6" layers of sand between rocks                                                             |
| 54  | 58  | Course sandrock & fine sand                                                                                                    |
| 58  | 63  | Fine black water sand                                                                                                          |
| 63  | 67  | Layers of fine black water sand & rock                                                                                         |
| 67  | 68  | Sandrock & hard rock                                                                                                           |
| 68  | 69  | Fine black water sand                                                                                                          |
| 69  | 71  | Layers of sandrock & fine black water sand                                                                                     |
| 71  | 75  | Fine black water sand with very little rock                                                                                    |
| 75  | 78  | Soft sandrock & fine black water sand                                                                                          |
| 78  | 82  | About 3" alternate layers of hard sandrock & fine black water sand                                                             |
| 82  | 83  | Fine black water sand                                                                                                          |
| 83  | 85  | Hard sandrock & fine sand                                                                                                      |
| 85  | 89  | Very hard sandrock                                                                                                             |
| 89  | 90  | Hard rock                                                                                                                      |
| 90  | 93  | Fine black water sand                                                                                                          |
| 93  | 100 | Fine black water sand with layers of rock 2" to 3" thick                                                                       |
| 100 | 104 | Fine black water sand with thin layers of rock                                                                                 |
| 104 | 111 | Fine black water sand                                                                                                          |
| 111 | 112 | Hard rock & sand                                                                                                               |
| 112 | 145 | Fine black water sand with few thin layers of rock (33' which would make good well without any of the other water formations.) |
| 145 | 153 | Sandrock & fine brown sand                                                                                                     |
| 153 | 187 | Sandrock & rock with fine sand                                                                                                 |
| 187 | 193 | Sandrock & rock                                                                                                                |
| 193 |     | Hit another rock fracture & lost water immediately                                                                             |
| 193 | 200 | Soft sandrock with thin layers of rock & runs of light brown sand                                                              |
| 200 | 208 | Soft sandrock & small layers of sand                                                                                           |
| 208 | 239 | Soft sandrock with layers of light brown sand & some rock layers                                                               |

Water level - - 36' 4"

PUMPS

SPRINKLING SYSTEMS

WELLS

irrigated cropland (mostly alfalfa hay). Above the U.S.G.S. gaging station bordering the Park, approximately 2700 ha are irrigated from diversions of the Niobrara River. Above Box Butte Reservoir approximately 5200 ha are irrigated (Hydrodata 1989).

Center pivot irrigation circles also occur upstream of the AFBNM. The underground water area of the Niobrara in the AFBNM are part of the Northern Panhandle Tableland Region. Groundwater levels in the region have declined because of pumping for irrigation (Nebraska Soil and Water Conservation Commission 1971). The 1971 test well at the AFBNM indicated groundwater levels at about 11 m (Fig. 2-1).

The AFBNM is part of the Great Plains Physiographic Province, which extends east from the base of the Rocky Mountains (about 1675 m) to approximately the 100th meridian (also the 600 m contour and 50 cm rainfall line), the boundary between short and tall grass prairie (Hunt 1974). Along with the Osage Plains Province, it makes up the prairie region of North America (Matthews 1986). The AFBNM lies in the "dissected plains" topographic region. The plains are rolling with the relief ranging from 1 m to 60 m (Nebraska Natural Resources Commission 1974). The AFBNM falls on the boundary of two of Omernick's (1987) ecoregions, the Northwestern Great Plains and Western High Plains.

Within the AFBNM, aside from a narrow river corridor, the vegetation is classified as prairie (Stubbendieck and Willson 1986). Stubbendieck and Willson (1986) reported that the Küchler potential natural vegetation as the grama-needlegrass-wheatgrass

type (blue grama, Bouteloua gracilis (H.B.K.); needlegrass, Stipa comata Trin & Rupr; western wheatgrass Agropyron smithii Rydb.) (Küchler 1964). The prairie has been reported to be in good condition (Landers 1975) and a prairie restoration and management program is ongoing.

Historically, homesteading began in the North Platte Valley around the turn of the century. Between 1904 and 1950 the Agate Fossil Beds were the focus of scientific excavations. Until creation of the Park, the land was grazed by livestock with local areas of cultivation and areas of sustained heavy grazing (Landers 1975).

The AFBNM lies in the arid northwestern region of Nebraska. A National Climatic Data Center weather station is located on the AFBNM and the climate data and statistical analysis may be accessed through the Climatedata (1989) CD-ROM data base. From May 1948 through December 1988 the AFBNM received an average of 369 mm of precipitation. May received the highest mean precipitation, and December the lowest. The mean monthly precipitation is presented in Table 2-1. The average yearly snowfall was 793 mm, and the mean monthly snowfall is presented in Table 2-1 (Climatedata 1989).

The mean monthly, daily maximum temperature ranged from 2°C (January) to 31°C (July) for the time period of September 1964 through December 1988. The mean monthly daily maximum temperatures are presented in Table 2-2. The yearly, mean daily maximum temperature was 17°C. Mean daily minimum temperatures were

Table 2-1. Mean monthly and mean annual precipitation and snowfall at Agate Fossil Beds National Monument, Nebraska. Precipitation records May 1948 - December 1988. Snowfall records September 1948 - December 1988 (Climatedata 1989).

| Month       | Precipitation (mm) | Snowfall (mm) |
|-------------|--------------------|---------------|
| January     | 11                 | 133           |
| February    | 9                  | 91            |
| March       | 16                 | 159           |
| April       | 35                 | 118           |
| May         | 73                 | 29            |
| June        | 69                 | 2             |
| July        | 53                 | 0             |
| August      | 39                 | 0             |
| September   | 31                 | 18            |
| October     | 19                 | 39            |
| November    | 9                  | 83            |
| December    | 8                  | 113           |
| Mean Annual | 369                | 793           |

*1 in = 2.54 cm*

Table 2-2. Mean monthly and annual, daily minimum and maximum temperatures (°C), Agate Fossil Beds National Monument, Nebraska. Daily maximum temperatures records September 1964 - December 1988. Daily minimum temperatures records July 1965 - December 1988 (Climatedata 1989).

| Month       | Minimum              | Maximum            |
|-------------|----------------------|--------------------|
| January     | -14 <sup>61.8</sup>  | 2-35.6             |
| February    | -10                  | 5                  |
| March       | -6                   | 10                 |
| April       | -2                   | 16                 |
| May         | 3                    | 21                 |
| June        | 8                    | 27                 |
| July        | 11 <sup>51.8</sup>   | 31-87.9            |
| August      | 10                   | 30-86              |
| September   | 4                    | 25                 |
| October     | -2                   | 18                 |
| November    | -8                   | 9                  |
| December    | -14                  | 3                  |
| Mean Annual | -1 <sup>30.2 F</sup> | 17 <sup>62.6</sup> |

Celsius  
 Fahrenheit  
 $F = \frac{9}{5}C + 32$   
 $1.8$

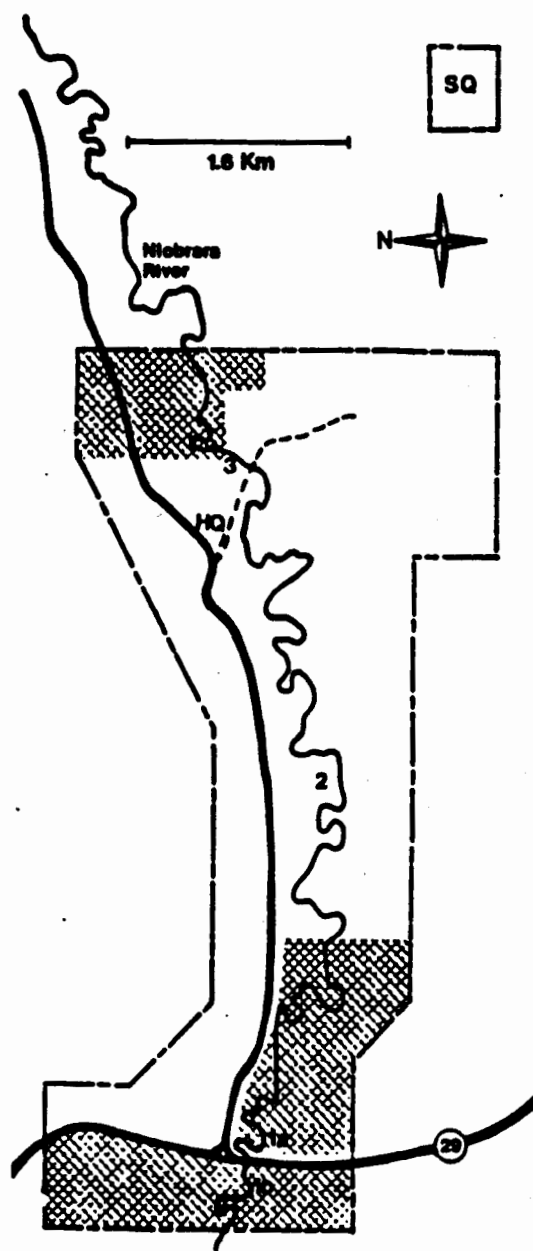
recorded from July 1965 through December 1988, ranged from  $-14^{\circ}$  to  $11^{\circ}\text{C}$ , and are presented in Table 2-2. The yearly, mean daily minimum temperature was  $-1^{\circ}\text{C}$  (Climatedata 1989). The frost free period is approximately 125 to 140 days (Nebraska Natural Resources Commission 1974).

A shifting sand and sand/mud substrate is characteristic throughout the length of the Niobrara River in the AFBNM. The aquatic macrophyte Potamogeton pectinatus L. was locally abundant, forming green mats covering the stream bottom. Several graminoid species overhang along the eroded and undercut banks, although willow is the dominant riparian vegetation along many reaches within the AFBNM. Two species of willow are found in the AFBNM. Sandbar willow (Salix exigua Nutt.) is the most abundant and peachtree willow (Salix amygdaloides Anderss.) occurs less frequently. An introduced Siberian Iris is locally abundant in the Park. In the winter months the river often occupies floodplain reaches within the AFBNM due to ice jams that form in an irrigation structure outside the eastern boundary.

## 2.1 Study Sites

Three study sites were established along the Niobrara River at the AFBNM in spring 1988 (Fig. 2-2). Site 1 (AFB1) was located east of the State Highway 29 bridge. The channel was narrow, about 1.3 m. The banks are being undercut and have an abrupt drop-off. Herbaceous vegetation dominated the streamside vegetation. In June 1989 Site 1 was relocated, to a location more suitable for the placement of Hester-Dendy artificial substrate samplers, about

Figure 2-2. Map of Agate Fossil Beds National Monument, Nebraska. Hatched area represents land within boundary that is privately owned; 'HQ' - Headquarters area; 'SQ' - Stenomylus Quarry, detached Monument land; '1a' - Site 1 for Hess sampling; '1b' - Site 1 for Hester-Dendy sampling; '2' - Site 2; '3' - Site 3 (Redrawn from National Park Service brochure).



110 m west of the Highway 29 bridge. Dense growth of Siberian Iris was present here, and a few cottonwood (Populus deltoides Marsh.) provided some canopy. Near the highway bridge groundwater upwelling is evident. Site 2 (AFB2) was located 25 m west of the road leading to the ranger residence. This site was not used in the 1989 - 1990 sampling year. A willow thicket was present on both banks. Site 3 (AFB3) was near the visitors center. It was 150 m east of visitors trail about 25 m before the trail crosses the river. The stream flows north at this site. A 2.5 m tall willow thicket dominated the east bank, while graminoids covered the west bank.



### 3.0 WATER QUALITY

Chemical characteristics of water depend primarily on local geology and climate (Reid and Wood 1976) and secondarily on the type and condition of terrestrial vegetation within a watershed. The physical environment and chemistry of surface waters in great part determines the species within the aquatic ecosystem. In turn, biological activity effects the chemical and physical environment. Alteration of one aspect may lead to changes in other components of the aquatic ecosystem.

There are both short- and long-term effects of water quality changes. Long-term effects include stresses on individuals that make them less able to survive, grow, reproduce, or causes an unfavorable behavioral change. Also, reactions among various water quality components must also be recognized. Increased water temperature, for example, lowers the ability of water to hold oxygen; pH affects the solubility and biological activity of many chemicals. Additionally, chemical and physical characteristics vary during the day and among microhabitats within the stream and alteration of this variation may be detrimental to aquatic life.

The goal of our physical and water chemistry analysis of this stream was to acquire baseline data for the physical aquatic environment of the Niobrara River in AFBNM. These data can be used with future biological surveillance or monitoring, compared with other sites in the region and with water quality standards, and used to identify areas of concern.

Although comparisons are made with established chemical water quality criteria, such as the U.S. Environmental Protection Agency's (1976) criteria for water quality, these criteria should only be used as a general guide. These criteria should only be used as a general guide, they do not reflect the requirements of all organisms that reside in every ecosystem because vast local and regional differences exist in natural water chemistry and biological communities. The data in this study are intended to summarize the range of conditions that exist, longitudinally and seasonally, in the Niobrara River through the AFBNM.

### 3.1 Methods

At each site, temperature, pH, dissolved oxygen and discharge were measured in the field. A surface water sample was taken and returned for analysis of selected parameters at the Colorado State University Soil Testing Laboratory. During the first sampling year each of the three sites was sampled, and the parameters included total phosphorus, total kjeldahl nitrogen, nitrate-nitrogen, and hardness. During the second sampling year, both sites were sampled, and the parameters measured were total phosphorus, total kjeldahl nitrogen, nitrate-nitrogen, ammonia-nitrogen, alkalinity, and total organic carbon. Additionally, during both years seston samples were obtained.

Dissolved oxygen and temperature were measured in the field with a Yellow Springs Instrument Co., Inc., Model 54A Oxygen Meter. Both measurements were obtained from water near the shore to prevent unnecessary disturbance of the stream bottom. The

instrument was calibrated to the proper altitude and temperature, and the dissolved oxygen measurements taken with the probe approximately 10cm below the water surface. Water temperature was also checked with a long-stem thermometer on some sampling dates.

The pH was measured the first year with an electronic hand held pH meter. The second year a Hellige comparator with phenol red indicator was used. Measurements were obtained by standing on the shore to prevent unnecessary disturbance of the stream bottom. Water samples were obtained by wading into the stream and filling water bottles by leaning upstream and dipping the sample bottle into the water. The second year total phosphorus and total organic carbon samples were preserved with sulfuric acid at a concentration of 2 ml/l. The water samples were taken before benthic sampling and downstream of the benthic sampling areas. The samples were placed on ice and returned to the Colorado State University Soil Testing Laboratory for analysis. The analytical methods used are presented in Table 3-1.

*floating  
organics* Seston was collected with a hand pump at several intervals across transects at Sites 1 and 3. A volume of 100 l was passed through a sieve set to obtain three size fractions. The seston divided into three size fractions: coarse (CPOM, < 1 mm), fine (FPOM, < 1 mm and > 0.063 mm), and ultrafine (UPOM, < 0.063 mm). Samples were analyzed for organic carbon at the Colorado State University Soil Testing Laboratory for analysis (Table 3-1).

A U.S.G.S. surface water gaging station is located approximately 100 m west of the bridge on State Highway 29, near

Table 3-1. Methodology used for water chemistry analysis at Soil Testing Laboratory, Colorado State University, Fort Collins, Colorado. Abbreviations: USEPA, U.S. Environmental Protection Agency; APHA, American Public Health Association; ICP, Inductively Coupled Plasma Atomic Emission Spectrometer.

|                                       |   |                                                                                                                                   |
|---------------------------------------|---|-----------------------------------------------------------------------------------------------------------------------------------|
| Total Phosphorus                      | - | H <sub>2</sub> SO <sub>4</sub> -K <sub>2</sub> S <sub>2</sub> O <sub>8</sub> digestion, ICP, APHA et al. (1989) Method 4500-P B-5 |
| Total Kjeldahl Nitrogen (TKN)         | - | H <sub>2</sub> SO <sub>4</sub> - CuSO <sub>4</sub> digestion, colorimetric, automated phenate, USEPA (1983) Method 351.1          |
| Nitrate-Nitrogen (NO <sub>3</sub> -N) | - | Ion chromatography, USEPA (1984) Method 300.0. Also checked with USEPA (1983) Method 353.2 except use Zn reduction                |
| Ammonia-Nitrogen (NH <sub>4</sub> -N) | - | Colorimetric, automated phenate, USEPA (1983) Method 350.1                                                                        |
| Hardness                              | - | Ca and Mg by ICP, USEPA (1983) Method 200.7                                                                                       |
| Calcium                               | - | Samples filtered through 0.45μm membrane filters; analysis by ICP, USEPA Method 200.7                                             |
| Magnesium                             | - | same as Ca                                                                                                                        |
| Alkalinity                            | - | Gran titration                                                                                                                    |
| Periphyton (Aufwuchs)                 | - | Dry wgt. - dry sample at 105°C<br>Ash wgt. - ash residues at 550°C in muffle furnace                                              |
| UPOM, Total Organic Carbon            | - | Wet chemical oxidation USEPA (1983) Method 415.1 and persulfate oxidation USEPA (1983) Method 415.2                               |
| FPOM, CPOM                            | - | Wet oxidation-diffusion (Snyder and Trofymow 1984)                                                                                |

the west border of the AFBNM. Discharge data is available from water year 1958 to the present. This data was examined to characterize the Niobrara River stream flow and determine trends over time. All regression analysis was performed using the PC SAS Procedure REG (SAS 1988).

In order to assess any notable changes in stream flow through the AFBNM, discharge was calculated at Sites 1 (near the river's entry into the AFBNM) and 3 (near the river's exit from the AFBNM). Current velocity was measured with a Price AA flow meter. Discharge was calculated by the six-tenths depth method (Buchanan and Somers 1969, Platts et al. 1983).

Periphyton production (aufwuchs accrual) was estimated in the first year of the study. Plexiglass hemispheres 5 cm in diameter were attached to the bottom substrate in the main portion of the stream by means of 18-cm spikes. The colony forming on the top surface was removed and ash-free dry weight determined according to the procedures in Vollenweider (1971) at the Colorado State University Soil Testing Laboratory.

### 3.2 Results and Description of Parameters

#### 3.2.1 Temperature

Life histories of much aquatic life depends on the water temperature and its variation (diel, microhabitat, and seasonal), and, therefore, temperature is a regulating or limiting factor in aquatic systems (Reid and Wood 1976). Invertebrates and fish are poikilothermic, having limited internal temperature regulation, so life cycles are expectedly dependent on the external temperature

regime. Species are classified as stenothermic, adapted to a narrow range of temperature, or eurythermic, tolerant to a broad temperature range. Typical life cycle factors that respond to temperature include egg maturation, adult fecundity, and growth and maturation. Additionally, temperature elicits behavioral responses, and on a community level influences trophic relations and species diversity (see review Ward and Stanford 1982). Other water quality parameters are also affected by temperature, notably dissolved oxygen. Large-scale water temperature changes are caused by large dams and power plant discharge. Changes in riparian vegetation or changes in stream discharge also influence water temperature. The summary of water temperature results are presented in Table 3-2.

### 3.2.2 Hydrogen Ion Activity (pH)

Hydrogen ion activity is the concentration of hydrogen ions and is expressed as pH (*potentia hydrogenii*), with a range of 1-14 (Cole 1979). At pH 7 the molar concentration of hydrogen is  $10^{-7}$ M. An increase in hydrogen ions results in a lowering of the pH. Hydrogen ion activity is dependent on alkalinity (see section 3.2.7). The pH of a stream is determined primarily by the chemical composition of the substrate, current, and biological processes (Reid and Wood 1976). The U.S. EPA (1976) water quality criteria for pH range for freshwater aquatic life is 6.5 - 9.0. The solubility and toxicity of other compounds is affected by changes in pH (U.S. EPA 1976).

Table 3-2. Water temperature (°C), Agate Fossil Beds National Monument, Nebraska. Sites 1 and 3 include sampling dates June 1988 to March 1990, Site 2 includes sampling dates June 1988 to October 1988.

| Site | Mean | Minimum | Maximum | N  |
|------|------|---------|---------|----|
| 1    | 15   | 0.5     | 24      | 13 |
| 2    | 19   | 10      | 25      | 8  |
| 3    | 16   | 2       | 24      | 12 |

The pH of the river through the AFBNM was slightly alkaline (Table 3-3). This is a characteristic of most unpolluted streams and is considered a favorable condition for aquatic life (Reid and Wood 1976).

### 3.2.3 Dissolved Oxygen

Oxygen is essential to all aerobic life and therefore it is one of the fundamental parameters of aquatic ecosystems. Dissolved oxygen in water is supplied by the atmosphere and photosynthetic plants and varies diurnally (Voshell and Hiner 1990). Oxygen solubility is inversely related to water temperature. Biochemical reactions, such as the oxidation of ammonia, are dependent on the concentration of dissolved oxygen (U.S. EPA 1976). The U.S. EPA (1976) water quality criteria for concentration of dissolved oxygen is a minimum of 5.0 mg/l.

Dissolved oxygen levels (Table 3-4) demonstrate that oxygen was available. Usually the level was near saturation, and as expected, levels are higher when the water was colder (Appendix B).

### 3.2.4 Total Phosphorus

Phosphorus occurs in various forms of phosphate (broad categories include: orthophosphate, condensed phosphate, and organic phosphate) in natural waters. Natural sources of phosphorus in water include the leaching of rock minerals and release from sediments (Hem 1985). Phosphorus, along with nitrogen, is a main limiting factor for primary productivity in a body of water. Eutrophication, or over enrichment of nutrients, can cause algal blooms and lead to depletion of oxygen in a lentic

Table 3-3. pH, Agate Fossil Beds National Monument, Nebraska. Sites 1 and 3 include sampling dates June 1988 to March 1990, Site 2 includes sampling dates June 1988 to October 1988.

| Site | Mean | Minimum | Maximum | N  |
|------|------|---------|---------|----|
| 1    | 7.9  | 7.7     | 8.2     | 13 |
| 2    | 7.9  | 7.7     | 8.2     | 8  |
| 3    | 8.1  | 7.8     | 8.4     | 12 |

Table 3-4. Dissolved oxygen, mg/l, Agate Fossil Beds National Monument, Nebraska. Sites 1 and 3 include sampling dates June 1988 to March 1990, Site 2 includes sampling dates June 1988 to October 1988.

| Site | Mean | Minimum | Maximum | N  |
|------|------|---------|---------|----|
| 1    | 8.9  | 7.3     | 12.6    | 12 |
| 2    | 8.5  | 7.0     | 10.4    | 8  |
| 3    | 8.3  | 6.2     | 12.1    | 11 |

or lotic system. Meybeck (1982) estimated the worldwide average of naturally occurring total dissolved phosphorus in rivers should average 0.025 mg/l. The U.S. Council on Environmental Quality (CEQ 1975) suggested a maximum "benchmark" level of 0.03 mg/l phosphorus for protection of aquatic life. Phosphorus is a major element in agricultural fertilizers which enter streams through surface water runoff. It is also a component of municipal and domestic wastewater, and animal wastes.

Phosphorus levels in the Niobrara within the AFBNM were low (Table 3-5) indicating minimal agricultural runoff at this time. All summer measures were < 0.01 mg/l, and most other measures were below the CEQ (1975) benchmark of 0.03 mg/l (Appendix B).

#### 3.2.5 Total Kjeldahl Nitrogen (TKN), Nitrate-Nitrogen (NO<sub>3</sub>-N), Ammonia-Nitrogen (NH<sub>4</sub>-N)

Nitrogen occurs various states (nitrate, nitrite, ammonia, and organic nitrogen) in natural waters. As with phosphorus, excess nitrogen is a cause of eutrophication. Nitrate is the form that is most often utilized by higher plants. A widely used criterion for drinking water quality is a maximum of 10 mg/l NO<sub>3</sub>-N (U.S. EPA 1976). The U.S. Council on Environmental Quality (CEQ 1975) suggested a maximum "benchmark" level of 0.6 mg/l nitrate-nitrogen for protection of aquatic life. High concentrations of nitrate in water have been attributed to livestock waste, fertilizer leaching, and municipal and domestic sewage. Kjeldahl nitrogen is a measure of organic nitrogen plus ammonia nitrogen, therefore the difference of kjeldahl nitrogen and ammonia nitrogen yields organic nitrogen

Table 3-5. Total phosphorus, mg/l, Agate Fossil Beds National Monument, Nebraska. Sites 1 and 3 include sampling dates June 1988 to March 1990, Site 2 includes sampling dates June 1988 to February 1989..

| Site | Median | Minimum | Maximum | N  |
|------|--------|---------|---------|----|
| 1    | <0.01  | <0.01   | 0.07    | 14 |
| 2    | <0.01  | <0.01   | 0.02    | 8  |
| 3    | <0.01  | <0.01   | 0.04    | 13 |

(American Public Health Association (APHA) et al. 1981). The unionized form of ammonia,  $\text{NH}_3$ , is known to be toxic to freshwater aquatic life in high concentrations. The toxicity of ammonia is dependent on pH, as well as other factors like temperature, because the hydrogen ion concentration governs the transition of  $\text{NH}_4^+$  to the toxic form  $\text{NH}_3$  (U.S. EPA 1976). In a tallgrass prairie stream it has been shown that lower nitrogen concentrations occur in the late spring and summer when terrestrial vegetation is growing (McArthur et al. 1985). Nitrogen values are presented in Table 3-6.

### 3.2.6 Hardness

The concentration of polyvalent cations causes the property of hardness in water. It is measured by the amount of  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  ions expressed as calcium carbonate ( $\text{CaCO}_3$ ). Other polyvalent metals such as aluminum, iron, manganese, strontium, and zinc are usually not present in significant quantities (Rodier 1975). Some groups of invertebrates appear indifferent to water hardness but to others it is important. For example, organisms that secrete calcium carbonate shells, such as many Crustacea and Mollusca, are typically more common in hard waters (Hynes 1970). According to the Durfor and Brecker (1964) classification Niobrara water is considered "hard" (Table 3-7). Calcium and Magnesium ions were measured in the summer 1988 to assess the main contributors to hardness (Table 3-7).

Table 3-6. Nitrogen measures, Agate Fossil Beds National Monument, Nebraska. Total kjeldahl nitrogen (TKN), mg/l, Nitrate-nitrogen ( $\text{NO}_3\text{-N}$ ), mg/l. Sites 1 and 3 include sampling dates June 1988 to March 1990, Site 2 includes sampling dates June 1988 to February 1989. Ammonia-nitrogen ( $\text{NH}_4$ ), mg/l, includes sampling dates June 1989 to March 1990.

TKN

| Site | Median | Minimum | Maximum | N  |
|------|--------|---------|---------|----|
| 1    | 0.2    | <0.1    | 0.7     | 14 |
| 2    | <0.1   | <0.1    | 0.5     | 8  |
| 3    | <0.1   | <0.1    | 1.5     | 13 |

$\text{NO}_3\text{-N}$

| Site | Mean | Minimum | Maximum | N  |
|------|------|---------|---------|----|
| 1    | 1.2  | 0.1     | 2.2     | 14 |
| 2    | 1.8  | 1.4     | 2.5     | 8  |
| 3    | 1.5  | 0.7     | 2.4     | 13 |

$\text{NH}_4$

| Site | Mean | Minimum | Maximum | N |
|------|------|---------|---------|---|
| 1    | 0.11 | 0.02    | 0.20    | 4 |
| 3    | 0.12 | 0.07    | 0.20    | 3 |

Table 3-7. Hardness classification of Durfor and Brecker (1964); Hardness expressed as mg/l of  $\text{CaCO}_3$ , Agate Fossil Beds National Monument, Nebraska, includes sampling dates June 1988 to March 1989; Calcium and Magnesium, mg/l, includes sampling dates June 1988 to July 1988.

Durfor and Brecker (1964) hardness classification

| Hardness range<br>(mg/l of $\text{CaCO}_3$ ) | Description     |
|----------------------------------------------|-----------------|
| < 60                                         | Soft            |
| 61-120                                       | Moderately hard |
| 121-180                                      | Hard            |
| > 180                                        | Very hard       |

Hardness, mg/l as  $\text{CaCO}_3$

| Site | Mean | Minimum | Maximum | N  |
|------|------|---------|---------|----|
| 1    | 170  | 158     | 198     | 10 |
| 2    | 164  | 145     | 198     | 9  |
| 3    | 169  | 154     | 196     | 10 |

Calcium

| Site | Mean | Minimum | Maximum | N |
|------|------|---------|---------|---|
| 1    | 47.3 | 45.3    | 49.1    | 3 |
| 2    | 44.2 | 42.7    | 46.0    | 3 |
| 3    | 46.4 | 45.5    | 47.2    | 3 |

Magnesium

| Site | Mean | Minimum | Maximum | N |
|------|------|---------|---------|---|
| 1    | 10.6 | 10.2    | 19.9    | 3 |
| 2    | 9.9  | 9.3     | 11.1    | 3 |
| 3    | 10.3 | 9.8     | 11.2    | 3 |

### 3.2.7 Alkalinity

Alkalinity, or buffering capacity, is a measure of the ability of a solution to neutralize acid, and therefore, is an index of how sensitive a water body is to acidic deposition or any acid source. dioxide species, bicarbonate and carbonate, are the main contributors to alkalinity in natural waters, although noncarbonate sources may contribute. Carbon dioxide concentration in the atmosphere and in the soil are the principal sources of alkalinity in most natural systems (Hem 1985). Underlying geological formations and their degree of weathering influence alkalinity (Cole 1979). Alkalinity is responsible for much of the overall chemical environment because it is a major variable controlling the form, concentration, biological availability, and toxicity of many ions as well as the hydrogen ion activity (Feldman and Connor 1985). Gran titration alkalinity is presented in Table 3-8.

### 3.2.8 Carbon (seston, total organic carbon)

Sources of carbon in natural waters are both allochthonous and autochthonous. Allochthonous inputs include direct input of leaves and other organic matter, and indirect input from soil organic matter by overland flow and shallow groundwater flow. Autochthonous sources include extracellular excretion and cellular debris (from algae and macrophytes) (Lush 1981).

Seston is the particulate matter, organic and inorganic, suspended in the water column. In this study seston was evaluated as organic carbon and separated into three size fractions: coarse

Table 3-8. Gran titration alkalinity,  $\mu\text{eq/l}$ , Agate Fossil Beds National Monument, Nebraska, includes sampling dates June 1989 to March 1990.

| Site | Mean | Minimum | Maximum | N |
|------|------|---------|---------|---|
| 1    | 4813 | 3810    | 6797    | 4 |
| 3    | 5567 | 4174    | 6428    | 3 |

particulate organic matter (< 1 mm, CPOM), fine particulate organic matter (< 1 mm and > 0.063 mm, FPOM), and ultrafine particulate organic matter (< 0.063 mm, UPOM). Various organic carbon fractions are measured to assess the detrital food resources in water.

The UPOM fraction had the greatest concentration of organic carbon in this study (Table 3-9). FPOM and CPOM fractions seemed to have the highest volume sampled at the beginning of the summer.

The River Continuum Concept (RCC) (Vannote et al. 1980) provides a model of stream organization in which organic matter is processed along a longitudinal (downstream) profile, and to which streams may be compared. The RCC was developed for streams which have large amounts of leaf litter input (CPOM) in canopied headwaters, and therefore energy input is allochthonous in the headwaters. Downstream, the relative canopy cover decreases and energy input is increasingly autochthonous as more solar radiation reaches the benthic substrate and photosynthesis increases within the stream. Matthews (1988) discusses two major differences between prairie streams and the RCC model. First, the headwaters of prairie streams are usually open to sunlight and often downstream, even today, gallery forest provides a canopy. Second, whereas the RCC stream derives much of its allochthonous organic matter from leaf litter, prairie streams receive grass litter inputs (Gurtz et al. 1982) and detritus from grasslands.

Total organic carbon (TOC), when used with other parameters, is a measure of the productivity of a water body. Typically,

Table 3-9. Seston data, Agate Fossil Beds National Monument, Nebraska. A) Seston fractions (coarse particulate organic matter (< 1 mm, CPOM), fine particulate organic matter (< 1 mm and > 0.063 mm, FPOM), and ultrafine particulate organic matter (< 0.063 mm, UPOM)) expressed as mg organic carbon/l. B) Dry weight of FPOM and CPOM fractions retained in 100 l of river water, and percent carbon of the fractions.

| A) | Site 1     |      |      | Site 3 |      |      |      |
|----|------------|------|------|--------|------|------|------|
|    | Date       | UPOM | FPOM | CPOM   | UPOM | FPOM | CPOM |
|    | 16-VI-88   | 3.7  | 0.31 | 0.01   | 2.9  | 0.55 | 0.00 |
|    | 30-VI-88   | 12.6 | 0.73 | 0.06   | 2.7  | 1.20 | 0.05 |
|    | 14-VII-88  | 3.1  | 0.42 | 0.01   | 3.9  | 0.30 | 0.03 |
|    | 28-VII-88  | 15.9 | 0.06 | 0.00   | 3.9  | 0.21 | 0.00 |
|    | 11-VIII-88 | 2.4  | 0.03 | 0.00   | 1.0  | 0.07 | 0.00 |
|    | 25-VIII-88 | 0.6  | 0.02 | 0.00   | 1.6  | 0.02 | 0.00 |
|    | 16-IX-88   | 1.4  | 0.00 | 0.00   | 1.7  | 0.03 | 0.00 |
|    | 18-X-88    | 1.7  | 0.02 | 0.00   | 1.4  | 0.03 | 0.00 |
|    | 18-11-89   | 1.9  | 0.02 | 0.00   | 1.1  | 0.00 | 0.00 |
|    | 12-VI-89   | 2.4  | --   | --     | 2.6  | --   | --   |
|    | 16-IX-89   | 2.9  | 0.11 | 0.00   | 5.2  | 0.05 | 0.01 |
|    | 03-I-90    | 2.0  | 0.01 | 0.00   | --   | --   | --   |
|    | 31-III-90  | 3.3  | 0.00 | 0.00   | 4.3  | 0.00 | 0.00 |

| B)         | Site 1  |                  |       |                  | Site 3  |                  |      |                  |    |
|------------|---------|------------------|-------|------------------|---------|------------------|------|------------------|----|
|            | FPOM    |                  |       | CPOM             |         | FPOM             |      | CPOM             |    |
|            | Date    | Dry Wgt.<br>(mg) | %C    | Dry Wgt.<br>(mg) | %C      | Dry Wgt.<br>(mg) | %C   | Dry Wgt.<br>(mg) | %C |
| 16-VI-88   | 350.0   | 8.9              | 2.7   | 25.5             | 720.0   | 7.7              | 1.2  | 18.2             |    |
| 30-VI-88   | 14700.0 | 0.5              | 324.6 | 1.7              | 10010.0 | 1.2              | 14.2 | 32.3             |    |
| 14-VII-88  | 11119.8 | 0.4              | 491.3 | 0.2              | 884.6   | 3.4              | 19.0 | 13.8             |    |
| 28-VII-88  | 89.8    | 7.0              | 6.5   | 0.0              | 470.6   | 4.4              | 6.0  | 0.0              |    |
| 11-VIII-88 | 114.4   | 2.8              | 12.4  | 0.0              | 57.8    | 11.3             | 7.6  | 0.0              |    |
| 25-VIII-88 | 83.8    | 2.6              | 23.6  | 0.0              | 26.0    | 7.7              | 7.8  | 0.0              |    |
| 16-IX-88   | 13.8    | 0.0              | 9.1   | 0.0              | 29.4    | 9.9              | 10.3 | 0.0              |    |
| 18-X-88    | 50.4    | 3.7              | 8.0   | 0.0              | 45.7    | 5.9              | 18.8 | 0.0              |    |
| 18-III-89  | 60.5    | 3.0              | 3.7   | 10.0             | 2.5     | 0.0              | 1.1  | 2.0              |    |
| 12-VI-89   | 51.8    | --               | 6.1   | --               | 349     | --               | 6.7  | --               |    |
| 16-IX-89   | 49.8    | 22.0             | 2.8   | 15.0             | 20.5    | 23.0             | 4.0  | 13.0             |    |
| 03-I-90    | 38.8    | 2.0              | 0.0   | 0.0              | --      | --               | --   | --               |    |
| 31-III-90  | 0.7     | 0.0              | 196.0 | 0.0              | 0.3     | 0.0              | 9.3  | 0.0              |    |

natural waters will have concentrations of organic carbon from 0.1 to 10 mg/l (Stumm and Morgan 1970). In this study TOC measures were around 4 mg/l (Table 3-10), and the lowest TOC concentration was found in the winter (Appendix B).

### 3.2.9 Discharge

Discharge, or streamflow, is the volume of water moving past a cross section of a stream per unit time. Streamflow is a characteristic physical attribute of lotic systems (Poff and Ward 1989). Streamflow influences the structural attributes of a stream (Leopold et al. 1964, Hynes 1970); there is an interrelationship between vegetation cover and flow regime (Gregory and Gurnell 1988).

Above Site 1, the location of the U.S.G.S. gaging station, the Niobrara River drains approximately 2200 km<sup>2</sup> (840 mi<sup>2</sup>). The average discharge from 1957-1985 was 0.394m<sup>3</sup>/s (13.9 ft<sup>3</sup>/s or 10,070 acre-ft/yr) (Hydrodata 1989). Peak flows occur February through April and the lowest flows are July through September (Fig. 3-1). The peak flow periods are also the time when the greatest year to year variance of flow occurs (Fig. 3-2). The low variance during periods of low flow indicates that discharge is maintained by groundwater inputs. Discharge measurements obtained in this study did not indicate any noticeable difference in discharge between Sites 1 and 3 (Fig. 3-3).

Discharge data over the last 30 years indicate that stream flow has decreased in the Niobrara River (Fig. 3-4). A negative slope was found when yearly total flow data was regressed versus

Figure 3-1. Daily mean discharge (cubic feet/second) for each day of the water year (October 1 - September 30) over the period 1958-1988 at U.S.G.S. surface water gaging station 06454100 at Agate Fossil Beds National Monument, Nebraska. Straight line represents mean flow.

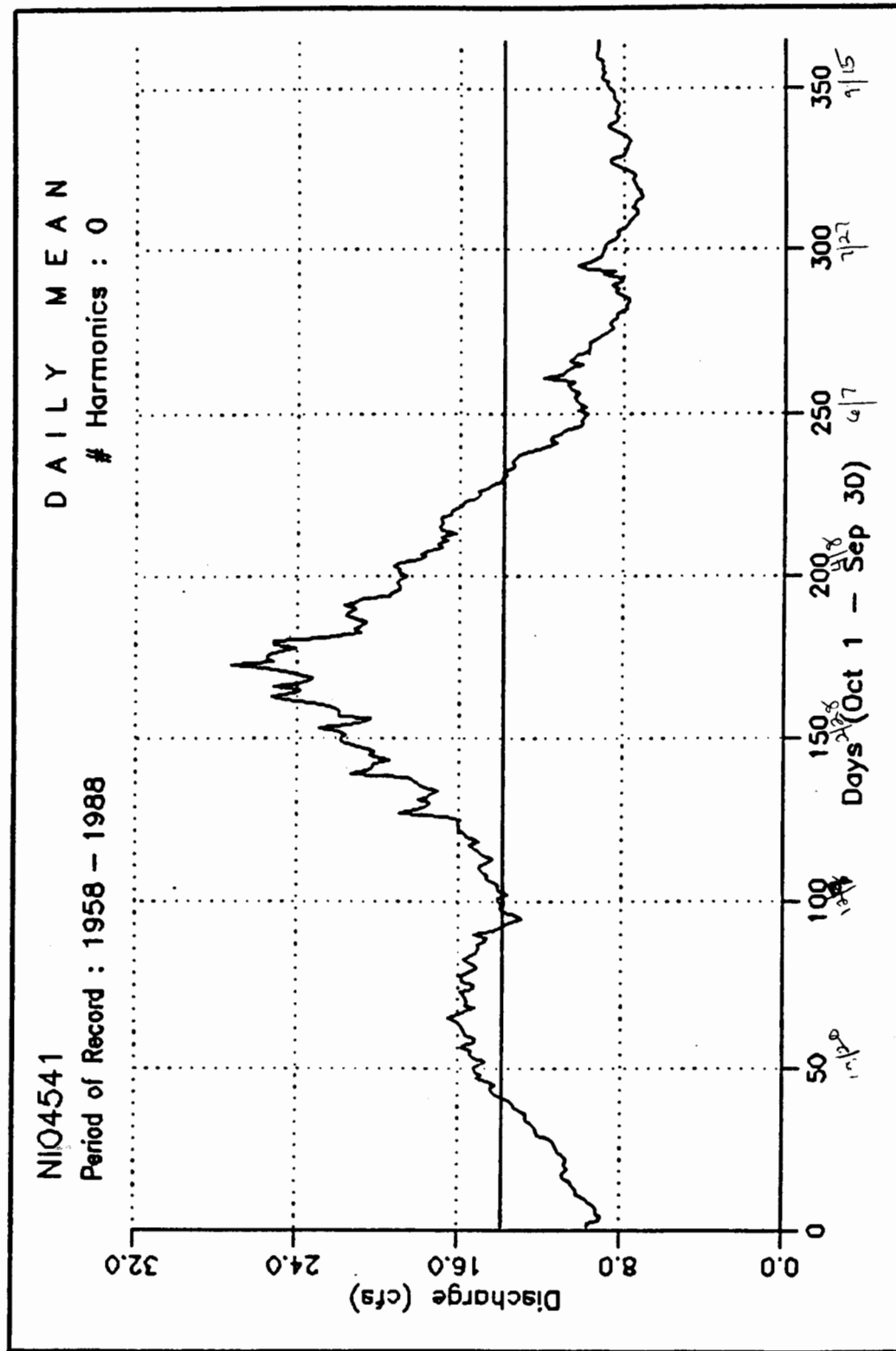


Figure 3-2. Daily standard deviation of discharge for each day of the water year (October 1 - September 30) over the period 1958-1988 at U.S.G.S. surface water gaging station 06454100 at Agate Fossil Beds National Monument, Nebraska. Smooth line was fit by Fourier series with seven harmonics.

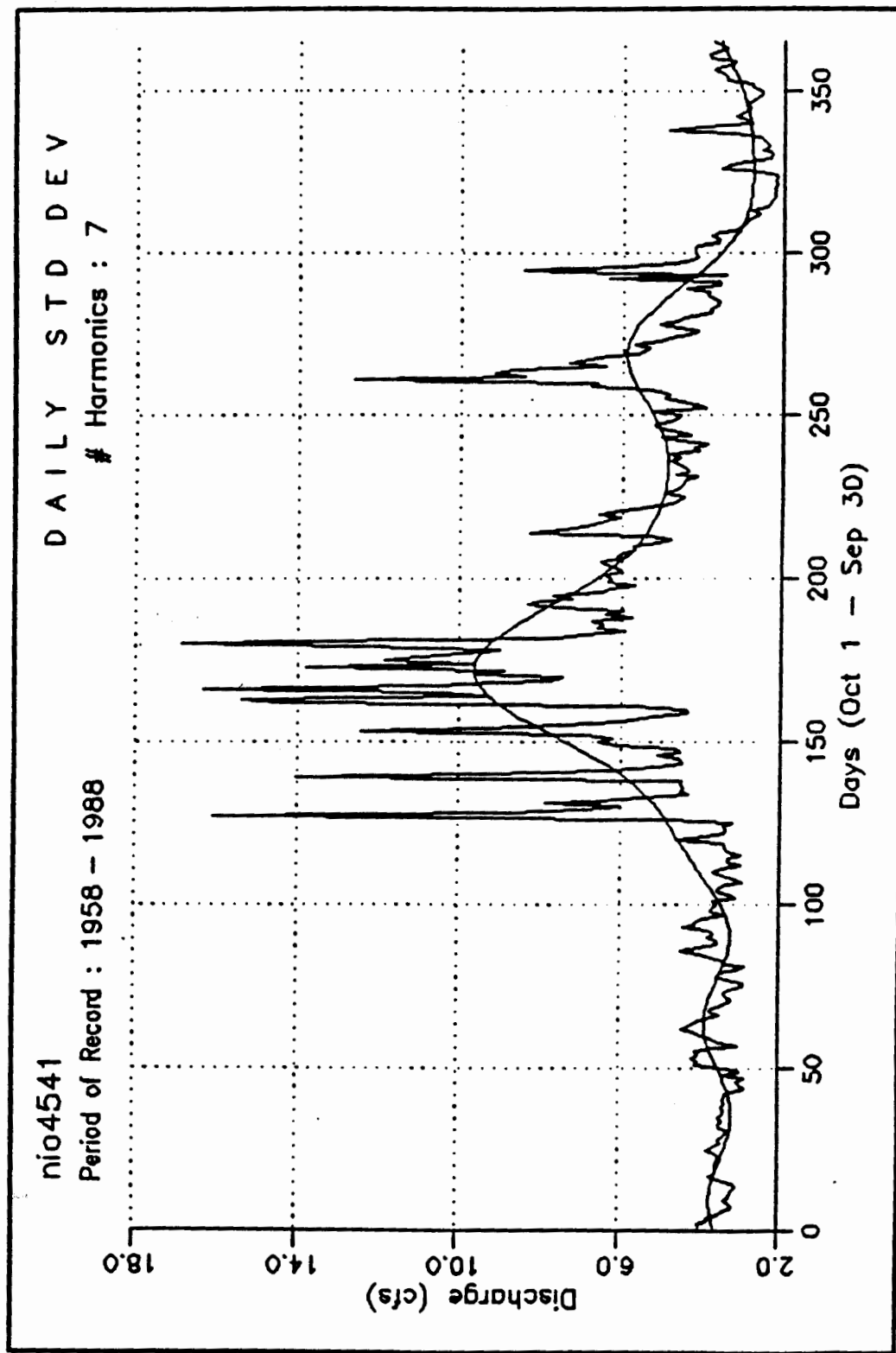


Figure 3-3. Discharge measures at Sites 1 and 3, Agate Fossil Beds National Monument, Nebraska, includes sampling dates June 1988 to March 1990.

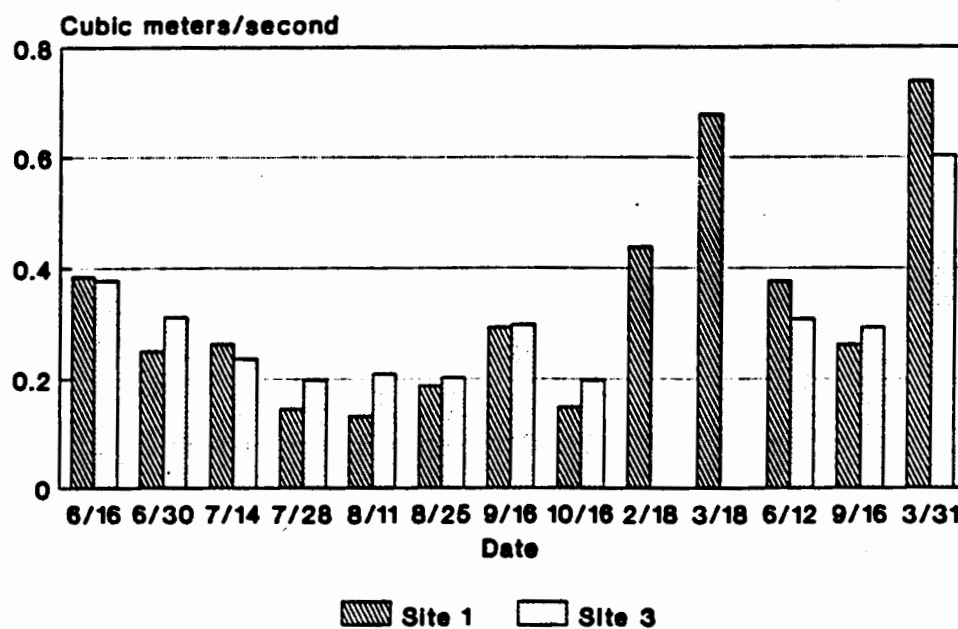


**Figure 3-4. Niobrara River discharge at Agate Fossil Beds National Monument, Nebraska, water years 1958-1988. Expressed as specific flow in mm. Specific flow is calculated by dividing the total volume of water that flows past a point in the river, by the drainage area of the river at that point.**

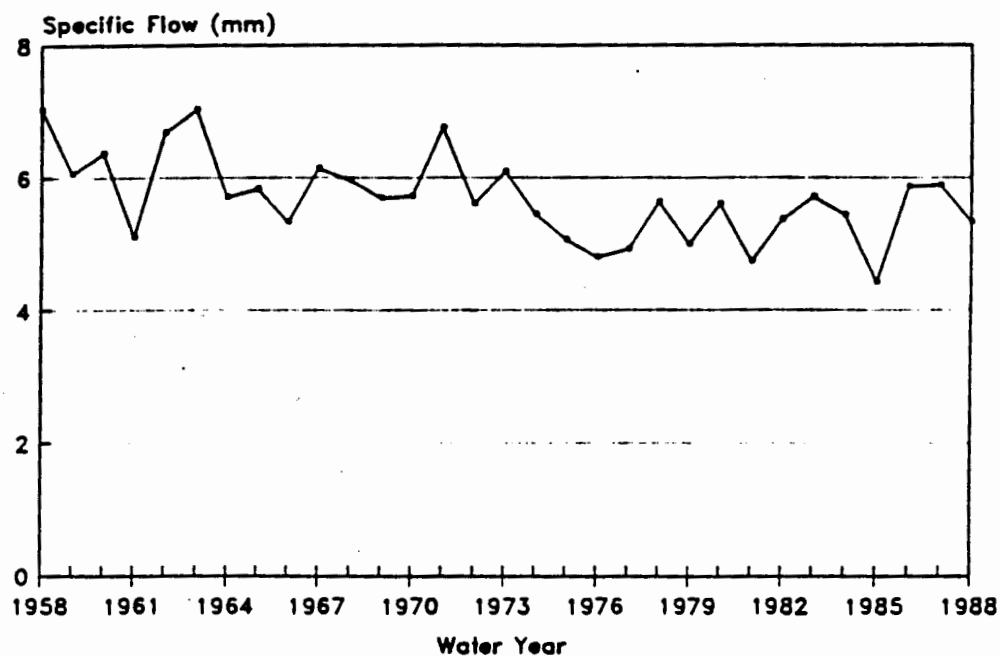


Table 3-10. Total organic carbon (TOC), mg/l, Agate Fossil Beds National Monument, Nebraska, includes sampling dates June 1989 to March 1990.

| Site | Mean | Minimum | Maximum | N |
|------|------|---------|---------|---|
| 1    | 3.6  | 2.0     | 4.6     | 4 |
| 3    | 4.3  | 4.2     | 4.4     | 3 |

water years 1958-1988 ( $t = -3.6$ ,  $p = 0.001$ ). In order to determine when flow was decreasing, monthly average discharge was regressed against water year. Over the period of record, flow decreased (significant,  $p < 0.05$ , negative slope in regression line) in November, December, January, and February (Table 3-11). In these months there is no irrigation in the watershed. Thus, the reduction in flow may be attributable to lowering of groundwater levels or reduction groundwater recharge within the watershed.

#### 3.2.10 Periphyton (Aufwuchs)

Periphyton growing on a variety of substances forms an important photosynthetic energy source in stream ecosystems and constitutes the principal algal community in stream ecosystems (Goldman and Horne 1983). Periphyton production has been employed as an index to estimate the comparative fertility of polluted and unpolluted waters (Vollenweider 1971). Because the periphyton community is difficult to quantitatively sample in situ, several investigators recommend the use of artificial substrates, especially those composed of transparent material (Schwoerbel 1970, Vollenweider 1971). Aufwuchs is the community of aquatic organisms and associated detritus that form a coating on submerged objects, of which periphyton often comprises a large part. The results of the periphyton (aufwuchs) collection in the Niobrara River are reported in Table 3-12 and can be used as a baseline for future measurements.

Qualitative periphyton samples were obtained from woody stem at Site 3 and the epipsammon (sand surface) at Site 1, during the

Table 3-11. Results of regression analysis of average monthly flow of Niobrara River at Agate Fossil Beds National Monument, Nebraska, over period 1958-1988. Slope indicates whether slope of regression line was positive or negative. Asterisk indicates significant slope,  $p < 0.05$ , 'ns' indicates not significant,  $p > 0.05$ .

| Month     | Slope | t    | p       |    |
|-----------|-------|------|---------|----|
| January   | -     | -5.2 | < 0.001 | *  |
| February  | -     | -2.5 | 0.02    | *  |
| March     | -     | -0.9 | 0.37    | ns |
| April     | -     | -2.0 | 0.06    | ns |
| May       | -     | 0.3  | 0.76    | ns |
| June      | -     | 0.8  | 0.44    | ns |
| July      | -     | -1.7 | 0.10    | ns |
| August    | -     | -0.9 | 0.38    | ns |
| September | +     | 0.2  | 0.81    | ns |
| October   | +     | 0.9  | 0.35    | ns |
| November  | -     | -2.3 | 0.03    | *  |
| December  | -     | -6.5 | < 0.001 | *  |

Table 3-12. Values of periphyton samples, Agate Fossil Beds National Monument, Nebraska, reported as dry weight (Dry Wgt.) and ash-free dry weight (AFDW) in grams.

| Date       | Site 1   |        | Site 2   |        | Site 3   |        |
|------------|----------|--------|----------|--------|----------|--------|
|            | Dry Wgt. | AFDW   | Dry Wgt. | AFDW   | Dry Wgt. | AFDW   |
| 14-VII-88  | 931.1    | 135.9  | 1342.2   | 75.0   | 1213.9   | 132.1  |
| 14-VII-88  | 674.8    | 121.1  | 159.0    | 15.1   | 481.2    | 69.8   |
| 14-VII-88  | --       | --     | 560.0    | 54.3   | 1016.9   | 779.0  |
| 14-VII-88  | --       | --     | 913.4    | 78.3   | 390.8    | 41.9   |
| 14-VII-88  | --       | --     | 399.0    | 42.0   | 511.3    | 76.3   |
| 11-VIII-88 | 1719.5   | 1633.2 | 315.3    | 282.3  | 1049.3   | 963.6  |
| 11-VIII-88 | 4193.7   | 4026.8 | 319.8    | 288.9  | 1197.9   | 1069.2 |
| 11-VIII-88 | 4328.0   | 4150.1 | 1522.1   | 1445.8 | 1071.0   | 909.9  |
| 11-VIII-88 | 7519.2   | 7300.8 | 1514.0   | 1394.0 | 105.3    | 79.4   |
| 11-VIII-88 | 8814.4   | 8608.1 | --       | --     | 1009.7   | 897.4  |
| 16-IX-88   | 2092.5   | 1991.5 | 378.2    | 353.6  | 488.1    | 439.7  |
| 16-IX-88   | 1475.2   | 1364.0 | 362.4    | 311.0  | 16571.0  | 1574.0 |
| 16-IX-88   | 3296.6   | 3180.8 | 642.1    | 588.0  | 506.1    | 379.0  |
| 16-IX-88   | 1135.0   | 1058.1 | 906.9    | 848.3  | 1282.3   | 1207.0 |
| 16-IX-88   | 1560.9   | 1469.0 | 441.0    | 401.0  | --       | --     |
| 16-X-88    | 1568.8   | 1492.5 | 2798.4   | 2726.8 | 723.2    | 669.6  |
| 16-X-88    | 1332.5   | 1279.6 | 645.2    | 623.0  | 621.2    | 562.4  |
| 16-X-88    | 711.6    | 677.2  | 1842.5   | 1792.0 | 801.8    | 737.2  |
| 16-X-88    | 1298.7   | 1470.5 | 3493.1   | 3405.3 | 1547.5   | 1462.0 |
| 16-X-88    | 765.7    | 739.5  | 3796.4   | 3704.2 | 1395.6   | 1303.5 |

July 1988. The species and relative abundance are presented in Table 3-13. The algae on the Site 3 woody stems made up a "crusty" type of growth. Within a mucilaginous algal matrix was a large amount of minute sand grains. The soft algae was primarily green algae (Chlorophyta), dominated by Chaetophora and Calothrix. Diatoms associated were mostly small, epiphytic, or attached in growth form. The epipsammon sample from Site 1 was greenish in appearance and dominated by blue-green algae (Cyanobacteria), primarily Anabaena. Sponge spicules were observed in the samples. Additionally, the adult of the sponge parasite Sisyra vicaria (Walker) (Neuroptera: Sisyridae) was collected by light trap at Site 1. The diatoms, in contrast to the Site 3 woody stem community, were larger in size, with a number of keeled and unattached forms.

### 3.3 Summary of Physical/Chemical Analysis

The Niobrara River is a perennial groundwater supplied stream. The flow is consistent with few flood or low water events. This contrasts it to many prairie streams which characteristically have large fluctuations (Matthews 1988). The concentrations of total nitrogen and phosphorus are relatively low compared to most streams indicating that few nutrients are being added. The organic carbon concentrations are low for a range of streams but within that expected for the prairie grassland region (Ford et al. 1990).

Table 3-13. Periphyton identified and relative abundance estimates from Agate Fossil Beds National Monument, July 1988. rare = 1, common = 4.

Woody Stem, Site 3

---

|                                              |   |
|----------------------------------------------|---|
| <u>Chaetophora</u> spp.                      | 4 |
| <u>Calothrix</u> ( <u>breviarticulata</u> )? | 4 |
| <u>Calothrix</u> ( <u>fusca</u> )?           | 3 |
| <u>Chaetonema</u> sp.                        | 3 |
| <u>Stigeoclonium</u> spp.                    | 3 |
| <u>Scytonema</u> ( <u>crispum</u> )?         | 2 |
| <u>Oedogonium</u> sp.                        | 2 |
| <u>Draparnaldia</u> sp.                      | 1 |
| <u>Oscillatoria</u> sp.                      | 1 |
| <u>Scenedesmus</u> sp.                       | 1 |
| <u>Plectonema</u> sp.                        | 1 |

Epipsammon sample, Site 1

---

|                         |   |
|-------------------------|---|
| <u>Anabaena</u> sp.     | 4 |
| <u>Oscillatoria</u> sp. | 3 |
| <u>Spirulina</u> sp.    | 1 |
| <u>Merismopedia</u> sp. | 1 |
| <u>Scenedesmus</u> sp.  | 1 |
| <u>Pediastrum</u> sp.   | 1 |
| <u>Closterium</u> sp.   | 1 |

## 4.0 BENTHIC MACROINVERTEBRATES

### 4.1 Quantitative Sampling Methods

#### 4.1.1 Samplers

Sampling methods available for characterizing benthic macroinvertebrate communities vary in their effectiveness. These sampling methods usually can be classified as being quantitative, semiquantitative, or qualitative. Quantitative sampling, used to obtain numerical data to estimate the absolute abundance of each species per unit area is usually habitat specific (Platts et al. 1983). This methodology provides data on population densities that may be used to detect variations in time and space. These types of techniques are often time consuming and expensive. Semiquantitative and qualitative designs yield data on species richness and relative abundance (Merritt et al. 1984, Lenat 1988). In addition to choosing a sampling device, the appropriate sampling design employed, including type of equipment, sampling frequency, number of samples and sampling habitats, needs to be carefully determined by considering the objectives of the study (Merritt et al. 1984, Platts et al. 1983).

The quantitative modified Hess bottom sampler (Merritt et al. 1984, Fig. 4-1) and the semiquantitative Hester-Dendy multiple plate sampler (Flannagan and Rosenberg 1982, Fig. 4-2) were used during the course of this study. Both are commonly used to sample shallow streams and rivers.

Bottom samplers, such as the Hess or the Surber sampler, are direct sampling methods. All organisms within the area of the

Figure 4-1. Hess bottom sampler.

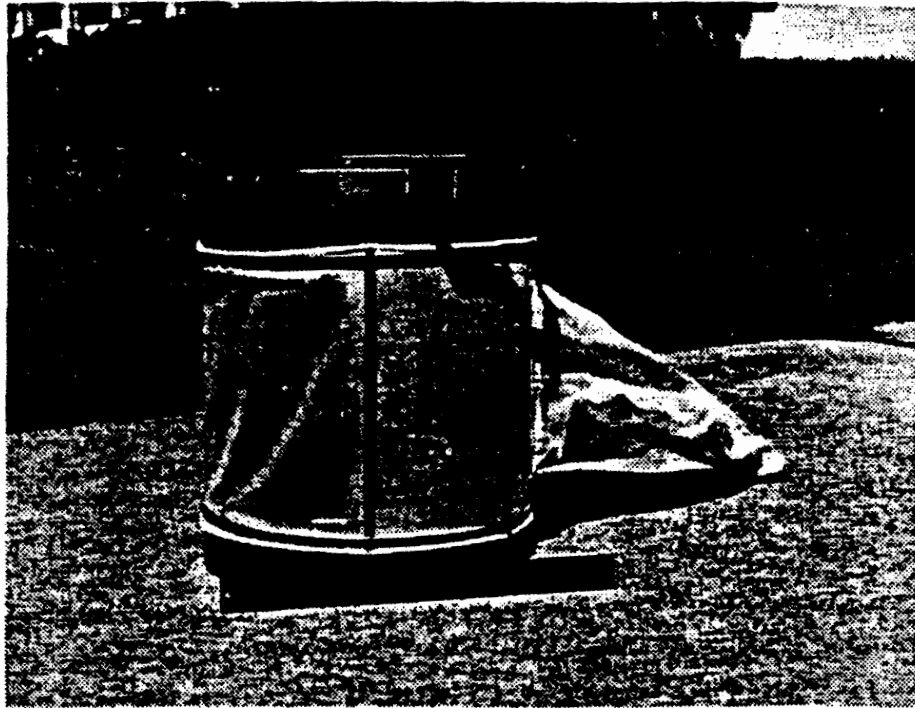
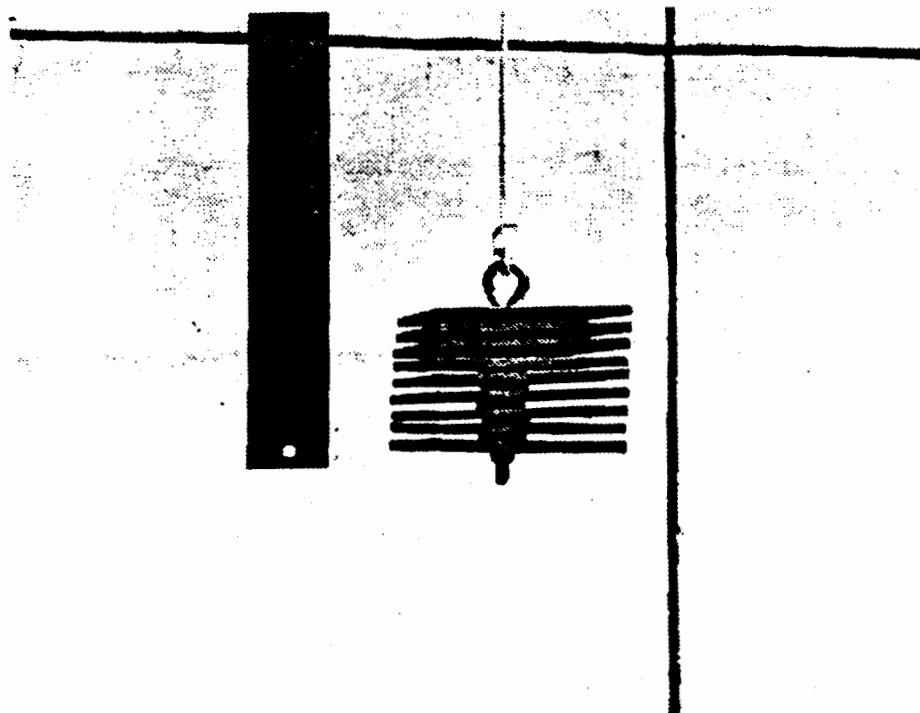


Figure 4-2. Hester-Dendy multiple plate sampler.



sampler on the natural stream bottom are collected. Bottom samplers are often employed to sample shallow rocky riffles rather than other stream areas (i.e. pools) because riffles generally have higher biotic diversity and greater accessibility (Platts et al. 1983). The Niobrara River within the Park boundaries is mostly a sand and sand/mud bottomed stream and has little rocky substrate to create long riffle reaches.

Artificial substrate samplers, such as the Hester-Dendy multiple plate sampler, are intended to provide standardized substrate that is comparable when placed in different habitats within the aquatic environment (Beak et al. 1973). They rely on invertebrates colonizing the sampler within a determined amount of time, after which the sampler is retrieved and the invertebrates collected. These substrates are recommended because they can reduce variation among samples and can be easier to use (Rosenberg and Resh 1982). The Hester-Dendy multiple plate sampler simulates woody retention structure or debris dam habitat; habitats that occurs naturally in the Niobrara and other Great Plains streams. This habitat is most often found in areas of woody riparian vegetation, which is a source of wood and leaf litter. A review and critique of the use of artificial substrates in studying freshwater benthic macroinvertebrate communities may be found in Rosenberg and Resh (1982).

Any type of sampler is designed specifically to be used for sampling one or more aquatic habitats (e.g. riffles, pools, vegetation etc.), and each sampler are more efficient at sampling

different types of organisms. For example, the Hester-Dendy sampler would not be expected to efficiently sample the burrowing mayfly Hexagenia limbata Serville (a common species in the Niobrara River), which burrows into the stream bottom, rather, it would favor organisms that attach or cling to exposed solid substrates in the flowing water column, such as black flies, Simulium spp. and baetid and heptageniid mayflies. The results obtained using different samplers also reflect the natural spatial (within stream) and temporal (diel and seasonal) variability of benthic macroinvertebrate communities. This natural variability combines with variability due to procedure. Procedural variability results from time of sampling, sampling frequency, number and type of habitats sampled, placement of the sampler, number of replicates, processing method, taxonomic resolution, and efficiency of different operators.

#### 4.1.2 Sampling Design

A Hess sampler (Fig. 4-1) was used to quantitatively sample the benthic macroinvertebrate community beginning June 1988. Each of three sites was sampled every two weeks in June, July and August, and monthly in September and October. Five replicate samples were taken at each site on each date. Sampling dates are presented in Table 4-1. An ice cover of 30 to 45 cm prevented sampling with the Hess sampler from November to March except for 18 February 1989 at Site 1. The bottom diameter of the sampler was 0.330 m (area = 0.0855 m<sup>2</sup>) and the mesh size of the catch net was 202  $\mu$ m.

Table 4-1. Sampling dates, Agate Fossil Beds National Monument, Nebraska. Unless noted, there were five replicates each date, at each site. Hester-Dendy dates include the date of placement of samplers and the date of retrieval.

---

Hess

16 June 1988  
30 June 1988  
14 July 1988  
28 July 1988  
11 August 1988  
25 August 1988  
16 September 1988  
16 October 1988  
18 February 1989 (site 1 only)

Hester-Dendy

12 June - 12 July 1989  
16 September - 21 October 1989 (site 3 - 4 replicates)  
3 January - 6 February 1990 (site 1 only)  
31 March - 3 May 1990

The Hess sampler was placed on the stream bottom in areas where depth (approximately 20 - 40 cm) and current were sufficient to wash dislodged organisms and debris into the catch net. The sand to sand/mud bottom was disturbed by hand to a depth of 8 - 10 cm. The catch net was washed several times to concentrate the contents into the end. Contents were placed into a labeled plastic bag by inverting the net, and preserved by adding formaldehyde to a concentration of approximately 5%. Macroinvertebrates were enumerated, and identified to the lowest practical taxonomic level (Table 4-2). Final storage of samples was in 80% ethanol.

In 1989-1990 Hester Dendy multiple plate samplers were used to obtain quarterly samples at Sites 1 and 3. Each sampler consisted of nine 7.6 cm x 7.6 cm hardboard plates, connected by a long eye bolt. The plates were separated by 3-mm spacers and provided 0.0929 m<sup>2</sup> of surface area for colonization. Five samplers at each site were suspended by nylon cord between the water surface and substrate. After a 30 - 35 day colonization period the samplers were pulled from the water and placed immediately in a labeled plastic bag with 5% formaldehyde solution. Macroinvertebrates were identified, enumerated, and placed in 80% ethanol for storage.

Four seasonal samples at both sites were planned. Samplers were collected in July 1989 (summer), October 1989 (autumn), and May 1990 (spring). One sampler was lost at Site 3 in October 1989. Samplers were collected from Site 1 in February 1990 (winter), but winter ice prevented winter sampling at Site 3. Sampling dates are presented in Table 4-1.

Table 4-2. Level of taxonomic resolution used in benthic sampling.

|                |                                       |
|----------------|---------------------------------------|
| Collembola:    | Order                                 |
| Ephemeroptera: | Genus/Species                         |
| Odonata:       | Genus                                 |
| Plecoptera:    | Species                               |
| Hemiptera:     | Genus                                 |
| Trichoptera:   | Genus                                 |
| Megaloptera:   | Genus                                 |
| Coleoptera:    | Genus                                 |
| Diptera:       | Family/Subfamily (Chironomidae)/Genus |
| Turbellaria:   | Class                                 |
| Nematoda:      | Phylum                                |
| Annelida:      | Class                                 |
| Amphipoda:     | Genus/Species                         |
| Decapoda:      | Genus                                 |
| Acarina:       | Order                                 |
| Gastropoda:    | Family                                |
| Pelecypoda:    | Family                                |

#### 4.1.3 Analysis

A sample was defined as the mean number of organisms of each taxon found in the five replicate samples at each site and date. The winter samples at Site 1 (18 February 1989 for the Hess sampler, and 6 February 1990 for the Hester-Dendy sampler) are reported separately below to allow for comparison among sites. Data from the macroinvertebrate samplers were analyzed to obtain basic benthic aquatic community data including taxa richness and density of macroinvertebrates. Sites and time periods are compared and life history information is also reported.

The number of qualitative EPT (Ephemeroptera/Plecoptera/Trichoptera) taxa was the number of taxa, in the three orders, represented in a sample. Many species in these three orders are considered pollution-sensitive (Hawkes 1979). Surveying the number of EPT taxa over time and comparing the number with streams with of similar size and in close proximity may be indicative of present and past water quality.

The measurement of diversity has two components: taxa richness and relative abundance. Richness is simply a count of the number of taxa (i.e. species) are present. Relative abundance, or evenness, is a description of how the number of organisms in a community are distributed among the taxa. In this study we are using three measures of diversity to describe the Niobrara benthic community: taxa richness, Shannon (or Shannon-Wiener) diversity index, and Simpson's index. One of the simplest and most basic measures used in aquatic ecology is taxa richness, which is simply

the number of different taxa found over a given space and time. The Shannon diversity index and Simpson's index utilize both of the components of diversity and are based on the proportional abundance of species. A recent review of the use and meaning of ecological diversity may be found in Magurran (1988). Washington (1984) reviewed the ecological application of diversity indices along with biotic and similarity indices.

The Shannon diversity index is based on information theory and relates to the uncertainty of the identity of an individual chosen at random (Washington 1984, Magurran 1988). Shannon's index was calculated as:

$$H' = -\sum p_i \ln p_i$$

where  $p_i$  is the proportion of individuals in taxon  $i$ , or more specifically,  $p_i = n_i/N$  where  $n_i$  is the number of individuals in the  $i^{\text{th}}$  taxon and  $N$  is the total number of individuals in the sample. The Shannon index is sometimes calculated with  $\log_2$  or  $\log_{10}$  rather than the natural log, and the values obtained would differ by a constant (Brower and Zar 1977, Magurran 1988). This index is one of the most widely reported in ecological literature (Washington 1984).

Simpson (1949) proposed a formula that gives the probability that two individuals drawn at random from a finite community will belong to different taxa (Washington 1984, Magurran 1988). Simpson's Index was calculated as:

$$D = (\sum n_i(n_i - 1)) / N(N - 1)$$

where  $n_i$  is the number of individuals in the  $i^{\text{th}}$  taxon and  $N$  is the total number of individuals in the sample. The value of Simpson's index ranges from 0 to 1 and decreases with increasing diversity. Simpson's complement ( $1 - D$ ) is presented in this report, since this modification makes higher values represent higher diversity. Simpson's Index is most sensitive to the abundant species, and less weighted toward sample size or species richness (Magurran 1988).

#### 4.1.2 Qualitative Sampling Methods

Qualitative benthic samples were taken with a standard D-frame kick net. The major objective was to obtain specimens from the many microhabitats of both streams that were not sampled with the quantitative device. Selected specimens were returned alive for rearing to adult stage for positive identification. Additionally, emergent adult insects were obtained with an aerial net by sweeping riparian vegetation or capturing flying insects, and attracting insects with a black light trap. Others were collected by carefully examining exposed debris and rocks. A voucher collection of selected species listed in Appendix A has been deposited in the Colorado State University Insect Collection, Fort Collins.

### 4.2 Results

#### 4.2.1 Hess

Cumulatively, over the Hess sampling period, 41 taxa were identified from benthic samples. Site 1 was the richest, with 35 taxa identified and Site 2 the poorest, with 29 taxa identified (Table 4-3). Site 3, even though 32 total taxa were reported over the year, usually had fewer taxa on individual sampling dates.

Table 4-3. Number of macroinvertebrate taxa for sites on Niobrara River, Agate Fossil Beds National Monument, Nebraska. Hess includes sampling dates June 1988 - February 1989, Hester-Dendy includes sampling dates July 1989 - May 1990.

Hess

| Site       | Total | Mean | Min. | Max. | N |
|------------|-------|------|------|------|---|
| 1          | 35    | 20   | 8    | 31   | 8 |
| 1 (winter) | 19    |      |      |      | 1 |
| 2          | 29    | 21   | 10   | 25   | 8 |
| 3          | 32    | 18   | 14   | 22   | 8 |

Hester-Dendy

| Site       | Total | Mean | Min. | Max. | N |
|------------|-------|------|------|------|---|
| 1          | 33    | 19   | 17   | 21   | 3 |
| 1 (winter) | 10    |      |      |      | 1 |
| 3          | 33    | 21   | 20   | 22   | 3 |

(Fig. 4-3). On 30 June at Sites 1 and 3, and on 28 July at Site 1 there was markedly low taxa richness. Of the taxa identified 10, 9, and 8 taxa, at Sites 1, 2, and 3 respectively, were in one of the EPT orders (Table 4-4). The number of EPT taxa in relation to the total taxa found on successive sampling dates appeared to be relatively constant (Fig. 4-4). The winter sample at Site 1 was comparable to the other sampling dates at the site in terms of taxa richness and EPT taxa.

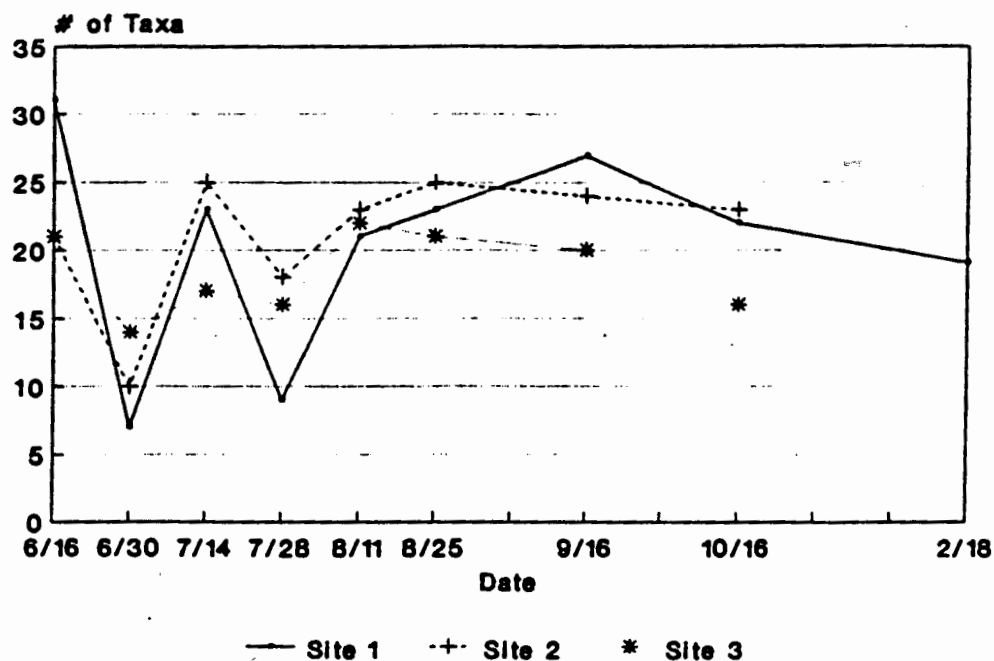
Mean density estimates over the year were 1991, 1658, and 576 individuals/m<sup>2</sup> of bottom substrate for Sites 1, 2, and 3 respectively (Table 4-5). Site 2 had consistently lower density estimates than the other two sites (Fig. 4-5). Sites 1 and 2 on 30 June and 28 July had lower estimates than the rest of the year. Site 1 on 16 June was much higher than on other dates. The winter Site 1 sample had lower density than most of the year.

The Ephemeroptera and Diptera were the two most abundant groups in terms of mean abundance for each site (Table 4-6). In the mean of the Hess samples these two groups accounted for between 73% and 75% of the individuals (Table 4-7). The Oligochaeta were the next most abundant group, comprising for between 10% and 13% of the individuals. Table 4-8 presents mean densities for each taxon.

Both diversity indices, Shannon's H' and Simpson's complement, indicated similar trends (Fig. 4-6). From the spring through the fall, at all three sites the Shannon diversity was usually between 2.0 and 2.5, and Simpson's complement usually was between 0.8 and 0.9. There were conspicuously low diversity numbers, however, for

Figure 4-3. Number of macroinvertebrate taxa found on each sampling date, Agate Fossil Beds National Monument, Nebraska, for a) Hess bottom sampler, b) Hester-Dendy multiple plate sampler.

a)



b)

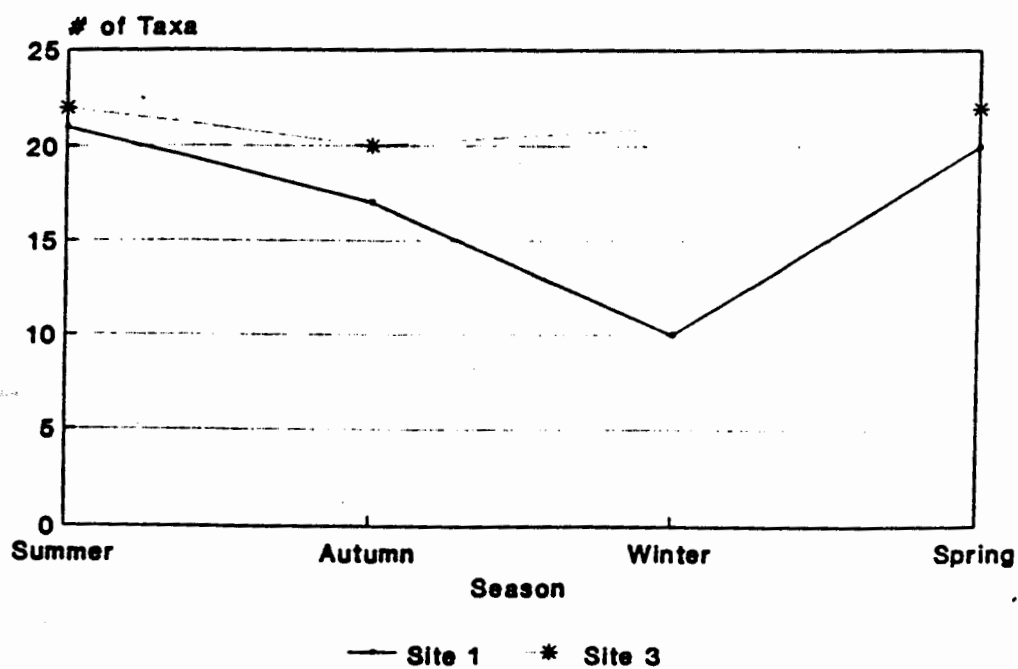


Figure 4-4. Number of taxa in one of the three orders: Ephemeroptera, Plecoptera, Trichoptera (EPT taxa), Agate Fossil Beds National Monument, Nebraska, found on each Hess sampling date for a) Site 1, b) Site 2, c) Site 3.

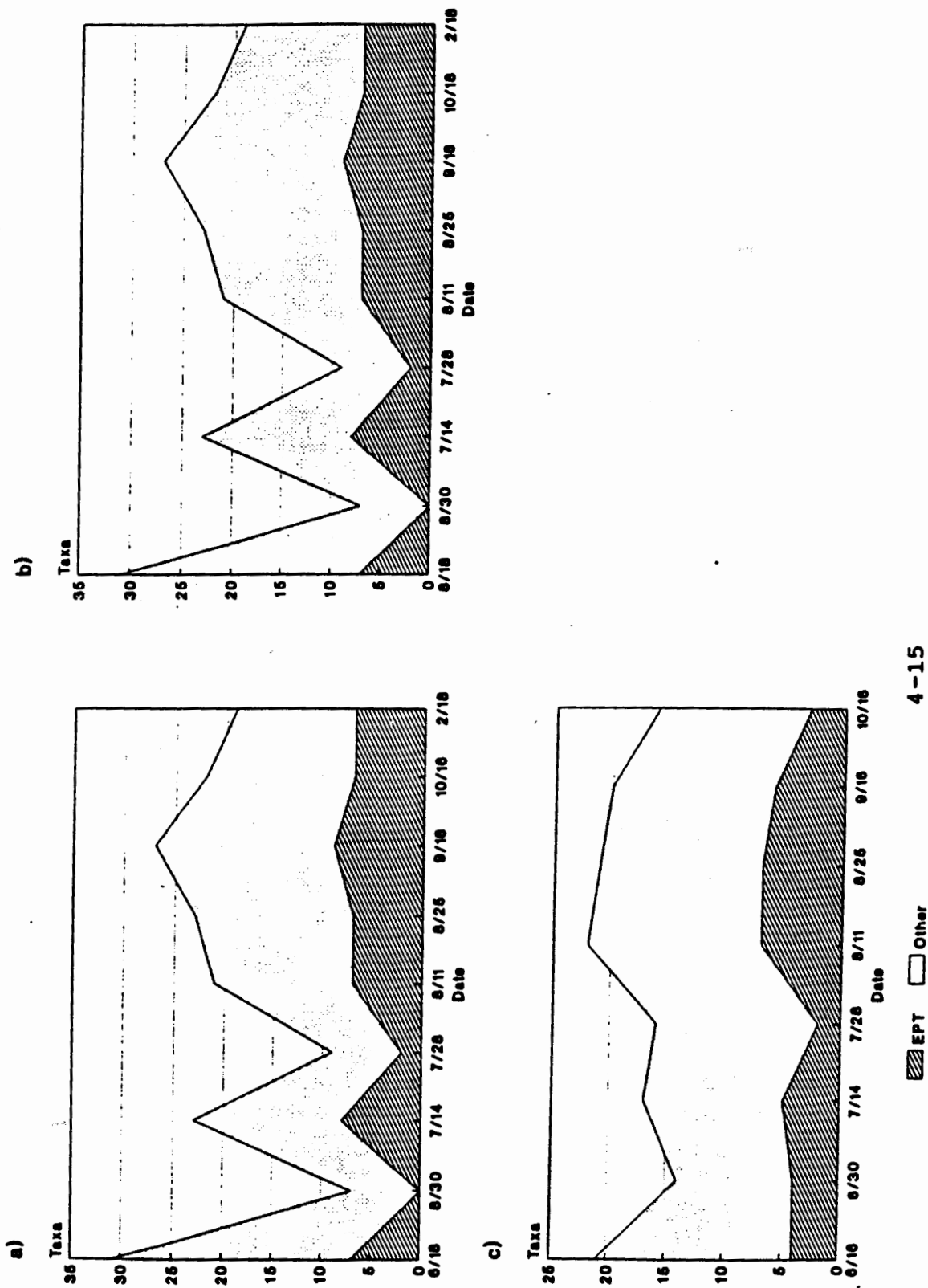
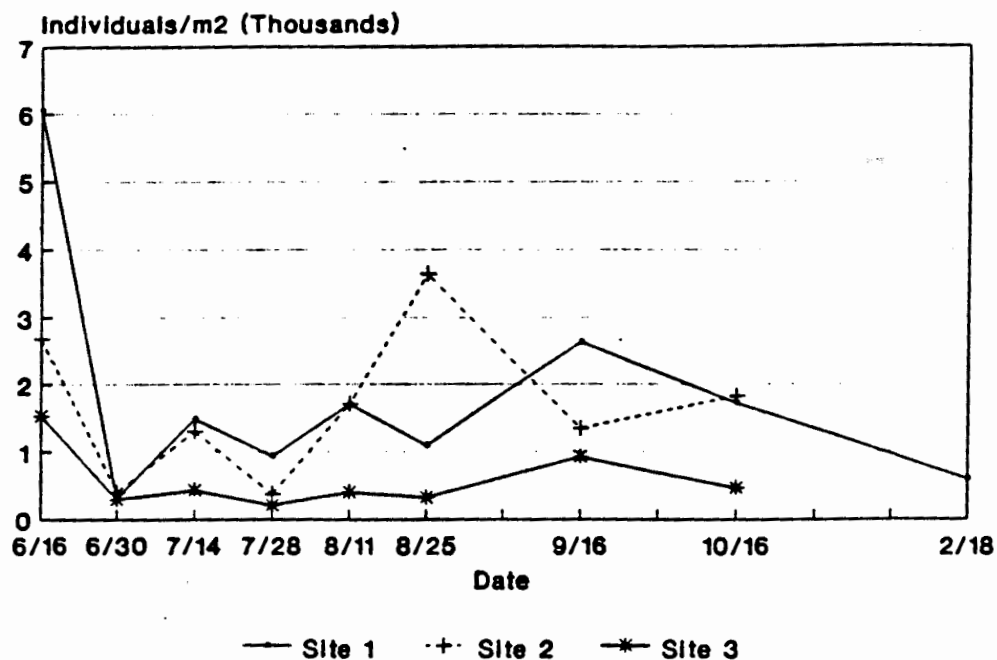


Figure 4-5. Macroinvertebrate density on each sampling date, Agate Fossil Beds National Monument, Nebraska, for a) Hess bottom sampler, b) Hester-Dendy multiple plate sampler.

a)



b)

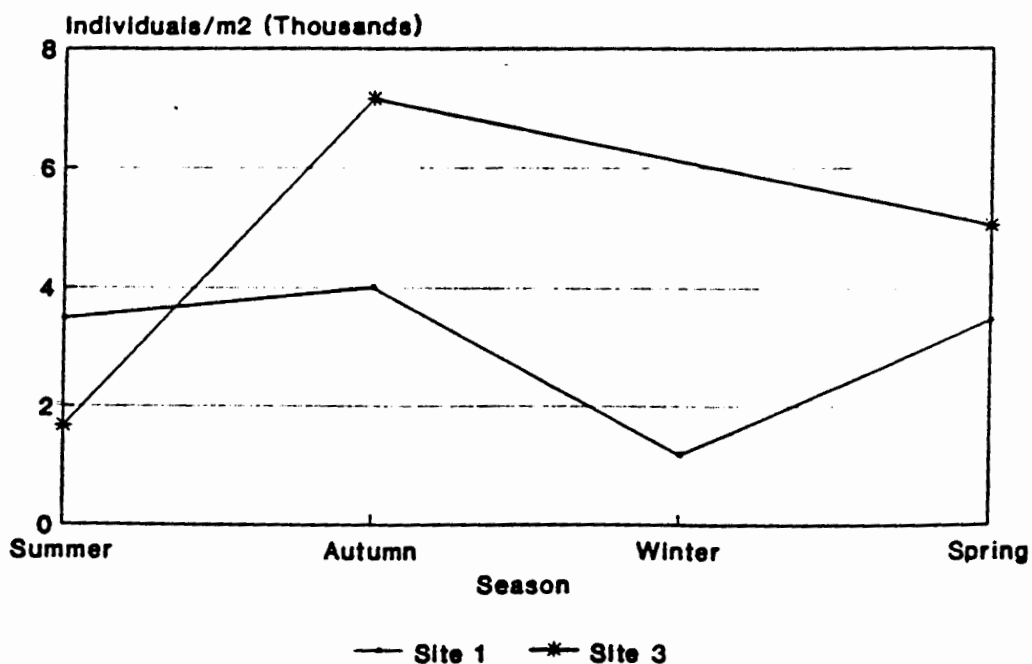
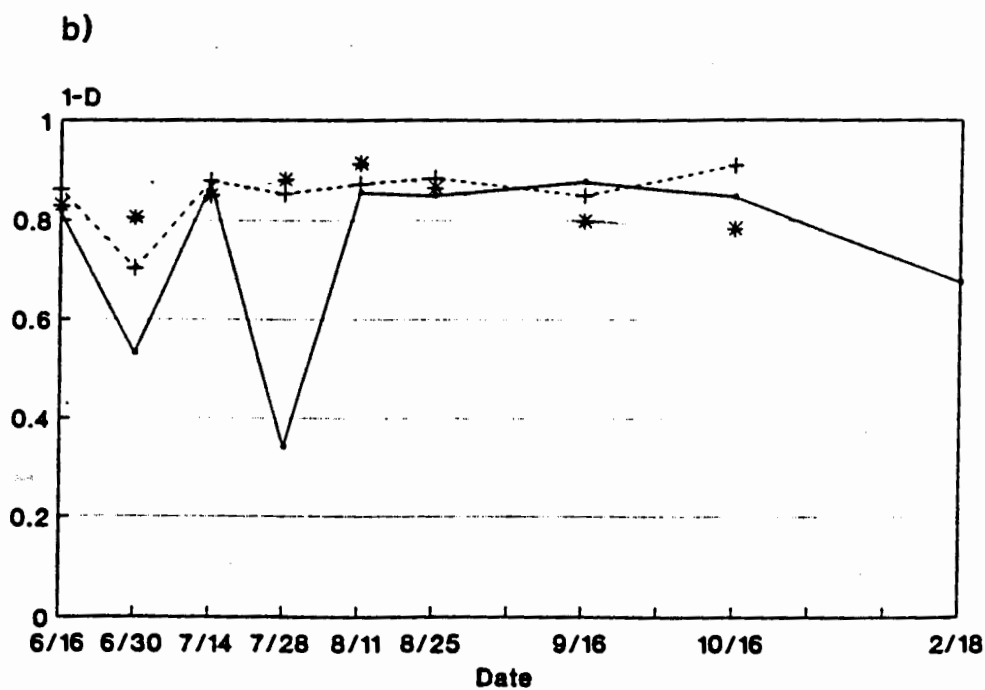
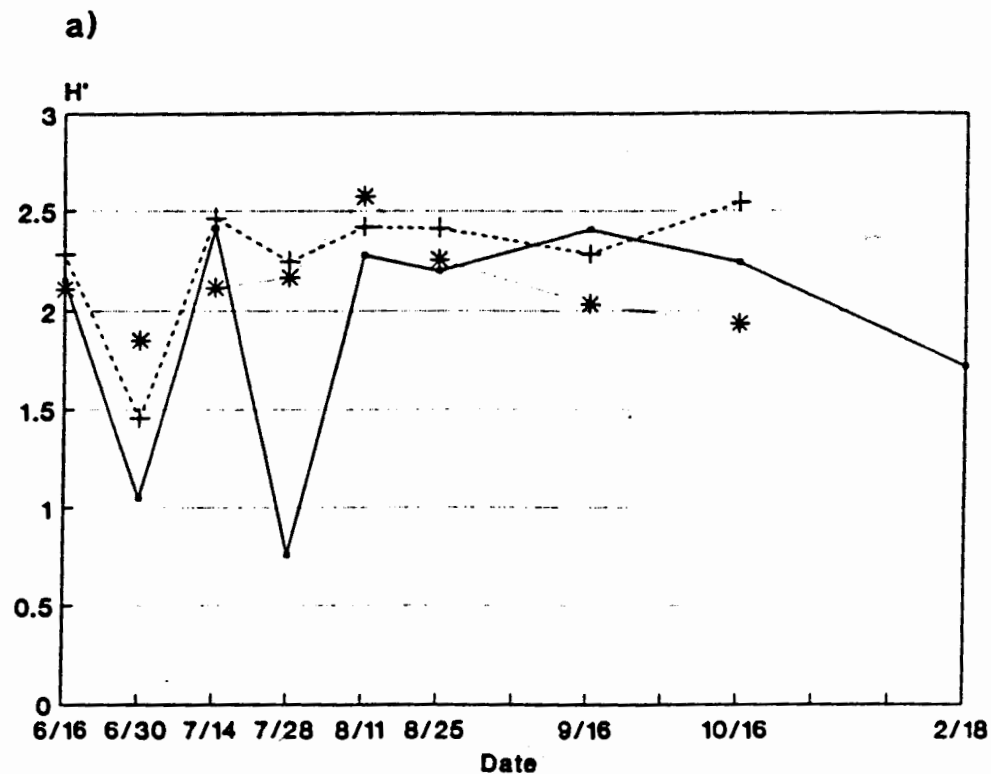


Figure 4-6. Macroinvertebrate diversity on each Hess sampling date, Agate Fossil Beds National Monument, Nebraska, calculated by a) Shannon diversity, b) Simpson's complement.



— Site 1    -+- Site 2    \* Site 3  
4-17

Table 4-4. Number of taxa in one of the three orders: Ephemeroptera, Plecoptera, Trichoptera (EPT taxa), Agate Fossil Beds National Monument, Nebraska. Hess includes sampling dates June 1988 - February 1989, Hester-Dendy includes sampling dates July 1989 - May 1990.

Hess

| Site       | Total | Mean | Min. | Max. | N |
|------------|-------|------|------|------|---|
| 1          | 10    | 6    | 0    | 9    | 8 |
| 1 (winter) | 3     |      |      |      | 1 |
| 2          | 9     | 7    | 1    | 8    | 8 |
| 3          | 8     | 5    | 2    | 7    | 8 |

Hester-Dendy

| Site       | Total | Mean | Min. | Max. | N |
|------------|-------|------|------|------|---|
| 1          | 12    | 6    | 5    | 7    | 3 |
| 1 (winter) | 3     |      |      |      | 1 |
| 3          | 12    | 7    | 6    | 9    | 3 |

Table 4-5. Macroinvertebrate density expressed as individuals/m<sup>2</sup> for sites on Niobrara River, Agate Fossil Beds National Monument, Nebraska. Hess includes sampling dates June 1988 - February 1989, Hester-Dendy includes sampling dates July 1989 - May 1990.

Hess

| Site       | Mean | Min. | Max. | N |
|------------|------|------|------|---|
| 1          | 1991 | 323  | 6047 | 8 |
| 1 (winter) | 599  |      |      | 1 |
| 2          | 1658 | 379  | 3638 | 8 |
| 3          | 576  | 215  | 1534 | 8 |

Hester-Dendy

| Site       | Mean | Min. | Max. | N |
|------------|------|------|------|---|
| 1          | 3655 | 3471 | 4007 | 3 |
| 1 (winter) | 1172 |      |      | 1 |
| 3          | 4450 | 1670 | 7169 | 3 |

Table 4-6. Average macroinvertebrate densities, number/m<sup>2</sup>, Agate Fossil Beds National Monument, Nebraska. Hess includes sampling dates from June 1988 - October 1988. Hester-Dendy includes dates July 1989, October 1989, and May 1990.

| Site          | Hess   |        |       | Hester-Dendy |        |
|---------------|--------|--------|-------|--------------|--------|
|               | 1      | 2      | 3     | 1            | 3      |
| Collembola    | 0.6    | 0.3    | 0     | 0            | 0      |
| Ephemeroptera | 707.1  | 797.4  | 250.2 | 887.4        | 489.6  |
| Odonata       | 3.2    | 22.8   | 5.0   | 0            | 0.7    |
| Plecoptera    | 16.4   | 2.9    | 0.0   | 153.5        | 15.4   |
| Trichoptera   | 64.6   | 33.3   | 2.6   | 17.2         | 91.5   |
| Megaloptera   | 0      | 0      | 0     | 3.6          | 0      |
| Coleoptera    | 21.3   | 38.3   | 7.6   | 0.7          | 1.5    |
| Hemiptera     | 0      | 0      | 0.6   | 0            | 0      |
| Diptera       | 751.8  | 439.3  | 180.1 | 1969.2       | 3682.5 |
| Tricladida    | 0.6    | 0      | 0     | 0            | 0.7    |
| Nematoda      | 30.1   | 47.4   | 14.6  | 81.8         | 31.5   |
| Oligochaeta   | 253.7  | 163.4  | 71.9  | 459.1        | 66.1   |
| Hirudinea     | 0.6    | 1.2    | 0.3   | 0            | 9.2    |
| Amphipoda     | 115.7  | 55.2   | 6.4   | 51.7         | 20.0   |
| Decapoda      | 6.7    | 21.3   | 6.4   | 1.4          | 1.5    |
| Acarina       | 6.7    | 4.1    | 2.3   | 12.2         | 27.7   |
| Gastropoda    | 11.4   | 31.0   | 28.1  | 17.2         | 10.8   |
| Pelecypoda    | 0.9    | 0      | 0     | 0            | 0      |
| Total         | 1991.4 | 1657.9 | 576.1 | 3655.1       | 4450.3 |

Table 4-7. Percent of individuals by group, Agate Fossil Beds National Monument, Nebraska. Hess includes sampling dates from June 1988 - October 1988. Hester-Dendy includes dates July 1989 - May 1990. "+" indicates present, but < 0.05%.

| Site          | Hess  |       |       | Hester-Dendy |       |
|---------------|-------|-------|-------|--------------|-------|
|               | 1     | 2     | 3     | 1            | 3     |
| Collembola    | +     | +     | 0.0   | 0            | 0     |
| Ephemeroptera | 35.5% | 48.1% | 43.4% | 24.3%        | 11.0% |
| Odonata       | 0.2   | 1.4   | 0.9   | 0.0          | +     |
| Plecoptera    | 0.8   | 0.2   | 0.0   | 4.2          | 0.3   |
| Trichoptera   | 3.2   | 2.0   | 0.5   | 0.5          | 2.1   |
| Megaloptera   | 0     | 0     | 0     | 0.1          | 0     |
| Coleoptera    | 1.1   | 2.3   | 1.3   | 0            | 0     |
| Hemiptera     | 0     | 0     | 0.1   | 0            | 0     |
| Diptera       | 37.8  | 26.5  | 31.3  | 53.9         | 82.7  |
| Tricladida    | +     | 0     | 0     | 0            | 0.1   |
| Nematoda      | 1.5   | 2.9   | 2.5   | 2.2          | 0.7   |
| Oligochaeta   | 12.7  | 9.9   | 12.5  | 12.6         | 1.5   |
| Hirudinea     | +     | 0.1   | 0.1   | 0            | 0.2   |
| Amphipoda     | 5.8   | 3.3   | 1.1   | 1.4          | 0.4   |
| Decapoda      | 0.3   | 1.3   | 1.1   | 0            | 0     |
| Acarina       | 0.3   | 0.2   | 0.4   | 0.3          | 0.6   |
| Gastropoda    | 0.6   | 1.9   | 4.9   | 0.5          | 0.2   |
| Pelecypoda    | +     | 0     | 0     | 0            | 0     |

Table 4-8. Average macroinvertebrate densities, number/m<sup>2</sup>, Agate Fossil Beds National Monument, Nebraska. Larvae unless noted. Hess includes sampling dates from June 1988 - October 1988. Hester-Dendy includes dates July 1989 - May 1990.

| Site                      | Hess  |       |       | Hester-Dendy |        |
|---------------------------|-------|-------|-------|--------------|--------|
|                           | 1     | 2     | 3     | 1            | 3      |
| Baetidae                  | 224.5 | 222.1 | 63.7  | 74.6         | 54.6   |
| Caenis sp.                | 56.1  | 104.1 | 18.1  | 30.9         | 3.8    |
| Hexagenia limbata         | 4.1   | 213.7 | 145.9 | 0            | 0      |
| Heptagenia diabasa        | 270.1 | 71.3  | 7.0   | 538.9        | 265.3  |
| Leptophlebia nebulosa     | 152.3 | 186.2 | 15.5  | 221.0        | 164.5  |
| Isonychia rufa            | 0     | 0     | 0     | 21.5         | 0      |
| Tricorythodes sp.         | 0     | 0     | 0     | 0.7          | 1.5    |
| Sympetrum spp.            | 0     | 0.3   | 0     | 0            | 0      |
| Calopteryx spp.           | 3.2   | 22.5  | 4.7   | 0            | 0      |
| Argia sp.                 | 0     | 0     | 0     | 0            | 0.8    |
| Enallagma spp.            | 0     | 0     | 0.3   | 0            | 0      |
| Taeniopteryx burksi       | 15.8  | 2.9   | 0     | 131.3        | 0.8    |
| Isoperla sp.              | 0.6   | 0     | 0     | 22.2         | 14.6   |
| Cheumatopsyche pettiti    | 0     | 0     | 0     | 1.4          | 10.0   |
| Hydropsyche spp.          | 44.7  | 21.9  | 1.2   | 8.6          | 73.8   |
| Ochrotrichia spp.         | 17.5  | 1.8   | 0.3   | 0            | 3.8    |
| Nectopsyche sp.           | 2.3   | 9.6   | 1.2   | 2.2          | 0.0    |
| Ptilostomis semifasciatus | 0     | 0     | 0     | 0            | 0.8    |
| Polycentropus spp.        | 0     | 0     | 0     | 5.0          | 3.1    |
| Sialis velata             | 0     | 0     | 0     | 3.6          | 0      |
| Dubiraphia sp.            | 20.2  | 38.3  | 7.6   | 0.7          | 1.5    |
| Dytiscidae                | 0.9   | 0     | 0     | 0            | 0      |
| Cenocorixa sp.            | 0     | 0     | 0.6   | 0            | 0      |
| Chrysops spp.             | 18.7  | 8.8   | 8.8   | 0            | 0      |
| Simulium spp.             | 83.6  | 62.6  | 6.4   | 449.9        | 1477.0 |
| Simulium spp. (pupae)     | 0     | 0     | 0     | 16.5         | 83.0   |
| Stratiomyidae             | 2.3   | 0     | 0     | 0            | 0      |
| Tipulidae                 | 0.6   | 0     | 0     | 0            | 0      |
| Dicranota sp.             | 0     | 0     | 0     | 12.2         | 0.8    |
| Ceratopogonidae           | 8.5   | 23.7  | 5.0   | 0.7          | 0.8    |
| Chironomidae (pupae)      | 17.8  | 13.2  | 5.8   | 62.4         | 71.5   |
| Chironomini               | 156.4 | 70.4  | 30.1  | 10.8         | 18.5   |
| Tanytarsini               | 245.8 | 131.2 | 54.4  | 96.2         | 148.4  |
| Orthocladinae             | 207.8 | 117.5 | 67.5  | 1268.0       | 1823.7 |
| Tanypododinae             | 9.4   | 12.0  | 1.8   | 35.2         | 39.2   |
| Diamesinae                | 0     | 0     | 0     | 10.0         | 6.2    |
| Heimerodromia sp.         | 0     | 0     | 0     | 7.9          | 14.6   |
| Ephydriidae               | 0.9   | 0     | 0.3   | 0            | 0      |
| Collembola                | 0.6   | 0.3   | 0     | 0            | 0      |
| Ancylidae                 | 10.8  | 29.8  | 22.2  | 15.8         | 10.8   |
| Lymnaeidae                | 0.6   | 0     | 0.9   | 0            | 0      |
| Physidae                  | 0     | 0     | 0.6   | 0.7          | 0      |
| Planorbidae               | 0     | 1.2   | 2.9   | 0.7          | 0      |
| Sphaeriidae               | 0.9   | 0     | 0     | 0            | 0      |
| other Gastropoda          | 0     | 0     | 1.5   | 0            | 0      |

Table 4-8 (continued).

| Site                      | Hess  |       |      | Hester-Dendy |      |
|---------------------------|-------|-------|------|--------------|------|
|                           | 1     | 2     | 3    | 1            | 3    |
| <u>Gammarus</u> sp.       | 115.7 | 55.2  | 6.4  | 51.7         | 20.0 |
| <u>Orconectes immunis</u> | 6.7   | 21.3  | 6.4  | 1.4          | 1.5  |
| <u>Oligochaeta</u>        | 253.7 | 163.4 | 71.9 | 459.3        | 66.1 |
| Hirudinea                 | 0.6   | 1.2   | 0.3  | 0            | 9.2  |
| Nematoda                  | 30.1  | 47.4  | 14.6 | 81.8         | 31.5 |
| Acarina                   | 6.7   | 4.1   | 2.3  | 12.2         | 27.7 |
| <u>Dugesia</u> sp.        | 0.6   | 0     | 0    | 0            | 2.3  |

the 30 June 1988 sample at Sites 1 and 2 and the 28 July 1988 sample at Site 1. The winter sample had lower diversity (Shannon 1.72, Simpson 0.67) than the remainder of the year.

#### 4.2.2 Hester-Dendy

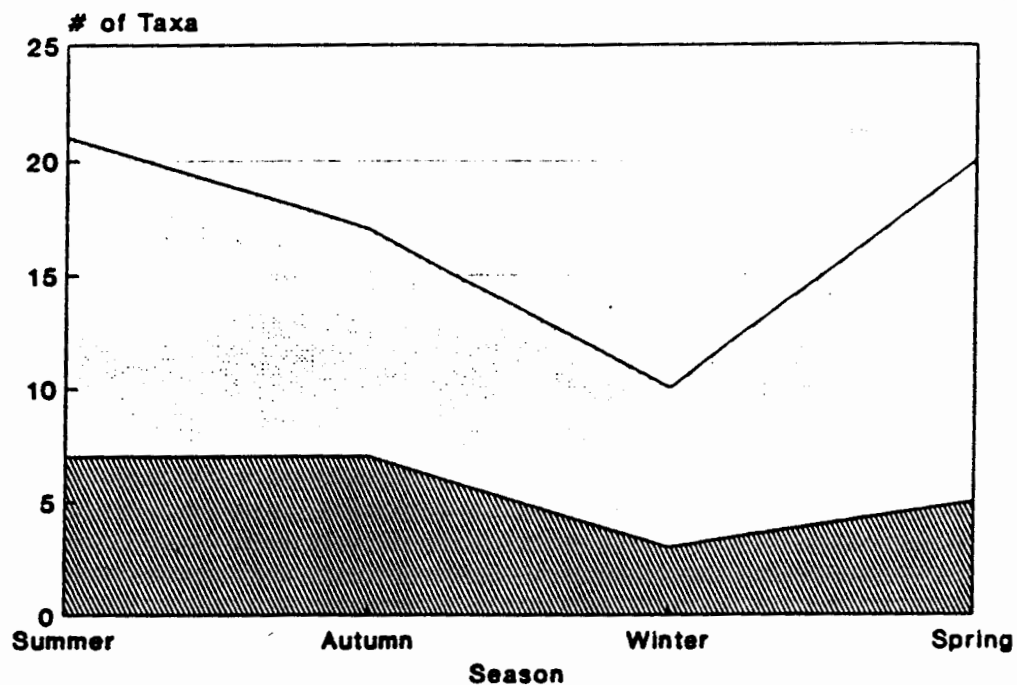
In the Hester-Dendy samples 39 taxa were identified, at site 1 there were 34 and Site 3 there were 33 (Table 4-3). Eleven of these taxa were not collected in the Hess sampler, and 16 taxa collected in the Hess sampler were not identified from Hester-Dendy samples. Fourteen of the taxa were in EPT orders, twelve at each site (Table 4-4). The number of EPT taxa in relation to the total taxa found on successive sampling dates appeared to be relatively constant (Fig. 4-7).

Hester-Dendy density estimates were 3655 and 4450 individuals/m<sup>2</sup> for Sites 1 and 3, respectively (Table 4-5). The autumn samples were highest at each site and the winter Hester-Dendy density estimate at Site 1 of 1173 individuals/m<sup>2</sup> was lower than other samples (Fig. 4-5). The Diptera were the most abundant group, constituting 54% and 83% of the individuals at Site 1 and 2 respectively, and the Ephemeroptera accounted for 24% and 11% of the individuals (Tables 4-6, 4-7). At Site 1 the Oligochaeta were the next most abundant group with almost 13% of the organisms. The mean densities for each taxon are presented in Table 4-8.

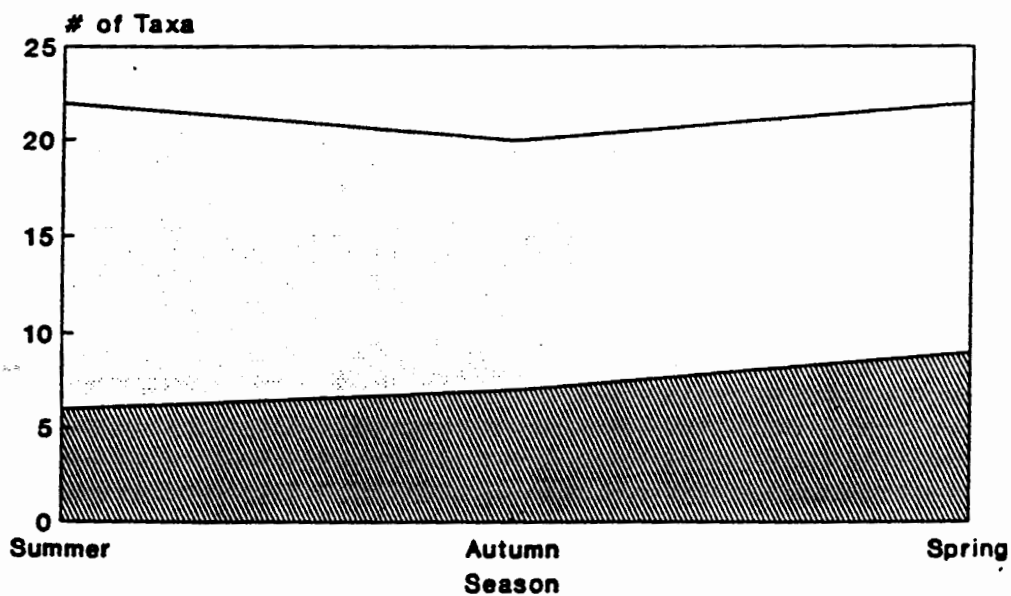
As with the Hess sampling results, both diversity indices performed similarly to each other (Fig. 4-8). Highest diversity values were found in the summer and the lowest in the winter and spring. Winter and spring samples were dominated by Orthocladinae

Figure 4-7. Number of taxa in one of the three orders: Ephemeroptera, Plecoptera, Trichoptera (EPT taxa), Agate Fossil Beds National Monument, Nebraska, found on each Hester-Dendy sampling date for a) Site 1, b) Site 3.

a)

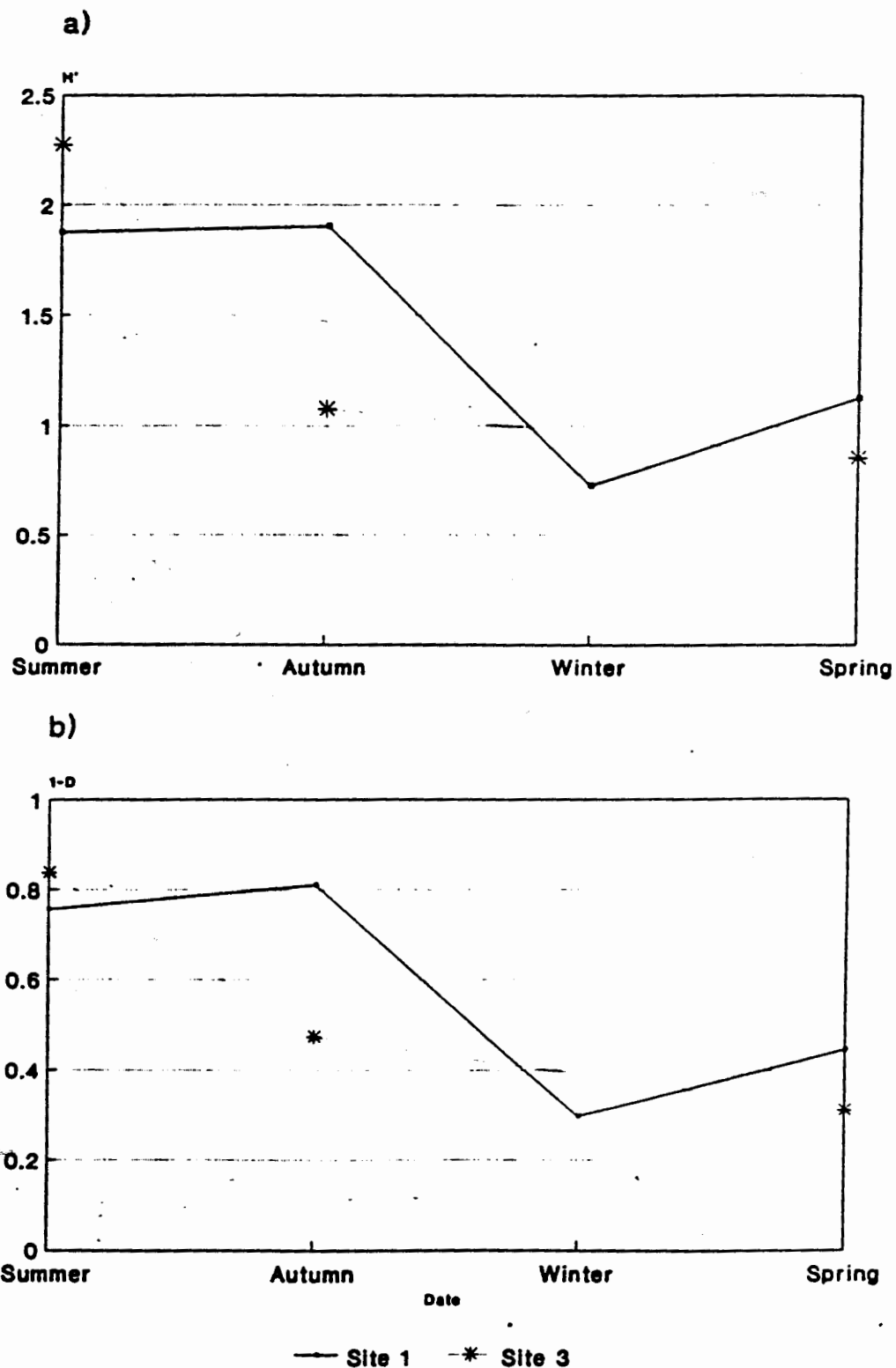


b)



EPT
  Other

Figure 4-8. Macroinvertebrate diversity on each Hester-Dendy sampling date, Agate Fossil Beds National Monument, Nebraska, calculated by a) Shannon diversity, b) Simpson's complement.



midges. The autumn diversity values indicated a substantial difference between Sites 1 and 3. Higher numbers of Simuliidae larvae at Site 3 during autumn accounted for these lower diversity values.

#### 4.3 Selected Benthic Macroinvertebrate Fauna

Population dynamics or life-table parameters of key species have been suggested as signs to monitor for indication of ecosystem change (Schindler 1987, Davis et al. 1988). Sensitivity to environmental perturbations and low powers of dispersal are attributes of species that are good indicators of indicate ecosystem changes (Schindler 1987). Presented below is life history information about some of the more commonly collected species occurring in the AFBNM.

##### 4.3.1 Ephemeroptera (Mayflies)

The Ephemeroptera were either the most or second most abundant group in the yearly mean for the benthic samples at each site (Tables 4-6, 4-7). The individuals in the benthic samples belonged to a number of different genera with a variety of life histories. The relative abundance of mayfly species in benthic sampling is presented in Table 4-9. Nine species were identified from the adults and larvae.

Three Baetidae species were commonly found in the Monument, Baetis dardanus McDunnough, Acentrella insignificans (McDunnough), and Fallceon quilleri (Dodds) (Appendix A). Individuals were only identified to family in the quantitative sampling. Until recently (Waltz and McCafferty 1987a, 1987b) these three species were

Table 4-9. Mayfly species abundance expressed as percent of mayflies collected, includes sampling dates from June 1988 - October 1988. Hester-Dendy includes dates July 1989 - May 1990.

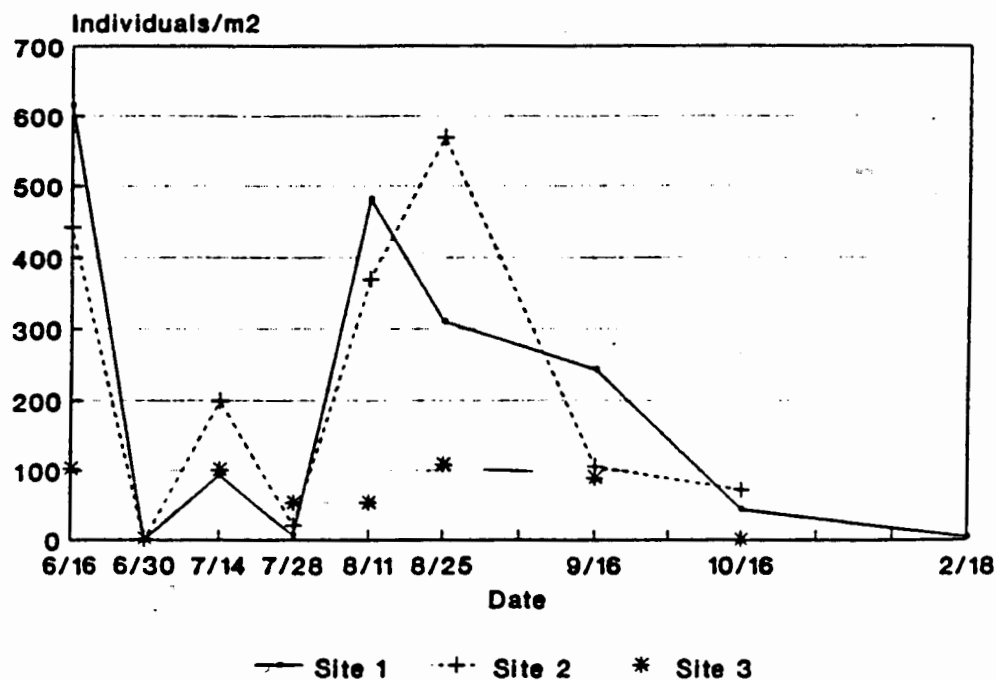
| Site                         | Hess  |       |       | Hester-Dendy |       |
|------------------------------|-------|-------|-------|--------------|-------|
|                              | 1     | 2     | 3     | 1            | 3     |
| Baetidae                     | 31.7% | 27.9% | 25.5% | 8.4%         | 11.1% |
| <u>Caenis</u> sp.            | 7.9   | 13.0  | 7.2   | 3.5          | 0.8   |
| <u>Hexagenia limbata</u>     | 0.6   | 26.8  | 58.3  | 0.0          | 0.0   |
| <u>Heptagenia diabasa</u>    | 38.2  | 8.9   | 2.8   | 60.7         | 54.2  |
| <u>Leptophlebia nebulosa</u> | 21.5  | 23.4  | 6.2   | 24.9         | 33.6  |
| <u>Isonychia rufa</u>        | 0.0   | 0.0   | 0.0   | 2.4          | 0.0   |
| <u>Tricorythodes</u> sp.     | 0.0   | 0.0   | 0.0   | 0.1          | 0.3   |

classified in the genus Baetis. McCafferty and Waltz (1990) review systematics changes in the family Baetidae. Maximum abundance of Baetidae was 615 individuals/m<sup>2</sup> at Site 1 on 16 June 1988. Baetis was also abundant during August and September in the Hess samples and was most abundant in the summer Hester-Dendy samples (Fig. 4-9). Baetis dardanus was apparently the most common Baetis species occurring at the AFBNM. Baetis dardanus is widely distributed across central and western North America (Soluk 1981). This species is apparently univoltine in the Niobrara and larvae prefer woody substrate or submerged aquatic plants. Carnevalo (1981) did not report this species from the Niobrara River. This may be due to the taxonomic literature available. Carnevalo (1981) does not cite three major references, Morihara and McCafferty (1979a, 1979b) and Soluk (1981) which clarified the taxonomy of this species and other species identified in his thesis.

Leptophlebia nebulosa (Walker) is widely distributed through much of North America (Edmunds et al. 1976). Larvae can be collected from ponds and on the edges of medium sized streams. Leptophlebia nebulosa has a univoltine life cycle in the Niobrara River (Fig. 4-10). Leptophlebia development and emergence is dependent on water temperature. In benthic stream samples the larvae were collected in the greatest numbers in late summer and fall (Fig. 4-10) and except for Site 3 during the Hess sampling, larvae made up over 20% of the mayflies collected (Table 4-9). After ice break the majority of the larvae migrate into the overflow areas of the flood plain of the river; however, some of

Figure 4-9. Baetidae density on each sampling date, Agate Fossil Beds National Monument, Nebraska, for a) Hess bottom sampler, b) Hester-Dendy multiple plate sampler.

a)



b)

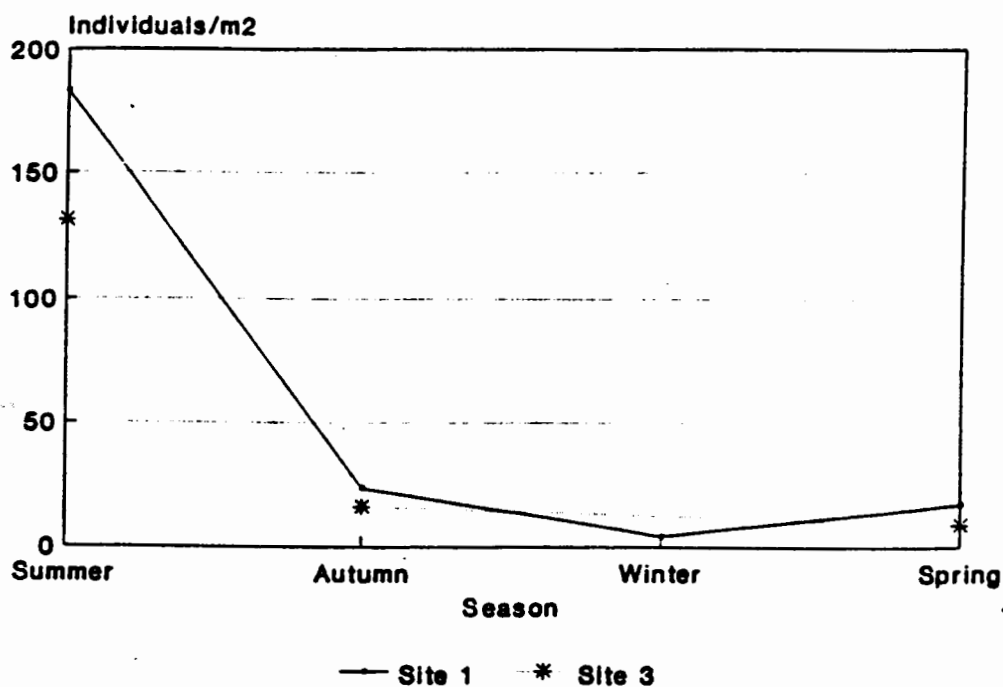
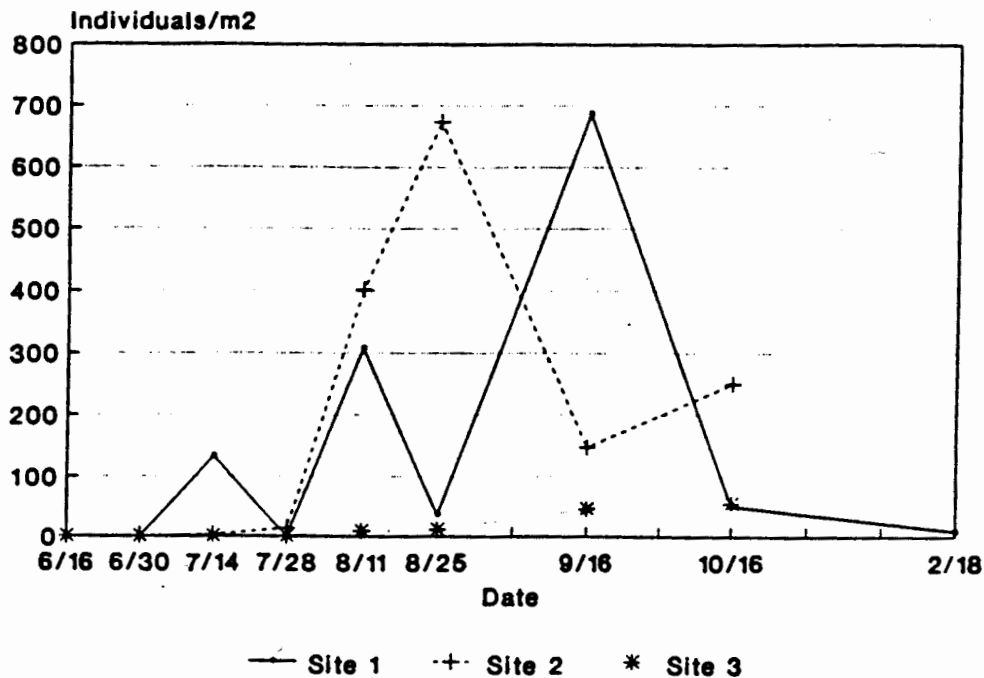
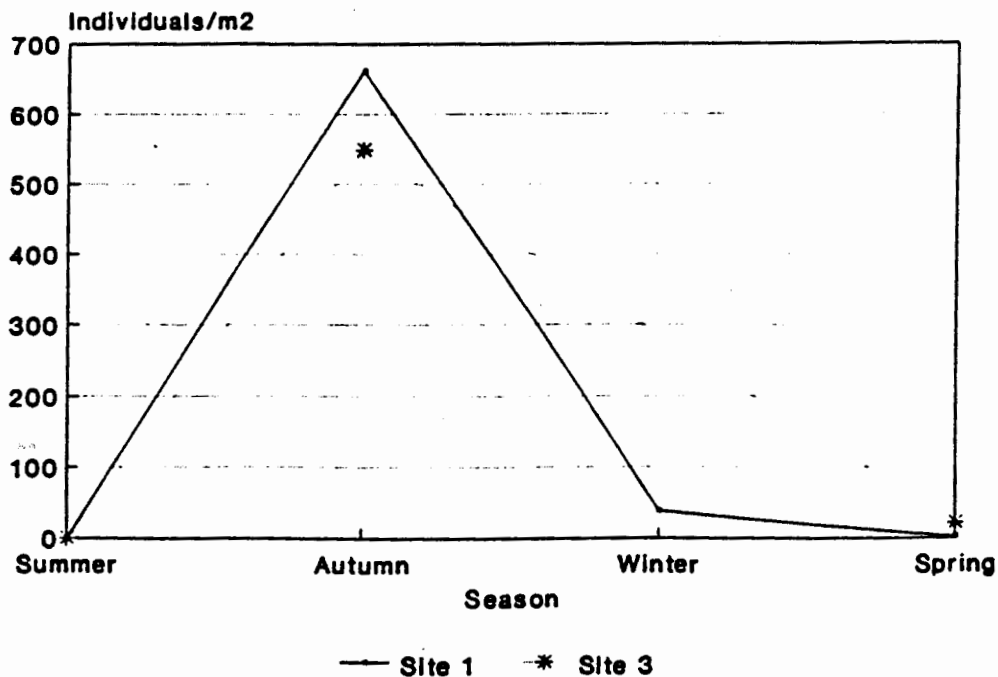


Figure 4-10. Leptophlebia density on each sampling date, Agate Fossil Beds National Monument, Nebraska, for a) Hess bottom sampler, b) Hester-Dendy multiple plate sampler.

a)



b)



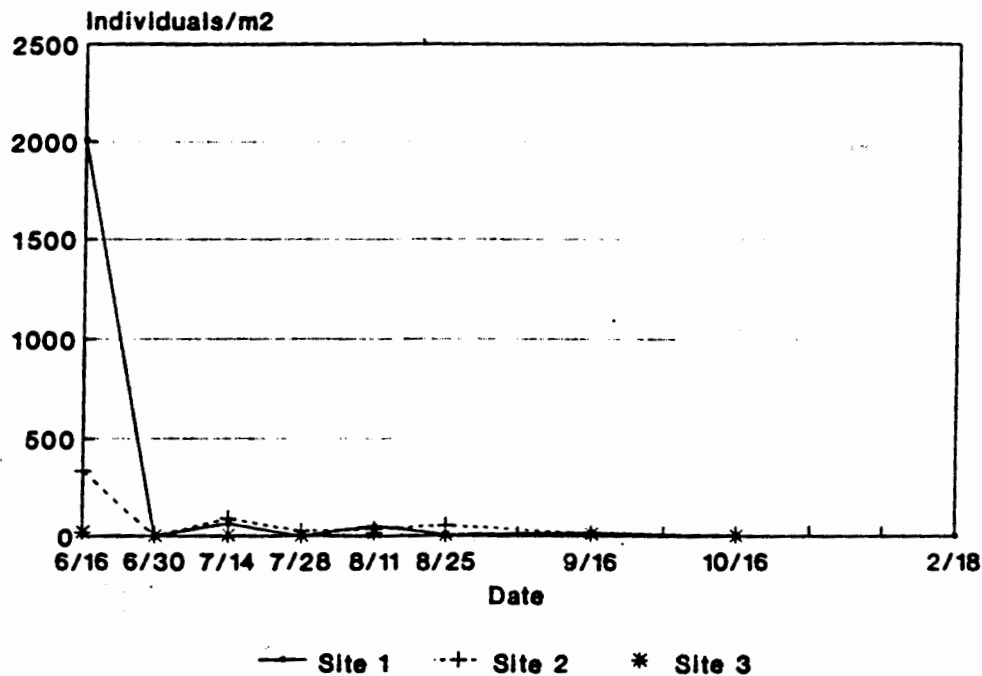
the larvae remain in the river. Clifford et al. (1979) suggested that this migration is a mechanism to escape from spring turbulence in the main channel. Leptophlebia larvae are classified as fine particle detritivores. Clifford et al. (1979) reported 96% of the diet of L. cupida (Say), a very closely related species, as detritus. They stated that this percentage actually represented the relative amounts of food particles in the stream, and was not selective feeding by the larvae.

Larvae of Heptagenia diabasa Burks, a large heptageniid mayfly, were most common in the AFBNM in the late spring and early summer. At Site 1 during the Hess sampling, this species averaged 270/m<sup>2</sup>, and the maximum density was 2006/m<sup>2</sup> on 16 June 1988 at Site 1 (Fig. 4-11). These active larvae are dorso-ventrally flattened and generally occur on firm surfaces and in debris in flowing water. This species is distributed throughout the central U.S. and Canada (Edmunds et al. 1976), and is univoltine. Heptagenia diabasa has been previously reported to be abundant throughout the Niobrara River system (Carnevalo 1981).

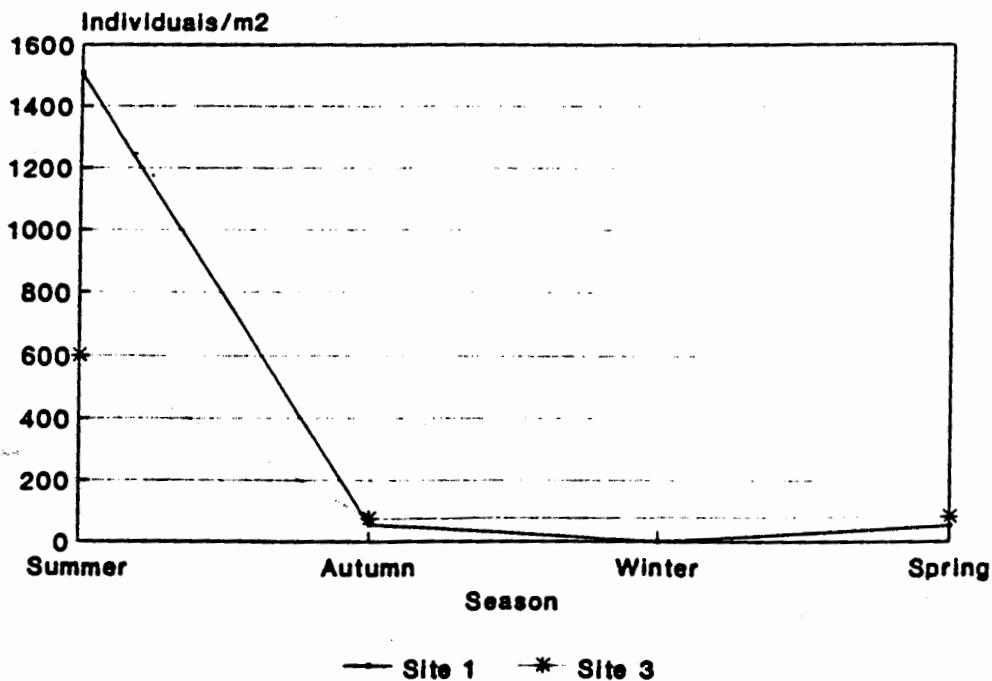
Larvae of the burrowing mayfly, Hexagenia limbata Serville, are easily recognized by the fringed gills that wave above the abdomen and curving mandibular tusks. In streams and lakes larvae dig a U-shaped burrow where, by action of their gills, they create a flow of water which carries food and oxygen. Hexagenia limbata is widely distributed throughout North America and can occur in extremely large numbers. They are usually found where the substrate is soft enough for burrowing, yet dense enough to support

Figure 4-11. Heptagenia density on each sampling date, Agate Fossil Beds National Monument, Nebraska, for a) Hess bottom sampler, b) Hester-Dendy multiple plate sampler.

a)



b)



the burrow, and have been reported to tolerate low oxygen conditions, even below 1 ppm (Edmunds et al. 1976). At Site 2, this species was found at an average density of 214/m<sup>2</sup>, and in the 25 August 1988 sample occurred at 596/m<sup>2</sup> (Fig. 4-12). It appears that Hexagenia limbata has a two year life cycle in the upper Niobrara. Adults can be commonly seen hanging on streamside vegetation throughout the summer.

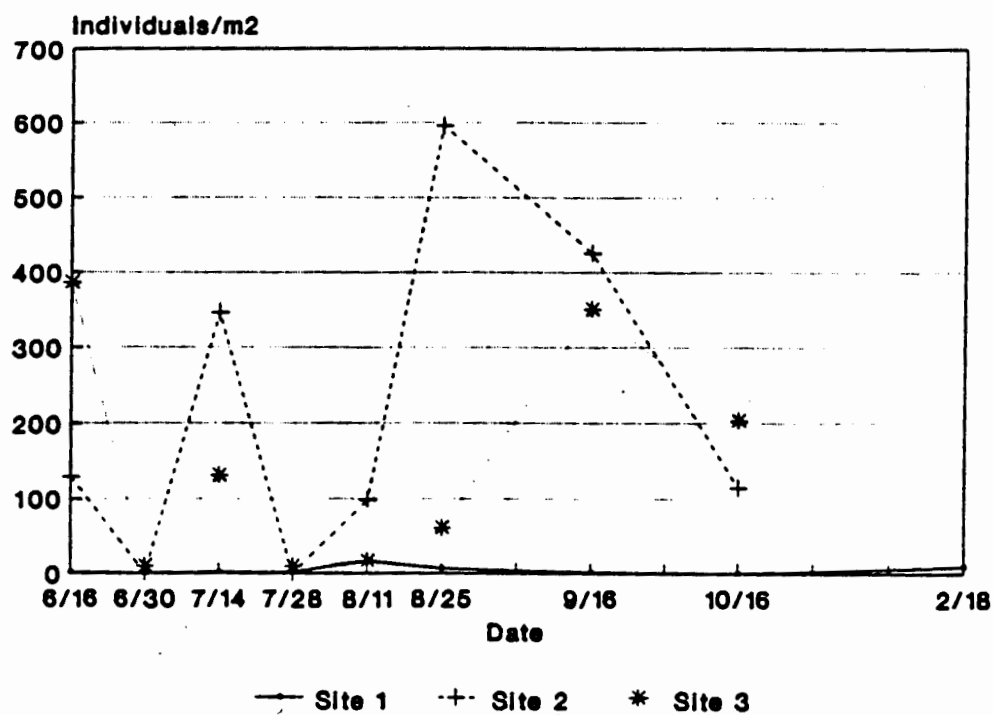
#### 4.3.2 Odonata (Dragonflies and Damselflies)

Twenty-three species of Odonata in seven families were identified from adults collected in the AFBNM this study (Appendix A). Most were collected only in qualitative collections. AFBNM visitors can observe the colorful adults flying along the river and adjacent wet areas throughout the summer months. Both of the sampling methods utilized probably under estimate the number of Odonata in the stream. Larvae prefer areas such as undercut banks and deeper pools.

Larvae in the family Calopterygidae were the most common Odonata in the benthic samples, and larvae and adults were commonly observed during qualitative sampling. The species found were Calopteryx maculata (Beauvois), Calopteryx aequabilis Say, Hetaerina americana (F.).

The common black-winged damselfly, Calopteryx maculata, begins emerging in early June. Adults live for about two weeks and become rare or absent by September. Territorial behavior by males is well-documented (Johnson 1962). Eggs are deposited by females in almost any kind of plant tissue throughout late June and July,

Figure 4-12. Hexagenia density on each Hess sampling date, Agate Fossil Beds National Monument, Nebraska.



and begin to hatch in 26-29 days (Martin 1939). The development period for the 11-12 instars is about a year. Larvae are general carnivores, feeding on other invertebrates.

The other species of Calopteryx, occurring in the upper Niobrara is Calopteryx aequabilis, and appears to be more abundant than C. maculata. As Martin (1939) reported, the life cycle of C. aequabilis is 2 years. In the Niobrara River, eggs are deposited into plant material during June and July and eggs hatch in about three weeks. Larvae spend two years feeding on other invertebrates. Emergence is generally in late May into June.

Adults of the Ruby-spot, Hetaerina americana, have longer flight periods, often until the first heavy frost in September. This species is not abundant in the AFBNM. It appears this species is univoltine at the study sites in the AFBNM.

#### 4.3.3 Plecoptera (Stoneflies)

Plecoptera is an order most often associated with cold mountain streams. Great Plains streams generally support only tolerant species, which often are geographically widespread. Four species of Plecoptera were identified from the AFBNM during this study.

Taeniopteryx burksi Ricker and Ross is widely distributed east of the Rocky Mountains (Ricker and Ross 1968, Kondratieff and Ward 1987). Larvae are usually found in slow moving water associated with leaf litter or organic debris. Taeniopteryx is one of the "large winter stoneflies," so called because adults are active from January to March. Eggs hatch from April to May. Larvae apparently

diapause deep in the substratum as 4th or 5th instar. Diapause is broken in late September to October with rapid growth until emergence. In the benthic samples Taeniopteryx burksi larvae were collected in greatest abundance in the autumn months at Site 1. The greatest larval density was 394/m<sup>2</sup> on the Hester-Dendy samplers at Site 1 on 21 October 1989. Mature larvae were observed in large numbers near Site 1 in February.

Two Isoperla species occurred in the Niobrara River in the AFBNM, a widespread, primarily western North American species, Isoperla quinquepunctata Banks, and an eastern and central North American species, I. marlynia Needham. Most life histories of Nearctic Isoperla species indicate univoltinism (Stewart and Stark 1988). I. quinquepunctata was commonly collected from the Niobrara in the AFBNM.

#### 4.3.4 Trichoptera (Caddisflies)

Sixteen species of Trichoptera in six families were identified, many only from light trap collections. Trichoptera species were not especially abundant in the benthic samples. Trichoptera ranged from < 1% to 3% of the individuals collected at each site during both years (Table 4-7).

Hydropsyche bronta Ross was the most common Trichoptera found at the AFBNM. All Hydropsyche are filter-feeders in running water. They capturing particles from the water column with a silk net. Hydropsyche bronta was originally described from Michigan and ranges from the Appalachians westward to Alberta and into southeastern Wyoming (Scheffer and Wiggins 1986). This species is

known to maintain large populations in streams disturbed by agriculture and runoff from roads and dilute treated sewage (MacKay 1984). Hydropsyche bronta prefers open shallow riffles of medium to larger streams where maximum summer temperatures exceed 24°C. This species has been reported to be trivoltine in southern Ontario (MacKay 1984, Rutherford and MacKay 1986). In the Niobrara River, H. bronta was commonly associated with woody debris, and from adult collections, the life cycle appears to be univoltine to bivoltine.

#### 4.3.5. Diptera (True Flies)

Dipteran larvae may be found in almost any aquatic habitat and they are often numerous. Eight families were represented from the Niobrara River in the AFBNM.

The family Chironomidae (midges) is an extremely large family with over 2000 species identified from the Nearctic Region and between 10,000 - 15,000 species worldwide (Coffman and Ferrington 1984). In freshwater ecosystems they are often the most abundant group of insects (Pinder 1986). Chironomidae were identified to subfamily, and to tribe in the subfamily Chironominae, during the benthic sampling. The subfamilies Orthoclaadiinae and Tanytarsini were most commonly encountered in the Hess samples (Fig. 4-13). Hester-Dendy samplers favored the Orthoclaadiinae and they had mean abundances of 1196 and 1824 individuals/m<sup>2</sup> at Sites 1 and 3 respectively (Fig. 4-14).

The orthoclads Eukiefferiella spp. and Orthocladius (Orthocladius) obumbratus Johannsen/doreus (Roback) were the most

Figure 4-13. Chironomidae density on each Hess sampling date, Agate Fossil Beds National Monument, Nebraska, for a) Site 1, b) Site 2, c) Site 3.

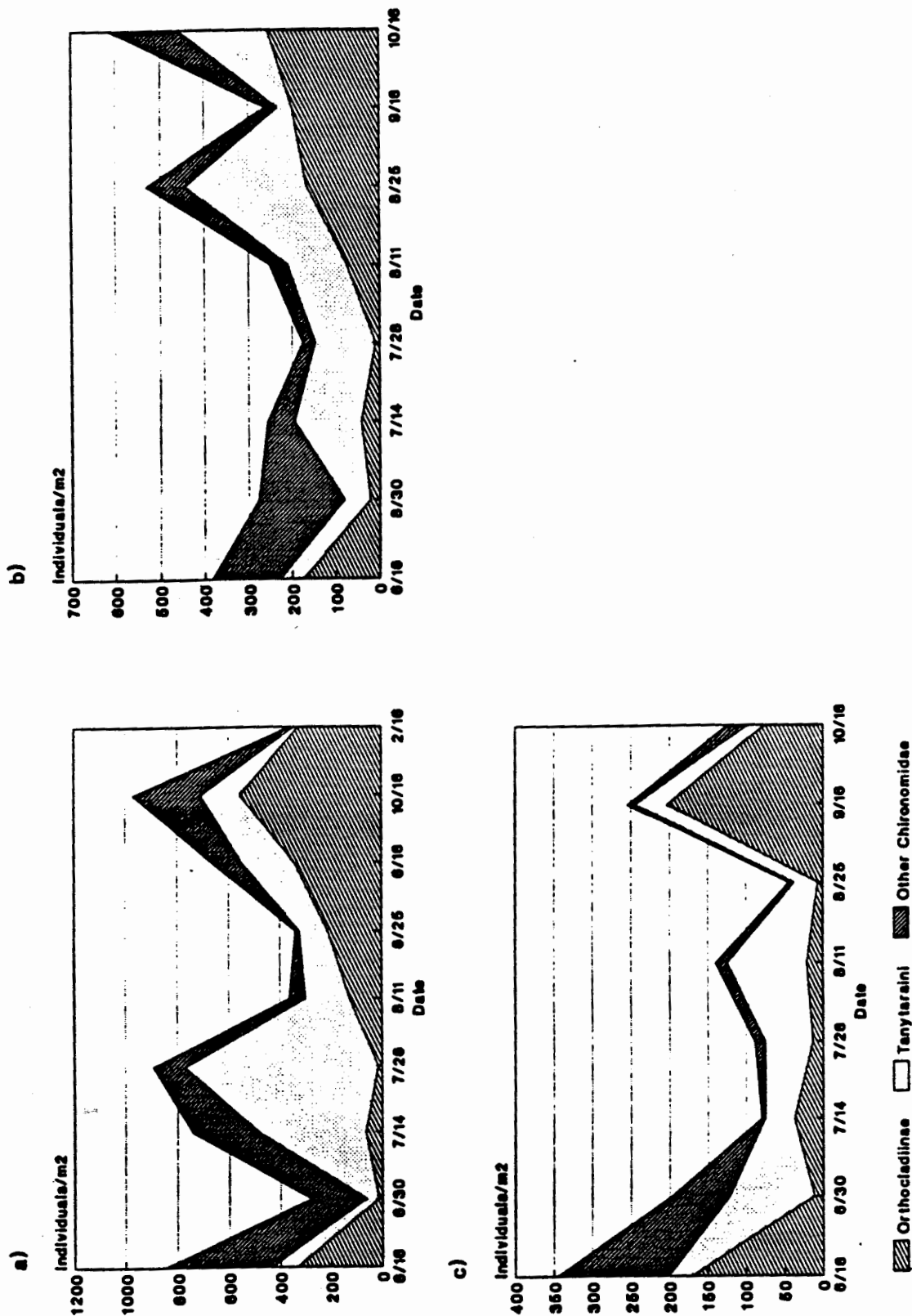
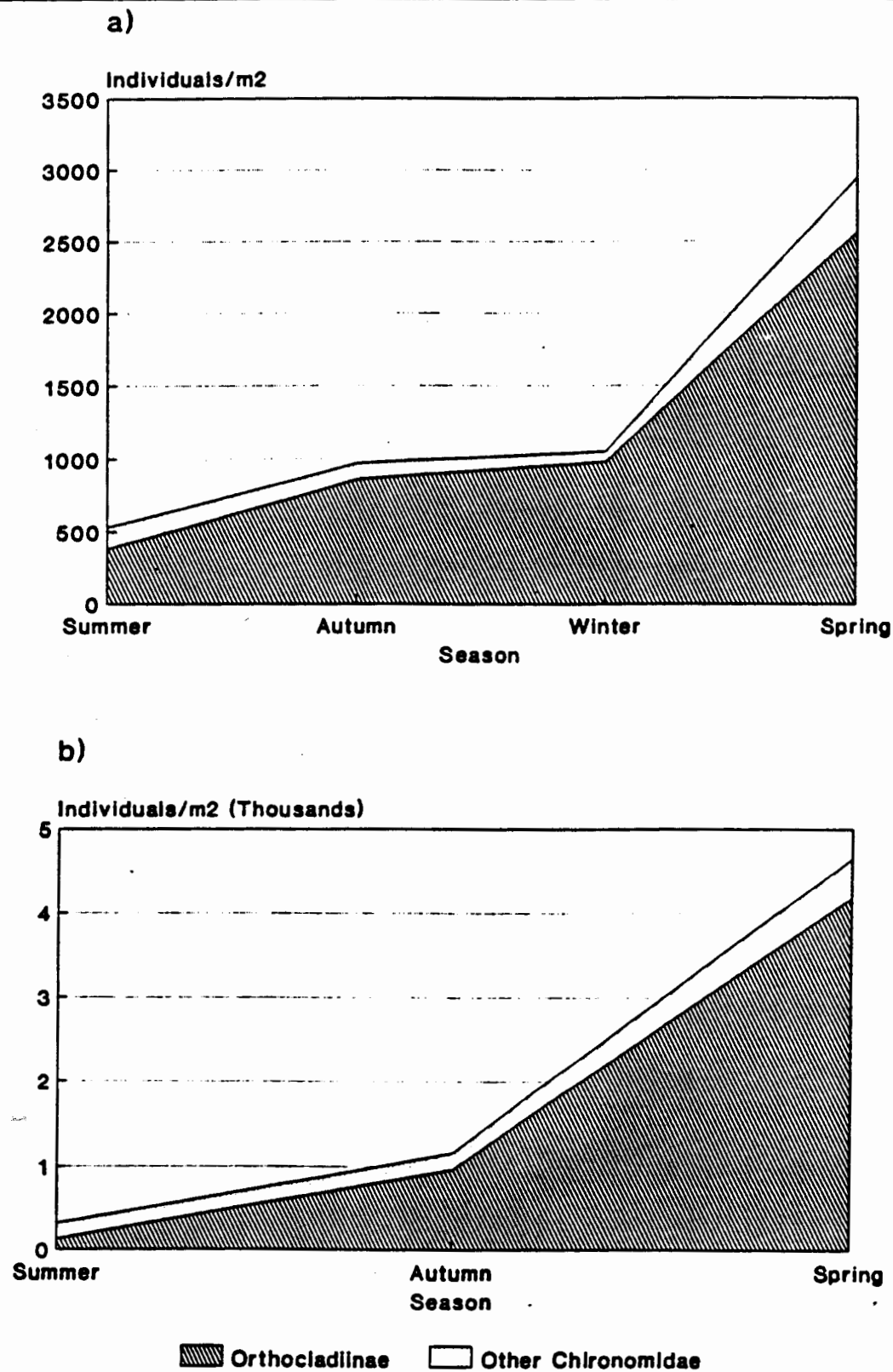


Figure 4-14. Chironomidae density on each Hester-Dendy sampling date, Agate Fossil Beds National Monument, Nebraska, for a) Site 1, b) Site 3.



common midges found in the benthic samples. Both these genera are difficult to separate from closely related groups.

Simulium vittatum complex Zetterstedt were the most common simuliidae (black flies) in the Niobrara River in the AFBNM. Pruess and Peterson (1987) reported that this species is found in almost every stream in Nebraska with appropriate habitat. They also reported it to be multivoltine with up to six generations. Larvae have a ring of hooked setae at the end of the abdomen for clinging to various substrates in flowing water. With both sampling techniques Simuliidae reached their peak abundance in the autumn. Larval density on the Hester-Dendy samplers at Site 3 on 21 October 1989 was  $> 5000$  individuals/m<sup>2</sup> (Fig. 4-15).

#### 4.3.6 Oligochaeta (Aquatic Earthworms)

Oligochaeta is a class of the phylum Annelida, the segmented worms. Individuals occupy the upper few cm of the substrate, and feeds by ingesting the sediment. Many oligochaetes can thrive in extremely low oxygen conditions (Pennak 1978). Oligochaeta were the most abundant non-insect in the benthic samples (Tables 4-6, 4-7)). The greatest density of 1356 individuals/m<sup>2</sup> was reached on 16 June 1988 at Site 1 (Fig. 4-16).

#### 4.4 Functional Analysis

Research in aquatic ecology has stressed the importance of examining the benthic community from a functional as well as a taxonomic standpoint. The functional aspect is important because it is indicative of ecological processes, including organic matter processing. In this study community function was examined

Figure 4-15. Simulium density on each Hester-Dendy sampling date, Agate Fossil Beds National Monument, Nebraska.

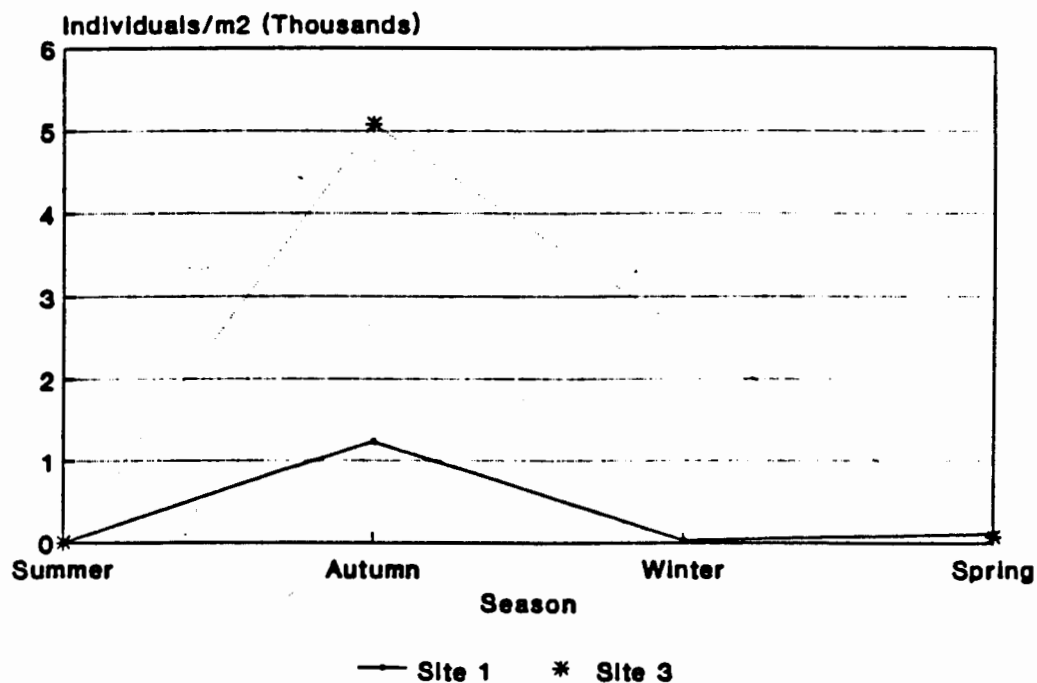
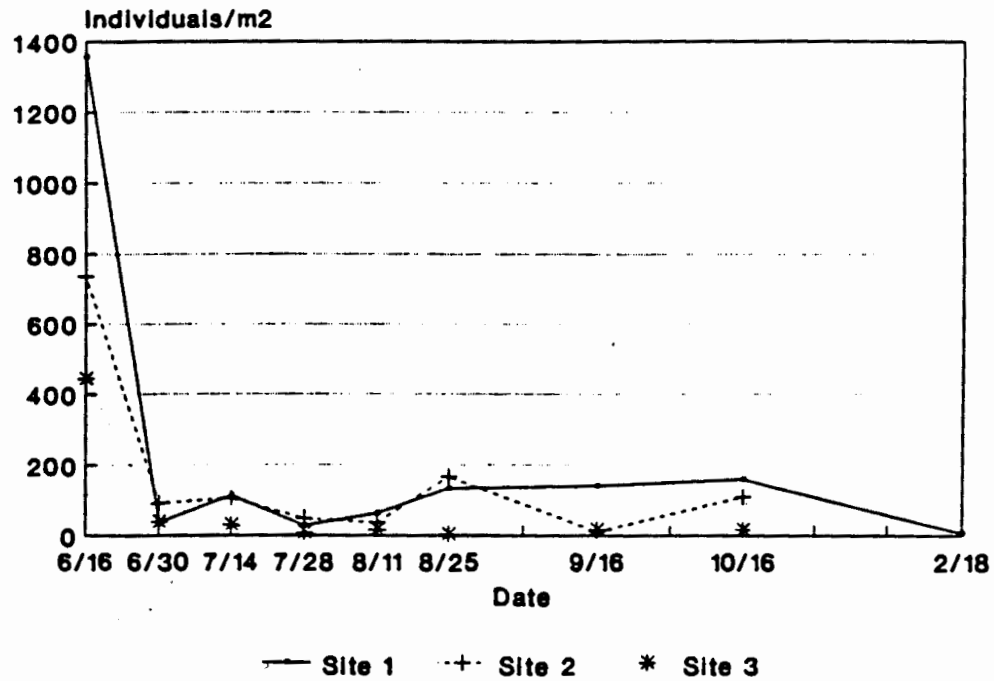
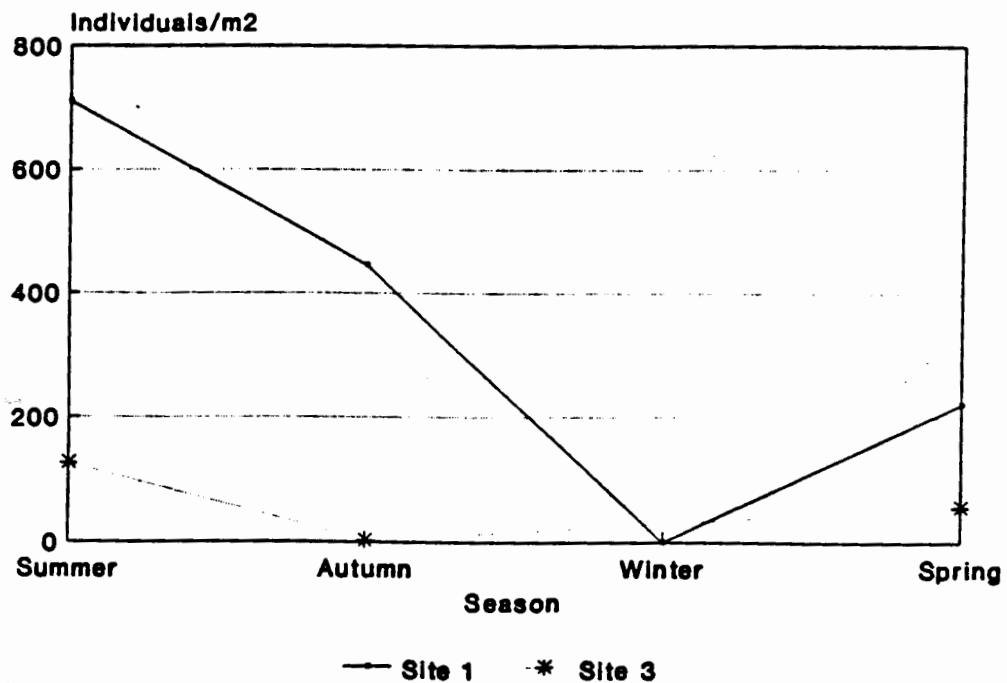


Figure 4-16. Oligochaeta density on each sampling date, Agate Fossil Beds National Monument, Nebraska, for a) Hess bottom sampler, b) Hester-Dendy multiple plate sampler.

a)



b)



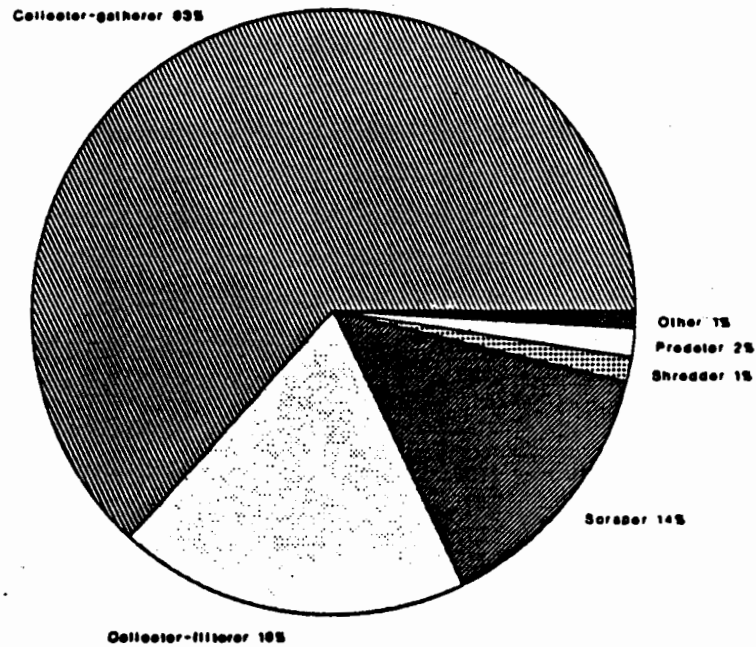
indirectly by classifying the macroinvertebrates into functional groups based on their modes of feeding (Table 4-10, Merritt and Cummins 1984).

The benthic macroinvertebrate community of the Niobrara River was clearly dominated by species considered to be collector-gatherers (Figs. 4-17, 4-18, Table 4-11). Collector-gatherers feed on fine particulate organic matter (FPOM, < 1 mm) that has been deposited on substrata. In the Hess samples collector-gatherers comprised 63%, 74%, and 78% of the individuals at Sites 1, 2, and 3 respectively (Fig. 4-17, Table 4-11), and in the Hester-Dendy samples, 60% and 49% for Sites 1 and 3 respectively (Fig. 4-18, Table 4-11). Collector-gatherers were abundant throughout the year, especially during Hess sampling (Fig. 4-19). They reached their greatest relative abundance in the winter and spring during Hester-Dendy sampling (Fig. 4-20). The major collector-gatherers were Ephemeroptera (including Baetis spp., H. limbata, L. nebulosa, and Caenis sp.), Oligochaeta, and Chironomidae (encompassing the subfamilies Orthocladinae, and Chironominae). Gammarus sp. was also a collector-gatherer abundant periodically at Sites 1 and 2.

The collector-filterers were the second most abundant functional group represented. Collector-filterers obtain FPOM from the current. For the Hess sampling, collector-filterers comprised 18%, 13%, and 11% of the individuals at Sites 1, 2, and 3 respectively (Fig. 4-17, Table 4-11), and 16% and 38% at Sites 1 and 3 for the Hester-Dendy sampling (Fig. 4-17, Table 4-11). The Tanytarsini midges and Simulium larvae were the most abundant

Figure 4-17. Percent of functional groups during Hess sampling period, Agate Fossil Beds National Monument, Nebraska, for a) Site 1 (does not include winter sample), b) Site 2, c) Site 3.

a)



b)

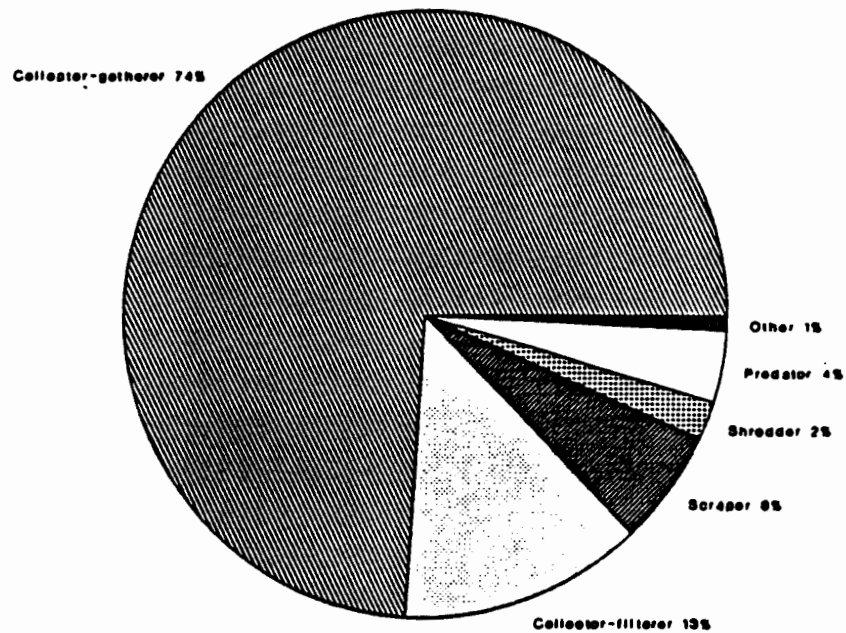


Figure 4-17 (continued).

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c)

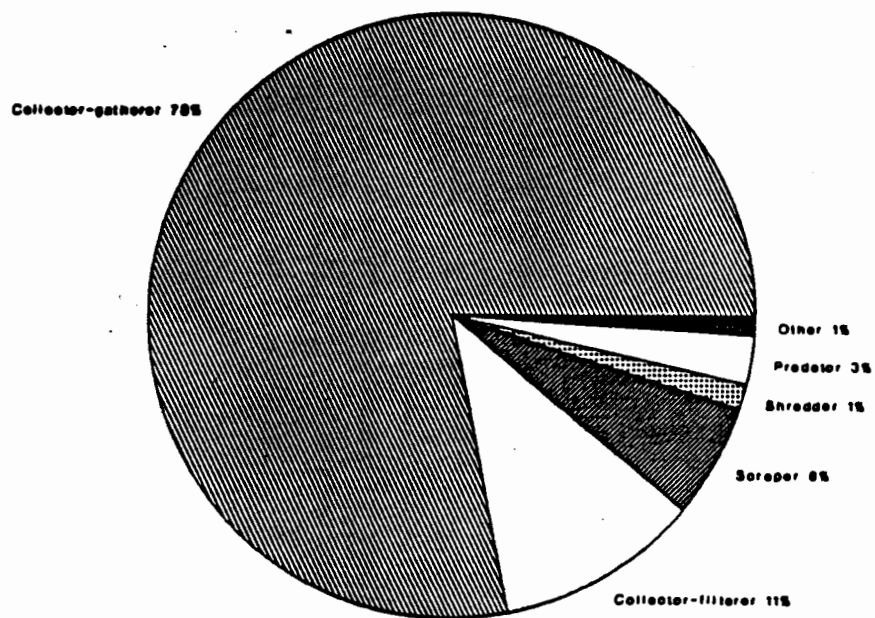
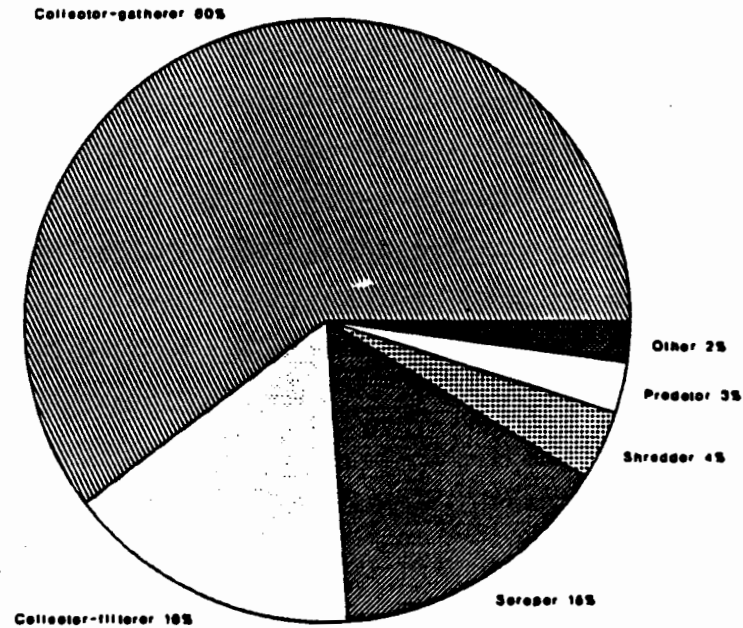


Figure 4-18. Percent of functional groups during Hester-Dendy sampling period, Agate Fossil Beds National Monument, Nebraska, for a) Site 1 (does not include winter sample), b) Site 3.

a)



b)

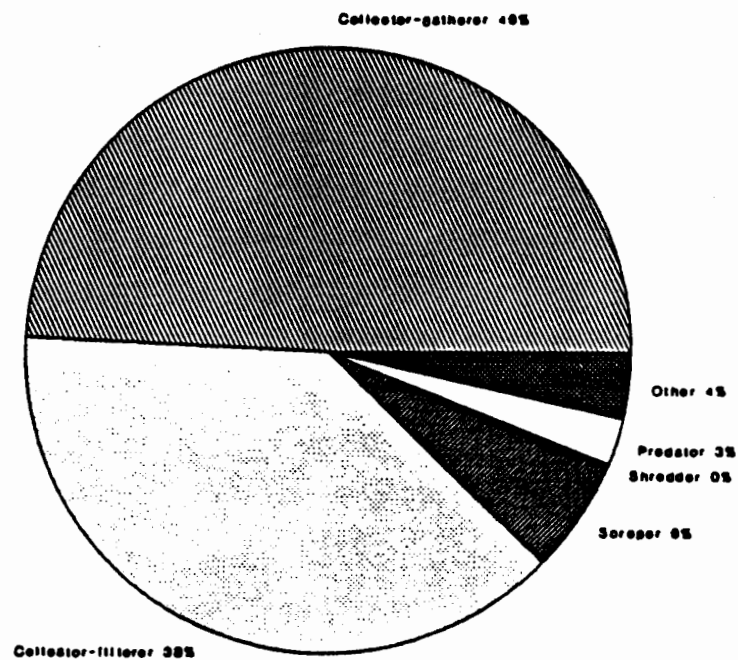


Figure 4-19. Cumulative percent of functional groups on each Hess sampling date, Agate Fossil Beds National Monument, Nebraska, for a) Site 1, b) Site 2, c) Site 3.

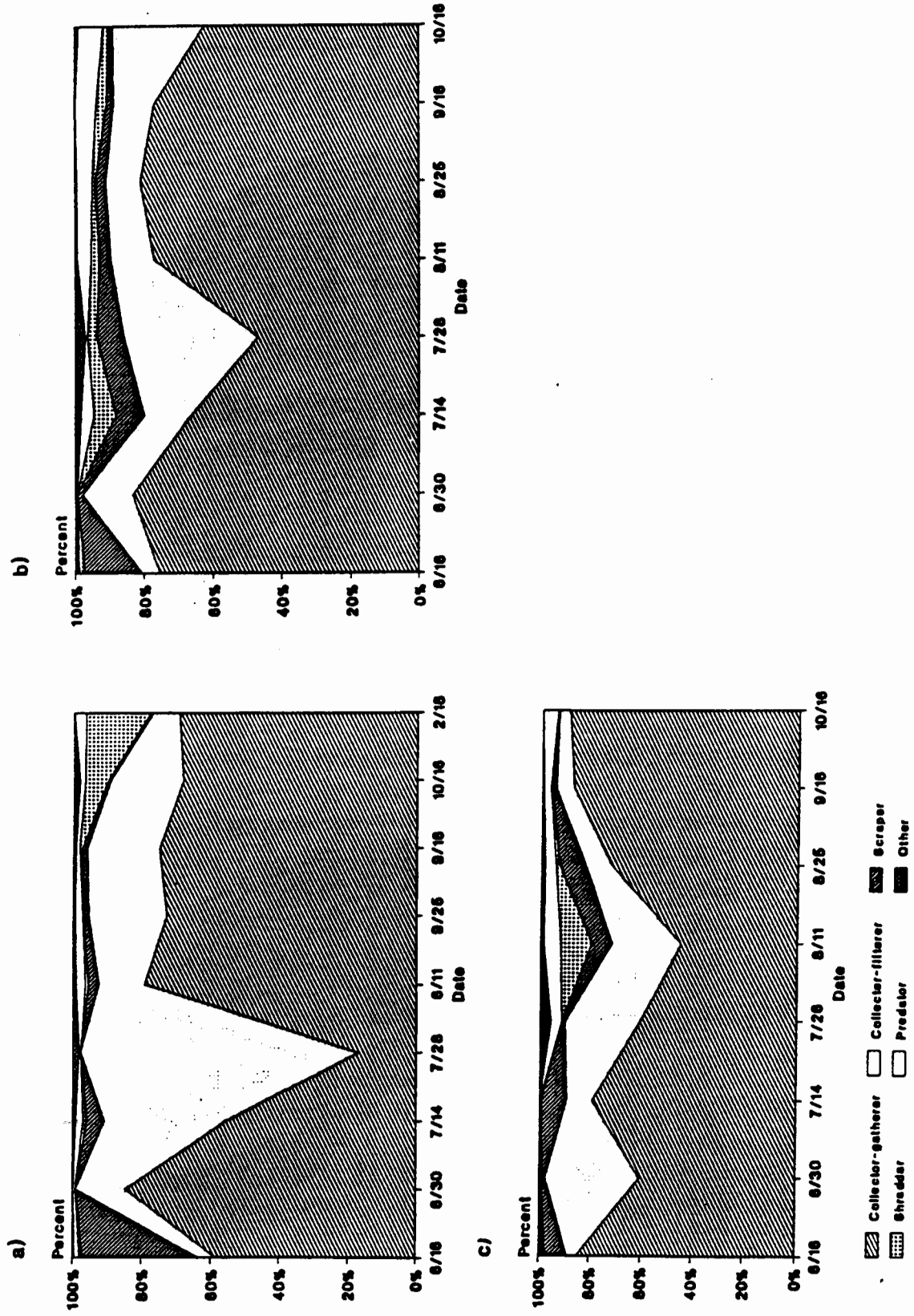
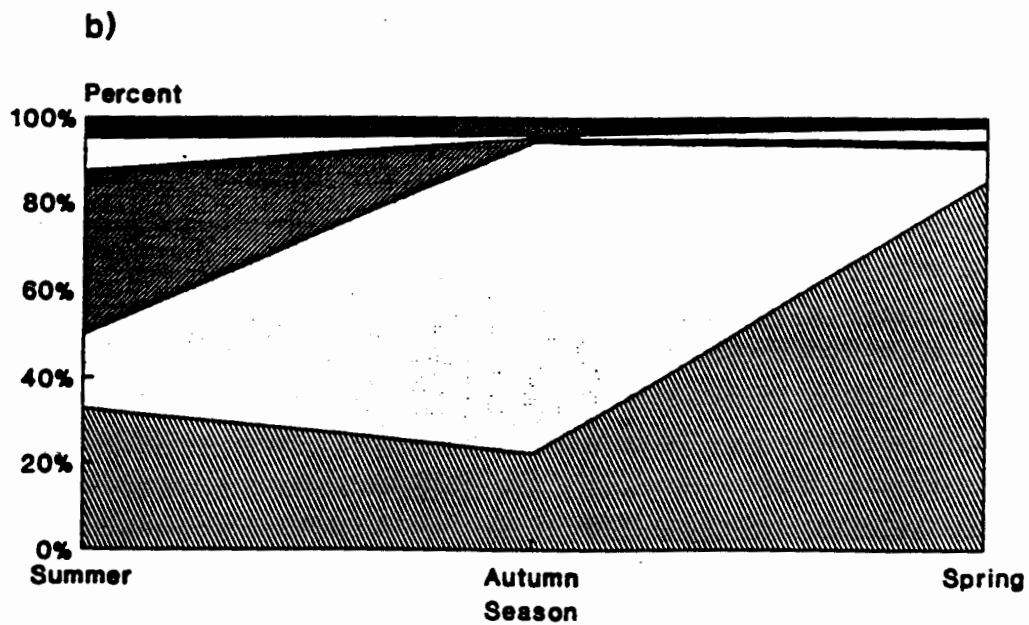
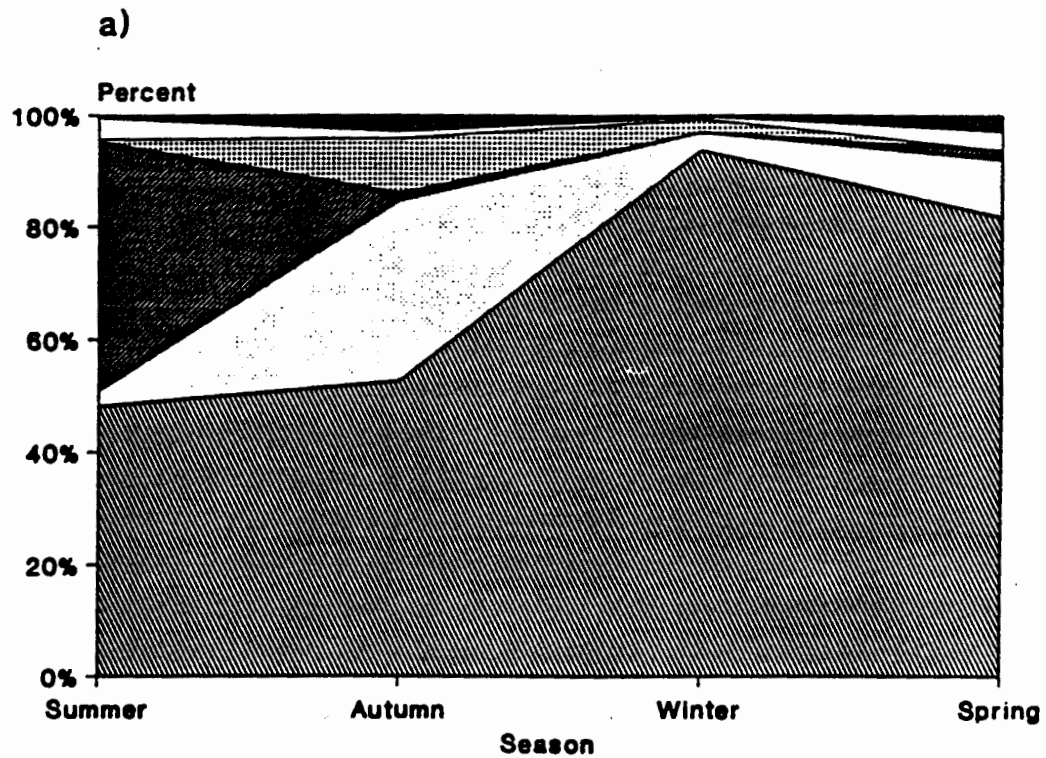


Figure 4-20. Cumulative percent of functional groups on each Hester-Dendy sampling date, Agate Fossil Beds National Monument, Nebraska, for a) Site 1, b) Site 3.



|                    |                    |         |
|--------------------|--------------------|---------|
| Collector-gatherer | Collector-filterer | Scraper |
| Shredder           | Predator           | Other   |

Table 4-10. General classification system for aquatic insect trophic relations (functional groups). Applicable only to immature and adult stages that occur in the water. (Cummins and Merritt 1984).

| Functional Group<br>(General category<br>based on feeding<br>mechanism) | Subdivision of Functional Group                                                                                |                                                                                                                                                                                                    | General<br>Particle Size<br>Range of Food<br>(microns) | Orders Having Dominant<br>Representatives |            |         |               |           |             |            |             |             |            |             |         |  |  |
|-------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------|-------------------------------------------|------------|---------|---------------|-----------|-------------|------------|-------------|-------------|------------|-------------|---------|--|--|
|                                                                         | Dominant Food                                                                                                  | Feeding Mechanism                                                                                                                                                                                  |                                                        | Collembola                                | Plecoptera | Odonata | Ephemeroptera | Hemiptera | Megaloptera | Neuroptera | Trichoptera | Lepidoptera | Coleoptera | Hymenoptera | Diptera |  |  |
| Shredders                                                               | Living vascular hydro-<br>phyte plant tissue                                                                   | Herbivores—chewers<br>and miners of live Ma-<br>crophytes                                                                                                                                          | >10 <sup>3</sup>                                       |                                           |            |         |               |           |             |            | +           | +           | +          |             | +       |  |  |
|                                                                         | Decomposing vascular<br>plant tissue—coarse<br>particulate organic mat-<br>ter (CPOM)                          | Detritivores—chewers<br>of CPOM                                                                                                                                                                    |                                                        |                                           | +          |         |               |           |             |            | +           |             | +          |             | +       |  |  |
|                                                                         | Wood                                                                                                           | Gougers—excavate and<br>gallery, wood                                                                                                                                                              |                                                        |                                           |            |         | (+)           |           |             |            | +           |             | +          |             | +       |  |  |
| Collectors                                                              | Decomposing<br>fine particulate<br>organic matter<br>(FPOM)                                                    | Detritivores—filterers or<br>suspension feeders                                                                                                                                                    | <10 <sup>3</sup>                                       | +                                         |            |         |               | +         | +           |            | +           |             | +          |             | +       |  |  |
|                                                                         |                                                                                                                | Detritivores—gatherers<br>or deposit (sediment)<br>feeders (includes feeders<br>on loose surface films)                                                                                            |                                                        |                                           |            |         |               |           |             |            |             |             |            |             |         |  |  |
| Scrapers                                                                | Periphyton—attached<br>algae and associated<br>material                                                        | Herbivores—grazing<br>scrapers of mineral and<br>organic surfaces                                                                                                                                  | <10 <sup>3</sup>                                       |                                           |            |         | +             | +         |             | +          | +           | +           |            | +           |         |  |  |
| Macrophyte Piercers                                                     | Living vascular hydro-<br>phyte cell and tissue<br>fluids or filamentous<br>(macroscopic) algal cell<br>fluids | Herbivores—pierce tis-<br>sues or cells and suck<br>fluids                                                                                                                                         | >10 <sup>3</sup> –10 <sup>4</sup>                      |                                           |            |         |               |           |             | +          | +           |             |            |             |         |  |  |
| Predators                                                               | Living animal tissue                                                                                           | Engulfers—carnivores,<br>attack prey and ingest<br>whole animals or parts<br><br>Piercers—carnivores, at-<br>tack prey, pierce tissues<br>and cells, and suck<br>fluids                            | >10 <sup>3</sup>                                       |                                           | +          | +       | (+)           |           | +           |            | +           |             | +          |             | +       |  |  |
| Parasites                                                               | Living animal tissue                                                                                           | Internal parasites of<br>eggs, larvae and pupae.<br>External parasites of<br>larvae, prepupae and<br>pupae in cocoons, pupal<br>cases or mines. Also, ex-<br>ternal parasites of adult<br>spiders. | >10 <sup>3</sup>                                       |                                           |            |         |               |           |             |            |             |             |            | +           | +       |  |  |

Table 4-11. Percent composition of functional groups, Agate Fossil Beds National Monument, Nebraska. Hess sampler includes sampling dates from June 1988 - October 1988. Hester-Dendy includes dates July 1989 - May 1990.

| Site       | Collector-Gatherer | Collector-Filterer | Scraper | Shredder | Predator | Other |
|------------|--------------------|--------------------|---------|----------|----------|-------|
| 1          | 63.3               | 18.8               | 14.1    | 1.3      | 1.5      | 0.9   |
| 1 (winter) | 69.5               | 7.4                | 0.8     | 18.8     | 3.5      | 0.0   |
| 2          | 74.1               | 13.0               | 6.2     | 2.1      | 3.8      | 0.8   |
| 3          | 78.2               | 10.8               | 6.1     | 1.3      | 2.6      | 1.0   |

Hester-Dendy

| Site       | Collector-Gatherer | Collector-Filterer | Scraper | Shredder | Predator | Other |
|------------|--------------------|--------------------|---------|----------|----------|-------|
| 1          | 60.4               | 15.8               | 15.2    | 3.7      | 2.7      | 2.2   |
| 1 (winter) | 93.8               | 3.1                | 0.0     | 2.4      | 0.6      | 0.2   |
| 3          | 49.3               | 38.4               | 6.2     | 0.1      | 2.5      | 3.5   |

collector-filterers over the course of this study. Simulium larvae were most abundant in the autumn samples, and in the autumn 1989 sample at Site 3, Simulium larvae, reached an abundance of 5080 individuals/m<sup>2</sup>, accounting for 71% of the organisms in the sample (Figs. 4-15, 4-20). Tanytarsini abundances were more consistent throughout the year, but in the 28 July 1988 Hess sample at Site 1 reached an abundance of at 755 individuals/m<sup>2</sup> (Figs. 4-13, 4-19). Other collector-filterers included the trichopterans Hydropsyche and Cheumatopsyche, the ephemeropteran Isonychia, and the freshwater clam family Sphaeriidae.

Scrapers shear attached algae and associated material from solid submerged substrata. The ephemeropteran H. diabasa was numerically the most common scraper. The Gastropoda families, Ancyliidae, Lymnaeidae, Physidae, and Planorbidae, were the other scrapers commonly encountered during the study. Heptagenia diabasa was especially abundant at Site 1 (Fig. 4-11), and scrapers accounted for 14% and 15% of the community in the first and second years. Scrapers made up about 6% of the fauna at the other sites during both years (Table 4-11).

Shredders are important in organic matter processing in many lotic systems because they help break down coarse particulate organic matter (CPOM > 1 mm), usually terrestrial leaf litter and associated microbes. Taeniopteryx burksi, Nectopsyche sp., Ptilostomis semifaciata (Say), Tipulidae, and Orconectes immunis (Hagen) were the shredders found in benthic collections. These taxa encompassed 2% or less of the individuals at each site during

the first sampling year. Shredders made up 4% of the individuals at Site 1 during Hester-Dendy sampling, and 0.1% at Site 3 (Table 4-11). The especially low number of shredders at Site 3 during the second year may be due to the multiple-plate sampler poorly sampling the crayfish Orconectes. The Hess sampler also probably underestimated the Orconectes population because crayfish prefer to reside in the undercut banks of the stream. Orconectes probably plays an important role in processing large particulate organic matter in the stream. The winter stonefly T. burksi, another important shredder, reached its greatest abundance in the fall samples at Site 1 correlated with the greatest leaf input. The Tipulidae were most abundant in the 18 February 1989 Hess sample, and at a density of 110 individuals/m<sup>2</sup> accounted for 18% of the macroinvertebrate numbers.

Predators comprised between 1.5% and 3.8% of the fauna at all the sites (Figs. 4-17, 4-18, Table 4-11). Despite the fact that numerous predators were in the Niobrara River, none were collected especially abundantly by the quantitative methods. For example, relatively few Odonata larvae were identified despite adults often being abundant during sampling. The common habitat of many of these species are undercut banks and streamside debris, habitats not sampled by techniques employed.

#### 4.5 Summary of Benthic Macroinvertebrate Data

The taxa identified from the AFBNM during the course of this study are presented in Appendix A. The Niobrara River in the AFBNM supports a fauna believed once typical of the western portion of

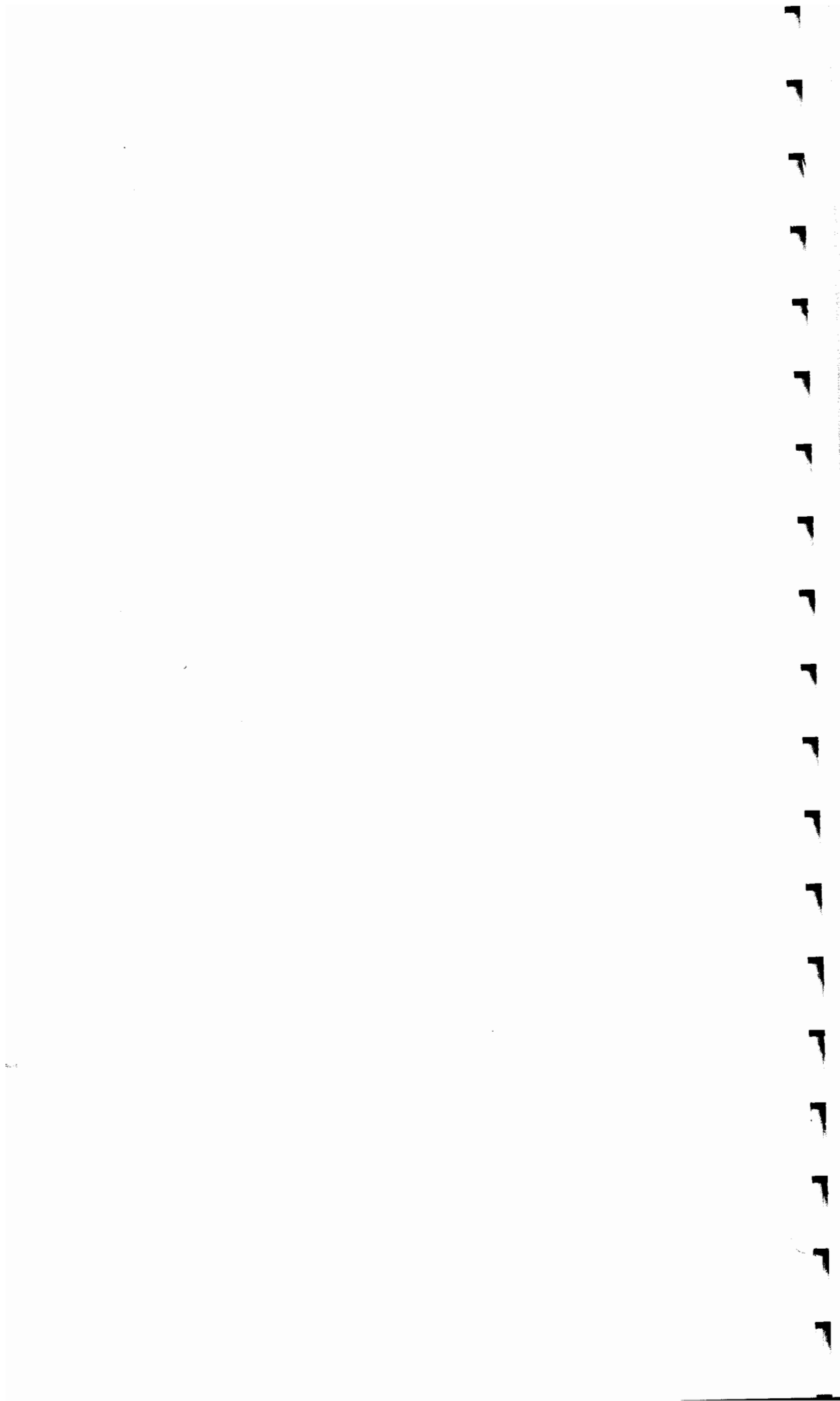
the Great Plains, a mixture of midwestern, Rocky Mountain, and widespread species. For example, the Ephemeroptera (mayflies) Heptagenia diabasa Burks, and Isonychia rufa McD., and the plecopteran (stonefly) Taeniopteryx burksi Ricker and Ross are species common in streams in Illinois, Ohio, and Indiana, whereas the odonate (dragonfly) Ophiogomphus severus Hagen is a Rocky Mountain species. The Trichoptera (caddisflies) Cheumatopsyche pettiti Banks, and Hydropsyche bronta Ross are widespread over the eastern half of North America.

Few studies of stream benthic macroinvertebrates have been conducted in the immediate region of the AFBNM. Kondratieff and Ward (1987) found similar species composition in their brief survey of an eastern Colorado stream. Carnevalo (1981) specifically surveyed the mayflies of the Niobrara River. McCafferty discussed the biogeographic affinities of mayflies in the Black Hills region of South Dakota. Additionally, there is some unpublished work on the Pine Ridge area north of Harrison. Even though the Pine Ridge area is in close proximity to the AFBNM it differs geomorphically and ecologically.

Matthews (1988) reviewed much of the ecological work performed in North American prairie streams. Work has been performed in the southern prairie region, including Texas (Davis 1980, Henry 1986) and Oklahoma (Morris and Madden 1978). Many ecological studies have been performed in King's Creek, a tallgrass prairie creek in the Konza Prairie Research Natural Area, Kansas. Research has included work on leaf litter processing (Smith 1986, Tate and Gurtz

1986), organic matter loading and processing (Gurtz et al. 1982, McArthur et al. 1985b), aquatic insect emergence (Gray 1989), and water quality (McArthur et al. 1985a). In the northern prairie, McCoy and Hales (1974) surveyed the biota, and physical and chemical characteristics of eight streams in eastern South Dakota. In his treatise on the Turtle River in eastern North Dakota, Neel (1985) documented annual and seasonal changes of the physical, chemical, and biotic features of this northern prairie stream.

The predominance of the two collector groups indicates that the food base in the Niobrara River is FPOM. Although the stream bottom presumably receives large amounts of solar radiation, the sandy substrate of the river does not allow much surface colonization by algae. The lack of a major source of terrestrial leaf litter may be one reason to account for the low numbers of shredders in the river. The sand to sand/mud substrate typical of much of the river bottom is not considered a good substrate for many species, especially when compared to rocky-bottomed prairie streams. Certain species prefer the refuge of undercut banks, including calopterygid damselflies, Orconectes, and several beetle species.



# Appendix B (continued).

## Site 3

| Date       | Temp.<br>(°C) | pH  | DO<br>(mg/l) | Total P<br>(mg/l) | TKN<br>(mg/l) | NO <sub>3</sub> -N<br>(mg/l) | NH <sub>4</sub> -N<br>(mg/l) | Hardness<br>(mg/l) | Ca<br>(mg/l) | Mg<br>(mg/l) | Alkalinity<br>(µeq/l) | TOC<br>(mg/l) |
|------------|---------------|-----|--------------|-------------------|---------------|------------------------------|------------------------------|--------------------|--------------|--------------|-----------------------|---------------|
| 16-VI-88   | 22            | 8.0 | 8.6          | <0.01             | 0.5           | 1.6                          | --                           | 196                | --           | --           | --                    | --            |
| 30-VI-88   | 17            | 8.1 | 7.3          | 0.02              | 0.5           | 1.7                          | --                           | 157                | 46.4         | 9.8          | --                    | --            |
| 14-VII-88  | 24            | 8.0 | 7.3          | <0.01             | 0.4           | 1.6                          | --                           | 164                | 47.2         | 11.2         | --                    | --            |
| 28-VII-88  | 21            | 8.3 | 6.7          | <0.01             | <0.1          | 1.6                          | --                           | 154                | 45.5         | 9.9          | --                    | --            |
| 11-VIII-88 | 21            | 8.1 | 7.9          | <0.01             | <0.1          | 1.5                          | --                           | 172                | --           | --           | --                    | --            |
| 25-VIII-88 | 17            | 8.2 | 8.6          | <0.01             | <0.1          | 1.4                          | --                           | 162                | --           | --           | --                    | --            |
| 16-IX-88   | 14            | 8.4 | --           | <0.01             | <0.1          | 1.8                          | --                           | 179                | --           | --           | --                    | --            |
| 16-X-88    | 9             | 8.5 | 9.5          | <0.01             | <0.1          | 2.4                          | --                           | 172                | --           | --           | --                    | --            |
| 21-II-89   | --            | --  | --           | 0.01              | <0.1          | 1.0                          | --                           | 172                | --           | --           | --                    | --            |
| 18-III-89  | 2             | 8.3 | 12.1         | 0.01              | <0.1          | 1.0                          | --                           | 163                | --           | --           | --                    | --            |
| 12-VI-89   | 18            | 7.8 | 6.2          | 0.02              | 1.5           | 0.7                          | 0.09                         | --                 | --           | --           | 6100                  | 4.2           |
| 16-IX-89   | 14            | 8.1 | 9.0          | 0.04              | 0.4           | 1.9                          | 0.07                         | --                 | --           | --           | 6428                  | 4.2           |
| 31-III-90  | 8             | 8.1 | 8.4          | 0.01              | 0.4           | 0.8                          | 0.20                         | --                 | --           | --           | 4174                  | 4.4           |

Appendix B. Water chemistry values, Agate Fossil Beds National Monument, Nebraska: Water temperature (Temp.), pH, dissolved oxygen (DO), total phosphorus (Total P), Total kjeldahl nitrogen (TKN), nitrate nitrogen (NO<sub>3</sub>-N), ammonia nitrogen (NH<sub>4</sub>-N), hardness as CaCO<sub>3</sub> (Hardness), Calcium (Ca), magnesium (Mg), gran alkalinity (Alkalinity), and total organic carbon (TOC) for Sites 1, 2, and 3.

Site 1

| Date       | Temp.<br>(°C) | pH  | DO<br>(mg/l) | Total P<br>(mg/l) | TKN<br>(mg/l) | NO <sub>3</sub> -N<br>(mg/l) | NH <sub>4</sub> -N<br>(mg/l) | Hardness<br>(mg/l) | Ca<br>(mg/l) | Mg<br>(mg/l) | Alkalinity<br>(μeq/l) | TOC<br>(mg/l) |
|------------|---------------|-----|--------------|-------------------|---------------|------------------------------|------------------------------|--------------------|--------------|--------------|-----------------------|---------------|
| 16-VI-88   | 23            | 7.7 | 7.8          | <0.01             | 0.5           | 0.1                          | --                           | 198                | --           | --           | --                    | --            |
| 30-VI-88   | 17            | 7.8 | 7.4          | 0.02              | 0.5           | 1.2                          | --                           | 165                | 49.1         | 10.2         | --                    | --            |
| 14-VII-88  | 24            | 7.9 | 7.3          | <0.01             | 0.7           | 1.1                          | --                           | 158                | 45.3         | 10.9         | --                    | --            |
| 28-VII-88  | 22            | 7.9 | 7.4          | <0.01             | <0.1          | 1.3                          | --                           | 162                | 47.4         | 10.6         | --                    | --            |
| 11-VIII-88 | 20            | 7.9 | 8.4          | <0.01             | 0.2           | 1.2                          | --                           | 164                | --           | --           | --                    | --            |
| 25-VIII-88 | 19            | 8.0 | 8.6          | <0.01             | <0.1          | 1.1                          | --                           | 161                | --           | --           | --                    | --            |
| 16-IX-88   | 14            | 7.8 | --           | <0.01             | <0.1          | 1.4                          | --                           | 175                | --           | --           | --                    | --            |
| 16-X-88    | 11            | 8.0 | 9.1          | <0.01             | <0.1          | 1.7                          | --                           | 175                | --           | --           | --                    | --            |
| 21-II-89   | --            | --  | --           | <0.01             | <0.1          | 0.9                          | --                           | 175                | --           | --           | --                    | --            |
| 18-III-89  | 3             | 8.2 | 13.0         | 0.01              | 0.1           | 1.1                          | --                           | 167                | --           | --           | --                    | --            |
| 12-VI-89   | 17            | 8.1 | 7.4          | 0.02              | 0.2           | 0.9                          | 0.06                         | --                 | --           | --           | 4555                  | 3.5           |
| 16-IX-89   | 14            | 8.0 | 9.0          | 0.04              | 0.1           | 1.4                          | 0.02                         | --                 | --           | --           | 6797                  | 4.4           |
| 3-I-90     | 1             | 7.8 | 12.6         | 0.07              | 0.6           | 2.2                          | 0.14                         | --                 | --           | --           | 3810                  | 2.0           |
| 31-III-90  | 9             | 8.1 | 9.1          | 0.01              | 0.5           | 0.7                          | 0.20                         | --                 | --           | --           | 4088                  | 4.6           |

Site 2

| Date       | Temp.<br>(°C) | pH  | DO<br>(mg/l) | Total P<br>(mg/l) | TKN<br>(mg/l) | NO <sub>3</sub> -N<br>(mg/l) | NH <sub>4</sub> -N<br>(mg/l) | Hardness<br>(mg/l) | Ca<br>(mg/l) | Mg<br>(mg/l) |
|------------|---------------|-----|--------------|-------------------|---------------|------------------------------|------------------------------|--------------------|--------------|--------------|
| 16-VI-88   | 25            | 7.7 | 10.4         | <0.01             | 0.4           | 1.6                          | --                           | 198                | --           | --           |
| 30-VI-88   | 18            | 7.8 | 7.0          | 0.02              | 0.5           | 1.4                          | --                           | 148                | 43.8         | 9.3          |
| 14-VII-88  | 24            | 7.8 | 7.1          | <0.01             | 0.5           | 1.7                          | --                           | 161                | 46.0         | 11.1         |
| 28-VII-88  | 23            | 7.9 | 8.3          | <0.01             | <0.1          | 1.8                          | --                           | 145                | 42.7         | 9.4          |
| 11-VIII-88 | 20            | 8.2 | 7.6          | <0.01             | 0.1           | 1.9                          | --                           | 160                | --           | --           |
| 25-VIII-88 | 18            | 7.8 | 9.2          | <0.01             | <0.1          | 1.5                          | --                           | 158                | --           | --           |
| 16-IX-88   | 15            | 8.2 | --           | <0.01             | <0.1          | 1.8                          | --                           | 172                | --           | --           |
| 16-X-88    | 10            | 8.0 | 9.8          | <0.01             | <0.1          | 2.5                          | --                           | 173                | --           | --           |
| 21-II-89   | --            | --  | --           | 0.01              | <0.1          | 1.0                          | --                           | 173                | --           | --           |

Appendix A (continued).

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Tipulidae  
    Dicranota sp.  
Turbellaria (Flatworms)  
    Planariidae  
        Dugesia  
Nematoda (Roundworms)  
Oligochaeta (Aquatic earthworms)  
Hirudinea (Leeches)  
Amphipoda (Sideswimmers)  
    Gammaridae  
        Gammarus sp.  
    Talitridae  
        Hyaella azteca (Saussure)  
Decapoda (Crayfish)  
    Cambaridae  
        Orconectes immunis (Hagen)  
Acarina (Mites)  
Gastropoda (Snails, Limpets)  
    Ancylidae  
    Lymnaeidae  
    Physidae  
    Planorbidae  
Pelecypoda (Clams, Mussels)  
    Sphaeriidae

Appendix A (continued).

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Megaloptera (Alderflies, in part)  
    Sialidae  
        Sialis velata Ross  
Neuroptera (Spongilla flies, in part)  
    Sisyridae  
        Sisyra vicaria (Walker)  
Coleoptera (Beetles)  
    Elmidae  
        Dubiraphia sp.  
    Dytiscidae  
        Agabus sp.  
        Colymbetes sulptilis Harris  
        Ilybius biguttulus Germar  
        Laccophilus sp.  
    Heteroceridae  
        Heterocerus brunneus Melsheimer  
        Heterocerus gnatho LeConte  
    Hydrophilidae  
        Enochrus hamiltoni (Horn)  
        Hydrobius fuscipes (Linne)  
        Tropisternus lateralis nimbatus (Say)  
Diptera (True Flies)  
    Ceratopogonidae  
    Chironomidae  
        Diamesinae  
        Chironominae  
            Chironomini  
                Paracladopelma sp.  
            Tanytarsini  
                Cladotanytasus sp.  
                Tanytarsus sp.  
    Orthocladinae  
        Eukiefferiella spp.  
        Orthocladus (Orthocladus) obumbratus  
        Johannsen/doreus (Roback)  
        Thienemanniella sp.  
    Tanypododinae  
        Thienemannimyia sp.  
Empididae  
    Hemerodromia sp.  
Ephydriidae  
Simuliidae  
    Simulium arcticum Malloch  
    Simulium vittatum Zetterstedt  
Stratiomyidae  
Tabanidae  
    Chrysops fulvaster Osten Sacken  
    Hybomitra frontalis Walker

Appendix A (continued).

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- Coenagrionidae
  - Argia emma Kennedy
  - Argia vivida Hagen
  - Amphiagrion abbreviatum (Selys)
  - Enallagma civile (Hagen)
  - Enallagma praevarum (Hagen)
  - Ischnura perparva Selys
- Plecoptera (Stoneflies)
  - Perlodidae
    - Isoperla quinquepunctata Banks
    - Isoperla marlynia Needham and Claassen
  - Perlidae
    - Perlesta decipiens (Walsh)
  - Taeniopterygidae
    - Taeniopteryx burksi Ricker and Ross
- Hemiptera (Bugs)
  - Corixidae
    - Cenocorixa sp.
  - Nepidae
    - Ranatra fusca Palisot de Beauvois
  - Veliidae
    - Rhagovelia obesa Say
  - Belostomatidae
    - Belostoma flumineum Say
- Trichoptera (Caddisflies)
  - Hydropsychidae
    - Cheumatopsyche pettiti Banks
    - Hydropsyche bronta Ross
    - Hydropsyche occidentalis Banks
  - Hydroptilidae
    - Agraylea multipunctata Curtis
    - Ochrotrichia stylata (Ross)
    - Ochrotrichia tarsalis (Hagen)
  - Leptoceridae
    - Ceraclea alagma (Ross)
    - Nectopsyche sp.
    - Oecetis cinerascens (Hagen)
    - Oecetis inconspicua (Walker)
  - Limnephilidae
    - Anabolia bimaculata (Walker)
    - Limnephilus diversus (Banks)
    - Pycnopsyche guttifer (Walker)
  - Phryganeidae
    - Ptilostomis semifasciata (Say)
  - Polycentropodidae
    - Polycentropus cinereus (Hagen)
    - Polycentropus interruptus (Banks)

Appendix A. Macroinvertebrates taxa collected from the Niobrara River in Agate Fossil Beds National Monument, Nebraska. Voucher specimens are deposited in the Colorado State University Insect Collection, Fort Collins, Colorado.

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Collembola (Springtails)

Ephemeroptera (Mayflies)

Baetidae

Acentrella insignificans (McDunnough)

Baetis dardanus McDunnough

Fallceon guilleri (Dodds)

Caenidae

Caenis sp.

Ephemeridae

Hexagenia limbata Serville

Heptageniidae

Heptagenia diabasa Burks

Leptophlebiidae

Leptophlebia nebulosa (Walker)

Oligoneuriidae

Isonychia rufa McDonnough

Tricorythidae

Tricorythodes sp.

Odonata (Dragonflies, Damselflies)

Anisoptera

Gomphidae

Ophiogomphus severus Hagen

Aeshnidae

Aeshna palmata Hagen

Corduliidae

Somatochlora ensigera Martin

Libellulidae

Libellula lydia Drury

Libellula pulchella Drury

Sympetrum corruptum (Hagen)

Sympetrum internum Montgomery

Sympetrum obstrusum (Hagen)

Sympetrum occidentale Bartenev

Sympetrum pallipes (Hagen)

Sympetrum rubicundulum (Say)

Sympetrum vicinum (Hagen)

Zygoptera

Calopterygidae

Calopteryx aequabilis Say

Calopteryx maculata (Beauvois)

Hetaerina americana (F.)

Lestidae

Lestes disjunctus Selys

Lestes dryas Kirby

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there is no major organic input. No major perturbations are apparent in the immediate vicinity of the AFBNM. In terms of risk analysis, two categories of threats to Niobrara River water quality are recognized.

The first threat involves modifications of stream flow. Modification includes change in discharge, impoundments, and channelization; effects of these modifications could include alteration of the natural meander of the river, and alteration of nutrient processing and therefore reduction of water quality. Reduction in the Niobrara River discharge over the past thirty years has been documented in Section 3.2.9 of this report. A possible cause of this flow reduction is change in the groundwater table from groundwater withdrawals. Impoundments or stream flow reduction could have a profound effect on the fauna of the river, including an increase of species preferring a lentic environment and exclusion of those requiring a lotic habitat.

The second threat concerns material input, including, organic nutrients, siltation, and toxic chemicals. Sources of organic inputs include agricultural fertilizers, municipal and domestic wastewater, and animal wastes. Alteration of streamside vegetation could lead to increased siltation. Toxic inputs may originate from agricultural pesticides, and municipal and industrial wastes. As there are no major urban areas in the upper Niobrara watershed, surveillance of agricultural and grazing practices would be the only action advisable at this time.

considerations and qualifications of biological integrity for water quality standards.

## 5.2 Plan for Long-term Monitoring Information

This report provides a comprehensive survey of the benthic macroinvertebrate community of the Niobrara River in AFBNM. Additionally, it reviews several physical and chemical characteristics associated with the river.

Hester-Dendy multiple plate samplers are recommended for future monitoring efforts. Cost and logistical effort are lower for Hester-Dendy samplers than for the Hess sampler. Macroinvertebrate identification and tabulation should proceed as reviewed in Appendix D. This methodology is standard, and familiar to aquatic ecologists. Standard ecological measures should be calculated for surveillance over time. These measures include density, taxa richness, EPT taxa, Shannon and Simpson indices, and functional groups percentages. Any additional measures, as desired, may be relatively easily calculated in the future with data stored in an up-to-date standard format.

The Surface Water Division of the Nebraska Department of Environmental Control is presently commencing a water quality monitoring program using Hester-Dendy samplers across the state of Nebraska. It may be desirable in the future to match their sampling methods and data storage in a cooperative effort.

## 5.3 Recommendation of Management Needs

Presently the Niobrara River supports a fauna once typical of a western Great Plains stream. Water chemistry data indicates that

Examples of endpoints include quantitative estimates of density of commercially important species or charismatic megafauna, invasion or introduction of pest species on a large scale, changes in the concentration of critical nutrients (either additions or losses), especially those nutrients such as nitrogen and phosphorus known to control primary production, and measure of community structure such as density, species richness, diversity, similarity, and dominance. Ecological endpoints can be arranged in profiles to characterize and monitor through time the ecological health of the resource and ecosystem in question. There is a twofold research thrust necessary to develop ecological endpoints for use in a park based monitoring program: 1) The technical aspects of ecological relevance, statistical rigor, QA/QC of sampling and analysis all are in great need of standardization, and are high priority items the current research agenda for applied ecologists, 2) The development of the decision making aspects of how to implement the use of ecological endpoints in a monitoring program needs to be developed with management personnel. These are the people who will eventually be using the information summarized by a set of ecological endpoints from a monitoring program. An critical aspect that is in acute need of development is methodology enabling management personnel to use the information in a decision making arena. The specific ecological endpoint recommended for the parks in this project in the status of the benthic macroinvertebrate community. These endpoints should be amenable to address

inventoried include major resource organisms such as commercially important fisheries or trees valued for timber, pest species, important charismatic megafauna, or endangered species. Inventories at the community level are commonly done to classify forest types, vegetation analysis, baseline data to establish regional profiles in biogeographic regions, and in assessment of environmental impact (Hunsaker et al, 1990). Examples of paradigms at the ecosystem level are the River Continuum Concept (RCC), which describes how physical, chemical, and biological conditions change as a small streams become larger and larger, eventually becoming a large river (Vannote et al, 1980).

In a fashion similar to human medicine approaches, sets of ecological endpoints should be formulated from the formal theory in ecological paradigms (Suter, 1990). An ecological endpoint is defined as an ecological parameter whose normal operating limits can be determined for the ecosystem in question. A major effort in ecosystem risk analysis is the identification of appropriate ecological endpoints that are indicators of ecological health and sensitive to early stages of anthropomorphic change. In order to relate to human society and values, these ecological endpoints should be associated with social, cultural, or economic consequences. From an operational aspect, ecological endpoints should be easily measured, quantifiable, and amenable to statistical analysis. They should be sensitive to early or defined status of ecological stress to allow for mitigation measures to be employed.

This approach uses the information from resource inventories and monitoring programs to identify changes before large scale damage has occurred. The information would be used to predict the ultimate change and to plan mitigation of the potential ecological damage. This form of assessment is retroactive in that it evaluates change that has already taken place, but is also proactive in that it uses estimations of change at an early stage and ecological knowledge from inventories to estimate the final state of a resource or ecosystem due to impacts from development. Condition of the resource or ecosystem rather than the source of stress is the beginning point of analysis.

In defining ecological health an analogy to characterizing human health is useful. Human health may be defined as the condition of the body as determined by a number of parameters such as certain physical characteristics as body temperature and structural integrity, height-weight relationship, the chemical condition of blood and other body fluids that are parameters of the biological condition of various organ systems etc. Measurement of these critical health attributes within certain ranges are considered healthy and when these limits are exceeded the individual is considered diseased or unhealthy, and some sort of medical action is warranted.

Ecological theory provides the basis for management, diagnosis and treatment of the ecosystem in the same fashion the human anatomy and physiology provides the basis for the practice of human medicine. For example, single species populations routinely

estimations of chemical fate, and batteries of laboratory toxicity tests to estimate the direct effects of such chemicals on representatives of important resource organisms. These methods of assessment do not, however, estimate indirect effects on other organisms, the effects at higher levels of organization such as community or ecosystem nor do they estimate the effects from non-chemical and multiple impacts.

The strategy for assessing and managing risks involving large scale ecological change using natural resource inventories include:

- 1] Development of the concept of **ecosystem health**,
- 2] Develop **regional profiles** of the health of ecosystems in terms of critical ecological characteristics and,
- 3] Formulation of ecological measurement **endpoints** to determine ecological health and provide a basis for monitoring.

The concept of *ecosystem health* can be developed from consideration of the age or stage of succession of an ecosystem. Ecosystems at early stages of development will have different characteristics and susceptibilities to stress than more mature ecosystems (Shaeffer et al, 1988). Operationally the concept of ecosystem health should include determination of keystone species and critical communities and not an elaboration and evaluation of overwhelming numbers of species. This will require some application of critical judgement and prioritization by ecologists conducting inventories.

E) There should be explicit plans for data storage, preservation, and archiving of appropriate samples. Considerations should be addressed as to who will be using the data and the time frame in which the data will be used.

F) The data should be subject to quantitative analysis that both establishes a basis for statistical parameters and forms a basis for accepting or rejecting the hypotheses generated by the resource management concerns.

G) Consideration of the final products in terms of written reports should be given before the inventory is begun.

Natural resource inventories in the past have included efforts to make catalogs of existing species, determine their distributions, the limits of their geographical ranges and stock assessments of major resource species such as volume of timber or numbers of fish. Natural resource inventories can be designed to provide key elements in an ecosystem risk analysis program that will provide risk assessment to critical natural resources if several steps are specified.

#### 5.1.2 Environmental Risk Analysis

Risk analysis in the life sciences in the past has focused on the factors directly affecting human health and mortality. For example, calculations can be made on the risk to the human population due to factors such as smoking, the use of certain medicines, or the development of nuclear generating plants. In the field of environmental sciences risk analysis has been applied to the use of pesticides and the release of industrial chemicals using

II. The second step is the formulation of scientific tasks that are directly predicated from the resource management concerns in the first step. The set of scientific tasks should address the prioritized Park natural resources concerns, and in certain cases may also address broader issues that include long-term issues of regional or national importance. An explicit framework to implement these scientific tasks is as follows:

A) The scientific tasks should be in the form of explicit sets of testable hypotheses that address the Park specific and broader NPS resource management concerns.

B) These hypotheses will entail specific data set requirements. The level of effort in the data collection will be directly related to how the data will be used, i.e. for general knowledge and interpretation vs. for legal defense of resources.

C) At the point there will be a comparison of resources available and costs against the prioritized list of natural resource concerns addressed. In effect, this step will determine what tasks can be done. Both resource managers and scientific personnel should reach a consensus on the content of the final scope of work.

D) The data collection should have a Quality Assurance and Quality Control (QA/QC) program in place before sampling takes place. This includes a precise statement of procedures of how data are to be collected, instrumentation used, use of chemicals or biological standards, and limits of detection.

interpretation of data in a resource inventory program, and 3) a rationale for using data generated in monitoring programs. Detailed aspects of risk analysis monitoring approaches for stream ecosystems will be covered in a workshop to be held at the Regional Office in Omaha in late summer 1991.

#### 5.1.1 Management Concerns

A primary role of resource managers is to secure information on threats and identify the needs for managing natural resources. Resource management needs should be put into a clear set of management objectives. It is the role of the research scientist to translate these management objectives into scientific hypotheses, data collection procedures, and conclusions. These two activities should be considered parallel and interacting.

I. The initial step is a clear statement of resource management programmatic concerns by the Park. These concerns may be mandated by legislation establishing the Park, come from pervasive threats such as pollution, result from land-use changes outside the Park boundaries, or be the consequences of management decisions. It is imperative that the statement of natural resource management concerns is both explicit and inclusive because it leads directly to and drives the other steps in the I&M process. This statement of concerns should be a joint effort between resource management and a research scientist. These individual resource management concerns should be arranged by priority to assign available resources.

## 5.0 DISCUSSION

### 5.1 Risk Analysis Framework

Recent interest within the National Park Service for a more comprehensive and systematic inventory of natural resources and periodic monitoring to determine condition and to assess any man-induced changes has been manifested in the Natural Resources Assessment Action Program. Many parks have some resource inventory and monitoring (I&M) activities, however, many of these same parks are often at a loss to interpret collected environmental data when confronted with some of the more pervasive, complex threats to the integrity of their resources. In the past, many inventories of natural resources have been little more than lists of species and locations of samples sites; many monitoring efforts have been restricted to those mandated by human health concerns comprising a loose collection of assorted chemical constituents, often directed at concerns about water quality.

This chapter introduces the integration of management and technical aspects, and introduces a risk analysis framework for conducting resource inventories and subsequent monitoring. Inventory and monitoring in the NPS is a responsibility shared between resource management and research. Therefore any program conducting environmental inventory and subsequent monitoring efforts should have certain critical elements that include: 1) a procedure for establishing clear co-responsibilities for resource managers and research scientists, 2) a concept of the ecological paradigm as a framework for the collection of information and

Appendix C.1. Taxa codes, functional group designation used in data analysis, Agate Fossil Beds National Monument, Nebraska. 'x' = only used in Hess sampling, 'y' = only used in Hester-Dendy.

| Order         | Family            | Taxon                           | x/y | Taxa Code | Functional Group   |
|---------------|-------------------|---------------------------------|-----|-----------|--------------------|
| Collembola    |                   | Collembola                      | x   | COLL      | Collector-gatherer |
| Ephemeroptera | Beetidae          | Beetidae                        |     | BAET      | Collector-gatherer |
|               | Caenidae          | Caenis sp.                      |     | CAEN      | Collector-gatherer |
|               | Ephemeridae       | <u>Hexagenia limbata</u>        | x   | HEXA      | Collector-gatherer |
|               | Heptageniidae     | <u>Heptagenia diabasa</u>       |     | HEPT      | Scraper            |
|               | Leptophlebiidae   | <u>Leptophlebia nebulosa</u>    |     | LEPT      | Collector-gatherer |
|               | Oligoneuriidae    | <u>Isonychia rufa</u>           | y   | ISON      | Collector-filterer |
|               | Tricorythidae     | <u>Tricorythodes</u> sp.        | y   | TRIC      | Collector-gatherer |
| Odonata       | Calopterygidae    | <u>Calopteryx</u> spp.          | x   | CALO      | Predator           |
|               | Coenagrionidae    | <u>Argia</u> spp.               | y   | ARGI      | Predator           |
|               |                   | <u>Enallagma</u> spp.           | x   | ENAL      | Predator           |
|               | Libellulidae      | <u>Sympetrum</u> spp.           | x   | SYMP      | Predator           |
| Plecoptera    | Taeniopterygidae  | <u>Taeniopteryx burksi</u>      |     | TABU      | Shredder           |
|               | Perlodidae        | <u>Isoperla</u> spp.            |     | ISOP      | Predator           |
| Trichoptera   | Hydropsychidae    | <u>Cheumatopsyche</u> sp.       | y   | CHEU      | Collector-filterer |
|               |                   | <u>Hydropsyche</u> spp.         |     | HYDR      | Collector-filterer |
|               | Hydroptilidae     | <u>Ochrotrichia</u> spp.        | x   | OCHR      | Collector-gatherer |
|               | Leptoceridae      | <u>Nectopsyche</u> sp.          |     | NECT      | Shredder           |
|               | Phryganeidae      | <u>Ptilostomis semifasciata</u> | y   | PTIL      | Shredder           |
|               | Polycentropodidae | <u>Polycentropus</u> spp.       | y   | POLY      | Predator           |
| Megaloptera   | Sialidae          | <u>Sialis velata</u>            | y   | SIAL      | Predator           |
| Coleoptera    | Elmidae           | Elmidae                         | x   | ELMI      | Collector-gatherer |
|               |                   | <u>Dubiraphia</u> sp.           | x   | DUBI      | Collector-gatherer |
|               | Dytiscidae        | Dytiscidae                      | x   | DYTI      | Predator           |
| Hemiptera     | Corixidae         | <u>Cenocorixa</u> sp.           | x   | CENO      | Other              |
| Diptera       | Ceratopogonidae   | Ceratopogonidae                 |     | CERA      | Predator           |
|               | Chironomidae      | Chironomidae pupae              |     | CHPU      | Other              |
|               |                   | Chironomini                     |     | CNMI      | Collector-gatherer |
|               |                   | Tanytarsini                     |     | TNYT      | Collector-filterer |
|               |                   | Diamessinae                     | y   | DIAM      | Collector-gatherer |
|               |                   | Orthocladinae                   |     | ORTH      | Collector-gatherer |
|               |                   | Tanyptododinae                  |     | TNYP      | Predator           |
|               | Epididae          | <u>Hemerodromia</u> sp.         | y   | HEME      | Predator           |
|               | Ephydriidae       | Ephydriidae                     | x   | EPHY      | Collector-gatherer |
|               | Simuliidae        | <u>Simulium</u> spp.            |     | SIMU      | Collector-filterer |
|               |                   | <u>Simulium</u> spp. pupae      | y   | SIMP      | Other              |
|               | Stratiomyidae     | Stratiomyidae                   | x   | STRA      | Collector-gatherer |
|               | Tabanidae         | <u>Chrysops</u> spp.            | x   | CHRY      | Collector-gatherer |
|               | Tipulidae         | Tipulidae                       | x   | TIPU      | Shredder           |
|               |                   | <u>Dicranota</u> sp.            | y   | DICR      | Shredder           |
| Turbellaria   | Planariidae       | <u>Dugesia</u> sp.              |     | DUGE      | Predator           |
| Nematoda      |                   | Nematoda                        |     | NEMA      | Collector-Gatherer |
| Oligochaeta   |                   | Oligochaeta                     |     | OLIG      | Collector-gatherer |
| Hirudinea     |                   | Hirudinea                       |     | HIRU      | Predator           |
| Amphipoda     | Gammaridae        | <u>Gammarus</u> sp.             |     | GAMM      | Collector-gatherer |
|               | Talitridae        | <u>Hyallela azteca</u>          | y   | HYAL      | Collector-gatherer |

# Appendix C.1 (continued).

|            |             |                           |   |      |                    |
|------------|-------------|---------------------------|---|------|--------------------|
| Decapoda   | Cambaridae  | <u>Orconectes immunis</u> | x | ORIM | Shredder           |
| Acarina    |             | Acarina                   |   | ACAR | Predator           |
| Gastropoda |             | Gastropoda                | x | GAST | Scraper            |
|            | Ancylidae   | Ancylidae                 |   | ANCY | Scraper            |
|            | Lymnaeidae  | Lymnaeidae                | x | LYMN | Scraper            |
|            | Physidae    | Physidae                  |   | PHYS | Scraper            |
|            | Planorbidae | Planorbidae               |   | PLAN | Scraper            |
| Pelecypoda | Sphaeriidae | Sphaeriidae               | x | SPHA | Collector-filterer |

Appendix C.2. Quantitative benthic macroinvertebrate data, from Hess and Hester-Dendy sampling, Agate Fossil Beds National Monument, Nebraska.

Hess Data

| OBS | SITE | DATE    | DEPTH | BA  | LE | CH | MS | SC  | ET | IM | ON | ME | DD | CC | CH |
|-----|------|---------|-------|-----|----|----|----|-----|----|----|----|----|----|----|----|
| S   | E    | E       | P     | T   | T  | N  | T  | P   | L  | U  | R  | R  | T  | I  | Y  |
| 1   | AFB1 | 16JUN88 | 1     | 19  | 0  | 10 | 0  | 31  | 0  | 0  | 0  | 2  | 0  | 0  | 0  |
| 2   | AFB1 | 16JUN88 | 2     | 184 | 0  | 66 | 1  | 737 | 0  | 0  | 0  | 35 | 17 | 4  | 0  |
| 3   | AFB1 | 16JUN88 | 3     | 14  | 0  | 2  | 0  | 15  | 0  | 0  | 0  | 6  | 0  | 0  | 0  |
| 4   | AFB1 | 16JUN88 | 4     | 21  | 0  | 15 | 0  | 64  | 0  | 0  | 0  | 9  | 12 | 0  | 0  |
| 5   | AFB1 | 16JUN88 | 5     | 25  | 0  | 0  | 0  | 11  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| 6   | AFB1 | 30JUN88 | 1     | 0   | 0  | 0  | 0  | 0   | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| 7   | AFB1 | 30JUN88 | 2     | 0   | 0  | 0  | 0  | 0   | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| 8   | AFB1 | 30JUN88 | 3     | 0   | 0  | 0  | 0  | 0   | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| 9   | AFB1 | 30JUN88 | 4     | 0   | 0  | 0  | 0  | 0   | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| 10  | AFB1 | 30JUN88 | 5     | 0   | 0  | 0  | 0  | 0   | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| 11  | AFB1 | 14JUL88 | 1     | 19  | 0  | 1  | 0  | 10  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| 12  | AFB1 | 14JUL88 | 2     | 0   | 2  | 1  | 0  | 1   | 0  | 0  | 0  | 0  | 1  | 0  | 0  |
| 13  | AFB1 | 14JUL88 | 3     | 17  | 55 | 14 | 1  | 17  | 0  | 0  | 0  | 40 | 0  | 2  | 0  |
| 14  | AFB1 | 14JUL88 | 4     | 0   | 0  | 0  | 0  | 0   | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| 15  | AFB1 | 14JUL88 | 5     | 4   | 0  | 0  | 0  | 1   | 0  | 0  | 0  | 1  | 0  | 0  | 0  |
| 16  | AFB1 | 28JUL88 | 1     | 1   | 0  | 0  | 0  | 0   | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| 17  | AFB1 | 28JUL88 | 2     | 1   | 0  | 0  | 0  | 0   | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| 18  | AFB1 | 28JUL88 | 3     | 0   | 0  | 0  | 0  | 0   | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| OBS | SS   | TC      | CC    | CT  | OT | TE | CG | AL  | PP | SS | GO | OH | NA | AD |    |
| S   | UA   | UA      | UA    | UA  | UA | UA | UA | UA  | UA | UA | UA | UA | UA | UA | UA |
| 1   | 1    | 0       | 1     | 1   | 1  | 75 | 13 | 34  | 3  | 0  | 0  | 0  | 0  | 1  | 0  |
| 2   | 19   | 2       | 0     | 4   | 8  | 18 | 7  | 37  | 7  | 2  | 2  | 0  | 2  | 0  | 0  |
| 3   | 0    | 0       | 0     | 0   | 0  | 27 | 2  | 17  | 1  | 0  | 0  | 0  | 1  | 0  | 0  |
| 4   | 4    | 2       | 0     | 7   | 7  | 26 | 20 | 32  | 1  | 0  | 0  | 0  | 12 | 0  | 0  |
| 5   | 6    | 0       | 0     | 0   | 1  | 2  | 1  | 22  | 0  | 0  | 0  | 0  | 1  | 0  | 0  |
| 6   | 0    | 0       | 0     | 0   | 0  | 4  | 0  | 0   | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| 7   | 0    | 0       | 0     | 0   | 0  | 1  | 1  | 0   | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| 8   | 0    | 0       | 0     | 0   | 0  | 53 | 6  | 3   | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| 9   | 0    | 0       | 0     | 0   | 0  | 15 | 5  | 3   | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| 10  | 0    | 0       | 0     | 0   | 0  | 19 | 8  | 0   | 0  | 1  | 0  | 0  | 0  | 0  | 0  |
| 11  | 0    | 0       | 0     | 0   | 0  | 4  | 32 | 8   | 0  | 0  | 0  | 0  | 1  | 0  | 0  |
| 12  | 0    | 0       | 0     | 1   | 0  | 33 | 36 | 3   | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| 13  | 0    | 0       | 0     | 0   | 6  | 27 | 13 | 13  | 8  | 0  | 0  | 0  | 3  | 0  | 0  |
| 14  | 0    | 0       | 0     | 0   | 0  | 24 | 94 | 0   | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| 15  | 1    | 0       | 0     | 0   | 0  | 8  | 5  | 3   | 0  | 0  | 0  | 0  | 1  | 0  | 0  |
| 16  | 0    | 0       | 0     | 0   | 0  | 5  | 67 | 0   | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| 17  | 0    | 0       | 0     | 0   | 0  | 2  | 61 | 0   | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| 18  | 0    | 0       | 0     | 2   | 2  | 13 | 83 | 0   | 0  | 0  | 0  | 0  | 0  | 0  | 0  |

# Appendix C.2 (continued).

| OBS | SITE | DARE    | BARE | LEP | CAE | HXA | HXP | SEY | CEA | TIAS | HYD | ONCE | NECM | DUY | DCY | CHRY |
|-----|------|---------|------|-----|-----|-----|-----|-----|-----|------|-----|------|------|-----|-----|------|
| 19  | AFB1 | 28JUL88 | 4    | 1   | 0   | 0   | 0   | 0   | 0   | 0    | 0   | 0    | 0    | 0   | 0   | 0    |
| 20  | AFB1 | 28JUL88 | 5    | 0   | 0   | 0   | 1   | 0   | 0   | 0    | 0   | 0    | 0    | 0   | 0   | 0    |
| 21  | AFB1 | 11AUG88 | 1    | 31  | 27  | 11  | 3   | 10  | 0   | 2    | 0   | 0    | 0    | 3   | 0   | 0    |
| 22  | AFB1 | 11AUG88 | 2    | 9   | 7   | 1   | 0   | 1   | 0   | 0    | 0   | 0    | 0    | 0   | 0   | 0    |
| 23  | AFB1 | 11AUG88 | 3    | 146 | 89  | 15  | 4   | 8   | 0   | 4    | 0   | 0    | 1    | 3   | 0   | 2    |
| 24  | AFB1 | 11AUG88 | 4    | 9   | 1   | 1   | 0   | 0   | 0   | 0    | 0   | 0    | 1    | 0   | 0   | 0    |
| 25  | AFB1 | 11AUG88 | 5    | 11  | 8   | 0   | 0   | 4   | 0   | 0    | 0   | 0    | 0    | 0   | 0   | 0    |
| 26  | AFB1 | 25AUG88 | 1    | 16  | 3   | 0   | 1   | 1   | 0   | 0    | 0   | 0    | 1    | 0   | 0   | 0    |
| 27  | AFB1 | 25AUG88 | 2    | 40  | 5   | 3   | 1   | 0   | 0   | 1    | 0   | 0    | 0    | 1   | 0   | 0    |
| 28  | AFB1 | 25AUG88 | 3    | 22  | 3   | 0   | 0   | 2   | 0   | 1    | 0   | 0    | 4    | 1   | 0   | 3    |
| 29  | AFB1 | 25AUG88 | 4    | 47  | 4   | 0   | 1   | 2   | 0   | 0    | 0   | 0    | 3    | 5   | 0   | 1    |
| 30  | AFB1 | 25AUG88 | 5    | 8   | 1   | 2   | 0   | 0   | 0   | 0    | 0   | 0    | 0    | 0   | 0   | 0    |
| 31  | AFB1 | 16SEP88 | 1    | 17  | 4   | 2   | 0   | 0   | 0   | 0    | 1   | 0    | 1    | 0   | 0   | 1    |
| 32  | AFB1 | 16SEP88 | 2    | 37  | 264 | 40  | 0   | 8   | 0   | 3    | 0   | 3    | 29   | 10  | 0   | 0    |
| 33  | AFB1 | 16SEP88 | 3    | 6   | 4   | 0   | 0   | 0   | 0   | 0    | 0   | 0    | 1    | 0   | 0   | 1    |
| 34  | AFB1 | 16SEP88 | 4    | 0   | 2   | 0   | 0   | 0   | 0   | 0    | 0   | 0    | 0    | 0   | 0   | 0    |
| 35  | AFB1 | 16SEP88 | 5    | 44  | 20  | 3   | 1   | 0   | 0   | 0    | 0   | 2    | 4    | 8   | 1   | 3    |
| 36  | AFB1 | 16OCT88 | 1    | 2   | 8   | 0   | 0   | 0   | 0   | 0    | 0   | 0    | 0    | 0   | 0   | 1    |

| OBS | SIT | SSR | TCR | CCP | CTM | OTY | TEH | CGS | ALY | PLM | PSN | GAM | ORL | ONIR | NAEC | DUARE |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|------|-------|
| 19  | 0   | 0   | 0   | 0   | 1   | 5   | 46  | 2   | 0   | 0   | 0   | 0   | 0   | 0    | 5    | 0     |
| 20  | 0   | 0   | 0   | 0   | 4   | 20  | 66  | 5   | 0   | 0   | 0   | 0   | 0   | 0    | 0    | 0     |
| 21  | 2   | 0   | 0   | 2   | 0   | 3   | 4   | 17  | 5   | 0   | 0   | 0   | 0   | 0    | 1    | 0     |
| 22  | 1   | 0   | 0   | 0   | 1   | 4   | 14  | 6   | 0   | 0   | 0   | 0   | 0   | 0    | 0    | 0     |
| 23  | 15  | 0   | 0   | 1   | 2   | 2   | 13  | 25  | 2   | 0   | 0   | 0   | 0   | 0    | 0    | 0     |
| 24  | 0   | 0   | 0   | 1   | 0   | 0   | 29  | 0   | 0   | 0   | 0   | 0   | 0   | 0    | 2    | 0     |
| 25  | 0   | 0   | 0   | 1   | 4   | 5   | 14  | 6   | 0   | 0   | 0   | 0   | 1   | 0    | 3    | 0     |
| 26  | 1   | 0   | 0   | 0   | 1   | 0   | 2   | 9   | 0   | 0   | 0   | 0   | 0   | 0    | 1    | 1     |
| 27  | 14  | 0   | 0   | 0   | 0   | 1   | 17  | 21  | 0   | 0   | 0   | 0   | 0   | 0    | 3    | 5     |
| 28  | 0   | 0   | 0   | 0   | 1   | 1   | 9   | 11  | 1   | 0   | 0   | 0   | 0   | 0    | 4    | 0     |
| 29  | 34  | 0   | 0   | 0   | 0   | 1   | 8   | 47  | 0   | 0   | 0   | 0   | 2   | 0    | 0    | 1     |
| 30  | 0   | 0   | 0   | 0   | 1   | 0   | 12  | 2   | 0   | 0   | 0   | 0   | 0   | 0    | 4    | 0     |
| 31  | 21  | 0   | 0   | 0   | 2   | 8   | 11  | 29  | 0   | 0   | 0   | 0   | 2   | 0    | 4    | 1     |
| 32  | 6   | 0   | 0   | 1   | 1   | 4   | 13  | 25  | 2   | 0   | 0   | 0   | 103 | 0    | 0    | 0     |
| 33  | 5   | 1   | 0   | 1   | 1   | 11  | 24  | 13  | 0   | 0   | 0   | 0   | 0   | 0    | 3    | 0     |
| 34  | 0   | 0   | 0   | 2   | 2   | 4   | 33  | 19  | 0   | 0   | 0   | 0   | 0   | 0    | 6    | 0     |
| 35  | 82  | 1   | 0   | 0   | 2   | 11  | 7   | 61  | 2   | 0   | 0   | 0   | 5   | 1    | 18   | 0     |
| 36  | 24  | 0   | 0   | 1   | 2   | 1   | 11  | 14  | 0   | 0   | 0   | 0   | 0   | 0    | 0    | 1     |

# Appendix C.2 (continued).

| O<br>B<br>S | S<br>I<br>T<br>E | D<br>A<br>T<br>E | R<br>E<br>P<br>T | B<br>A<br>T | L<br>E<br>P<br>T | C<br>A<br>P<br>T | H<br>E<br>X<br>A | H<br>E<br>Y<br>A | S<br>P<br>M<br>P | C<br>E<br>L<br>L<br>O<br>L | T<br>I<br>B<br>O<br>P | H<br>O<br>Y<br>D<br>R | N<br>C<br>H<br>R | E<br>C<br>M<br>T | D<br>U<br>B<br>I | D<br>Y<br>T<br>I | C<br>E<br>N<br>O | C<br>H<br>R<br>Y |
|-------------|------------------|------------------|------------------|-------------|------------------|------------------|------------------|------------------|------------------|----------------------------|-----------------------|-----------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| 37          | AFB1             | 16OCT88          | 2                | 2           | 2                | 2                | 0                | 1                | 0                | 0                          | 0                     | 12                    | 0                | 8                | 0                | 0                | 0                | 7                |
| 38          | AFB1             | 16OCT88          | 3                | 6           | 5                | 3                | 0                | 0                | 0                | 0                          | 0                     | 15                    | 2                | 0                | 0                | 0                | 0                | 7                |
| 39          | AFB1             | 16OCT88          | 4                | 0           | 0                | 0                | 0                | 0                | 0                | 0                          | 0                     | 0                     | 0                | 0                | 0                | 0                | 0                | 0                |
| 40          | AFB1             | 16OCT88          | 5                | 9           | 7                | 0                | 0                | 0                | 0                | 0                          | 0                     | 21                    | 0                | 6                | 0                | 0                | 0                | 22               |
| 41          | AFB1             | 18FEB89          | 1                | 0           | 2                | 1                | 0                | 0                | 0                | 0                          | 0                     | 1                     | 0                | 0                | 0                | 0                | 0                | 0                |
| 42          | AFB1             | 18FEB89          | 2                | 0           | 0                | 1                | 0                | 0                | 0                | 0                          | 0                     | 0                     | 0                | 0                | 0                | 0                | 0                | 0                |
| 43          | AFB1             | 18FEB89          | 3                | 0           | 0                | 0                | 0                | 0                | 0                | 0                          | 0                     | 1                     | 5                | 7                | 0                | 0                | 0                | 0                |
| 44          | AFB1             | 18FEB89          | 4                | 1           | 1                | 0                | 4                | 0                | 0                | 0                          | 0                     | 0                     | 0                | 0                | 0                | 0                | 0                | 0                |
| 45          | AFB1             | 18FEB89          | 5                | 1           | 1                | 0                | 0                | 0                | 0                | 0                          | 0                     | 0                     | 0                | 0                | 0                | 0                | 0                | 0                |
| 46          | AFB2             | 16JUN88          | 1                | 0           | 0                | 0                | 0                | 0                | 0                | 0                          | 0                     | 0                     | 0                | 0                | 0                | 0                | 0                | 0                |
| 47          | AFB2             | 16JUN88          | 2                | 17          | 0                | 3                | 0                | 33               | 0                | 0                          | 0                     | 0                     | 0                | 1                | 0                | 0                | 0                | 1                |
| 48          | AFB2             | 16JUN88          | 3                | 13          | 0                | 3                | 1                | 15               | 0                | 0                          | 0                     | 0                     | 0                | 0                | 0                | 0                | 0                | 0                |
| 49          | AFB2             | 16JUN88          | 4                | 128         | 0                | 11               | 45               | 32               | 0                | 0                          | 0                     | 0                     | 0                | 0                | 1                | 0                | 0                | 1                |
| 50          | AFB2             | 16JUN88          | 5                | 31          | 0                | 7                | 9                | 64               | 0                | 0                          | 0                     | 0                     | 0                | 1                | 0                | 0                | 0                | 0                |
| 51          | AFB2             | 30JUN88          | 1                | 0           | 0                | 0                | 0                | 0                | 0                | 0                          | 0                     | 0                     | 0                | 0                | 0                | 0                | 0                | 1                |
| 52          | AFB2             | 30JUN88          | 2                | 0           | 0                | 0                | 0                | 1                | 0                | 0                          | 0                     | 0                     | 0                | 0                | 0                | 0                | 0                | 0                |
| 53          | AFB2             | 30JUN88          | 3                | 0           | 0                | 0                | 0                | 0                | 0                | 0                          | 0                     | 0                     | 0                | 0                | 0                | 0                | 0                | 0                |
| 54          | AFB2             | 30JUN88          | 4                | 0           | 0                | 0                | 0                | 0                | 0                | 0                          | 0                     | 0                     | 0                | 0                | 0                | 0                | 0                | 0                |

| O<br>B<br>S | S<br>I<br>M<br>U | S<br>T<br>R<br>U<br>A | T<br>I<br>P<br>U | C<br>E<br>R<br>A<br>U | C<br>E<br>N<br>P<br>U | C<br>N<br>M<br>I | T<br>N<br>Y<br>T | O<br>R<br>T<br>H | T<br>N<br>Y<br>P | E<br>P<br>H<br>Y | C<br>O<br>L<br>T | G<br>A<br>S<br>T | A<br>N<br>C<br>Y | L<br>Y<br>M<br>N | P<br>H<br>Y<br>S | P<br>L<br>A<br>N | S<br>P<br>H<br>A | G<br>A<br>M<br>M | O<br>R<br>I<br>M | O<br>L<br>I<br>G | H<br>I<br>R<br>U | N<br>E<br>M<br>A | A<br>C<br>A<br>R | D<br>U<br>G<br>E |
|-------------|------------------|-----------------------|------------------|-----------------------|-----------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| 37          | 11               | 1                     | 0                | 2                     | 8                     | 10               | 25               | 80               | 0                | 0                | 0                | 0                | 1                | 0                | 0                | 0                | 0                | 0                | 0                | 30               | 0                | 4                | 2                | 0                |
| 38          | 16               | 0                     | 1                | 0                     | 3                     | 74               | 13               | 68               | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 7                | 0                | 0                | 0                | 0                |
| 39          | 0                | 0                     | 0                | 1                     | 0                     | 11               | 4                | 6                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 7                | 0                | 0                | 0                | 0                |
| 40          | 23               | 1                     | 0                | 1                     | 0                     | 3                | 12               | 70               | 0                | 0                | 0                | 0                | 3                | 1                | 0                | 0                | 0                | 0                | 0                | 20               | 0                | 4                | 2                | 0                |
| 41          | 4                | 2                     | 8                | 0                     | 0                     | 0                | 2                | 48               | 1                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 1                | 0                | 1                | 0                | 0                |
| 42          | 0                | 0                     | 6                | 0                     | 0                     | 0                | 4                | 7                | 0                | 0                | 0                | 0                | 0                | 1                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                |
| 43          | 1                | 2                     | 7                | 0                     | 0                     | 0                | 0                | 27               | 0                | 0                | 0                | 0                | 0                | 1                | 0                | 0                | 0                | 1                | 0                | 1                | 0                | 0                | 0                | 0                |
| 44          | 0                | 2                     | 7                | 0                     | 0                     | 0                | 0                | 26               | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 1                | 0                | 0                |
| 45          | 1                | 4                     | 19               | 0                     | 0                     | 4                | 0                | 32               | 2                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 2                | 0                | 1                | 0                | 0                | 0                | 0                |
| 46          | 0                | 0                     | 0                | 0                     | 0                     | 6                | 0                | 3                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 5                | 0                | 1                | 0                | 0                |
| 47          | 2                | 0                     | 0                | 0                     | 1                     | 13               | 6                | 9                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 25               | 0                | 1                | 0                | 0                |
| 48          | 10               | 0                     | 0                | 0                     | 5                     | 15               | 9                | 25               | 0                | 0                | 0                | 0                | 6                | 0                | 0                | 0                | 0                | 1                | 1                | 58               | 0                | 30               | 0                | 0                |
| 49          | 12               | 0                     | 0                | 1                     | 2                     | 8                | 3                | 11               | 0                | 0                | 0                | 0                | 7                | 0                | 0                | 0                | 0                | 6                | 8                | 78               | 0                | 53               | 0                | 0                |
| 50          | 6                | 0                     | 0                | 2                     | 0                     | 15               | 5                | 26               | 2                | 0                | 0                | 0                | 37               | 0                | 0                | 1                | 0                | 1                | 8                | 169              | 0                | 31               | 0                | 0                |
| 51          | 0                | 0                     | 0                | 0                     | 0                     | 31               | 6                | 1                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 13               | 0                | 1                | 0                | 0                |
| 52          | 0                | 0                     | 0                | 0                     | 0                     | 15               | 7                | 1                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 6                | 0                | 0                | 0                | 0                |
| 53          | 0                | 0                     | 0                | 0                     | 0                     | 16               | 2                | 4                | 0                | 0                | 0                | 0                | 1                | 0                | 0                | 0                | 0                | 0                | 0                | 3                | 0                | 0                | 0                | 0                |
| 54          | 0                | 0                     | 0                | 0                     | 0                     | 14               | 4                | 3                | 0                | 0                | 0                | 0                | 1                | 0                | 0                | 0                | 0                | 0                | 0                | 9                | 0                | 0                | 0                | 0                |

# Appendix C.2 (continued).

| OBS | SITE | DATEREPT | BARET | LEPTN | CAEN | HEXP | HXP | S  | C | E | T | I | H | O  | N | E | D | D | C | C |
|-----|------|----------|-------|-------|------|------|-----|----|---|---|---|---|---|----|---|---|---|---|---|---|
| S   | E    | E        | P     | T     | N    | A    | T   | P  | O | L | U | P | R | R  | T | I | I | I | O | Y |
| 55  | AFB2 | 30JUN88  | 5     | 0     | 0    | 0    | 0   | 0  | 0 | 0 | 0 | 0 | 0 | 0  | 0 | 0 | 0 | 0 | 0 | 0 |
| 56  | AFB2 | 14JUL88  | 1     | 17    | 0    | 1    | 72  | 5  | 0 | 1 | 0 | 0 | 0 | 2  | 0 | 2 | 0 | 5 | 0 | 0 |
| 57  | AFB2 | 14JUL88  | 2     | 48    | 0    | 2    | 38  | 12 | 0 | 9 | 0 | 0 | 0 | 0  | 0 | 1 | 0 | 1 | 0 | 0 |
| 58  | AFB2 | 14JUL88  | 3     | 6     | 1    | 0    | 8   | 2  | 0 | 0 | 0 | 1 | 0 | 0  | 0 | 0 | 0 | 3 | 0 | 0 |
| 59  | AFB2 | 14JUL88  | 4     | 13    | 0    | 1    | 27  | 19 | 0 | 1 | 0 | 0 | 0 | 4  | 0 | 1 | 0 | 1 | 0 | 0 |
| 60  | AFB2 | 14JUL88  | 5     | 1     | 0    | 1    | 3   | 1  | 0 | 0 | 0 | 0 | 0 | 0  | 0 | 0 | 0 | 1 | 0 | 0 |
| 61  | AFB2 | 28JUL88  | 1     | 2     | 2    | 2    | 0   | 2  | 0 | 0 | 0 | 0 | 0 | 0  | 0 | 1 | 0 | 8 | 0 | 0 |
| 62  | AFB2 | 28JUL88  | 2     | 0     | 1    | 0    | 0   | 0  | 0 | 0 | 0 | 0 | 0 | 0  | 0 | 0 | 0 | 0 | 0 | 0 |
| 63  | AFB2 | 28JUL88  | 3     | 0     | 1    | 0    | 0   | 0  | 0 | 0 | 0 | 0 | 0 | 0  | 0 | 0 | 0 | 2 | 0 | 0 |
| 64  | AFB2 | 28JUL88  | 4     | 0     | 0    | 0    | 0   | 1  | 0 | 0 | 0 | 0 | 0 | 0  | 0 | 0 | 0 | 0 | 0 | 0 |
| 65  | AFB2 | 28JUL88  | 5     | 7     | 2    | 0    | 0   | 8  | 0 | 0 | 0 | 0 | 0 | 4  | 0 | 1 | 0 | 1 | 0 | 0 |
| 66  | AFB2 | 11AUG88  | 1     | 32    | 2    | 4    | 10  | 0  | 0 | 2 | 0 | 0 | 0 | 0  | 0 | 1 | 0 | 2 | 0 | 0 |
| 67  | AFB2 | 11AUG88  | 2     | 18    | 2    | 3    | 4   | 3  | 0 | 0 | 0 | 0 | 0 | 0  | 0 | 1 | 0 | 2 | 0 | 0 |
| 68  | AFB2 | 11AUG88  | 3     | 65    | 148  | 8    | 3   | 9  | 0 | 0 | 0 | 0 | 0 | 22 | 0 | 2 | 0 | 5 | 0 | 0 |
| 69  | AFB2 | 11AUG88  | 4     | 18    | 0    | 6    | 19  | 1  | 0 | 1 | 0 | 0 | 0 | 1  | 0 | 2 | 0 | 1 | 0 | 0 |
| 70  | AFB2 | 11AUG88  | 5     | 25    | 20   | 3    | 6   | 3  | 0 | 3 | 0 | 0 | 0 | 0  | 1 | 0 | 0 | 4 | 0 | 0 |
| 71  | AFB2 | 25AUG88  | 1     | 43    | 28   | 11   | 0   | 11 | 0 | 0 | 0 | 0 | 0 | 15 | 2 | 2 | 0 | 1 | 0 | 0 |
| 72  | AFB2 | 25AUG88  | 2     | 52    | 68   | 22   | 0   | 6  | 0 | 4 | 0 | 0 | 0 | 2  | 0 | 0 | 0 | 1 | 0 | 0 |

| OBS | S | S | T | C | C | C | T  | O  | T | E | C | G | A | L | P | P | S | G  | O  | O  | H | N  | A | D |
|-----|---|---|---|---|---|---|----|----|---|---|---|---|---|---|---|---|---|----|----|----|---|----|---|---|
| S   | U | A | U | A | U | I | T  | H  | P | Y | L | T | Y | N | S | N | A | M  | M  | G  | U | A  | R | E |
| 55  | 0 | 0 | 0 | 0 | 1 | 8 | 6  | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0  | 0  | 8  | 0 | 7  | 0 | 0 |
| 56  | 3 | 0 | 0 | 4 | 0 | 2 | 5  | 6  | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0  | 3  | 21 | 1 | 4  | 0 | 0 |
| 57  | 0 | 0 | 0 | 0 | 3 | 1 | 0  | 1  | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 2  | 19 | 1  | 0 | 0  | 0 | 0 |
| 58  | 0 | 0 | 0 | 1 | 2 | 1 | 3  | 4  | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 2  | 0  | 6  | 0 | 1  | 0 | 0 |
| 59  | 0 | 0 | 0 | 1 | 4 | 8 | 5  | 2  | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 3  | 8  | 6  | 1 | 0  | 0 | 0 |
| 60  | 0 | 0 | 0 | 1 | 0 | 5 | 52 | 5  | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1  | 0  | 11 | 0 | 16 | 0 | 0 |
| 61  | 0 | 0 | 0 | 0 | 3 | 1 | 10 | 2  | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7  | 1  | 11 | 0 | 1  | 0 | 0 |
| 62  | 0 | 0 | 0 | 0 | 0 | 2 | 25 | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1  | 0  | 4  | 0 | 0  | 0 | 0 |
| 63  | 0 | 0 | 0 | 0 | 1 | 2 | 5  | 1  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1  | 0  | 1  | 0 | 0  | 0 | 0 |
| 64  | 0 | 0 | 0 | 0 | 1 | 0 | 7  | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0  | 0  | 1  | 0 | 0  | 0 | 0 |
| 65  | 0 | 0 | 0 | 0 | 0 | 1 | 12 | 1  | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 4  | 1  | 4  | 0 | 0  | 0 | 0 |
| 66  | 2 | 0 | 0 | 3 | 2 | 0 | 19 | 2  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1  | 1  | 1  | 0 | 0  | 0 | 0 |
| 67  | 3 | 0 | 0 | 2 | 2 | 0 | 9  | 2  | 2 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 4  | 1  | 3  | 0 | 1  | 0 | 0 |
| 68  | 2 | 0 | 0 | 0 | 0 | 0 | 11 | 20 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 79 | 5  | 4  | 0 | 0  | 0 | 0 |
| 69  | 2 | 0 | 0 | 0 | 0 | 0 | 7  | 3  | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0  | 2  | 0  | 0 | 0  | 0 | 0 |
| 70  | 1 | 0 | 0 | 5 | 0 | 0 | 12 | 5  | 3 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 3  | 2  | 8  | 0 | 3  | 0 | 0 |
| 71  | 1 | 0 | 0 | 0 | 1 | 0 | 19 | 18 | 3 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 22 | 0  | 28 | 0 | 0  | 2 | 0 |
| 72  | 0 | 0 | 0 | 2 | 5 | 6 | 61 | 17 | 5 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 11 | 0  | 17 | 0 | 0  | 2 | 0 |

# Appendix C.2 (continued).

| OBS | SITE  | DATEREPT | BAREPT | LEPT  | CAREN | MHEXP | MHEATP | SALANOL | ETALUP | IONCELR | ONCELR | EDUY | EDUY | CCENRY |     |     |     |     |     |     |     |   |   |   |
|-----|-------|----------|--------|-------|-------|-------|--------|---------|--------|---------|--------|------|------|--------|-----|-----|-----|-----|-----|-----|-----|---|---|---|
| 73  | AFB2  | 25AUG88  | 3      | 33    | 76    | 84    | 1      | 3       | 0      | 4       | 0      | 0    | 0    | 17     | 0   | 5   | 0   | 12  | 0   | 0   | 0   |   |   |   |
| 74  | AFB2  | 25AUG88  | 4      | 40    | 46    | 57    | 90     | 1       | 0      | 16      | 0      | 0    | 0    | 0      | 0   | 4   | 0   | 21  | 0   | 0   | 0   |   |   |   |
| 75  | AFB2  | 25AUG88  | 5      | 75    | 70    | 38    | 164    | 3       | 0      | 16      | 0      | 0    | 0    | 0      | 2   | 2   | 0   | 5   | 0   | 0   | 1   |   |   |   |
| 76  | AFB2  | 16SEP88  | 1      | 11    | 13    | 6     | 64     | 1       | 0      | 1       | 0      | 0    | 0    | 0      | 1   | 3   | 0   | 4   | 0   | 0   | 0   |   |   |   |
| 77  | AFB2  | 16SEP88  | 2      | 21    | 29    | 10    | 38     | 4       | 1      | 1       | 0      | 0    | 0    | 1      | 0   | 1   | 0   | 1   | 0   | 0   | 1   |   |   |   |
| 78  | AFB2  | 16SEP88  | 3      | 5     | 6     | 4     | 13     | 2       | 0      | 8       | 0      | 0    | 0    | 0      | 0   | 1   | 0   | 1   | 0   | 0   | 0   |   |   |   |
| 79  | AFB2  | 16SEP88  | 4      | 1     | 10    | 7     | 28     | 0       | 0      | 5       | 0      | 0    | 0    | 0      | 0   | 0   | 0   | 2   | 0   | 0   | 0   |   |   |   |
| 80  | AFB2  | 16SEP88  | 5      | 7     | 5     | 3     | 39     | 0       | 0      | 5       | 0      | 0    | 0    | 0      | 0   | 1   | 0   | 6   | 0   | 0   | 0   |   |   |   |
| 81  | AFB2  | 16OCT88  | 1      | 10    | 27    | 30    | 6      | 0       | 0      | 0       | 0      | 4    | 0    | 2      | 0   | 0   | 0   | 8   | 0   | 0   | 0   |   |   |   |
| 82  | AFB2  | 16OCT88  | 2      | 11    | 23    | 6     | 4      | 1       | 0      | 0       | 0      | 1    | 0    | 0      | 0   | 0   | 0   | 0   | 0   | 0   | 1   |   |   |   |
| 83  | AFB2  | 16OCT88  | 3      | 0     | 3     | 3     | 1      | 0       | 0      | 0       | 0      | 0    | 0    | 1      | 0   | 0   | 0   | 0   | 0   | 0   | 0   |   |   |   |
| 84  | AFB2  | 16OCT88  | 4      | 7     | 23    | 8     | 0      | 1       | 0      | 0       | 0      | 4    | 0    | 2      | 0   | 0   | 0   | 2   | 0   | 0   | 0   |   |   |   |
| 85  | AFB2  | 16OCT88  | 5      | 3     | 31    | 12    | 38     | 0       | 0      | 0       | 0      | 0    | 0    | 0      | 0   | 1   | 0   | 4   | 0   | 0   | 1   |   |   |   |
| 86  | AFB3  | 16JUN88  | 1      | 0     | 0     | 0     | 0      | 0       | 0      | 0       | 0      | 0    | 0    | 0      | 0   | 0   | 0   | 0   | 0   | 0   | 0   |   |   |   |
| 87  | AFB3  | 16JUN88  | 2      | 2     | 0     | 0     | 2      | 0       | 0      | 0       | 0      | 0    | 0    | 0      | 0   | 0   | 0   | 0   | 0   | 0   | 1   |   |   |   |
| 88  | AFB3  | 16JUN88  | 3      | 13    | 0     | 3     | 21     | 1       | 0      | 0       | 0      | 0    | 0    | 0      | 0   | 0   | 0   | 1   | 0   | 0   | 2   |   |   |   |
| 89  | AFB3  | 16JUN88  | 4      | 1     | 0     | 0     | 4      | 0       | 0      | 0       | 0      | 0    | 0    | 0      | 0   | 0   | 0   | 0   | 0   | 0   | 0   |   |   |   |
| 90  | AFB3  | 16JUN88  | 5      | 28    | 0     | 3     | 138    | 7       | 0      | 1       | 0      | 0    | 0    | 0      | 0   | 0   | 0   | 1   | 0   | 0   | 2   |   |   |   |
| OBS | STIRP | CTEHN    | CTEHN  | CTEHN | OTEN  | OTEN  | OTEN   | OTEN    | OTEN   | ALP     | ALP    | ALP  | ALP  | ALP    | ALP | ALP | ALP | ALP | ALP | ALP | ALP |   |   |   |
| 73  | 0     | 0        | 0      | 2     | 2     | 0     | 16     | 13      | 7      | 0       | 0      | 0    | 3    | 0      | 0   | 0   | 0   | 28  | 0   | 22  | 0   | 1 | 0 | 0 |
| 74  | 3     | 0        | 0      | 1     | 1     | 3     | 10     | 14      | 4      | 0       | 0      | 0    | 8    | 0      | 0   | 0   | 0   | 2   | 0   | 2   | 1   | 0 | 0 | 0 |
| 75  | 0     | 0        | 0      | 0     | 0     | 0     | 12     | 9       | 1      | 0       | 0      | 0    | 6    | 0      | 0   | 0   | 0   | 3   | 1   | 2   | 0   | 0 | 0 | 0 |
| 76  | 0     | 0        | 0      | 1     | 0     | 1     | 3      | 18      | 1      | 0       | 0      | 0    | 1    | 0      | 0   | 0   | 0   | 0   | 1   | 0   | 0   | 0 | 0 | 0 |
| 77  | 51    | 0        | 0      | 4     | 0     | 2     | 5      | 24      | 0      | 0       | 0      | 0    | 4    | 0      | 0   | 0   | 0   | 3   | 0   | 3   | 1   | 0 | 0 | 0 |
| 78  | 1     | 0        | 0      | 1     | 0     | 0     | 0      | 11      | 1      | 0       | 0      | 0    | 0    | 0      | 0   | 0   | 0   | 0   | 4   | 0   | 0   | 0 | 0 | 0 |
| 79  | 0     | 0        | 0      | 0     | 1     | 5     | 4      | 9       | 0      | 0       | 0      | 0    | 0    | 0      | 0   | 0   | 0   | 0   | 3   | 0   | 0   | 0 | 0 | 0 |
| 80  | 0     | 0        | 0      | 5     | 0     | 2     | 2      | 23      | 0      | 0       | 0      | 0    | 0    | 0      | 0   | 0   | 0   | 1   | 2   | 2   | 0   | 0 | 0 | 0 |
| 81  | 70    | 0        | 0      | 28    | 6     | 15    | 59     | 44      | 0      | 0       | 0      | 0    | 5    | 0      | 0   | 0   | 0   | 2   | 0   | 0   | 0   | 1 | 1 | 0 |
| 82  | 4     | 0        | 0      | 5     | 0     | 18    | 9      | 14      | 0      | 0       | 0      | 0    | 0    | 0      | 0   | 0   | 0   | 0   | 0   | 9   | 0   | 1 | 2 | 0 |
| 83  | 3     | 0        | 0      | 1     | 0     | 8     | 3      | 6       | 0      | 0       | 0      | 0    | 0    | 0      | 0   | 0   | 0   | 0   | 0   | 1   | 0   | 4 | 0 | 0 |
| 84  | 38    | 0        | 0      | 0     | 2     | 16    | 14     | 37      | 1      | 0       | 0      | 0    | 1    | 0      | 0   | 0   | 0   | 1   | 0   | 33  | 0   | 1 | 6 | 0 |
| 85  | 0     | 0        | 0      | 11    | 0     | 1     | 2      | 8       | 0      | 0       | 0      | 0    | 2    | 0      | 0   | 0   | 0   | 0   | 2   | 4   | 0   | 4 | 1 | 0 |
| 86  | 0     | 0        | 0      | 0     | 2     | 3     | 0      | 4       | 0      | 0       | 0      | 0    | 0    | 0      | 0   | 0   | 0   | 0   | 0   | 1   | 0   | 2 | 0 | 0 |
| 87  | 0     | 0        | 0      | 0     | 2     | 28    | 4      | 14      | 0      | 0       | 0      | 0    | 0    | 0      | 0   | 0   | 0   | 0   | 0   | 10  | 0   | 3 | 0 | 0 |
| 88  | 4     | 0        | 0      | 0     | 3     | 7     | 3      | 17      | 2      | 0       | 0      | 1    | 11   | 0      | 2   | 0   | 0   | 2   | 0   | 20  | 0   | 7 | 1 | 0 |
| 89  | 0     | 0        | 0      | 0     | 1     | 11    | 3      | 13      | 0      | 0       | 0      | 0    | 0    | 0      | 0   | 0   | 0   | 0   | 0   | 10  | 0   | 3 | 1 | 0 |
| 90  | 6     | 0        | 0      | 0     | 1     | 2     | 3      | 25      | 0      | 0       | 0      | 2    | 35   | 0      | 0   | 0   | 0   | 5   | 1   | 149 | 0   | 0 | 1 | 0 |

# Appendix C.2 (continued).

| OBS | SITE | DATEREP | BAREP | LEP | CAEN | HEXAT | HEP | SEMP | CALPO | ENALU | TASOP | ISODR | HCNRT | ELMI | DUBII | DYTI | CEN | CHRY |
|-----|------|---------|-------|-----|------|-------|-----|------|-------|-------|-------|-------|-------|------|-------|------|-----|------|
| 91  | AFB3 | 30JUN88 | 1     | 1   | 0    | 0     | 3   | 0    | 0     | 0     | 0     | 0     | 0     | 0    | 0     | 0    | 0   | 2    |
| 92  | AFB3 | 30JUN88 | 2     | 0   | 0    | 0     | 1   | 0    | 0     | 0     | 0     | 0     | 0     | 0    | 0     | 0    | 0   | 1    |
| 93  | AFB3 | 30JUN88 | 3     | 0   | 0    | 0     | 0   | 0    | 0     | 0     | 0     | 0     | 0     | 0    | 0     | 0    | 0   | 0    |
| 94  | AFB3 | 30JUN88 | 4     | 0   | 0    | 1     | 0   | 1    | 0     | 0     | 0     | 0     | 0     | 0    | 0     | 2    | 0   | 0    |
| 95  | AFB3 | 30JUN88 | 5     | 0   | 0    | 0     | 0   | 0    | 0     | 0     | 0     | 0     | 0     | 0    | 0     | 0    | 0   | 0    |
| 96  | AFB3 | 14JUL88 | 1     | 7   | 0    | 0     | 1   | 0    | 0     | 0     | 0     | 0     | 0     | 0    | 0     | 0    | 0   | 2    |
| 97  | AFB3 | 14JUL88 | 2     | 2   | 0    | 0     | 3   | 0    | 0     | 0     | 0     | 0     | 0     | 1    | 0     | 0    | 0   | 1    |
| 98  | AFB3 | 14JUL88 | 3     | 32  | 0    | 0     | 46  | 2    | 0     | 0     | 0     | 0     | 1     | 0    | 0     | 1    | 0   | 1    |
| 99  | AFB3 | 14JUL88 | 4     | 1   | 0    | 0     | 0   | 0    | 0     | 0     | 0     | 0     | 0     | 0    | 0     | 0    | 0   | 0    |
| 100 | AFB3 | 14JUL88 | 5     | 1   | 0    | 0     | 6   | 0    | 0     | 0     | 0     | 0     | 0     | 0    | 0     | 0    | 0   | 2    |
| 101 | AFB3 | 28JUL88 | 1     | 0   | 0    | 0     | 0   | 0    | 0     | 0     | 0     | 0     | 0     | 0    | 1     | 0    | 0   | 2    |
| 102 | AFB3 | 28JUL88 | 2     | 5   | 0    | 0     | 2   | 0    | 0     | 0     | 0     | 0     | 0     | 0    | 0     | 0    | 0   | 2    |
| 103 | AFB3 | 28JUL88 | 3     | 0   | 0    | 0     | 2   | 0    | 0     | 0     | 0     | 0     | 0     | 0    | 0     | 0    | 0   | 4    |
| 104 | AFB3 | 28JUL88 | 4     | 7   | 0    | 0     | 0   | 0    | 0     | 0     | 0     | 0     | 0     | 0    | 1     | 0    | 0   | 2    |
| 105 | AFB3 | 28JUL88 | 5     | 11  | 0    | 0     | 0   | 0    | 0     | 2     | 1     | 0     | 0     | 0    | 1     | 0    | 0   | 0    |
| 106 | AFB3 | 11AUG88 | 1     | 0   | 0    | 0     | 0   | 0    | 0     | 0     | 0     | 0     | 0     | 0    | 0     | 0    | 0   | 0    |
| 107 | AFB3 | 11AUG88 | 2     | 14  | 4    | 1     | 4   | 1    | 0     | 4     | 0     | 0     | 0     | 0    | 0     | 0    | 0   | 0    |
| 108 | AFB3 | 11AUG88 | 3     | 4   | 0    | 1     | 1   | 3    | 0     | 0     | 0     | 0     | 0     | 0    | 2     | 0    | 0   | 0    |

| OBS | SSIT | CC | C | T | O | T  | E  | C  | G | A | L | P | P | S | G | O | O  | N | N | A | D |
|-----|------|----|---|---|---|----|----|----|---|---|---|---|---|---|---|---|----|---|---|---|---|
| S   | U    | A  | U | A | U | I  | T  | H  | P | Y | L | T | Y | N | S | N | G  | I | R | M | A |
| 91  | 0    | 0  | 0 | 0 | 0 | 8  | 18 | 2  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2  | 0 | 0 | 0 | 0 |
| 92  | 0    | 0  | 0 | 0 | 0 | 1  | 0  | 1  | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 3  | 0 | 2 | 0 | 0 |
| 93  | 0    | 0  | 0 | 0 | 0 | 3  | 0  | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1  | 0 | 2 | 0 | 0 |
| 94  | 0    | 0  | 0 | 0 | 0 | 15 | 24 | 2  | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 0  | 4 | 0 | 0 | 0 |
| 95  | 0    | 0  | 0 | 0 | 1 | 5  | 5  | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7  | 0 | 4 | 0 | 0 |
| 96  | 0    | 0  | 0 | 0 | 0 | 2  | 4  | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6  | 0 | 4 | 0 | 0 |
| 97  | 0    | 0  | 0 | 0 | 0 | 0  | 1  | 1  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0  | 0 | 0 | 0 | 0 |
| 98  | 1    | 0  | 0 | 0 | 0 | 0  | 7  | 11 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 1  | 5 | 0 | 0 | 0 |
| 99  | 0    | 0  | 0 | 0 | 0 | 0  | 4  | 3  | 0 | 0 | 0 | 0 | 2 | 3 | 0 | 9 | 0  | 0 | 0 | 2 | 0 |
| 100 | 0    | 0  | 0 | 0 | 0 | 0  | 0  | 1  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0  | 2 | 0 | 2 | 0 |
| 101 | 0    | 0  | 0 | 0 | 0 | 1  | 3  | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0  | 0 | 1 | 0 | 0 |
| 102 | 0    | 0  | 0 | 0 | 0 | 0  | 6  | 4  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0  | 0 | 1 | 0 | 0 |
| 103 | 0    | 0  | 0 | 0 | 2 | 0  | 5  | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0  | 2 | 0 | 2 | 0 |
| 104 | 0    | 0  | 0 | 0 | 0 | 0  | 4  | 2  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0  | 1 | 0 | 0 | 0 |
| 105 | 1    | 0  | 0 | 1 | 2 | 1  | 8  | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0  | 0 | 0 | 0 | 0 |
| 106 | 0    | 0  | 0 | 0 | 0 | 0  | 4  | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0  | 0 | 0 | 0 | 0 |
| 107 | 0    | 0  | 0 | 0 | 0 | 0  | 10 | 2  | 1 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 18 | 0 | 0 | 0 | 0 |
| 108 | 0    | 0  | 0 | 0 | 0 | 1  | 0  | 0  | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3  | 0 | 0 | 0 | 0 |

# Appendix C.2 (continued).

| O<br>B<br>S | S<br>I<br>T<br>E | D<br>A<br>T<br>E | R<br>E<br>P | B<br>A<br>S<br>E | L<br>E<br>P<br>T | C<br>A<br>P<br>T | H<br>E<br>X<br>A | H<br>E<br>P<br>T | S<br>Y<br>M<br>P | C<br>A<br>L<br>P | E<br>N<br>A<br>L | T<br>A<br>B<br>U | I<br>S<br>O<br>P | H<br>Y<br>D<br>R | O<br>C<br>H<br>R | N<br>E<br>C<br>T | E<br>L<br>M<br>I | D<br>U<br>B<br>I | D<br>Y<br>T<br>I | C<br>E<br>N<br>O | C<br>N<br>R<br>Y |
|-------------|------------------|------------------|-------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| 109         | AFB3             | 11AUG88          | 4           | 4                | 0                | 12               | 1                | 3                | 0                | 2                | 0                | 0                | 0                | 2                | 0                | 2                | 0                | 3                | 0                | 0                | 2                |
| 110         | AFB3             | 11AUG88          | 5           | 1                | 0                | 0                | 1                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 1                | 0                | 0                | 0                |
| 111         | AFB3             | 25AUG88          | 1           | 1                | 0                | 0                | 9                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                |
| 112         | AFB3             | 25AUG88          | 2           | 19               | 0                | 1                | 1                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 1                | 0                | 1                | 0                | 0                | 0                |
| 113         | AFB3             | 25AUG88          | 3           | 1                | 0                | 0                | 5                | 1                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 1                | 0                | 0                | 0                |
| 114         | AFB3             | 25AUG88          | 4           | 0                | 0                | 1                | 5                | 0                | 0                | 0                | 0                | 0                | 0                | 1                | 0                | 0                | 0                | 0                | 0                | 0                | 0                |
| 115         | AFB3             | 25AUG88          | 5           | 25               | 5                | 8                | 6                | 1                | 0                | 4                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 1                | 0                | 0                | 0                |
| 116         | AFB3             | 16SEP88          | 1           | 22               | 7                | 11               | 45               | 2                | 0                | 2                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 1                | 0                | 0                | 0                |
| 117         | AFB3             | 16SEP88          | 2           | 6                | 0                | 0                | 41               | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 1                |
| 118         | AFB3             | 16SEP88          | 3           | 1                | 0                | 0                | 13               | 0                | 0                | 1                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                |
| 119         | AFB3             | 16SEP88          | 4           | 0                | 1                | 1                | 2                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                |
| 120         | AFB3             | 16SEP88          | 5           | 9                | 12               | 13               | 49               | 2                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 1                | 0                | 3                | 0                | 0                | 2                |
| 121         | AFB3             | 16OCT88          | 1           | 0                | 0                | 0                | 10               | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                |
| 122         | AFB3             | 16OCT88          | 2           | 0                | 0                | 0                | 14               | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                |
| 123         | AFB3             | 16OCT88          | 3           | 0                | 6                | 3                | 30               | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 3                | 0                | 2                | 0                |
| 124         | AFB3             | 16OCT88          | 4           | 0                | 1                | 0                | 3                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                |
| 125         | AFB3             | 16OCT88          | 5           | 0                | 17               | 3                | 30               | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 1                | 0                | 0                | 1                |

| O<br>B<br>S | S<br>I<br>T<br>E | S<br>T<br>A<br>T<br>E | C<br>I<br>T<br>Y | C<br>O<br>U<br>N<br>T | C<br>O<br>U<br>N<br>T | T<br>O<br>T<br>A<br>L | O<br>T<br>H<br>E<br>R | E<br>C<br>C<br>E<br>N<br>T | G<br>A<br>L<br>L<br>E<br>R<br>Y | A<br>L<br>P<br>H<br>A | P<br>P<br>L<br>E | S<br>P<br>A<br>C<br>E | O<br>O<br>R<br>D<br>I<br>N<br>A<br>T<br>E | H<br>I<br>S<br>T<br>O<br>R<br>Y | N<br>E<br>W<br>S | A<br>D<br>D<br>I<br>T<br>I<br>O<br>N | D<br>U<br>B<br>I<br>T |
|-------------|------------------|-----------------------|------------------|-----------------------|-----------------------|-----------------------|-----------------------|----------------------------|---------------------------------|-----------------------|------------------|-----------------------|-------------------------------------------|---------------------------------|------------------|--------------------------------------|-----------------------|
| 109         | 1                | 0                     | 0                | 4                     | 2                     | 2                     | 27                    | 4                          | 0                               | 0                     | 0                | 0                     | 4                                         | 0                               | 0                | 0                                    | 0                     |
| 110         | 0                | 0                     | 0                | 0                     | 0                     | 0                     | 3                     | 3                          | 0                               | 0                     | 0                | 0                     | 0                                         | 0                               | 0                | 0                                    | 0                     |
| 111         | 0                | 0                     | 0                | 0                     | 0                     | 0                     | 2                     | 0                          | 0                               | 0                     | 0                | 0                     | 0                                         | 0                               | 0                | 0                                    | 0                     |
| 112         | 0                | 0                     | 0                | 0                     | 1                     | 0                     | 1                     | 0                          | 0                               | 0                     | 0                | 1                     | 0                                         | 0                               | 0                | 0                                    | 0                     |
| 113         | 0                | 0                     | 0                | 0                     | 0                     | 0                     | 3                     | 0                          | 0                               | 0                     | 0                | 0                     | 0                                         | 0                               | 0                | 1                                    | 0                     |
| 114         | 0                | 0                     | 0                | 0                     | 0                     | 0                     | 5                     | 1                          | 0                               | 1                     | 0                | 0                     | 0                                         | 0                               | 0                | 0                                    | 0                     |
| 115         | 0                | 0                     | 0                | 1                     | 1                     | 0                     | 2                     | 2                          | 1                               | 0                     | 0                | 0                     | 10                                        | 0                               | 0                | 0                                    | 0                     |
| 116         | 3                | 0                     | 0                | 0                     | 0                     | 1                     | 2                     | 40                         | 0                               | 0                     | 0                | 0                     | 0                                         | 0                               | 0                | 0                                    | 0                     |
| 117         | 1                | 0                     | 0                | 2                     | 1                     | 1                     | 0                     | 8                          | 0                               | 0                     | 0                | 0                     | 0                                         | 0                               | 0                | 0                                    | 0                     |
| 118         | 0                | 0                     | 0                | 1                     | 0                     | 0                     | 12                    | 14                         | 0                               | 0                     | 0                | 0                     | 0                                         | 0                               | 0                | 0                                    | 0                     |
| 119         | 1                | 0                     | 0                | 0                     | 0                     | 0                     | 2                     | 6                          | 0                               | 0                     | 0                | 0                     | 1                                         | 0                               | 0                | 0                                    | 0                     |
| 120         | 4                | 0                     | 0                | 4                     | 1                     | 0                     | 2                     | 19                         | 0                               | 0                     | 0                | 0                     | 4                                         | 0                               | 0                | 0                                    | 0                     |
| 121         | 0                | 0                     | 0                | 1                     | 0                     | 2                     | 3                     | 10                         | 0                               | 0                     | 0                | 0                     | 0                                         | 0                               | 0                | 0                                    | 3                     |
| 122         | 0                | 0                     | 0                | 1                     | 0                     | 1                     | 2                     | 2                          | 0                               | 0                     | 0                | 0                     | 0                                         | 0                               | 0                | 0                                    | 1                     |
| 123         | 0                | 0                     | 0                | 2                     | 0                     | 4                     | 1                     | 13                         | 1                               | 0                     | 0                | 0                     | 0                                         | 0                               | 0                | 5                                    | 2                     |
| 124         | 0                | 0                     | 0                | 0                     | 0                     | 1                     | 1                     | 2                          | 0                               | 0                     | 0                | 0                     | 0                                         | 0                               | 0                | 0                                    | 0                     |
| 125         | 0                | 0                     | 0                | 0                     | 0                     | 3                     | 2                     | 5                          | 0                               | 0                     | 0                | 0                     | 1                                         | 0                               | 0                | 0                                    | 0                     |

# Appendix C.2 (continued).

## Hester-Dendy Data

|    | S    | D       | B | C  | H  | L   | I  | T  | A | T | I  | C | H | O | N | P | P | S | D |
|----|------|---------|---|----|----|-----|----|----|---|---|----|---|---|---|---|---|---|---|---|
| O  | I    | A       | A | A  | E  | E   | S  | R  | R | A | S  | H | Y | C | E | T | O | I | U |
| B  | T    | T       | E | E  | P  | P   | O  | I  | G | B | O  | E | D | H | C | L | L | A | B |
| S  | E    | E       | P | T  | T  | T   | N  | C  | I | U | P  | U | R | R | T | Y | L | L | I |
| 1  | AFB1 | 12JUL89 | 1 | 12 | 3  | 160 | 0  | 3  | 0 | 0 | 0  | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 2  | AFB1 | 12JUL89 | 2 | 10 | 10 | 183 | 0  | 14 | 0 | 0 | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3  | AFB1 | 12JUL89 | 3 | 1  | 10 | 73  | 0  | 0  | 0 | 0 | 0  | 0 | 0 | 0 | 0 | 0 | 2 | 4 | 0 |
| 4  | AFB1 | 12JUL89 | 4 | 29 | 14 | 115 | 0  | 6  | 0 | 0 | 0  | 0 | 0 | 1 | 0 | 0 | 0 | 3 | 1 |
| 5  | AFB1 | 12JUL89 | 5 | 33 | 3  | 168 | 0  | 7  | 0 | 0 | 0  | 0 | 0 | 0 | 2 | 0 | 2 | 0 | 0 |
| 6  | AFB1 | 21OCT89 | 1 | 0  | 0  | 4   | 77 | 0  | 1 | 0 | 43 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7  | AFB1 | 21OCT89 | 2 | 11 | 1  | 6   | 52 | 0  | 0 | 0 | 43 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 8  | AFB1 | 21OCT89 | 3 | 0  | 2  | 8   | 78 | 0  | 0 | 0 | 37 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9  | AFB1 | 21OCT89 | 4 | 0  | 0  | 6   | 52 | 0  | 0 | 0 | 35 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| 10 | AFB1 | 21OCT89 | 5 | 0  | 0  | 3   | 48 | 0  | 0 | 0 | 25 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 0 |
| 11 | AFB1 | 06FEB90 | 1 | 0  | 0  | 0   | 1  | 0  | 0 | 0 | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | AFB1 | 06FEB90 | 2 | 0  | 0  | 0   | 0  | 0  | 0 | 0 | 2  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 13 | AFB1 | 06FEB90 | 3 | 1  | 0  | 0   | 5  | 0  | 0 | 0 | 1  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | AFB1 | 06FEB90 | 4 | 1  | 0  | 0   | 9  | 0  | 0 | 0 | 7  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15 | AFB1 | 06FEB90 | 5 | 0  | 0  | 0   | 3  | 0  | 0 | 0 | 3  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 16 | AFB1 | 03MAY90 | 1 | 1  | 0  | 4   | 1  | 0  | 0 | 0 | 0  | 6 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 17 | AFB1 | 03MAY90 | 2 | 2  | 0  | 6   | 0  | 0  | 0 | 0 | 0  | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 18 | AFB1 | 03MAY90 | 3 | 2  | 0  | 0   | 0  | 0  | 0 | 0 | 0  | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

|    | S   | S | D | C | C  | C | T  | O   | T  | D  | H | A | P | P | G  | H | O | O  | H | N  | A | D |
|----|-----|---|---|---|----|---|----|-----|----|----|---|---|---|---|----|---|---|----|---|----|---|---|
| O  | I   | I | I | E | N  | N | N  | R   | N  | I  | E | N | H | L | A  | Y | R | L  | I | E  | C | U |
| B  | M   | M | C | R | P  | M | Y  | T   | Y  | A  | M | C | Y | A | M  | A | I | I  | R | M  | A | G |
| S  | I   | P | R | A | U  | I | T  | N   | P  | M  | E | Y | S | N | M  | L | M | G  | U | A  | R | E |
| 1  | 0   | 0 | 0 | 0 | 4  | 5 | 0  | 22  | 2  | 0  | 1 | 1 | 1 | 0 | 16 | 0 | 0 | 90 | 0 | 9  | 1 | 0 |
| 2  | 0   | 0 | 0 | 0 | 0  | 7 | 2  | 13  | 5  | 0  | 0 | 6 | 0 | 0 | 6  | 0 | 1 | 57 | 0 | 4  | 0 | 0 |
| 3  | 0   | 0 | 0 | 0 | 0  | 0 | 1  | 10  | 4  | 0  | 0 | 6 | 0 | 0 | 9  | 0 | 0 | 16 | 0 | 33 | 2 | 0 |
| 4  | 0   | 0 | 0 | 0 | 3  | 2 | 4  | 95  | 18 | 0  | 1 | 6 | 0 | 0 | 38 | 0 | 1 | 94 | 0 | 7  | 3 | 0 |
| 5  | 0   | 0 | 0 | 0 | 1  | 1 | 6  | 36  | 6  | 0  | 1 | 1 | 0 | 0 | 3  | 0 | 0 | 73 | 0 | 10 | 6 | 0 |
| 6  | 24  | 2 | 1 | 0 | 7  | 0 | 2  | 82  | 0  | 0  | 0 | 0 | 0 | 0 | 0  | 0 | 0 | 45 | 0 | 2  | 0 | 0 |
| 7  | 75  | 0 | 9 | 0 | 7  | 0 | 1  | 71  | 1  | 0  | 0 | 0 | 0 | 0 | 0  | 0 | 0 | 15 | 0 | 2  | 0 | 0 |
| 8  | 31  | 2 | 5 | 0 | 12 | 0 | 1  | 81  | 1  | 0  | 0 | 0 | 0 | 0 | 0  | 0 | 0 | 68 | 0 | 5  | 1 | 0 |
| 9  | 200 | 4 | 0 | 0 | 7  | 0 | 1  | 69  | 1  | 0  | 0 | 0 | 0 | 0 | 0  | 0 | 0 | 53 | 0 | 13 | 0 | 0 |
| 10 | 246 | 9 | 1 | 0 | 6  | 0 | 3  | 97  | 0  | 0  | 0 | 0 | 0 | 0 | 0  | 0 | 0 | 26 | 0 | 29 | 1 | 0 |
| 11 | 4   | 0 | 1 | 0 | 0  | 0 | 0  | 134 | 0  | 11 | 0 | 0 | 0 | 0 | 0  | 1 | 0 | 0  | 0 | 0  | 0 | 0 |
| 12 | 3   | 0 | 0 | 0 | 1  | 0 | 0  | 48  | 0  | 1  | 0 | 0 | 0 | 0 | 0  | 0 | 0 | 0  | 0 | 4  | 0 | 0 |
| 13 | 4   | 0 | 0 | 0 | 0  | 0 | 0  | 116 | 0  | 6  | 0 | 0 | 0 | 0 | 0  | 0 | 0 | 0  | 0 | 0  | 0 | 0 |
| 14 | 5   | 0 | 2 | 0 | 0  | 0 | 0  | 59  | 0  | 9  | 0 | 0 | 0 | 0 | 0  | 0 | 0 | 0  | 0 | 0  | 0 | 0 |
| 15 | 1   | 0 | 0 | 0 | 0  | 0 | 0  | 99  | 0  | 3  | 0 | 0 | 0 | 0 | 0  | 0 | 0 | 0  | 0 | 0  | 0 | 0 |
| 16 | 7   | 0 | 0 | 0 | 14 | 0 | 37 | 400 | 2  | 1  | 2 | 0 | 0 | 0 | 0  | 0 | 0 | 39 | 0 | 0  | 1 | 0 |
| 17 | 9   | 4 | 0 | 1 | 10 | 0 | 22 | 169 | 1  | 4  | 1 | 0 | 0 | 0 | 0  | 0 | 0 | 8  | 0 | 0  | 0 | 0 |
| 18 | 20  | 0 | 1 | 0 | 3  | 0 | 13 | 197 | 2  | 2  | 1 | 2 | 0 | 1 | 0  | 0 | 0 | 12 | 0 | 0  | 1 | 0 |

# Appendix C.2 (continued).

| O<br>B<br>S | S<br>I<br>T<br>E | D<br>A<br>T<br>E | R<br>E<br>P | B<br>A<br>E<br>T | C<br>A<br>E<br>N | H<br>E<br>P<br>T | L<br>E<br>P<br>T | I<br>S<br>O<br>N | T<br>R<br>I<br>C | A<br>R<br>G<br>I | T<br>A<br>B<br>U | I<br>S<br>O<br>P | C<br>H<br>E<br>U | H<br>Y<br>D<br>R | O<br>C<br>H<br>R | N<br>E<br>C<br>T | P<br>T<br>I<br>L | P<br>O<br>L<br>Y | S<br>I<br>A<br>L | D<br>U<br>B<br>I |
|-------------|------------------|------------------|-------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| 19          | AFB1             | 03MAY90          | 4           | 2                | 0                | 1                | 0                | 0                | 0                | 0                | 0                | 13               | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                |
| 20          | AFB1             | 03MAY90          | 5           | 1                | 0                | 14               | 0                | 0                | 0                | 0                | 0                | 7                | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                |
| 21          | AFB3             | 12JUL89          | 1           | 11               | 1                | 33               | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 8                | 2                | 0                | 0                | 0                | 0                | 1                |
| 22          | AFB3             | 12JUL89          | 2           | 13               | 0                | 74               | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 14               | 0                | 0                | 0                | 1                | 0                | 0                |
| 23          | AFB3             | 12JUL89          | 3           | 9                | 0                | 49               | 0                | 0                | 0                | 1                | 0                | 0                | 0                | 9                | 0                | 0                | 0                | 0                | 0                | 0                |
| 24          | AFB3             | 12JUL89          | 4           | 18               | 0                | 88               | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 39               | 0                | 0                | 0                | 0                | 0                | 0                |
| 25          | AFB3             | 12JUL89          | 5           | 10               | 0                | 35               | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 9                | 3                | 0                | 0                | 0                | 0                | 0                |
| 26          | AFB3             | 21OCT89          | 2           | 0                | 2                | 11               | 50               | 0                | 0                | 0                | 0                | 0                | 0                | 2                | 0                | 0                | 0                | 0                | 0                | 0                |
| 27          | AFB3             | 21OCT89          | 3           | 5                | 0                | 8                | 41               | 0                | 0                | 0                | 1                | 0                | 0                | 7                | 0                | 0                | 0                | 0                | 0                | 0                |
| 28          | AFB3             | 21OCT89          | 4           | 0                | 0                | 1                | 44               | 0                | 0                | 0                | 0                | 0                | 0                | 3                | 0                | 0                | 0                | 0                | 0                | 0                |
| 29          | AFB3             | 21OCT89          | 5           | 1                | 0                | 8                | 69               | 0                | 0                | 0                | 0                | 0                | 0                | 1                | 0                | 0                | 1                | 0                | 0                | 0                |
| 30          | AFB3             | 03MAY90          | 1           | 1                | 0                | 8                | 0                | 0                | 0                | 0                | 0                | 4                | 2                | 3                | 0                | 0                | 0                | 0                | 0                | 0                |
| 31          | AFB3             | 03MAY90          | 2           | 3                | 0                | 8                | 3                | 0                | 1                | 0                | 0                | 2                | 3                | 0                | 0                | 0                | 0                | 1                | 0                | 0                |
| 32          | AFB3             | 03MAY90          | 3           | 0                | 0                | 13               | 2                | 0                | 0                | 0                | 0                | 6                | 5                | 1                | 0                | 0                | 0                | 1                | 0                | 0                |
| 33          | AFB3             | 03MAY90          | 4           | 0                | 0                | 7                | 0                | 0                | 0                | 0                | 0                | 5                | 1                | 0                | 0                | 0                | 0                | 0                | 0                | 0                |
| 34          | AFB3             | 03MAY90          | 5           | 0                | 2                | 2                | 5                | 0                | 1                | 0                | 0                | 2                | 2                | 0                | 0                | 0                | 0                | 1                | 0                | 1                |

| OBS | SIM | SIMP | DIR | CE | CH | CN | TY | OTH | TMP | DIA | HME | ANC | PHY | PLA | GAM | HYA | ORL | OLIG | HIR | NEA | AC | DUG |
|-----|-----|------|-----|----|----|----|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|-----|-----|----|-----|
| 19  | 15  | 2    | 0   | 0  | 13 | 0  | 22 | 314 | 1   | 7   | 2   | 0   | 0   | 0   | 0   | 0   | 0   | 22   | 0   | 0   | 1  | 0   |
| 20  | 0   | 0    | 0   | 0  | 0  | 0  | 19 | 111 | 5   | 0   | 2   | 0   | 0   | 0   | 0   | 0   | 0   | 22   | 0   | 0   | 0  | 0   |
| 21  | 0   | 0    | 0   | 0  | 2  | 18 | 16 | 24  | 4   | 0   | 2   | 4   | 0   | 0   | 3   | 0   | 2   | 15   | 0   | 6   | 7  | 0   |
| 22  | 0   | 5    | 0   | 0  | 0  | 1  | 12 | 13  | 1   | 0   | 4   | 5   | 0   | 0   | 15  | 0   | 0   | 17   | 11  | 3   | 4  | 0   |
| 23  | 0   | 19   | 0   | 0  | 0  | 0  | 13 | 9   | 0   | 0   | 0   | 2   | 0   | 0   | 3   | 0   | 0   | 13   | 0   | 4   | 3  | 0   |
| 24  | 0   | 4    | 0   | 0  | 0  | 1  | 5  | 0   | 3   | 0   | 3   | 1   | 0   | 0   | 2   | 0   | 0   | 6    | 0   | 1   | 6  | 0   |
| 25  | 0   | 8    | 0   | 0  | 0  | 1  | 6  | 17  | 2   | 0   | 2   | 0   | 0   | 0   | 3   | 0   | 0   | 8    | 1   | 4   | 4  | 0   |
| 26  | 374 | 5    | 0   | 0  | 10 | 0  | 1  | 18  | 0   | 0   | 3   | 0   | 0   | 0   | 0   | 0   | 0   | 1    | 0   | 5   | 4  | 0   |
| 27  | 819 | 26   | 1   | 0  | 17 | 0  | 2  | 104 | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0    | 0   | 8   | 0  | 0   |
| 28  | 650 | 23   | 0   | 0  | 22 | 2  | 4  | 179 | 0   | 0   | 1   | 2   | 0   | 0   | 0   | 0   | 0   | 0    | 0   | 8   | 1  | 0   |
| 29  | 45  | 1    | 0   | 0  | 8  | 1  | 1  | 60  | 1   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0    | 0   | 2   | 1  | 0   |
| 30  | 16  | 4    | 0   | 0  | 9  | 0  | 32 | 491 | 4   | 5   | 1   | 0   | 0   | 0   | 0   | 0   | 0   | 8    | 0   | 0   | 0  | 0   |
| 31  | 15  | 6    | 0   | 0  | 5  | 0  | 64 | 328 | 9   | 3   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 9    | 0   | 0   | 1  | 0   |
| 32  | 2   | 6    | 0   | 0  | 9  | 0  | 10 | 305 | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 1    | 0   | 0   | 0  | 0   |
| 33  | 0   | 0    | 0   | 0  | 3  | 0  | 12 | 338 | 10  | 0   | 1   | 0   | 0   | 0   | 0   | 0   | 0   | 3    | 0   | 0   | 0  | 1   |
| 34  | 0   | 1    | 0   | 1  | 8  | 0  | 15 | 486 | 17  | 0   | 2   | 0   | 0   | 0   | 0   | 0   | 0   | 5    | 0   | 0   | 5  | 2   |



## Appendix D.1. Processing and analysis of field collected macroinvertebrate samples.

This appendix presents the methods for field collection of water chemistry and benthic macroinvertebrate samples, using Hester-Dendy multiple plate samples. Additionally, it summarizes macroinvertebrate sample processing methods. It is helpful to keep a field notebook in order to record site code, date, persons doing the field work, and any observations, comments and questions. Other sections of this appendix include a sample field checklist and data sheet (Appendix D.2), field and laboratory equipment list (Appendix D.3), a list of equipment vendors potential suppliers (Appendix D.4), and a benthic macroinvertebrate data sheet (Appendix D.5).

### Sentinel Sites

Two permanent sampling sites have been established at Agate Fossil Beds National Monument (AFBNM) for water quality monitoring, Site 1 (AFB1) near the western boundary of the AFBNM and Site 3 (AFB3) near the visitor's center. These sites are described in greater detail in Section 2 within the main body of this report. It is suggested that these two sites be marked with distinct, long-lasting site markers.

The following method to affix markers is modified from Voshell and Hiner (1990, Fig. D-1). The markers are 0.9 m (3 ft) high, 5 cm (2 inch) diameter PVC pipe and are secured to 102 cm (40 inch) long, 1.3 cm (1/2 inch) diameter sharpened steel rebar. Before going to the field, drill a 1 cm (5/16 inch) hole in the PVC about

30 cm (12 inches) from the bottom. Drive the rebar about 2/3 the length into the ground and attach a chain link to the rebar with a hose clamp. Pass a 0.6 x 7.6 cm (1/4 x 3 inch) hexhead bolt through the chain link and pre-drilled holes in the PVC pipe. Finally, attach an end cap to the PVC pipe. For greatest visibility, we suggest the PVC markers be white with black end caps.

### Water Chemistry

Water samples should be collected before the stream is disturbed by macroinvertebrate collecting. Collect samples in an area of flowing water, but not in areas so rapid as where the current causes splashes. Fill bottles by leaning from shore or standing in stream while leaning upstream so as not to disturb the stream bottom. Hold the bottle near the bottom and slant it slightly upstream to reduce the possibility of contamination by the operator. Many water quality samples need to be kept as cool as possible to protect their integrity. Additionally, other methods of sample preservation may be desired, including chemical addition or filtering. Consult with the laboratory doing the chemical analysis for preferred sampling methodology and sample preservation. After water samples have been taken, in situ measures, including temperature, pH, and dissolved oxygen, should be conducted. Take these measures in moving water, out of direct sunlight.

### Benthic Macroinvertebrates

Macroinvertebrates are generally considered those invertebrates, such as worms, mollusks, and arthropods, large enough to be seen with the unaided eye (Weber 1973). However, the very early stages of these organisms are often only detectable with the aid of a stereomicroscope or magnifier. The term benthic refers to organisms living on the bottom of aquatic environments or on firm substrates protruding above the bottom. Benthic faunal communities usually contain a wide variety of organisms. Many of the community members are the immature stages (nymphs and larvae) of insects which leave the water for a terrestrial adult stage. During this period reproduction and dispersal takes place.

Quantitative benthic sampling is accomplished with a Hester-Dendy multiple plate sampler (Merritt et al. 1984, Fig. 4-2). Five replicate multiple plate samplers should be placed at each permanent sentinel site. Hang the samples with nylon rope insuring that the samplers remain submerged at least 6 cm from the bottom substrate and 6 cm below the surface. Allow a four week colonization period.

Sample labels, preservative, Zip-loc bags, and a knife are needed for sample retrieval. Sample retrieval is not recommended during high water events. Plastic labeling tape (such as Dymo brand) with the back still attached makes an effective permanent label. Carefully retrieve the samplers by slowly lifting each one out and placing it directly into a Zip-loc plastic bag. Be sure that the sample identification label is in bag. Add an appropriate

preservative. After preservative is added, squeeze bag to let as much air out as possible before sealing the bag. To insure integrity of sample, place this sealed bag into another bag. If the samples are to be processed within 24 hours the plastic bags may be placed on ice, to be kept as near freezing as possible, in lieu of adding preservative.

Several fluids are commonly used to preserve benthic samples, including formaldehyde, ethanol and isopropyl alcohol. Formaldehyde is recommended for benthic samples because of bacterial load of the detritus and sediment in the samples. There are health concerns associated with formaldehyde, so it must be used with caution. The final dilution of formaldehyde should be 5% of the standard stock solution. The standard stock solution, sometimes called formalin, contains about 37% formaldehyde, therefore, the final concentration of formaldehyde in the sample is approximately 2%. (Voshell and Hiner 1990). To preserve the sample with formaldehyde solution, add some stream water to the bag with the sampler and add enough preservative to equal about 5% of the liquid. It is recommended that the Hester-Dendy samplers be processed as soon as possible so as to reduce absorption of the preservative by the hardboard plates of the sampler. Before reusing the sampler it must be soaked to leach the formaldehyde.

Ethanol and isopropyl alcohol are adequate substitutes for formaldehyde. Use a 70% solution of these alcohols. Special attention must be given to dilution when preserving with alcohol. Lower concentrations are not adequate to retard bacterial

decomposition, and higher concentrations make specimens brittle. We recommend that when preserving by this method, if the samples are to be stored for longer than a week, the alcohol be replaced by laboratory diluted solution of 70% alcohol to ensure protection from bacterial decomposition.

Qualitative sampling of macroinvertebrates may be desired at this time. This sampling is conducted to supplement the species list. In order to obtain adult stages of benthic insects, an aerial net should be used to sweep the riparian vegetation up and down the stream banks. Selected specimens may be retained in a small bottle with 70-80% ethanol and at least a temporary site label. A standard D-frame kick net may be used to obtain specimens from stream microhabitats not sampled with the quantitative sampler. Hold net downstream and dislodge organisms by hand or by kicking. Common microhabitats to sample include leaf packs, underneath log, underneath large rocks, and by exposed roots and vegetation. As with the aerial net sampling, preserve selected specimens in a small bottle with 70-80% ethanol. Additionally, mature specimens may be returned to a laboratory for rearing to adult stages, if facilities are available.

#### Sampling Frequency

We recommend quantitative sampling be conducted once every season, spring, summer and fall. Winter sampling is probably not practical at AFBNM in most years.

### Sample Processing

Store bags with Hester-Dendy samplers in airtight containers to reduce escape of formaldehyde fumes. The processing steps for benthic macroinvertebrate samples are 1) washing, 2) sorting, and 3) identification and enumeration. It is important to keep the sample label with the sample through all the steps, and keeping a log that includes the date each step was completed, initials of the person completing the step, and any notes, is recommended.

The first step in sample analysis is to wash organisms and formaldehyde preservative from the sampler. First rinse the sampler over a fine mesh sieve with tap water. A U. S. standard No. 60 sieve (sieve openings 0.25 mm) was used in this study. Others recommend sieves with larger openings, such as No. 30 (sieve openings 0.6 mm, Weber 1973). A finer sieve retains early instars, while a coarser sieve reduces sample volume, and therefore hastens processing. Unscrew the wing nut so the hardboard plates of the sampler slide off the bolt. Rinse both sides of each plate over the sieve. Gently stir the sample and shake the sieve under the water to clean the sample, but take care not to damage the delicate specimens. Transfer the sample from the sieve into a glass beaker. Cover the sample with water if it is to be picked immediately, or add 70% ethanol if not. Always keep the original sample tag with the sample. The sampler should soak in water to leach the formaldehyde from the plates.

Picking the organisms from the sample, or sorting, is the next step. Into the bottom of a clear petri dish, pour enough of the

sample to cover the bottom of the dish. Under a binocular dissecting microscope at low power (about 10X) separate the invertebrates from the debris and place the specimens in a vial with 70-80% ethanol. Patent lip vials with neoprene stoppers or screw cap vials with a polyethylene liner are both adequate for storage of samples and reducing evaporation of alcohol. The 7 g (4 dram, usually 7 \* 21 mm) size vials are a good size for storage of samples. Look through the petri dish in a systematic manner, and then scan the dish again to check the work. Depending on the expertise of the person sorting the sample, different taxa may be separated into a sorting tray or separate vials. It is imperative that every vial have a label. If paper is used for the label it should be have at least 50% rag content, preferably 90-100%, and written with #2 pencil or India ink.

The final step in processing the sample is identifying the organisms to the lowest practical taxonomic level and counting the number in each taxon. Each specimen needs to be examined with a good quality binocular dissecting microscope. Taxonomic publications with descriptions and keys are utilized to make identifications. Merritt and Cummins (1984) thoroughly treat all the aquatic and semiaquatic insect orders. More specialized works for individual orders include Edmunds et al. (1976), Ephemeroptera (mayflies); Stewart and Stark (1989), Plecoptera (stoneflies); and Wiggins (1977), Trichoptera (caddisflies). A good reference for macroinvertebrates other than insects is Pennak (1989). Benthic

macroinvertebrates should be identified to at least the following taxonomic levels:

Insecta - genus, species (except Diptera)

Diptera - family (except Chironomidae - subfamily)

Collembola - order

Turbellaria - genus

Nematoda - class

Annelida - class

Amphipoda - genus

Decapoda - family

Acarina - order

Gastropoda - family

Pelecypoda - family

It may not be possible to identify early stages of macroinvertebrates to these levels. Note that taxonomic references are written for people who are already familiar with the taxonomic group covered. Formal training with a specialist is necessary for accurate identifications. It is also a good idea to have representative specimens verified by specialists. Appendix D.5 is a data sheet that includes many of the species encountered during benthic sampling of the Niobrara River in AFBNM. The list is meant for use as a general guide and does not list all species or all life stages that may be encountered.

Each sample may be stored in a single vial or several vials, separated by taxonomic group. Every vial needs to have an identifying label, with site, date and replicate, and the original

field label should be kept with the corresponding sample. Inevitably, through the data entry and analysis process, questions will be raised and specimens need to be reexamined. Cardboard unit trays are available for vial storage. The AFBNM must decide how long to keep the samples after identification, data entry, and data analysis. A minimum of one year after data analysis is recommended. It is helpful to keep several specimens of each taxon collected each year as a voucher collection. This voucher collection can serve as a tool to answer taxonomic questions, is helpful in training employees or consultants, and may be used as an educational tool (Voshell and Hiner 1990).

#### Data Analysis

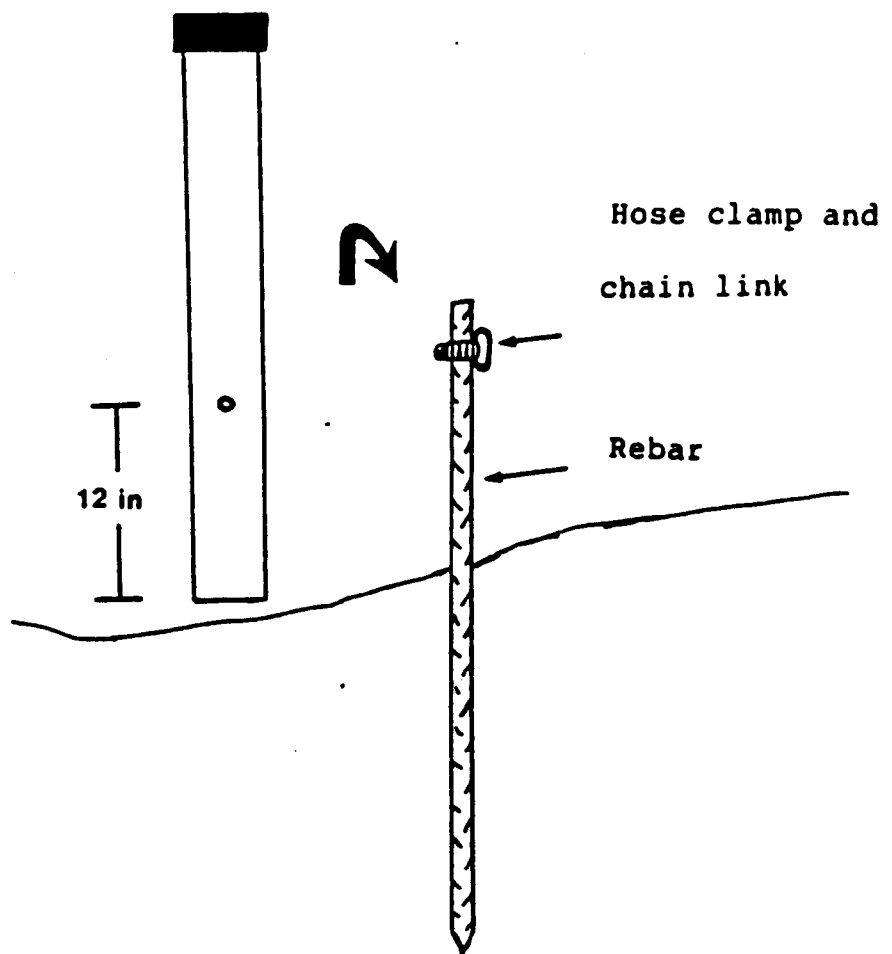
For preparation of this report, data was entered on a spreadsheet and SAS (SAS 1988) programs were written for all calculations. Taxa codes are presented in Appendix C.1. In order to facilitate data analysis, a dBase III+ computer program is being developed to store and examine the data. This program is scheduled to be demonstrated and distributed at a Midwest Region, National Park Service, workshop in August 1991.

Density, taxa richness, EPT taxa richness, Shannon and Simpson indices, and relative abundance of functional feeding groups were the analyses used in this report. Sample values were obtained by calculating the mean number of each taxon found in the five replicates samples at each site and date. Analyses were performed with the sample values. Density values, on a  $m^2$  basis, were obtained by dividing the number of organisms collected by the

surface area of the samplers (each Surber = 0.0929 m<sup>2</sup>). Taxa richness and EPT taxa richness were obtained by simply counting the number of nonzero taxa within a sample. The Shannon and Simpson indices were computed using the formulas described in Section 4.1.3. Calculation of percent functional feeding groups involved several steps. A functional feeding group was assigned to each taxon (Appendix B.1). Then the relative abundance (expressed as percent) of these groups for each sample were calculated.

**Figure D-1. Streamside marker (Voshell and Hiner 1990).**

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Appendix D.2. Field checklist and data sheet.

FIELD RECORDS

Site \_\_\_\_\_ Date \_\_\_\_\_

Workers \_\_\_\_\_

Air temp. \_\_\_\_\_ °C

H<sub>2</sub>O temp. \_\_\_\_\_ °C

pH \_\_\_\_\_ Method: \_\_\_\_\_

D.O. \_\_\_\_\_ mg/l Method: \_\_\_\_\_

Water Samples: \_\_\_\_\_

Hester-Dendy Samples: \_\_\_\_\_

All samples labeled?

Notes: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

### Appendix D.3. Equipment list.

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#### I. General Field

- \_\_\_\_\_ Hip Waders
- \_\_\_\_\_ Field Notebook
- \_\_\_\_\_ Pencil

#### II. Water Chemistry Sampling

- \_\_\_\_\_ Water bottles for samples
- \_\_\_\_\_ Cooler with ice left in vehicle
- \_\_\_\_\_ pH meter or Hellige colorimeter
- \_\_\_\_\_ DO meter
- \_\_\_\_\_ Thermometer

#### III. Benthic Macroinvertebrate Sampling

##### Quantitative sampler retrieval

- \_\_\_\_\_ Knife or scissors
- \_\_\_\_\_ Zip-loc bags (10 per site)
- \_\_\_\_\_ Sample labels (Site, Date, Replicate)
- \_\_\_\_\_ Preservative (Formaldehyde recommended)

##### Qualitative sampling

- \_\_\_\_\_ Aerial net
- \_\_\_\_\_ D-frame kick net
- \_\_\_\_\_ enamel pan
- \_\_\_\_\_ small bottles with ethanol
- \_\_\_\_\_ rag paper for labels

#### IV. Macroinvertebrate Sample Processing

- \_\_\_\_\_ Binocular dissecting microscope
- \_\_\_\_\_ Sieve
- \_\_\_\_\_ Ethanol
- \_\_\_\_\_ Beakers
- \_\_\_\_\_ Petri dishes
- \_\_\_\_\_ Fine forceps
- \_\_\_\_\_ Sorting tray
- \_\_\_\_\_ Vials for storage
- \_\_\_\_\_ Cardboard unit trays
- \_\_\_\_\_ Tally counter

Appendix D.4 List of suppliers of selected equipment needed for field and laboratory procedures. There are alternative vendors for most items.

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| <u>Item</u>                                            | <u>Vendor</u>                                                                                                    |
|--------------------------------------------------------|------------------------------------------------------------------------------------------------------------------|
| Polyethylene or glass, water sample collection bottles | Baxter Scientific<br>1118 Clay St.<br>Kansas City, MO 64116<br>800-892-2433 (MO)<br>800-821-2206 (other than MO) |
| pH meter                                               | Baxter Scientific                                                                                                |
| Dissolved oxygen meter                                 | Baxter Scientific                                                                                                |
| Hester-Dendy sampler                                   | Forestry Suppliers, Inc.<br>205 W. Rankin St.<br>P.O. Box 8397<br>Jackson, MS 39204-0397<br>800-647-5368         |
| Aerial net, D-frame kick net                           | Bio Quip Inc.<br>17803 LaSalle Ave.<br>Gardena, CA 90248<br>213/324-0620                                         |
| Glass vials                                            | Bio Quip Inc.                                                                                                    |

Appendix D.5. Macroinvertebrate data sheet. Includes many of the species encountered during benthic sampling of the Niobrara River in Agate Fossil Beds National Monument, Nebraska. This list is meant for use as a general guide and does not list all species or all life stages that may be encountered. Taxon refers to larvae, unless noted.

# BENTHIC MACROINVERTEBRATE DATA

Site \_\_\_\_\_ Sample Date \_\_\_\_\_ Replicate \_\_\_\_\_

Identifier \_\_\_\_\_

|                          | Number | Comments |
|--------------------------|--------|----------|
| Collembola               | _____  | _____    |
| Ephemeroptera            | _____  | _____    |
| Baetidae                 | _____  | _____    |
| Baetis spp.              | _____  | _____    |
| Caenidae                 | _____  | _____    |
| Caenis sp.               | _____  | _____    |
| Ephemeridae              | _____  | _____    |
| Hexagenia limbata        | _____  | _____    |
| Heptageniidae            | _____  | _____    |
| Heptagenia diabasa       | _____  | _____    |
| Leptrophlebiidae         | _____  | _____    |
| Leptophlebia sp.         | _____  | _____    |
| Oligoneuriidae           | _____  | _____    |
| Isonychia rufa           | _____  | _____    |
| Tricorythidae            | _____  | _____    |
| Tricorythodes            | _____  | _____    |
| Odonata                  | _____  | _____    |
| Anisoptera               | _____  | _____    |
| Libellulidae             | _____  | _____    |
| Sympetrum spp.           | _____  | _____    |
| Zygoptera                | _____  | _____    |
| Calopterygidae           | _____  | _____    |
| Calopteryx spp.          | _____  | _____    |
| Hetaerina americana      | _____  | _____    |
| Lestidae                 | _____  | _____    |
| Lestes spp.              | _____  | _____    |
| Coenagrionidae           | _____  | _____    |
| Enallagma spp.           | _____  | _____    |
| Trichoptera              | _____  | _____    |
| Hydropsychidae           | _____  | _____    |
| Hydropsyche              | _____  | _____    |
| Hydroptilidae            | _____  | _____    |
| Ochrotrichia spp.        | _____  | _____    |
| Leptoceridae             | _____  | _____    |
| Nectopsyche sp.          | _____  | _____    |
| Polycentropodidae        | _____  | _____    |
| Polycentropus sensu lato | _____  | _____    |

Appendix D.5 (continued).

|                    | Number | Comments |
|--------------------|--------|----------|
| Megaloptera        |        |          |
| Sialidae           |        |          |
| Sialis             |        |          |
| Coleoptera         |        |          |
| Elmidae            |        |          |
| Dubiraphia sp.     |        |          |
| Dytiscidae         |        |          |
| Diptera            |        |          |
| Ceratopogonidae    |        |          |
| Chironomidae       |        |          |
| Chironomidae Pupae |        |          |
| Chironominae       |        |          |
| Chironomini        |        |          |
| Tanytarsini        |        |          |
| Diamesinae         |        |          |
| Orthocladinae      |        |          |
| Tanypododinae      |        |          |
| Ephydriidae        |        |          |
| Simuliidae         |        |          |
| Simulium sp.       |        |          |
| Stratiomyidae      |        |          |
| Tabanidae          |        |          |
| Chrysops spp.      |        |          |
| Hybomitra spp.     |        |          |
| Tipulidae          |        |          |
| Turbellaria        |        |          |
| Planariidae        |        |          |
| Nematoda           |        |          |
| Oligochaeta        |        |          |
| Hirudinea          |        |          |
| Amphipoda          |        |          |
| Gammaridae         |        |          |
| Gammarus           |        |          |
| Hyaella            |        |          |
| Talitridae         |        |          |
| Decapoda           |        |          |
| Cambaridae         |        |          |
| Orconectes immunis |        |          |
| Acarina            |        |          |
| Gastropoda         |        |          |
| Ancylidae          |        |          |
| Lymnaeidae         |        |          |
| Physidae           |        |          |
| Planorbidae        |        |          |
| Pelecypoda         |        |          |
| Sphaeriidae        |        |          |



