DRAFT
STUDY PLAN

Development of a Long-term Ecological Monitoring Program at Denali National Park and Preserve (SIS#5001243)

Design of Methods for Detecting Change in Aquatic Invertebrate Populations & Lotic Communities

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Executive Summary

This study plan describes research to be carried out during 1999-2001 to design methods for detecting change in aquatic invertebrate populations and lotic communities in Denali National Park and Preserve, Alaska. This effort is part of a larger effort aimed at developing a Long-term Ecological Monitoring program for Denali NP.

This report has two sections. The first describes the research already conducted which examined the benthic macroinvertebrate communities of the streams and rivers in Denali National Park & Preserve (Denali NP) as part of the long term ecological monitoring program (LTEM). The second outlines the objectives and methodology to be used in the next 3 years to further refine the monitoring protocol and answer many of the remaining questions.

The research carried out since 1994 described the benthic invertebrate communities at a large number of sites throughout Denali NP. Once the basic inventory information had been collected, sites were classified into groups based upon their invertebrate fauna. This classification served as a basis for exploring links between the invertebrate communities and a number of environmental variables. In order to understand the natural variability of the communities, both the spatial and temporal variations in invertebrate community structure were examined. Finally, the two most commonly used bioassessment techniques were examined to assess their utility in the Denali NP context. These techniques included the multivariate, or predictive, approach, widely used in the United Kingdom and other parts of Europe, and Australia, and the multimetric approach, developed by the U.S. Environmental Protection Agency and the common approach taken in the United States.

The field, laboratory, data analysis, and bioassessment techniques used since 1994 are described, and an explanation and justification as to why each of the techniques was chosen is provided. A summary of the results obtained since 1994 is also included, although readers should consult Sarah Conn’s thesis for a more detailed description of these findings.

The remaining sections of the report are devoted to explaining the study plan for 1999 - 2001. Work to be done includes examining the sensitivity of the bioassessment techniques in detecting impairment, examining biovolume, Chironomidae, and periphyton communities as potential bioassessment tools. Field and laboratory methods will be compared with other techniques available to see if they can be simplified without losing any information. Finally, causes and ranges of natural variability in community structure, and links to the riparian zone will be explored in more detail.

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Glossary of Terms

[1]**Bioassessment** - Bioassessment is the term given to the concept of using organisms as tools to monitor environmental conditions. In aquatic systems, macroinvertebrates are the biotic group most commonly used for biomonitoring although the use of other groups such as fish and periphyton is becoming more common.

[2]**Multivariate** - A multivariate technique is one which uses quantitative data which are examined using a series of multivariate statistical techniques (i.e analysis methods in which the relationships between more than two variables are examined concurrently). These techniques are often used to develop a predictive model. The characteristics of a site under investigation are entered into the model which predictes the invertebrate taxa of the site. This is the compared to the actual fauna collected from the site.

[3]**Multimetric** - A multimetric approach is one which describes the benthic invertebrate community in terms of a number of measures, or metrics. For example the number of insect taxa collected, or the percentage of the population which are Plecoptera (stoneflies) etc.

[4]**Instar** – Insects have a number of life stages before they metamorphose into adults. Each of these stages is called an instar. Each instar stage is separated from the next by a moult allowing the insect larvae to grow. Most aquatic insects have five instar stages before they reach maturity.

[5]**RPB** – Rapid Bioassessment Protocols, are techniques such as those used by the US-Environmental Protection Agency (EPA), which are designed to minimise the cost and time taken for sampling and analysis, while providing descriptors of the sampled stream’s biota which can then be compared to a predetermined reference condition based upon normal, “healthy” systems.

1 - INTRODUCTION

1.1 - Outline of the Report

This report is part of the cooperative agreement with USGS-BRD and comprises two parts - the PhD thesis of Sarah C. Conn, (Conn 1998) and this separate variables assessment report and study plan. The thesis provides a detailed coverage of the aims, methods, results, and conclusions of research carried out in Denali National Park & Preserve (Denali NP) since 1994. This second part of this document aims to describe and explain how, and why the benthic macroinvertebrate communities of Denali NP were sampled, and how this information was examined and interpreted. The report seeks to set the research carried out within Denali NP in context with other long term ecological monitoring programs and water quality assessment techniques, particularly with respect to studies being carried out in Alaska. The final section of the report is a proposed work plan for 1999 - September 2000.

1.2 - Brief History of Aquatic Invertebrate Sampling in Denali NP Prior to 1994

Prior to the inventory and monitoring (I&M) program, few data existed on benthic macroinvertebrate communities of Denali NP. The majority of studies had focused on the Kantishna area of the park (Figures 1 & 2) and were related to the impact of placer mining on the lotic environment (Mangum, 1986; Johnson, 1987; and Oswood et al., 1990). Other records of the benthic macroinvertebrate communities of the park were isolated but include a study by Brown (1987). Between 1986 and 1988, Piorkowski (1994) undertook some brief qualitative collections of streams along the park road corridor. These observations were made by picking specimens from rocks rather than by systematic sampling. Piorkowski noted however, that there was considerable variation in the diversity of the invertebrate communities in different streams of the park.

In 1992, as part of the National Park Service's (NPS) I&M program benthic macroinvertebrates sampling began in Rock Creek, a small second order watershed close to the park headquarters area. The aim of the sampling was to develop a baseline data set, and establish methodologies which could be used for long term ecological monitoring

Figure 1 - Map showing the location of Denali National Park & Preserve (Denali NP) in Alaska.

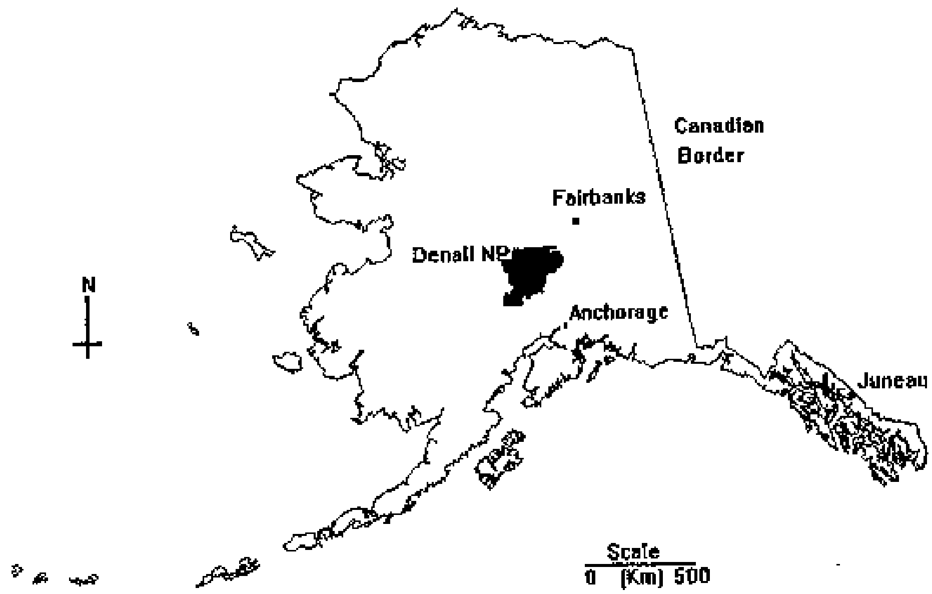
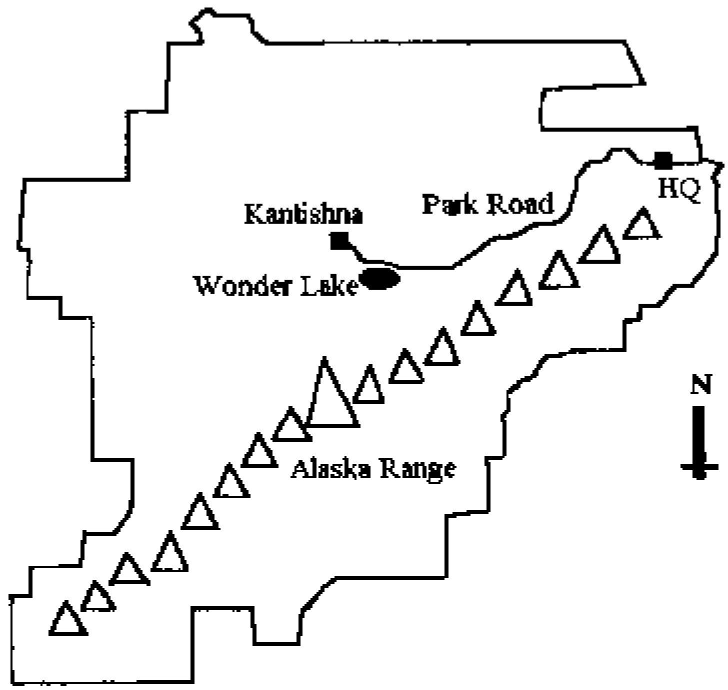


Figure 2 - Diagram showing the main features of Denali National Park & Preserve



(LTEM) to detect changes within the watershed. However, the results from data collected in 1992 and 1993 indicated that Rock Creek supported low numbers of macroinvertebrates and only 3 taxa were identified (Milner & Gabrielson 1993). The authors felt that the depauperate nature of the benthic invertebrate community in Rock Creek made it unsuitable for detecting subtle changes in the watershed.

The first comprehensive survey of macroinvertebrate communities of streams within Denali NP took place in 1994 (Milner & Roberts 1995). A total of 27 sites extending west along the park road from the headwaters were examined during the study. The results of the survey indicated that streams and rivers could clearly be divided into separate groups based upon their invertebrate fauna, and that the benthic macroinvertebrate community of Rock Creek was not typical of other watersheds located along the Denali NP road corridor. This study also provided a valuable data set for the whole of interior Alaska where most of the studies have been small scale and intensive in nature.

1.3 - Benthic Macroinvertebrates in streams are important monitoring tools

Benthic macroinvertebrate communities in streams serve as effective indicators of watershed characteristics by integrating processes such as surface geology, vegetation, water source, geomorphology and ecosystem processes (Reice & Wohlenberg 1993). Their use as a monitoring tool to examine water quality and assess ecosystem change is common throughout the world (e.g. Bargos et al. 1990; Eaton & Lenat 1991; and Growns et al. 1995). Benthic invertebrates are effective for monitoring and [1]bioassessment as they are a diverse group of sedentary species, whose life cycle often spans more than one year. They also react in a predictable way to a wide range of anthropogenic disturbances (Cairns & Pratt 1993). Their long life cycles allow the effects of intermittent pollution events, which are often not detected by chemical testing, to be quantified.

1.4 - Summary of the I&M Project Goals - Aquatic Invertebrates

The first aim of the project was to examine the benthic macroinvertebrate communities of as wide a range of rivers and streams as possible within Denali NP. This basic inventory information was crucial before any long term monitoring could be conducted. A classification scheme based upon the benthic macroinvertebrate communities was developed. This information was then used to examine the relationships between the benthic macroinvertebrate community assemblages and a large number of environmental variables.

A second aim of the project was to examine both the spatial and temporal variation of the benthic macroinvertebrate communities in Denali NP. This information is needed to evaluate the robustness of the classification scheme, and to estimate when, and where sampling for benthic macroinvertebrates should be conducted before a monitoring and bioassessment protocol for the rivers of Denali NP could be developed. It is crucial that natural variability of communities be understood if effective monitoring programs are to be established (McElravy et al. 1989). In addition this type of knowledge is also fundamental for the accurate calibration of bioassessment methods (Barbour et al. 1996).

In addition to temporal variability of benthic macroinvertebrate communities, spatial changes in community structure and functioning of lotic communities has long been documented, often in relation to the river continuum concept (RCC) (Vannote et al. 1980). This concept predicts a transition as stream order (a measure of stream size) increases, from a heterotrophic invertebrate community where the major food source comes from the surrounding riparian area (e.g. from leaves), to an autotrophic system in which macrophytes and algae provide most of the carbon for secondary production. If this transition was occurring in the rivers within Denali NP it could be expected that sites in different portions of a watershed may lie in different classification groups, thus within watershed community differences may be greater than between watersheds. Spatial patterns in the lotic invertebrate communities of Denali NP were therefore examined.

The final aim of the project was to use the information collected from Denali NP and suggest a suitable bioassessment[1] protocol for examining and monitoring watershed health in Denali NP using the benthic macroinvertebrate fauna. This technique would be based upon the knowledge gained throughout the course of the study and would be specific to the interior of Alaska, not relying on results obtained in other regions which may support different aquatic invertebrate communities.

2 - TECHNIQUES USED FOR LOTIC INVERTEBRATE STUDIES IN DENALI NP SINCE 1994

2.1 - Field Sampling Techniques

When selecting a sampling technique a clear idea of the type of data required is essential, along with an appreciation of the environmental conditions present at the sites which are to be sampled. In order for sites to be compared spatially and temporally it was necessary to use the same sampling strategy throughout the project.

Benthic macroinvertebrates as their name suggests live on, and in the substratum of a river and there are numerous techniques available for sampling these organisms depending upon the nature of the habitat. However, the techniques are often divided into two groups, quantitative and qualitative methods. As the data were to be used to compare benthic macroinvertebrate communities over time and space, a quantitative sampling technique was selected. This follows the recommendations of Vinson & Hawkins (1996) who found that comparisons of taxa richness between streams was difficult when qualitative samples were used. As noted by Brinkhurst (1993) many statistical procedures are rooted in quantitative data and for these reasons a quantitative sampling method was selected.

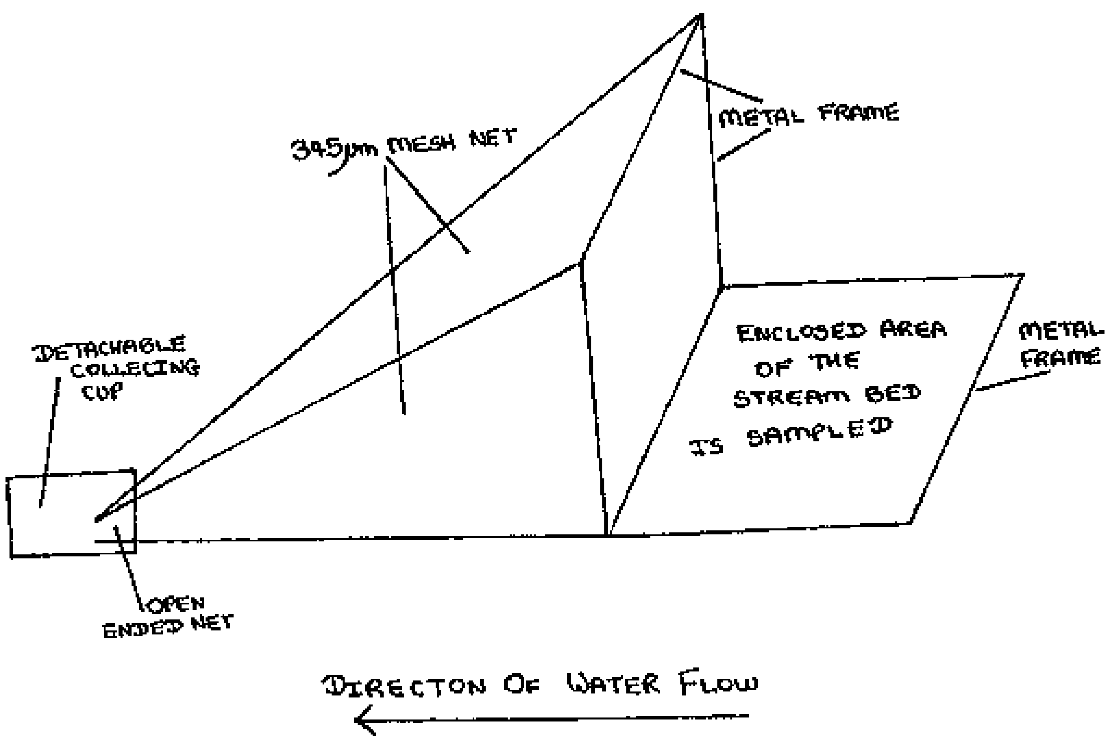
A river is not a uniform environment, and is commonly comprised of a series of different habitats such as pools, snags and riffles. While noting that there is still much debate on whether single or multiple-habitat sampling is the best approach for invertebrates, Karr & Chu (1999) suggest that sampling a single habitat is often adequate, especially where the area is dominated by that habitat type. Resh & McElravy (1993) found that where only one habitat is sampled the riffle area is the most commonly used habitat. A riffle is a shallow area of the river where the surface of the water is broken. In common with other predominantly headwater systems, riffles are by far the most dominant habitat in the lotic systems of Denali NP. These habitats are easy to define and identify in the field (Karr & Chu 1999) and are the most diverse, and productive habitats (Plafkin et al. 1989). By sampling only one habitat type, inter-sample variance is reduced which increases the sensitivity of the technique in detecting environmental change (Resh & McElravy 1993). Parsons & Norris (1996) also advocate the riffle-only approach so that spatial and temporal comparisons are made between equivalent environmental units. Following these suggestions only riffle areas were sampled.

The Surber sampler (Figure 3) is the most common and effective method used to sample shallow riffle areas quantitatively (Winterbourn 1985). The Surber sampler encloses a fixed area of substratum from which the invertebrates are collected producing a quantitative sample. A Surber sampler with a mesh size of 345µm was used, this mesh size will retain all but the smallest instars. As these very small [4]instars are often impossible to accurately identify, their loss should not decrease the accuracy of the sampling method and will reduce the time taken to sort and identify the sample. This size of mesh was used in 50% of the bioassessment studies reviewed by Resh & McElravy (1993). The Surber net was mounted in an aluminium frame with 3cm compressed foam to provide better adherence to the substratum.

In order to carry out statistical analysis of the data more than one sample from each site was required. The number of replicates is an important consideration of experimental design. In the majority of lotic studies between three and five replicates are collected (Voshell et al. 1989), while Karr & Chu (1999) recommend the use of 3 replicates in bioassessment studies. The aim of the sampling was to provide as much information as possible within the constraints of a fixed time and budget. Russek (1993) in a study in Anchorage, Alaska concluded there were no significant differences in several bioassessment measures when 3 or 10 replicates were used. For the Denali NP study 3 replicates were used so that the maximum number of sites could be examined while still producing accurate, and statistically useful data.

In a number of bioassessment protocols in use at the present time, samples are often sub-sampled and not all the individuals collected are identified. The effectiveness and accuracy of sub-sampling is a topic of much debate among aquatic ecologists (Courtenmanch, 1996; Vinson & Hawkins, 1996; and Cao et al., 1998). Many authors

FIGURE 3 - SURBER SAMPLER



claim that it reduces the accuracy of bioassessment techniques (Hannaford & Resh 1995) and often leads to the omission of rare taxa which are often the most sensitive to water quality degradation (Cao et al. 1998). The positive aspect of sub-sampling is that it reduces the time taken to sort and identify the taxa within a sample. As this study was designed to inventory the lotic resources of Denali NP as well as devise a long term ecological monitoring / bioassessment protocol, we felt that it was appropriate to invest the time needed to accurately characterise the benthic macroinvertebrate community by counting the entire sample rather than run into the controversy of sub-sampling and its implications for data analysis. In the future sub-sampling may be used but it will require an examination of its effectiveness compared to whole sample counts within the Denali NP context.

As wide a range of sites as possible were sampled from throughout the park. The project was constrained by the overwhelming size of Denali NP and the access problems this poses. A large number of sites were sampled along the parks road corridor. During 1995 access to a number of remote sites, including 11 on the southside of the Alaska Range was provided by working in collaboration with a water chemistry project which was taking place in the park (Edwards & Tranel 1998). In order to assess the effects of seasonality on the benthic macroinvertebrate communities of the parks rivers sites were sampled on three separate occasions during the ice free period of 1995. The collection and use of data from several sampling periods reduces the effect on the data of different life cycle patterns shown by benthic invertebrates, ensuring that all taxa present in the lotic systems are recorded at some point during their lifecycles.

2.2 - Data Analysis Techniques

The data analysis techniques used during the study are described in detail in Sarah C. Conn's PhD thesis. However, a summary of the major procedures used is provided below.

As discussed in section 1.4, the first aim of the project was to examine the benthic macroinvertebrate communities of a wide range of river and streams throughout Denali

NP, and examine links between the invertebrate community and its surrounding watershed. This work produced a large amount of complex data and, in common with much science, to aid comprehension the data set was broken down into smaller, more manageable sub-units. Often when examining a new, unknown area, one of the first stages in trying to understand the processes which are taking place is to produce a classification system. At present, Alaska has been classified into 6 large hydrologic units (Oswood, 1989; and Milner et al., 1997), or 20 ecoregions (Gallant et al. 1995). Although these units are useful on a macroscale level there may be other features which are of greater importance in determining the types of benthic invertebrate communities, which may operate at a much smaller scale. By reducing the scale of the classification units key processes which are influencing the systems may be better examined. However, the mechanism by which these smaller sub-units or groups are formed must be relevant to the questions which are being asked.

There are a large number of studies from different areas of the world which developed classification schemes as a preliminary stage to aid understanding of how environmental factors influence aquatic invertebrate community structure (Wade et al. 1989; Quinn & Hickey, 1990; Storey et al., 1990; and Bull & Hall, 1992). In common with these studies, the classification of sites in Denali NP was carried out using two-way indicator species analysis (TWINSPAN) (Hill 1979a). TWINSPAN arranges sites into groups based on the similarity of the taxa present (Hill 1979a). TWINSPAN analysis was carried out using an amalgamation of data from all three sampling seasons as Furse et al. (1984) noted that the accuracy of a TWINSPAN based classification system was much higher when using data from 3 or more sampling periods. A similar result was found by Ormerod (1987) who concluded the accuracy of site classification by TWINSPAN was improved by using combined seasons data. The use of data from several sampling periods reduces the effect of the different life cycle patterns shown by benthic invertebrates, ensuring that all taxa present in the lotic systems are recorded at some point during the sampling cycles. This is especially crucial for lotic systems in interior Alaska where species diversity is low.

Sites were also ordinated using detrended correspondence analysis (DECORANA). This technique arranges sites along four axes, with sites supporting similar communities clustering closest together in ordinal space (Hill 1979b). The axis scores from the DECORANA analysis can then be correlated with the physico-chemical variables recorded at each of the sites to investigate their relationship with the invertebrate communities. This method contrasts with the one taken by Craig & McCart (1975) who classified stream types in the Beaufort sea area of Alaska based upon their environmental characteristics and then examined if the macroinvertebrate community fitted the patterns expected. The approach taken by Craig & McCart made assumptions about what environmental factors were the most important in terms of the benthic macroinvertebrate community. In the Denali NP study, the invertebrate communities were first described and classified, and then links with a broad range of physical and chemical parameters were established making no *a priori* assumptions as to the relative importance of each of the environmental variables.

A number of standard statistical techniques such as ANOVA, Kruskal-Wallis, Spearman Rank Correlations, and Principal Components Analysis and descriptive measures such as Jaccards Similarity Index, and Van Sickle's Jaccards Similarity Dendrograms were used throughout the study to examine patterns of community composition and change in more detail. Care was taken to ensure that data which were not normally distributed were examined using non-parametric analysis.

The final aim of the project was to examine the utility of both [2]multivariate (predictive) and [3]multimetric methods of bioassessment for the lotic communities of Denali NP. A predictive model was produced by following similar methods used in the development of the highly successful River InVertebrate Prediction And Classification Scheme (RIVPACS) by Furse et al. (1984), Wright et al. (1984), and Moss et al. (1987) which is now the standard bioassessment method used in the UK and which is being developed for use in Australia and Scandinavia (Monahan & Milner in press).

A large number of metrics, or measures, were examined to see if any were suitable for use in Denali NP. Before analysis of the metrics could be carried out a “reference condition” has to be established. This is fundamental to multimetric methods, and is a technique by which reference sites which have environmental conditions similar to those at any new site to be examined are identified (Reynoldson et al. 1995). The reference condition can be determined in a number of ways. Barbour et al (1996) defined the reference condition as being equal within small geographical regions, the boundaries of which were based upon vegetation types, climate and geomorphology. That is, all of the sites within the defined region are expected to support a similar benthic macroinvertebrate community. When applied over a large geographical area, or at a large scale of resolution, the method has been criticised, for example by Reynoldson et al. (1997). The major focus of these criticisms was that the aquatic invertebrate communities may not always reflect ecoregion features which were selected to divide the landscape into units. Reynoldson et al. (1997) suggested that a multivariate approach such as that using TWINSPAN and then multiple discriminant analysis (MDA) was a less subjective way of determining the reference condition at a site. As the technique makes no *a priori* assumptions about the invertebrate community of a site, sites are grouped according to their fauna.

The data collected from Denali also indicated that the invertebrate communities at sites were not similar within geographical regions, but were instead responding to other environmental variables such as stream morphology etc. (Conn 1998). Thus it is possible that neighbouring streams may support quite different macroinvertebrate communities. Therefore, following the recommendations of Reynoldson et al. (1997) each of the TWINSPAN classification groups served as a separate set of reference sites. Metric variability and redundancy were then examined for each separate reference group following the procedures outlined by Barbour et al. (1996).

2.3 - Bioassessment Techniques

The concept of using organisms as tools to monitor environmental conditions is not new. Since the turn of the century the presence of certain taxa of aquatic organisms has been linked to the degree of pollution, as described by the Saprobian system developed by Kolkwitz (1908) and Marsson (1909) cited by Cairns & Pratt (1993). This system was widely used throughout Europe although it found little acceptance in North America where chemical testing of water quality remained dominant until recently (Cairns & Pratt 1993). In the early 1980’s the Saprobian system and chemical testing were replaced by diversity indices, and more recently with multimetrics in North America, and scoring systems, and multimetric predictive techniques in Europe such as the Biological Monitoring Working Party (BMWP) and the RIVPACS model (Cairns & Pratt 1993). The BMWP was developed by Armitage et al. (1983) and calculates a score for a site based upon the type of invertebrate taxa present and their tolerance to polluted waters. Although macroinvertebrates remain the biotic group most commonly used for biomonitoring in recent years these techniques have shifted again and there is now an increased emphasis placed upon recognising the differences in fauna in different physio-graphic regions (Monaghan & Milner in press). Test sites are now compared in a number of ways to pristine sites within a region.

There are currently two major approaches in monitoring and bioassessment using benthic macroinvertebrates : (1) The predictive techniques, such as the RIVPACS model (Wright 1995), and (2) multimetric techniques such as those advocated by Barbour et al. (1996). Although there has been much debate over which of the two approaches is most effective (Gerritsen 1995; Norris 1995; and Reynoldson et al. 1997), the two techniques are not mutually exclusive. A number of studies have suggested that the multivariate (predictive) approach is more accurate in detecting differences between reference sites and impacted sites (Hawkins et al., in press; and Reynoldson et al., 1997), while the elements of the multimetric technique may provide a more diagnostic indication as to the source of the contamination or habitat impairment (Monaghan & Milner in press). Hence, as they provide different information; a combination of the two methods may provide a powerful tool for detecting anthropogenically induced change within a watershed.

The predictive approach uses quantitative data which are examined using a series of multivariate statistical techniques (Norris & Georges 1993). A model is developed based upon a large data set obtained from pristine, unimpaired sites which have been classified into a number of groups. A new site can then be classified into a group based upon a set of the physico-chemical conditions recorded at the site. The “health” of the site is then assessed by comparing its invertebrate community structure to that of other group members (Wright et al. 1984). The technique is particularly useful in an area such as Denali NP, where it is not feasible to sample every river due to the size of the park. Once established, the predictive ability of the model allows sites which have not previously been sampled to be assessed. The main criticisms of the multivariate, predictive approach is that it involves complex statistics and a comprehensive, and therefore expensive, data set to develop the model before it can be used to test sites (Gerritsen 1995). In addition, the model may have a decreased accuracy if it is based only on data from a single year and the area to be tested shows a high degree of annual variation in the invertebrate community (Bunn 1995).

A multimetric approach is one which describes the benthic invertebrate community in terms of a number of measures, or metrics. It was first developed by Karr (1981) and has since been refined and modified for different areas, and project aims. There are a large number of metrics available each of which is sensitive to different stresses. The metrics operate by detecting a change in the invertebrate community when a metric score deviates significantly from the value which would be expected at a pristine site with similar environmental conditions. One of the main concerns with the multimetric approach such as that used by the US Environmental Protection Agency (EPA) is the division of metrics into water quality classes is arbitrary and subjective and is not based upon empirical data with no statistical analyses being applied between the different water quality classes (Monaghan & Milner in press). Very often the data used for calculating the metrics are collected using rapid bioassessment protocols which involve sub-sampling and in some cases identifying to a much coarser taxonomic resolution than that used in multivariate methods. Although this reduces the overall cost of the technique many authors believe that it also greatly reduces its accuracy. Cao et al. (1998) found that if a sub-sample of 100 organisms were counted 75% of species were not accounted for. As it is often the rare species which are most sensitive to water quality degradation they suggest that sub-samples of 100-300 organisms used by the EPA-RPB method are too small, and often greatly underestimate the differences between impacted and unimpacted sites. Often metrics are combined to produce one overall score for a site. This procedure has been heavily criticised (e.g. Suter, 1993; Norris & Georges, 1993; and Reynoldson et al. 1997). Critics suggest that information is lost by combining the metric scores and unless care is taken to remove redundant metrics, the final score is severely skewed leading to a site being mis-classified.

Although the concept of assessing water quality using biotic communities can be traced back to the early 20th century (Cairns & Pratt 1993), no published records of the use of bioassessment to assess water quality in Alaska were found by Milner & Oswood (1995). It was not clear if either the metrics or predictive model would be sensitive to changes in water quality as the fauna of the region is so depauperate, and dominated by Chironomidae (Oswood et al. 1995). As Karr & Chu (1999) caution “metrics should be based on sound ecology and adapted only with great care beyond the regions and habitats for which they were developed”. This statement could also apply to the predictive approach to bioassessment. The final aim of this project was to use the data collected within Denali NP to examine both the predictive and multimetric approaches, and assess if either or both could be a useful tool for monitoring and assessing water quality in the rivers of Denali NP.

3 - SUMMARY OF THE RESULTS OBTAINED 1994 - 1996

In this section, we provide a summary of the results obtained from our work in Denali NP between 1994 and 1996. This work has been published in the PhD thesis of Sarah C. Conn (Conn 1998), and several manuscripts are currently being prepared for the peer reviewed literature. This summary is intended to facilitate the readers understanding of the proposed future work, however, readers are encouraged to consult the thesis document for more detailed information on the aims, methods and results of the project.

The study revealed much new information about the lotic benthic macroinvertebrate communities of Denali NP. Communities were dominated by the Diptera family Chironomidae (non-biting midges) in all the areas of the park sampled. Other Diptera taxa, along with some Plecoptera, Ephemeroptera, and Trichoptera, families were also present within park streams. No individuals from orders such as Odonata, Megaloptera, and Coleoptera were identified in any of the collected samples. The only non-insect taxa collected were Oligochaeta worms. In general, the rivers of Denali NP supported low numbers of taxa although the density of benthic macroinvertebrate individuals was high in a number of streams. These trends were similar to those found in other studies conducted in interior Alaska (Irons III 1988; Oswood 1989; and Oswood et al. 1995).

TWINSPAN analysis classified rivers based on their macroinvertebrate communities into six distinct groups:

1. Clearwater rivers with a stable channel, and riparian zones with abundant growth of alder and willow trees, for example East Fork Tributary.
2. Small (1-5m wide), spring-fed creeks with a high degree of channel stability and a close border of riparian vegetation, for example Hogan Creek.
3. Kantishna area rivers and creeks which support the greatest diversity of benthic macroinvertebrates found within Denali NP and possess a well developed riparian zone for example Moose Creek.
4. Larger river systems, some of which were partially fed by glacier-melt water, for example Sanctuary River.

5. Small, unstable systems with creeks of low order, high gradient and actively migrating channel, for example Highway Pass Creek.
6. Glacier-fed rivers and Rock Creek. Sites in this group had a low abundance and diversity of benthic macroinvertebrates for example Toklat River.

The classification of sites was not solely based on geographical location. Benthic macroinvertebrate communities from streams on the north side of the Alaska range (Yukon hydrologic region) were very similar to benthic macroinvertebrate communities from streams on the south side of the range (Southcentral hydrologic region). The physical characteristics of sites, in particular the stability of the river channel, appeared to be more significant in determining community structure than was geographical location or hydrologic region. While the TWINSPAN groups appeared to be stable over the range of years sampled, benthic macroinvertebrate communities did not remain constant within a year. Results from the 1995 study indicated a large degree of seasonality in macroinvertebrate community structure. These differences were particularly marked in the group 4 (larger rivers), 5 (small, unstable creeks) and 6 (glacier-fed rivers). In addition, samples collected during the autumn period had the highest abundance of Plecoptera and Trichoptera. These taxa are frequently shredders and their lifecycles reflect the autumn input of leaf litter and allochthonous material into the aquatic systems of the area.

Although the TWINSPAN classification groups could be identified in all three years, there were some changes in the benthic macroinvertebrate communities. The groups which had the highest degree of channel stability, groups 1 (clearwater rivers), 2 (spring-fed creeks), and 3 (Kantishna rivers) showed a significant difference in the number of taxa recorded at each site between 1994 (Milner & Roberts 1995) 1995, and 1996. In contrast, groups 5 (small, unstable creeks) and 6 (glacier-fed rivers) which were characterised by having a highly unstable channel, showed no significant differences in their community structure between the 3 years. These sites are typified by low density and diversities of benthic macroinvertebrates, which are relatively constant between years.

A study of longitudinal variation of the benthic macroinvertebrate communities along the lengths of a number of watersheds indicated that the communities were very similar along the length of each watershed. Sites showed a much higher degree of similarity to sites within their watershed than to other sites in different watersheds. There were some downstream changes in communities particularly at the upper and lower ends of the longitudinal profile. These changes were particularly notable in the two glacier-fed rivers examined, the Thorofare River, and the East Arm of the Toklat River. Following the patterns described by Milner & Petts (1994), the benthic macroinvertebrate communities of these two rivers increased in both density and diversity as the distance downstream from their feeder glaciers increased. However, in general longitudinal variation in the benthic macroinvertebrate communities within watersheds was low, suggesting that one site located in the middle reaches may be sufficient for detecting large scale changes.

No significant relationship was found between coarse benthic organic matter (CBOM) and macroinvertebrate community structure. Furthermore, the amount of CBOM was not related to any measured physico-chemical variable. The amounts of CBOM recorded for Kantishna area rivers (group 3) was similar to levels recorded by Brown (1987) in an earlier study. In contrast, primary productivity, as indicated by chlorophyll a, was highly correlated with benthic macroinvertebrate communities, being highest in the broad, unshaded, clearwater Kantishna rivers (1995 TWINSPAN group 3) and the lowest in the 1995 TWINSPAN group 6 (glacier-fed rivers). The amount of chlorophyll a found in this study of Denali NP rivers was similar to the amounts found in other interior Alaska streams by La Perriere et al. (1989), and La Perriere (1994), and was highly correlated to channel stability, water turbidity, and concentration of magnesium.

A predictive model was developed with the data collected in Denali NP during 1995 and using the procedures outlined by Furse et al. (1984) and Wright et al. (1984). This multivariate model allowed sites to be classified to stream groups based upon 3 physical variables (channel stability, site altitude, and the distance of the site from it's principal water source). The model was field-tested in 1996 using new sites that had not been sampled in 1995. The benthic macroinvertebrate fauna of the sites were predicted and compared to the fauna collected from the sites. The accuracy of the model was extremely high - over 86%. Water quality of a site can be assessed using this method by calculating the ratio of the predicted taxa to the observed taxa, at a particular probability of occurrence level. Due to the low number of taxa found in the lotic systems of Denali NP, the observed (O) to predicted, or expected (E), taxa ratio could only be calculated at the 50% probability of occurrence level. The method was not appropriate to use when examining sites which are predicted to occur in TWINSPAN groups 5 (small, unstable creeks), and 6 (glacier-fed rivers), due to the low numbers of taxa found at these sites. A preliminary test of the multivariate model using unimpaired sites which were sampled during 1996 showed that sites were classified into the correct groups. The calculated O/E ratios for the sites were within 25% of unity which indicated that the sites were not impaired.

A wide range of “metrics” in common use, for example those used by the EPA-RPB protocols, were also examined using the data collected during 1995 to determine their effectiveness as monitoring and assessment tools under high latitude conditions. An effort was made to try and minimise the potential errors noted by Reynoldson et al. (1997).

Metrics examined were : number of taxa, number of EPT taxa, number of insect families, number of EPT individuals, ratio of EPT individuals to the number of EPT + Chironomidae individuals, ratio of EPT individuals to the total number of individuals, and the Family Biotic Index (FBI)(Hilsenhoff 1988). These metrics covered most aspects of community structure such that little information was lost. Metric redundancy was assessed, and those metrics which did not contribute any unique information were discarded. No additive metrics were used, and an effort was made to examine the effects of seasonality on metric scores.

Despite all the precautions to minimise errors associated with the application of metrics, the metrics using the 1995 sampling data from Denali NP showed a tremendous amount of variation in metric scores for sites for sites within the same TWINSPAN groups, thereby limiting their potential for use in detecting changes in water quality in the rivers and streams of Denali NP. No significant differences in metric scores were found between any of the TWINSPAN groups despite obvious differences in their community structure. Again the greatest variation in the metric scores occurred in the group 5 (small, unstable creeks) and 6 (glacier-fed rivers) sites. Compounding the problem was that there were very significant differences in the metric scores between each of the three 1995 sampling seasons. However, we recognise that the revised RBP's no longer favour ratio metrics so we will reanalyse the data including "tolerance" metrics as recommended in the proposed Alaska Stream Condition Index (Major et al. 1998).

A fundamental requirement of any technique used to monitor water quality is the ability to distinguish natural variability from perturbation - induced changes (Resh et al. 1995). With metric scores displaying such a large variation, it would be difficult to develop threshold / impairment criterion levels. Only very large changes in community structure could be detected by the metric methods, so that a slight degradation in water quality may go unnoticed.

In summary, 6 distinct groups, or types, of rivers were identified in Denali NP. These groups supported different benthic macroinvertebrate communities. The groups were not isolated by their geographical location and it appeared that physical features of the watershed were most important in determining lotic invertebrate community structure. There were distinct seasonal patterns in the invertebrate assemblages and there was a significant amount of inter-annual variation for rivers many of the groups. Although some patterns of downstream change occurred, particularly in glacier-fed rivers, it appeared that within watershed variation was less than between watershed variability. Preliminary analysis suggests that that a predictive model developed using discriminant analysis is an effective tool for classifying sites allowing water quality assessments to be made. Many of the most commonly used metrics were found to be highly variable and hence insensitive to detecting subtle changes in water quality.

4 - WORK PROPOSED FOR 1999 - 2001

In this section of the report we aim to describe our proposals to continue and develop the aquatic invertebrate LTEM protocols in Denali NP in 1999 - 2001. The objectives of the proposed work are described and explained in detail, and a description of the techniques which will be used to achieve the aims is provided. An approximate timetable of field, laboratory and report etc. writing activities is included.

4.1 - Personnel

Sarah C. Conn - Post-doctoral research associate.

Katrina Magnusson - Post-graduate student (Chironomidae section of the project).

Dr. Alexander M. Milner, - Principal Investigator.

4.2 - Project Goal

The overall aim of this project is to increase our general understanding of river processes, and community structure of the lotic systems in Denali NP. To accomplish this goal, we need to refine the methods used for the long term ecological monitoring of rivers and streams in Denali NP. As so little information is available on the stream ecology of this area an increased understanding of the structure and functioning of the lotic communities is essential for Park staff to make effective and informed decisions over the management of watersheds within the park. Techniques cannot necessarily be directly imported from lower lattitudes, where the majority of the work developing stream monitoring techniques has occured. This workplan aims to describe and outline the tasks to be undertaken, why these tasks are important, and provides a timetable of the proposed research activities and reports due.

4.3 - Project Timespan

Work commenced on this phase of the project in February 1999 and was mainly concerned with developing a detailed work plan, and summarising the information from previous studies in the Denali NP 1994 and 1998. Draft manuscripts were also being prepared to be submitted to journals. Work is proposed to continue through 2001.

4.4 - Objectives

1. Compare the predictive (multivariate) and multimetric bioassessment techniques sensitivity in their ability to detect impaired sites.
2. Compare Surber samples with other methods, particularly the qualitative techniques and sub-sampling methods used in the Alaska Stream Condition Index (Major et al. 1998). For each method the minimum number of replicates required to provide accurate results will be determined.
3. Examine the biovolume of collected invertebrates at sites in different groups and from impaired areas to examine the potential of biovolume as a bioassessment tool for Denali NP.
4. Using the new EPA-RBP protocols, examine the periphyton communities and explore their role as possible bioassessment tools both in terms of biomass and community composition.
5. Try to document the range of natural variation and identify some of the causes of the large year-to-year variation observed in the macroinvertebrate communities of Denali NP (e.g. climatic effects etc.).
6. Examine the overall physical stability of the systems and explore links with community persistence, and inter / intra annual community variability.
7. Examine food availability and retention of the systems in more detail to develop a greater understanding of links between invertebrate communities and the riparian zone.
8. Chironomid identification - what taxa are present, do they vary between classification groups, do they show such a high degree of inter / intra annual variation.
9. Effectively communicate the results of the research to park staff and the wider scientific community.

5 - DETAILED AIMS & METHODOLOGY

5.1 – Examining the Effectiveness of Techniques in Detecting Impairment (Objective 1)

Both the predictive (multivariate) method, and the multimetric bioassessment techniques were examined by Conn (1998). However, their variability and accuracy was only assessed in relation to pristine sites. For a bioassessment technique to be effective not only does the natural variability of the benthic invertebrate community need to be considered (discussed later) the technique must be able to detect impairment. The next stage is to examine the sensitivity of these techniques by sampling sites which are known to be suffering from some impairment. It is planned to sample sites which have been exposed to recent placer mining in the Kantishna area of the park, and any others which park resource management staff suggest may be suffering from impairment. As the predictive model, and the reference condition data base were established over three sampling seasons in 1995, potentially impaired sites will be sampled during these same three seasons during the 1999 field season. On each occasion two separate sets of samples will be collected using a Surber sampler. One will be examined using the same protocol which was used to develop the bioassessment models and a second set will be used to examine the effects of subsampling on the detection of impairment.

5.2 - Examining other Field & Laboratory Sampling Methods (Objective 2)

5.2.1 - Field Methods

As the aim of the project is provide a technique which park resource management staff can use for long term ecological monitoring (LTEM) the techniques need to be as simple as possible so that they can be carried out at minimal cost. To do this an assessment of the effectiveness and comparability of different field sampling techniques will be made. A number of different techniques (e.g. D-Nets, Surber samplers etc.) will be used to collect samples from the same site to allow comparisons of the methods to be carried out. In addition, as a separate study, the number of replicate samples from each site required to obtain accurate results will also be examined. These features may vary between each of the different classification groups, and the different sampling seasons so each will be examined separately.

5.2.2 - Laboratory Methods

In several rapid bioassessment techniques a qualitatively collected sample of benthic invertebrates is sub-sampled to provide the data on community structure. Although this approach is often cheaper, and quicker than quantitative sampling its effectiveness and accuracy is debated (Courtenmanch, 1996; and Vinson & Hawkins, 1996). Several authors have claimed that it reduces the accuracy of commonly used metrics (Hannaford & Resh 1995), and may not detect rare, but important taxa, so decreasing the sensitivity of the method (Cao et al., 1997; Karr & Chu, 1999).

There are two major techniques for sub-sampling, either the establishment of predetermined counts (e.g. count only the first 100 organisms in a sample), or proportions (e.g. count only the organisms in 3/5 of the sample). Care must be taken to avoid bias towards counting large, mobile, colourful specimens (Resh & Jackson 1993). In addition Resh & Jackson (1993) suggest that the examination of low numbers of specimens may not be appropriate for streams as they tend to have diverse communities which have a patchy distribution. The aim of sub-sampling is to reflect what is actually in the community. In order to assess the accuracy of sub-samples results will be compared to the results obtained when entire samples are analysed. An analyses of different sub-sampling methods will be carried out for sites in each of the classification groups, for each sampling season on samples collected during the 1999 field season.

5.3 – Examination of Biovolume (Objective 3)

Although a range of metrics were examined in relation to the Denali NP data set, some were highly variable and therefore unlikely to be sensitive to water quality degradation. However, not all of the available metrics could be examined. In particular those relating to functional feeding groups and the productivity of systems were not assessed. An examination of biovolume (a surrogate for biomass) for each of the classification groups, for each season and over time will be made as biomass has been shown to be an effective indicator of environmental stress (Meire & Derue 1990). In addition Piorkowski & Milner (unpublished) found a significant link between the biovolume of invertebrates and the time of recovery after placer mining in streams in the interior of Alaska. Little technical expertise is required to measure the biovolume of an invertebrate sample and therefore it may provide a very simple, but effective measure of aquatic ecosystem health. Unlike many methods of measuring biomass, biovolume measures are non-destructive therefore samples can be examined and archived (Smit et al. 1993). All of the samples which have been collected from Denali NP are preserved and are available for examination using this technique allowing the assessment of annual and seasonal variation in biovolume.

5.4 - Periphyton Community Analysis (Objective 4)

As biotic groups vary in their sensitivity to different pollution events focusing solely on one group of organisms as a tool to detect stress may bias the assessment. As a result, in recent years other species assemblages are being examined and used in biomonitoring. For example, benthic diatoms have been used in many areas as indicators of different pollution events such as mining (Besch et al., 1972; and Deniseger et al. 1986), and changes in water quality (Hodgkiss & Law 1983; and Lobo et al. 1995). There has been some work carried out in Alaska which indicates that they may be very effective monitoring tools, particularly if a stressor acting upon a system produces an increase in water turbidity (Lloyd et al. 1987). The revised EPA rapid bioassessment protocols, which will be available in May 1999 use periphyton communities as a bioassessment technique. The effectiveness of these techniques, chlorophyll a concentrations (a surrogate for algal biomass) and algal community structure, as potential monitoring and bioassessment tools in Denali NP will be examined.

5.5 – Documenting the Range and Causes of Natural Variation (Objective 5)

Throughout the duration of this project one of the principal goals will be to establish the range of natural variation in the benthic invertebrate communities of Denali NP, and identify the causes of this variation. This information is crucial if effective monitoring programs are to be established (McElravy et al. 1989) and is a fundamental requirement in order to accurately calibrate bioassessment methods (Barbour et al. 1996). The inter-annual variation data are required to produce an effective reference condition data set.

The streams and rivers which have been sampled in Denali NP have been classified into 6 groups based upon their benthic macroinvertebrate communities. Initial data collected from 1994 onwards indicates that there was considerable inter, and intra annual variation in benthic invertebrate community composition (Conn 1998). However, this variation was not constant across all of the classification groups. Therefore, to effectively separate natural variation from variation caused by anthropogenic influences it is necessary to sample watersheds in each of the classification groups. Fourteen long-term reference sites including representatives of each of the six classification groups have been established. These sites (Table A) have been sampled each year since 1994 and will again be sampled each year, throughout the project. All of the sites lie close to the road corridor so that they can be easily accessed without reliance upon helicopters which may not be available in the long term (Figure 4).

Each of the long term data set sites will be sampled three times during the ice free periods in each year (1999 - 2001). In order to compare the data collected with that from previous years, samples will be collected using a modified Surber sampler with 345µm mesh size. Three replicate samples will be collected on each occasion from a riffle area at each site to allow comparative statistical analysis of the data to other environmental parameters be carried out as recommended by Karr & Chu (1999).

Map of Long Term
Ecological Monitoring
Sites in Denali NP

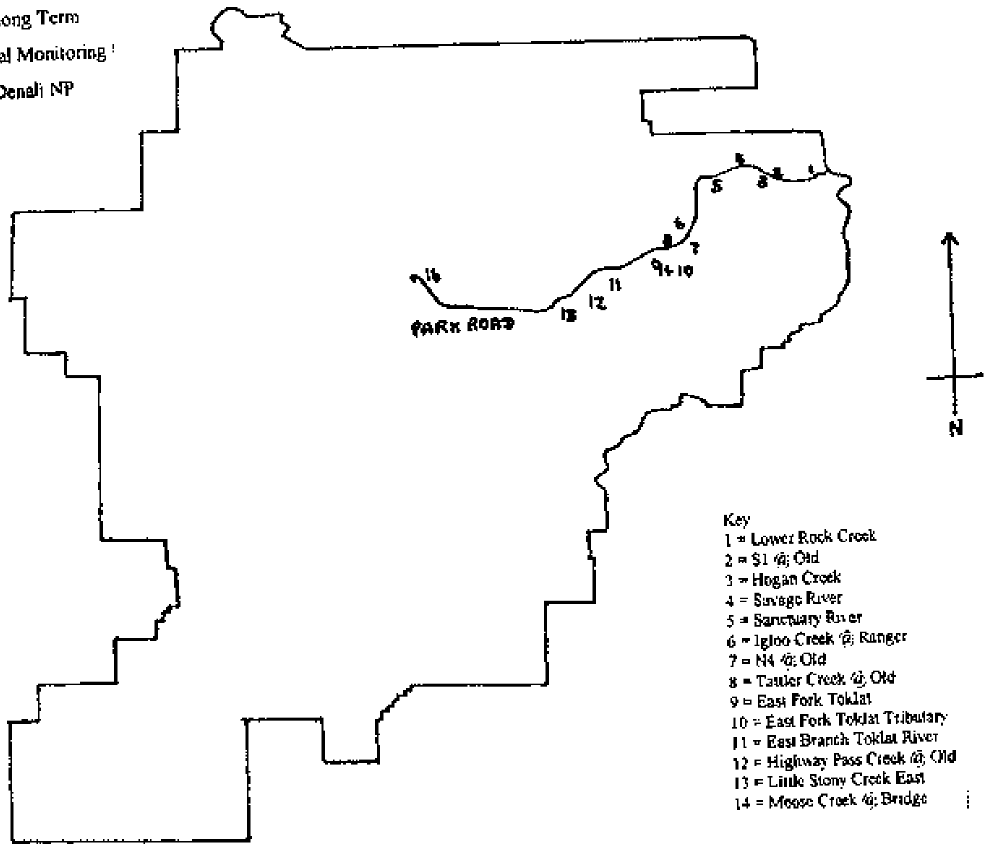


Table A - Sites sampled during 1998, their TWINSPAN grouping and years in which they have been previously sampled are also shown.

Site Name	Site	Group	1994	1995	1996
Tattler Creek @ Old	1	1	Yes	Yes	Yes
East Fork Tributary	2	1	Yes	Yes	No
S1 @ Old	3	2	Yes	Yes	Yes
Hogan Creek	4	2	Yes	Yes	Yes
Little Stony Creek East	5	2	Yes	Yes	Yes
Moose Creek @ Bridge	6	3	Yes	Yes	Yes
Savage River	7	4	Yes	Yes	No
Sanctuary River	8	4	Yes	Yes	No
Igloo Creek @ Ranger Station	9	4	Yes	Yes	Yes
N4 @ Old	10	5	Yes	Yes	Yes
Highway Creek @ Old	11	5	Yes	Yes	Yes
East Fork Toklat	12	6	Yes	Yes	No
East Branch Toklat @ Old	13	6	Yes	Yes	Yes
Rock Creek Lower	14	6	Yes	Yes#	Yes#

Data from Lisa Popovics.

5.6 - Physical Stability and Invertebrate Community Persistence (Objective 6)

In addition to examining the amount of inter and intra annual variation an effort will be made to try and identify which features are controlling this variation. There is some evidence that community variability may be linked to the physical stability of the sites (Conn 1998). The results agree with the findings of Death & Winterbourn (1994) who found that stable sites generally had more persistent communities than did unstable sites. The authors examined and described the physical stability of a site in terms of both its geomorphological characteristics and its temperature regime. The timing and number of degree days experienced by a river or stream has been demonstrated to have a significant effect on riverine fauna (Oswood 1997). Vinson & Hawkins (1998) found that water temperature was a major variable in the distribution of invertebrate fauna when compared to other factors. The effects of temperature on the benthic invertebrate community will be examined in more detail through the use of small temperature data loggers which are installed in representative sites in each of the classification groups.

5.7 - Riparian / Stream Invertebrate Interactions (Objective 7)

One of the most fundamental ways in which the riparian area directly interacts with the benthic invertebrate community is through the input of material such as leaf litter, and shading effects. Data from Conn (1998) suggested that the amount of epilithic algae (expressed by chlorophyll a concentration) was significantly related to the benthic invertebrate community, while coarse particulate organic matter (CPOM) did not show a significant link. However, these links were not explored in relation to the different riparian vegetation assemblages. A study on the retention of organic matter, and the feeding behaviour of invertebrates using gut content analysis in different habitat types will take place in order to examine linkages more closely. This type of information is also essential if invertebrates are to be assigned to the correct functional feeding group (Cummins 1988 cited by Hannaford & Resh 1995). Functional feeding group information is often used as a metric in the multimetric approach, and these data will allow an examination of the usefulness of this type of metric within the Denali NP context. If time allows an examination of the role aquatic invertebrates play as a food source for other riparian species may be carried out. In particular links with bird populations, such as Harlequin ducks who feed on the aquatic larval stages, and passerines which may feed on the emerging adults will be explored.

In recent years, more and more emphasis is being placed upon integrating habitat assessment data when conducting a bioassessment. There are a large number of habitat assessment techniques available and several of these, in particular the methods being tested on the Kenai peninsula area of Alaska by Major et al. (1998) will be examined at the long term sites in Denali NP. This will improve the comparability between the Denali NP data set and the pilot data set being collected by Major et al.

5.8 - The use of Chironomidae in Denali NP for LTEM (Objective 8)

Chironomidae are the most ubiquitous invertebrate group in freshwater and a wide diversity of species are a key component of invertebrate communities in both pristine and polluted waters (Cranston 1995). Chironomidae are involved in the processing of organic matter at all levels in streams including collectors, grazers and predators. Chironomidae have been used extensively in the classification of running waters (Agar 1992) and indicator taxa or groups of taxa have been shown to be important indicators of organic enrichment (Wilson 1991), acidification (Leuven et al. 1987), toxic metals and chemicals (Warwick 1990, Clarke 1993) and a number of other impacts including increase in water temperature (Rossaro 1991), road construction and timber harvest (Lindegaard 1995).

With increasing latitude in unimpaired streams in Alaska, Chironomidae increase in their contribution to stream communities (Oswood et al. 1995). From an analysis of 48 streams in the Yukon hydrological region Oswood et al. (1995) found the Diptera (predominantly Chironomidae) made up on average 56% of the fauna. In Denali NP from a study of 58 streams, Roberts & Milner (1996) determined that this contribution was nearly 67% for streams on the north side of the Alaska Range. In analyses to date in Denali NP, Chironomidae have remained at the family level due to the time consuming techniques typically needed to identify them in large numbers. Other groups have typically been identified to at least the genus level or lower.

The aim of this aspect of the project is then to tap the tremendous resources of information that remains within the Chironomidae in the streams of Denali NP with respect to stream ecosystem function and water quality. This would involve identifying the Chironomidae within the samples that are already sorted from 1995 and 1996 and therefore no additional fieldwork is necessary. Identification of Chironomidae to genus and species is a specialist task and involves mounting the head capsule of the organism on a slide and microdissecting the mouthparts. We have a student, Katrina Magnusson, that has extensive experience in this area and has been responsible for identifying all the Chironomidae collected from 16 streams in Glacier Bay National Park in May 1997.

From these data we should add to our knowledge about the true diversity of taxa in the streams of Denali NP and be able to add specific Chironomidae taxa to the taxa characteristic of the stream groups that have been identified. The Chironomidae taxa can then be evaluated as potential indicator taxa for long term changes in water quality as outlined above. In addition it would be one of the few studies that would fully elucidate the relationships between invertebrates at the same taxonomic level in interior Alaskan streams and increase our understanding of these systems considerably.

5.9 - Communicating the Results (Objective 9)

One of the key aspects of the project will be effectively communicating the results of the work carried out in Denali NP to both park staff and the wider scientific community. In both December 1999 and December 2000 an end of year report will be produced. This will document in detail all the work carried out within that year, the results obtained, and a discussion of the significance of the findings. It is hoped that an active relationship can be developed between the investigators and park staff so that new ideas and suggestions can be incorporated into the project, and modifications to field plans made as required.

In order for the results from Denali to be available, and useful to resource managers, planners, and scientists, outside Denali NP it is critical that they be published in peer-reviewed, scientific journals. Throughout the duration of the project it is hoped that a number of scientific papers will be submitted for publication. In addition to the transfer of information through formal journal articles, metadata and less technical summaries, and results of the project will be made available to park resource managers and other interested parties through workshops, world wide web pages and discussion.

As the debate over different bioassessment and monitoring approaches continues, the State of Alaska is investigating a range of different techniques for monitoring and measuring water quality using biotic communities. The results of the research carried out in Denali NP may not only have implications within the park but could make important contributions to the larger scale debate, particularly within Alaska. The first journal manuscripts will focus on this aspect of the project, it is envisaged that they will have the following content:-

1. A discussion of metric variation both seasonally and annually with reference to the multimetric and predictive approaches. This paper will include a discussion of the natural variation in community composition in Denali NP and it's implications for biomonitoring. To the Journal of the North American Benthological Society.

2. A discussion on the classification of rivers in Denali NP outlining the significant variables driving the characteristics of rivers in this part of Alaska. To Freshwater Biology.

3. A discussion on the development and field testing of the predictive model and its potential for use in areas such as the interior of Alaska with its relatively depauperate fauna. Journal undecided.

As the project progresses it is hoped that a number of other papers will be produced. Perhaps one of the most key issues is the range of natural variation of the invertebrate community assemblages in this high latitude area. The data set from Denali will provide one of the few comprehensive, long term data sets from this area which will be very valuable information and will be submitted for publication as appropriate. The results from testing the two bioassessment methods at sites which are known to be impaired will be very important in relation to devising water quality protocols for Alaska. Other information will be published in appropriate journals as it become available.

6 - DELIVERABLES & PRODUCTS

In addition to the scientific papers submitted for publication (as described in section 2.10) an annual progress report describing the past summers study effort for NPS Administrative report will be completed by December 31st in 1999, and 2000.

Yearly summary reports will be provided by March 15th in 1999, 2000, 2001 and the final report for the project will be completed by the September 2001 deadline.

Supplemental to formal written information, it is anticipated that personnel will take place in meetings and workshops as appropriate so that the results can effectively be communicated to as wide a range of people as possible.

All invertebrate samples collected from Denali NP will continue to be preserved and examined using non-destructive techniques. Once analysis has been completed the specimens are labelled, stored and archived so that they will be available in future years.

7 - PROJECT TIMETABLE

7.1 - 1999

May -	Plan field season in detail, finalise work plan.
June -	Phase 1 Sampling - (to take place as early as possible).
July -	Phase 2 Sampling - (late July/ early August).
August -	Carry out sample sorting, identifying, and lab work around the field work. Chironomidae identification work will start at this time.
September -	Phase 3 Sampling - (to take place as late as possible).
October -	Lab work - complete sorting and invertebrate identifying.
November -	Compiling the results and data analysis.
December -	Finish data analysis. Write and submit end of year report.

The field work to be carried out during summer of 1999 is to be concentrated into three discrete time periods. In each of these three sampling periods similar procedures will be carried out.

Benthic Macroinvertebrates :- Surber samples will be collected from sites which are known to be impaired (after consultation with park staff) so that both the multivariate and multimetric methods can be assessed in terms of their sensitivity in detecting impairment. Concurrently all of the "reference" sites (Table A) will be sampled using the same technique. This will also allow the long term data set to be continued. Extra samples will be taken from each site to examine sub-sampling effects, and the number of replicates required. In addition several quantitative sampling methods will be examined.

Periphyton Communities :- The periphyton communities of streams and rivers in Denali NP will be examined during all three of the sampling periods in 1999 to examine seasonal effects. Samples will be collected from both the impaired sites and the long term reference sites (Table A). It is envisaged that chlorophyll a concentrations (a substitute for biomass) and community composition will be examined following the guidelines described in the EPA-RPB protocols.

7.2 - 2000

January -	Examine the biovolume of different taxa groups from stored samples.
February -	Examine weather data etc. for possible links to the invertebrate community. Write Yearly summary report.
March -	Work on articles for publication in peer reviewed journals.
April -	Continue to work on publications & plan for 2000 field season.
May -	Field season planning, beginning field work in late May.
June -	Phase 1 sampling (as early as possible).
July -	Phase 2 sampling (late July / early August).
August -	Lab work (sorting, etc. as appropriate)
September -	Phase 3 sampling (as late as possible).
October -	Lab work - complete sorting and invertebrate identification etc.
November -	Compiling results and data analysis.
December -	Write and submit end of year report.

As in 1999 the long term reference sites will be sampled for invertebrates using the standard Surber samples in three discrete sampling periods throughout the ice free period in 2000. Depending upon the results obtained in 1999, other sampling methods for benthic macroinvertebrates may also be employed. However, again depending upon results obtained from the 1999 field season, the main emphasis of the field work carried out in 2000 will be to examine in more detail riparian / lotic community interactions. Of particular interest will be interactions between different food sources for the invertebrate community, and the retention of material within the systems. Again the periphyton communities will be examined and additional work on leaf litter retention maybe carried out during the autumn. If biovolume appeared to be a potentially useful metric the invertebrate samples collected during 2000 will be examined for biovolume in the lab.

7.3 – 2001

January -	More analysis of the results, in particular the long term data set, and relate
February -	it to climatic and other features. Linking in the Chironomidae
	identification work – community structure, functional feeding groups etc.
March -	Write and submit yearly summary reports.
April -	Planning any remaining field work to answer unresolved questions.
May -	Field / Lab work as appropriate, writing papers
June -	Field / Lab work as appropriate, writing papers
July -	Field / Lab work as appropriate, writing papers / protocol.
August -	Finish data analysis & Lab work, start writing the final report.
September -	Complete and submit final report.

It is anticipated that less fieldwork will be carried out during 2001 than in the previous two years as less time will be available for processing samples and analysing the data. However, it is hoped that a final set of benthic invertebrate, and, dependent upon the results from 1999 and 2000, periphyton samples will be collected from each of the LTEM sites. At this point the number of samples required for accurate data should be known and any sub-sampling / alternate methods will be in place. Laboratory work and data analysis on the 2001 samples will be occurring concurrently with field sampling.

In addition to the final project report which will discuss in detail all of the work carried out during the project, the results and provided detailed conclusions, it is also envisaged that a shorter, less technical document will be provided, principally to park resource management staff. This report would provide a detailed description of the protocol developed, and site descriptions such that the monitoring effort can be continued by park staff after this project has finished. In addition it is hoped that closer ties can be made with park staff throughout the project so that information is more effectively communicated between the researchers and park staff both in regard to practical field methodology and data interpretation and results.

8 - LITERATURE CITED

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