The Alberta Biodiversity Monitoring Program: Monitoring Aquatic Systems

Brian Eaton

March 11, 2005

Alberta Research Council
P.O. Bag 4000
Vegreville, Alberta
T9C 1T4

Disclaimer
The views, statements, and conclusions expressed in this report are those of the authors and should not be construed as conclusions or opinions of the ABMP. Development of the ABMP has continued since this report was produced. Thus, the report may not accurately reflect current ideas.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

The Alberta Biodiversity Monitoring Program (ABMP) is designed to monitor changes in biodiversity within Alberta. The ABMP uses the definition of biodiversity developed by the Convention on Biodiversity: *biodiversity means the variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part including diversity within species, between species and of ecosystems*. The program has been under development for several years, and sampling of terrestrial biota and habitats is underway. Aquatic sampling protocols have not yet been finalized.

This document reviews major monitoring programs or agencies in Alberta and elsewhere in North America, and provides background on past aquatic sampling and protocol development in the ABMP. Based on this past work and information from other aquatic monitoring programs, a set of protocols for sampling biotic and abiotic parameters in large lakes, large rivers, wetlands, and streams in Alberta is provided. Estimates of time needed to complete protocols and costs for equipment are also given.

Large lakes and rivers (approximately 100 of each) should be sampled across Alberta to provide provincial-scale data on biodiversity trends in these habitats. Biotic elements suggested for sampling in lakes include phytoplankton, zooplankton, and fish. In rivers fish, benthic macroinvertebrates, and benthic algae will be sampled.

Streams and wetlands should be sampled at higher densities than lakes and rivers. Streams and wetlands should be sampled at the same density as terrestrial plots, which are arranged on a 20 x 20 km grid. This results in a total of 1656 sampling points across the province. I suggest that streams be sampled near those terrestrial points that fall in the Rocky Mountain and foothills ecoregions, while wetlands should be sampled everywhere else in the province. Benthic macroinvertebrates and benthic algae will be sampled at stream sites, while aquatic macroinvertebrates and vascular plants will be sampled at wetland sites. Abiotic factors, such as water physiochemistry, will also be sampled at all sites.

The ABMP has defined statistical targets related to detection of trends in biodiversity. These include detection of a change of 3% per year in biodiversity parameters within a region (a region is defined as approximately 50 sampling points) after 15 years of surveys (three full sampling rotations) with a 90% certainty; detection of a difference of 50% between regions after five years of surveys (one complete sampling rotation) with a 90% certainty; and a <10% probability of declaring a difference in these parameters when one does not exist. The number of sites that must be sampled to meet these statistical targets depends on variance in the groups being sampled. The aquatic groups proposed here for inclusion in the ABMP have levels of variance acceptable under the statistical guidelines for the ABMP.

The protocols outlined in this document should be tested during the 2005 field season. A field test is necessary to ensure time and cost estimates are accurate, that sampling equipment is compatible with sampling sites which must be accessed by quad or helicopter, and to determine if there are any procedural or equipment problems which must be addressed. Sampling protocols

can be adjusted based on this field test, before the aquatic sampling protocols are fully implemented as part of the ABMP.

1 INTRODUCTION

The Alberta Biodiversity Monitoring Program (ABMP) is designed to track changes in biodiversity and habitat elements over time and space across the province of Alberta. The ABMP uses the definition of biodiversity developed by the Convention on Biodiversity: *biodiversity means the variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part including diversity within species, between species and of ecosystems*. The ABMP samples terrestrial and aquatic habitats and biota, and landscape-scale elements. When fully implemented, the ABMP will sample terrestrial elements at approximately 1650 points distributed across Alberta on a 20 x 20 km grid (Figure 1). Aquatic elements will be sampled at two scales: larger entities (lakes and rivers) will be sampled at a provincial scale (100 sites across the province), while smaller aquatic habitats (streams, wetlands) will be sampled at an intensity similar to that for terrestrial elements. Each point will be sampled once every five years on a rotational basis.

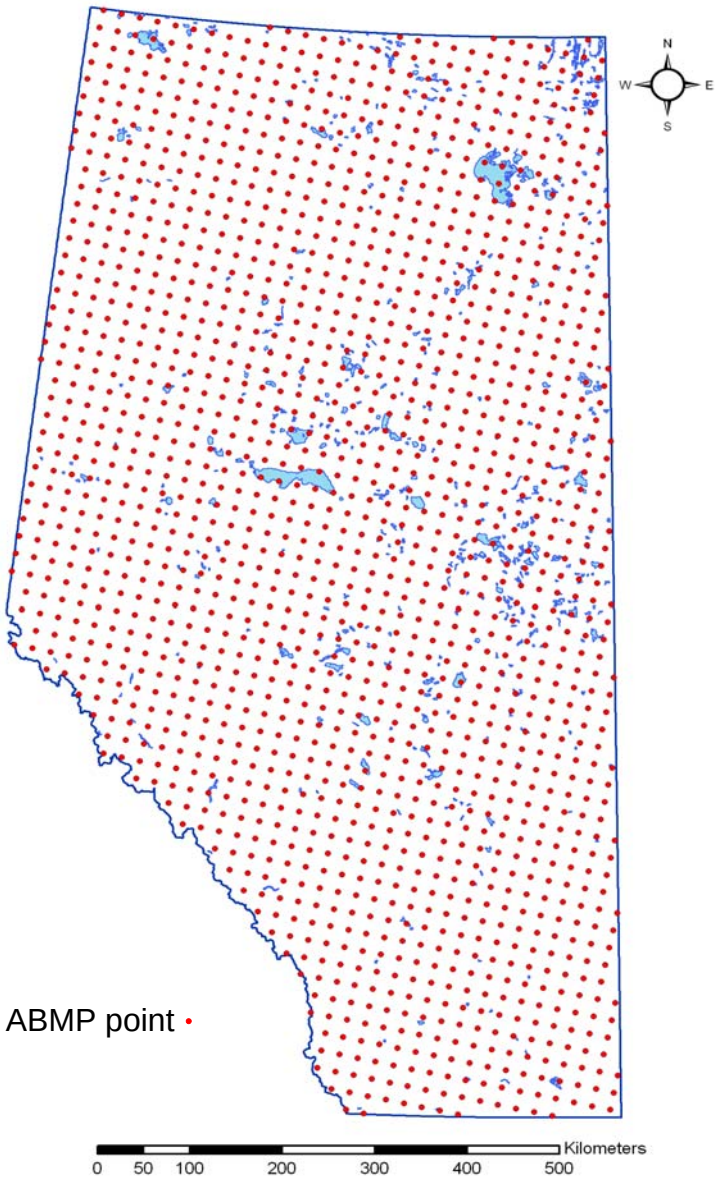

Figure 1. Alberta Biodiversity Monitoring Program terrestrial sampling points.

The overall statistical goals of the ABMP are to: (1) detect a change of 3% per year in select parameters within a region after 15 years of surveys (three full sampling rotations) with a 90% certainty. The selected parameters include (a) species richness of targeted groups, (b) population density of select species, (c) physical / structural habitat characteristics. (2) detect a difference of 50% in the select parameters between regions after five years of surveys (one complete sampling rotation) with a 90% certainty. (3) have a <10% probability of declaring a difference in these parameters when one does not exist.

Although the general structure of the ABMP has been determined, development of individual sampling protocols is continuing. Here I provide information on the development

of aquatic sampling protocols. The objectives of this report are to (1) provide an overview of the ABMP; (2) provide an overview of the statistical power expected within the ABMP sampling framework; (3) review existing literature on the structure and protocols of other aquatic monitoring programs to help in the design of the ABMP aquatic program; (4) provide background on past development of aquatic protocols for the ABMP and what development is still required; and (5) describe aquatic sampling protocols recommended for the ABMP. Procedures that relate to the ABMP as a whole, such as data management, analyses, and reporting of survey results, are being developed by other research teams within the program, and are beyond the scope of this document. Please see the following website for more details on the program: http://www.abmp.arc.ab.ca/. Reports which may be particularly relevant include (a) "The Alberta Biodiversity Monitoring Program (ABMP): a cost-effective, multi-species, broad-scale, long-term biodiversity monitoring program" (url: http://www.abmp.arc.ab.ca/Documents/Prototype%20Summary.with%20fig.pdf), and (b) "A Biodiversity Index and Decision-Support System for Alberta" (url: http://www.abmp.arc.ab.ca/Documents/Annual%20Reports/ABMP%20CRD%20Annual% 20report%20Oct%202004.pdf).

The overall goal of the ABMP is to monitor status and trend of biodiversity in Alberta. To achieve this goal assemblages being sampled should have some or all of the following characteristics: (1) contain multiple species, (2) respond to anthropogenic stressors, (3) it should be possible to identify specimens to species, (4) represent a high profile group, and (5) generate high quality data in an efficient manner using rapid assessments (Shank et al. 2002). Aquatic elements chosen for the ABMP each exhibit many of these characteristics. Fish, for example, are a high profile group with 62 species in Alberta (Alberta Environment 2002); fish respond to anthropogenic disturbances and most can be readily identified in the field. Benthic macroinvertebrates respond to a variety of stressors, contain numerous species, and can be sampled rapidly and efficiently. Wetland plants are diverse, easy to sample, and are relatively easy to identify. Similar statements can be made for the remaining groups discussed in this document.

Another guiding principle of the ABMP is that the program must be cost effective. Every effort is made within the ABMP to ensure that sampling and processing is achieved at reasonable cost. Some assemblages, though of interest, will not be sampled because the cost of sampling and/or identification is prohibitive and/or there are too few species in the assemblage to justify the cost of sampling. A good example of the latter case is amphibians: only 10 species occur in Alberta, and few sites will have more than two or three species. For this reason amphibians are not being monitored in the ABMP.

2 VARIABILITY AND STATISTICAL POWER ACHIEVED FOR AQUATIC SURVEY COMPONENTS

The variance in species richness and abundance estimates collected during the aquatic survey portion of the ABMP is presently unknown, but can be expected to differ across species groups. Estimates of species richness based on presence / non-detection of species, are likely to exhibit less variance than abundance estimates.

Using data from the literature, Gibbs (2000) modeled the impact of variance in annual counts or indices of species abundance to estimate how many samples would be needed to detect different levels of population change (e.g. 50%, 25%, and 10%) over 10 years of monitoring. He found that relatively few plots (10 – 30 plots; one visit to a site per year) were needed to detect

large (~50%) changes in abundance for most animal groups, while substantially more were necessary to detect smaller (~10%) changes (40 - >500 plots; one visit to a site per year). Using similar data, and the same modeling software (Gibbs 1995), Schieck (2002) estimated the number of sample plots necessary to be able to detect different levels of exponential decrease in abundance or species richness; the levels modeled were 1%, 2%, and 3% per year, which translate into 9%, 18%, and 26% changes over 10 years, respectively. He found that, for most animal groups, a 3% exponential decrease could be detected when less than 40 sites were sampled per region, even when the coefficient of variation exhibited by a group was 3.0. Although the variation that will be encountered for different groups has not been assessed for ABMP sites, literature values tabulated by Gibbs (2000) provide some indication of the variance that can be expected for different groups (Table 1). These suggest that trends in many aquatic groups can be adequately assessed in a region consisting of 40 sampling points. Changes in the physical environment are expected to exhibit low variability, and thus will be more than adequately sampled with 40 sampling points per region (Schieck 2002).

Table 1. Variability estimates for local populations of aquatic, or aquatic-associated, animal groups. Coefficients of variation were derived from studies where data was collected for more than five years (Gibbs 2000).

Group	Number of count series	Mean coefficient of variation (range)
Fishes, salmonids	42	0.473 (0.14 – 1.24)
Caddisflies	15	0.497 (0.24 – 1.23)
Dragonflies	8	0.566 (0.33 – 1.09)
Fishes, nonsalmonids	30	0.709 (0.11- 1.73)
Pond-breeding salamanders	10	0.859 (0.45 – 2.31)
Frogs and toads	21	0.932 (0.05 – 2.78)

Patalas (1990) found that >90% of the zooplankton species in a region were generally found by sampling 20 lakes, so sampling 100 lakes across the province should give a reasonable picture of zooplankton species richness at a provincial scale. Models of the ability to detect trends in species richness in zooplankton based on variance estimates derived from field data collected by the Ecological Monitoring and Assessment Program (EMAP) suggests that a 3% annual change would be detectable with 90% certainty after 15 years of sampling (Urquhart et al. 1998). EMAP has a similar revisit schedule to that used in the ABMP.

If the aquatic elements chosen for sampling within the ABMP show low enough variance that sampling 40 sites can detect exponential decreases of 3% per year, it appears a number of different regional comparisons for wetlands and streams will be possible. Approximately 353 streams will be sampled, while approximately 1303 wetlands will be sampled (Table 2). Assuming 40 sites per region, these numbers translate into roughly 9 and 30 regions, respectively. With only 100 sites sampled for lakes and rivers, I suggest that data collected in these habitats is sufficient only for provincial scale tracking of biodiversity. The time and cost to sample these larger entities at the same intensity as streams and wetlands would be prohibitive within the context of the ABMP, where aquatic sampling must be balanced against sampling terrestrial habitats and biota, and tracking landscape-scale changes using remote sensing.

Table 2. Number of ABMP points within each ecoregion in Alberta

Ecoregion (habitat type to be sampled)	Number of ABMP points in an ecoregion
Grassland (wetland)	243
Parkland (wetland)	150
Foothills (stream)	241
Rocky Mountains (stream)	112
Boreal Forest (wetland)	871
Canadian Shield (wetland)	39

In conclusion, the variance present in aquatic groups monitored by the ABMP is expected to be within acceptable limits to allow detection of a 3% cumulative change in abundance or species richness within a region (40 sites) after three complete sampling rotations within that region. This translates into 9 regions for streams and 30 regions for wetlands. Data from lakes and rivers will probably be sufficient to track biodiversity change at a provincial scale, but not at regional scales.

3 BIODIVERSITY MONITORING PROGRAMS IN USE OR IN DEVELOPMENT IN NORTH AMERICA

Here I provide a brief review of some of the major biodiversity or aquatic monitoring programs in North America focusing on Alberta. In each case I provide the following information: (a) the objective of the program, (b) elements sampled in the program, (c) protocols that were adopted by the ABMP, and (d) protocols that were not included in the ABMP and why. This is not an exhaustive list of aquatic or biodiversity sampling programs in North America, but a selection of some of the larger initiatives or those more relevant to the ABMP. This section does not provide details of protocols that are suggested for use in the ABMP; these details are provided later in this document. The focus of this section is to review aquatic sampling protocols, so terrestrial elements of these monitoring programs will not be discussed.

3.1 Inventory and Monitoring Program (U.S. National Park Service)

This program was developed to (1) complete basic inventories of species occurring in each national park and on which monitoring efforts can be based, (2) evaluate alternative monitoring designs and strategies, and (3) implement operational monitoring of critical parameters (which are termed "vital signs" within the program) at all natural resource parks (U.S. National Park Service: Inventory and Monitoring *undated*). The approximately 270 federal natural resource parks in the USA are clustered into 32 networks based on similarities in geographic and natural resource characteristics. Each network contains three to 17 parks.

At each national park a core set of indicators are monitored to allow comparison and synthesis of data at large scales. Additional elements are added at the network/ecosystem and park scales so that more specific monitoring objectives can be addressed and local partnerships can be pursued. This results in variation in the monitoring programs implemented at individual parks, although development of all programs follows a common process. This process includes

conceptual models of ecosystem components, selection of indicators and specific monitoring objectives, and appropriate sampling design and sampling protocols. The National Park Service also encourages peer review of proposed monitoring plans.

Within the framework of the Inventory and Monitoring Program a small number of water quality parameters are sampled at all monitoring stations in U.S. national parks. These include temperature, specific conductance, pH, and dissolved oxygen for both flowing and standing water habitats. At standing water sites, these data are collected as a vertical profile. A qualitative assessment of flow for flowing water, and level/stage for non-flowing water bodies, is also made at each site, and a digital photo of the site is taken (Irwin 2004).

In addition to core water quality parameters, data on other aquatic elements is collected in some parks. Some of the additional elements include aquatic macroinvertebrates, stream fish, amphibians, stream water chemistry, pond / wetland vegetation, stream physical habitat, lake water quality, and plankton. In some parks this additional sampling focuses on a particular species (e.g. brook trout), or on particular sites with potential human impacts (e.g. road development). Because different parks must deal with different management issues, sampling protocols lack consistency across parks. For example, the method used to sample benthic macroinvertebrates in flowing water in one park includes seven different methods (kick-net, sweep-net, leaf-pack, fine-mesh rock/log wash, sand, visual, and aerial) while two different methods (Surber and Hester-Dandy samplers) are used in another park.

Some of the sampling methods used by the U.S. National Park Service (NPS) are similar to those proposed for the ABMP. The ABMP protocol for water physiochemistry is very similar to the core water quality data collected by the NPS, while there are similarities between the ABMP stream benthic macroinvertebrate sampling protocol and that used in some U. S. parks. Other protocols used by the NPS have not been adopted by the ABMP. For instance, snorkeling, angling, and mark-recapture techniques are used to estimate fish populations in one park. For the ABMP these approaches would take too much time and probably produce similar data as using experimental gillnets and minnow traps. Amphibians are not being sampled during the ABMP because only 10 species occur in the province (Russell and Bauer 2000), and few species are likely to occur at any particular site.

One major difference between aquatic sampling within the NPS and the ABMP is that protocols are standardized across all habitats of the same type (e.g. wetlands) within the ABMP, while sampling methods may differ across parks within the NPS.

3.2 Multiple Species Inventory and Monitoring (MSIM) program

This program was developed by the United States Department of Agriculture (USDA) Forest Service so land managers and conservationists could assess the success of management programs (Manley et al. 2004). Sampling sites within MSIM are offset 100 m in a random direction from existing national Forest Inventory and Analysis (FIA) grid points; vegetation and soil are sampled at FIA points once every 10 years. FIA points are distributed on a systematic hexagonal grid, with centres of each hexagon 5.4 km apart. MSIM is only used on lands within the National Forest System and on land belonging to collaborating organizations.

MSIM uses standard protocols to detect the presence / absence of the more common species in an area. MSIM assumes that temporal changes in the proportion of sites occupied by relatively common species can be used to evaluate the success of management actions or the degree of human impact in a region. Currently MSIM protocols focus on vertebrates, with a heavy emphasis on terrestrial forms. Aquatic sampling amounts to visual surveys along the edge of lakes, streams, and other water bodies. Any amphibians, reptiles, birds or mammals observed

during these surveys are recorded to species. Aquatic habitats are surveyed for fish by snorkeling in deeper waters, or wading in shallow water. Habitat parameters are also sampled; these include depth, substrate, floating and submerged logs, and woody debris density for all aquatic sites. Basin area, perimeter, and emergent vegetation are also measured at lentic sites; channel geometry, width, gradient, and pool frequency and proportion are measured at lotic sites. At present no protocols for sampling invertebrates or aquatic plants have been developed. Protocols for aquatic site selection are under development.

Although some of the parameters measured in MSIM are similar to those considered for the ABMP, the methods used are not consistent with the needs of the ABMP. Surveys of aquatic habitats in MSIM consist of walking completely around lentic sites, regardless of their size, and searching for aquatic and aquatic-associated vertebrates. For lotic sites, a 1000 m length of the channel is surveyed for the same groups. MSIM therefore does not use sampling methods that target specific groups (e.g. nets for fish), but relies on surveys to detect the presence/absence of a broad range of species. Within MSIM, each site is visited on two occasions, separated by a minimum of two weeks. This method is not consistent with the ABMP, where aquatic sites are visited on one occasion to keep costs at a manageable level. In addition, specific groups (e.g. fish) are targeted in the ABMP to obtain a reasonable picture of the diversity within that group at each sample site. In the ABMP there is an upper limit on the size of a sample plot (e.g. 75 ha on a lake) so that the sampling unit is consistent between sites. Overall, the MSIM approach does not mesh well with that of the ABMP, and no protocols were adopted from the MSIM.

3.3 Environmental Monitoring and Assessment Program (EMAP; U. S. Environmental Protection Agency)

The Environmental Monitoring and Assessment Program (EMAP) is a long-term research initiative by the U.S. Environmental Protection Agency (EPA). EMAP began in the late 1980's and underwent more than a decade of protocol development, testing, and regional demonstration projects (Hughes et al. 2000). The main goals of EMAP are to (1) develop the science for a state-based statistical monitoring framework to determine condition, and detect trends in condition, for all of the U.S.'s aquatic ecosystems; (2) transfer this technology to states, tribes, and regions, and (3) have the EMAP approach implemented by states, tribes, and regions (McDonald et al. 2002). The EMAP sampling design provides unbiased, representative monitoring of aquatic resources with a known confidence level.

Site selection in EMAP is accomplished using a type of survey sampling called a Generalized Random Tessellation Stratified (GRTS) design. This approach spatially balances sample sites across the resource of interest (e.g. lakes) using unequal probability selection. This means that the probability that an individual entity (e.g. a lake) is selected can be related to the size (or other attribute) of that entity, depending on how the user weights the value of different entities (Stevens and Olsen 1999). Thus, a 200 ha lake might be twice as likely to be randomly chosen as a 100 ha lake. Because a GRTS approach uses probability selection to define the population of sample sites, data collected at these sites can be applied to the total population of potential sites, allowing estimation of parameters such as variance for the entire population (see http://www.epa.gov/nheerl/arm/designpages/monitdesign/survey_overview.htm). This can significantly reduce the number of sites that must be sampled to achieve a given level of precision. For example, 4219 lakes (out of a potential population of approximately 11,076 lakes) in the north eastern United States were chosen for sampling related to phosphorus levels and the incidence of algal blooms. Because the sample lakes were not chosen using a probability survey design (lake selection was biased toward problem lakes), results of the survey could not be

applied to the entire population of lakes. Using a probability survey, an estimate of the condition of all lakes could be made, with known statistical uncertainty, by sampling only 344 lakes (see http://www.epa.gov/NHEERL/arm/documents/whyprobsurv.pdf). Selection of study sites by non-probability methods can result in less reliable, and potentially misleading, conclusions from monitoring data (Peterson et al. 1999). An additional property of site selection using GRTS is that if a sample site is "lost" because it is a non-target (does not have the correct characteristics when it is ground-truthed) or is inaccessible (e.g. landowner will not allow access) this site can be replaced while maintaining good spatial balance over the population of potential sample sites (Stevens and Olsen 2004).

The ABMP should more fully explore the use of the site selection procedures developed by EMAP. Site selection using a Generalized Random Tessellation Stratified (GRTS) design should be applicable to both provincial (lakes and rivers) and regional (wetlands and streams) scale elements within the ABMP. To ensure this procedure would work, a professional statistician should examine the methods used by EMAP and ensure they are applicable to the ABMP. For provincial scale elements the province can easily be chosen using GRTS because data from these sites will always be analyzed as a whole. In contrast, data for regional scale elements may be broken up into numerous subsets of data defined by a variety of characteristics such as land use or ecoregion. Thus, if regional scale elements are not distributed across the province in a roughly regular pattern, the data from these elements cannot easily be combined with those from terrestrial sites in the same area. This may limit integration of terrestrial and aquatic data when examining overall biodiversity changes across regions. It should be possible to use a GRTS design to choose an aquatic sampling site associated with each terrestrial site, perhaps by centering a 20 x 20 km grid cell on each terrestrial site and using appropriate aquatic sites within this cell as the potential sampling universe. The GRTS method could then be used to pick several sites within the cell; multiple sites would be chosen to ensure at least one is acceptable and accessible.

One potential problem with the use of a GRTS design for selecting regional elements in the ABMP is that it may be difficult to define the potential sampling universe. A complete inventory of wetlands, for example, is presently lacking; completion of a National Wetlands Inventory, which is presently being promoted by the Canadian federal government, may address this need.

Within EMAP different groups focus on different types of aquatic habitats, such as lakes, Great Lakes, wetlands, large rivers, and streams. Protocols are built around three or four person teams, with the number of days at a site related to the amount of work to be done. For instance, four people sample a stream site in one day, while lakes are sampled over two days by a three-person team. The types of data collected include biological data (e.g. benthic macroinvertebrate species richness), contaminant data (e.g. mercury in fish tissue), physical / structural data (e.g. stream substrates), chemical data (e.g. nutrient levels in lakes), and landscape level data (e.g. land use). Data on multiple assemblages are monitored for each aquatic habitat type, as different groups are differentially sensitive to different impacts and at different spatial scales (Hughes et al. 2000).

EMAP uses indicators to assess the condition of ecological resources being monitored. Indicators include vertebrates (fish, amphibians, riparian birds), invertebrates (benthic macroinvertebrates, zooplankton, zebra mussels), algae (sediment diatoms, chlorophyll *a*, stream periphyton), microbes, water characteristics (temperature, dissolved oxygen, pH, nutrients, Secchi depth), hydrological and substrate conditions, riparian vegetation, large woody debris,

toxic chemicals (fish tissue contaminants, sediment toxicity), climate, elevation, land use, human population density, channel or flow modification, catchment area, water body size, and channel slope (Hughes et al. 2000). Ecological condition at a specific site is compared to similar sites (benchmark sites) that are thought to be in a relatively pristine state to determine if the study site is ecologically impaired (McDonald et al. 2002).

Many of the protocols being used in EMAP are similar to those adopted for the ABMP. These include vertical profiles of temperature and dissolved oxygen, Secchi depth, collection of zooplankton, stream benthic macroinvertebrates, benthic algae, lake and river fish, stream and lake physical characteristics, large woody debris, and landscape characteristics. A number of EMAP protocols are not being used in the ABMP. In the ABMP sediment diatoms will not be sampled, as diatom species will be present in the phytoplankton sample. Some fish sampling methods (seines and trap nets) will not be used because they are not suitable for all lakes (seines) or are too bulky to get to remote sites easily (trap nets). Data on birds at aquatic sites will not be collected, as data on birds will be collected during terrestrial sampling; approximately 20% of terrestrial sampling plots are expected to be wholly or partially covered with water (Shank et al. 2002). Fish tissue and sediment contaminant data will not be collected in the ABMP as it is not relevant to biodiversity. Bacteria will not be sampled in the ABMP as culturing and identifying these organisms would be costly and time-consuming. Amphibians will not be sampled in the ABMP as there are only 10 species in the entire province, few species can be expected at any particular site, and some species can be very difficult to detect.

The major differences between EMAP and the ABMP are (1) EMAP focuses on aquatic habitats, while the ABMP incorporates data from remote sensing, terrestrial, and aquatic monitoring, (2) EMAP uses the condition and character of sites with minimal human impact as a benchmark with which to compare data from sample sites; the ABMP does not use this approach, but rather compares changes in biodiversity over time and space at a regional scale (approximately 40 sampling sites) (No the comparison is done statistically), (3) EMAP samples factors (e.g. toxicity) which are not directly related to biodiversity, and (4) EMAP samples a more complete range of taxa and habitat parameters than is possible during the ABMP due to logistic and monetary constraints. The ABMP focuses on groups that can be sampled in a cost-effective manner while providing high-quality data on biodiversity.

3.4 Ecological Monitoring and Assessment Network (EMAN)

This Canadian federal agency promotes use of standardized protocols to sample ecological parameters. EMAN also collects data at approximately 100 sites across Canada to monitor national trends in ecosystem health and provide early warning of ecosystem change (Tegler et al. 2001). Although EMAN funds production of standardized protocols and supports initiatives such as FrogWatch, WormWatch, IceWatch, and the Ontario Benthos Biomonitoring Network, the mandate of the agency is not to operate at a provincial scale, but to take a broader, national approach to biological monitoring.

EMAN has funded production of sampling guidelines for benthic macroinvertebrates, fish parasites, phytoplankton, and zooplankton. These guidelines contain general information on each group, sampling considerations, and a variety of recommended sampling and sample processing methods. The ABMP is using modified versions of the protocols recommended for benthic macroinvertebrates in streams, and phytoplankton and zooplankton in lakes. Benthic macroinvertebrates will be sampled using a kick net to sample multiple habitats, and a Marchant box will be used to subsample the macroinvertebrate samples. An integrated phytoplankton sample will be collected using a tube. An integrated zooplankton sample will be collected using

a plankton net. Fish parasites are not being assessed in the ABMP as this would require extensive handling and sacrificing of fish, and greatly increase the time required in the field and lab to process samples.

3.5 Ontario Benthos Biomonitoring Network (OBBN)

The Ontario Benthos Biomonitoring Network (OBBN) uses a reference condition approach that relies on the identification of unimpaired reference sites with which test sites may be compared. Therefore, the overall approach of the OBBN does not mesh well with the design of the ABMP, which does not use a reference condition approach or any *a priori* judgement regarding whether a specific site is impacted or not. Some of the protocols designed for the OBBN, however, may be useful in the ABMP.

The OBBN uses a set of flexible protocols for sampling, subsampling, and taxonomic identification so a range of users can participate in the program. Protocols for sampling, processing, and identifying benthos in lakes, streams, and wetlands are provided by the OBBN (Jones et al. 2004). A 100-specimen subsample from each site is identified. Twenty-seven taxonomic groups are used, with identification down to Class, Order, Suborder, or Family, depending on the group.

The preferred sampling method for streams in the OBBN is a travelling kick and sweep using a 500 μm D-ring net; this method is recommended for sampling streams in the ABMP as it is quick, samples multiple habitats within a stream, and can be used with a variety of substrate types. Other methods recommended by the OBBN include grab samples and artificial substrates. Grab samplers will not work with all types of substrates and are not recommended for the ABMP. Artificial substrates require a second visit to a site to retrieve the substrate; this method is not recommend for the ABMP as it substantially increases the cost of sampling, especially in remote sites that are accessed by helicopter.

The preferred subsampling method for the OBBN is the Marchant box, which is a container subdivided into 100 cells; the raw sample is randomly distributed between the cells and a number of cells are randomly chosen until a target number of specimens is identified. This is also the method recommended for the ABMP, as it produces a random subsample of the raw sample. Although the OBBN recommends identification of 100 specimens to a variety of taxonomic levels, I suggest 500 specimens be identified in the ABMP. These specimens should be identified to as fine a taxonomic level as possible. In addition, a large/rare search should be used on the entire sample after the subsampling process is complete. This method is outlined in the stream sampling section below.

I do not recommend sampling benthic macroinvertebrates in lakes or wetlands in the ABMP. Aquatic macroinvertebrates will be sampled from the water column in wetlands using a D-ring net, but this will not include benthic invertebrates. Therefore the methods described by the OBBN for these habitats are not relevant to the ABMP.

3.6 Alberta Environment – Monitoring and Evaluation Branch

Alberta Environment runs long-term monitoring programs for both large lakes and rivers. The lake monitoring program includes the Alberta Lake Management Society's LakeWatch program, and Alberta Environment's Parks Program and Long Term Lake Monitoring Network. Taken together, these programs sample a total of 69 lakes. These lakes are spread fairly well across the mid to southern portion of the province, but sampling sites in the north are lacking (Figure 2). Lakes are not necessarily sampled every year, but most are sampled once every few years. Standard protocols are used at all lakes; these include collection of water, zooplankton, and

phytoplankton samples. Although biological samples are collected, they are not presently processed, but are archived for potential analysis in the future (Ron Zurawell, personal communication).

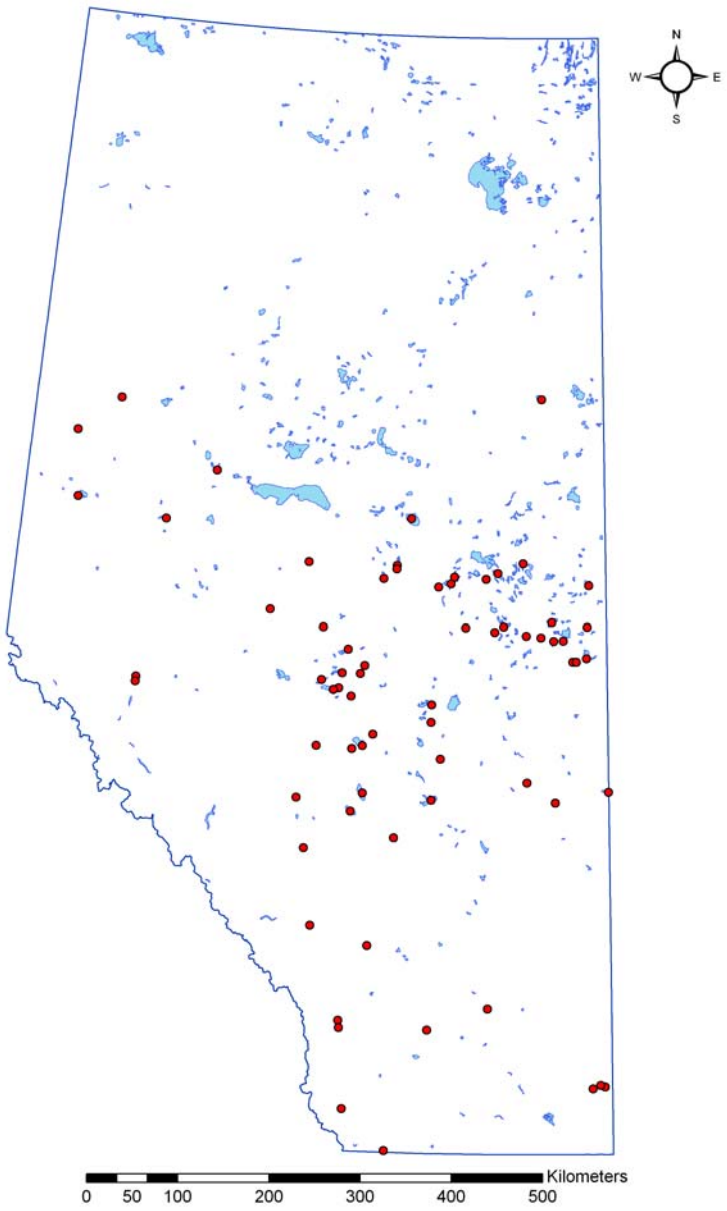

Figure 2. Location of long-term monitoring lakes sampled by Alberta Environment and partners.

I recommend adoption of the sampling protocols similar to those used by Alberta Environment for sampling water, zooplankton, and phytoplankton in lakes. A composite sample for each of these parameters (water, zooplankton, and phytoplankton) should be collected at 3 sites at each lake; one of these sites would be the deepest spot in the lake or sampling plot in the lake. Water samples should be analysed for total nitrogen (TN), total phosphorus (TP), and dissolved organic carbon (DOC). TN and TP provide an indication of the trophic status of a lake and the amount of nutrients present in the lake. DOC is important in determining the penetration of ultraviolet radiation into lakes, which influences the depth of the thermocline (Schindler 2001). The depth of the thermocline influences a number of abiotic and biotic parameters in a lake, such as the depth of the euphotic zone, and the length of the ice-free season for a lake.

A vertical profile of pH, temperature, conductivity, and dissolved oxygen should be done at the deepest spot in the lake or sampling plot. Additional details on sample collection and processing are provided in the lake sampling section below. I do not recommend that the ABMP sample the additional water chemistry parameters monitored by Alberta Environment (e.g. hardness, total dissolved solids), as doing so would be add substantially to the cost of the ABMP.

Alberta Environment also runs a long-term river-monitoring network. Twenty-three sites located in major rivers across the province are sampled on a monthly basis for water

physiochemical parameters (Figure 3). Sampling stations are often established upstream and downstream of point sources of pollution, such as cities (Darcy MacDonald, personal communication). There is no biological sampling associated with the long-term river monitoring network, except for sampling of bacteria such as fecal coliforms.

I recommend sampling water physiochemistry in rivers by collecting a grab sample of water (see river sampling section below for details). A vertical profile of pH, temperature, conductivity, and dissolved oxygen should be done at ABMP river sites; this is also done by Alberta Environment. In addition, Alberta Environment samples a number of other parameters, including bacteria, phytoplankton chlorophyll *a*, true colour, and total dissolved and suspended solids. Sampling these parameters is not recommended for the ABMP as it would substantially increase the cost of the program.

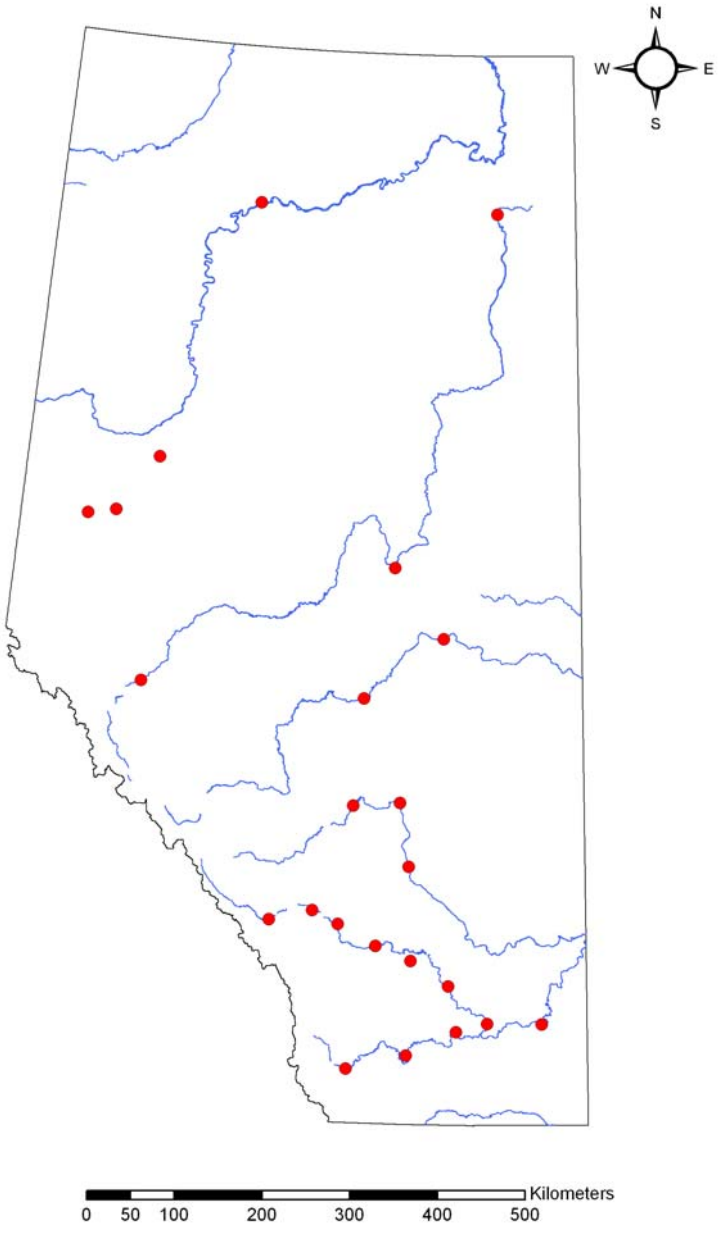

Figure 3. Location of long-term river monitoring sites sampled by Alberta Environment.

3.7 Alberta Environment – Sustainable Resource Development (SRD)

Sustainable Resource Development samples fish for two reasons: enforcement and scientific research. For enforcement, fish are sampled to determine population status; this information is used when setting catch limits and fishing seasons at specific water bodies. At a provincial level, the SRD enforcement group samples priority water bodies, including lakes and rivers, approximately once every five years (Ken Bodden, personal communication). The sites that are sampled depend partly on public pressure and harvesting pressure. At the regional level, managers may choose to sample additional water bodies. The principal focus of this sampling is estimating the population size of game fish species, and related parameters such as fish health and contaminant studies. Lake sampling is done using gillnets, while river sampling is done with electrofishing boats. Because lake fish sampling for policy enforcement usually targets only game fish, nets used by SRD are not suitable for inventory work.

Scientific sampling of lake fish is done using Nordic multimesh

gillnets; fish in rivers are sampled using electrofishing boats (Michael Sullivan, personal communication). Eight to 10 lakes are sampled each year using this method; lakes are sampled on an approximately five-year cycle. A total of five to 21 net nights are used per lake. In rivers a reach up to five kilometres long may be sampled.

I suggest the ABMP use Nordic multimesh gillnets (Nordic nets), combined with Gee minnow traps, to sample fish in lakes. Nordic nets provided a better inventory of the lake fish community during tests in two Ontario lakes than either Spring Littoral Index Netting (SLIN) or Near Shore Community Index Netting (NSCIN) (Hughes and Brady 2003). Rivers should be sampled using electrofishing boats, as these provide a good indication of the fish community in a sampled reach.

3.8 Cows and Fish (Alberta Riparian Habitat Management Society)

The Alberta Cows and Fish Project was established in 1992 to protect riparian zones while allowing their use as livestock grazing areas, and to develop understanding of the relationships between livestock grazing, riparian vegetation health, and stream channel dynamics (Fitch and Adams 1998). Since its inception, the program has expanded to include assessment of riparian zones of both standing and flowing water systems. Approximately 80% of recent assessments performed by Cows and Fish have been on rivers, and approximately 70% of all sites have been related to grazing of some type (Norine Ambrose, personal communication).

The Cows and Fish program focuses on riparian vegetation and bank structure characteristics. No sampling of the aquatic environment occurs, except that emergent vegetation, such as cattails, is sometimes recorded. There are no permanent long-term sites sampled by Cows and Fish on a regular basis, although resampling of some early sites is now occurring. Most of the work done under this program is presently occurring in southwest Alberta.

Few of the protocols used by Cows and Fish is suitable for the aquatic portion of the ABMP, as they deal mainly with terrestrial vegetation and habitat characteristics. The ABMP terrestrial group is already sampling terrestrial vegetation. A few of the measurements made under the Cows and Fish program are recommended for the ABMP. These include estimating bank stability, substrate composition, and recording the cause of bank instability in streams.

3.9 Alberta Conservation Association (ACA)

The ACA takes a very active role in monitoring fish populations within Alberta. Each year ACA personnel sample fish in 300 – 500 stream reaches and 20 – 30 lakes (Garry Scrimgeour, personal communication). There are few repeat visits in the stream sampling, but lakes are often sampled once every five to seven years; these lakes are principally large angling lakes. Streams are sampled with electroshocking equipment, while lakes are sampled with multimesh experimental gillnets. Both methods provide a good estimate of fish community composition.

As indicated previously, I recommend that the ABMP use Nordic multimesh gillnets and minnow traps to sample lake fish, and electrofishing boats to sample fish in rivers. I recommend that the ABMP sample 1st and 2nd order, high gradient streams in the mountains and foothills; fish will be relatively scarce in these streams, so I do not recommend they be sampled in streams.

3.10 Canadian Wildlife Service (CWS)

The Canadian Wildlife Service tracks changes in wetland distribution and use by ducks across the prairie regions of Manitoba, Saskatchewan, and Alberta. This involves flying transects across the prairie regions and counting wetlands and ducks, followed by ground-truthing a subsample of the flight transects to gather additional information, such as depth of waterbodies

(Michael Watmough, personal communication). In addition, the Prairie Habitat Joint Venture (PHJV) Habitat Monitoring Program is collecting data on land use change, and changes in wetland status over time at a number of sites across the prairies. These data are being collected on 32 transects in Alberta (mean length of transect is 19.2 km) on which alternating quarter sections are assessed (Watmough et al. 2002). Although this program does not extend across the entire province, and PHJV monitoring transects may not overlap many ABMP sampling sites, data from the PHJV may be useful in providing a context for changes in wetlands that are monitored as part of the ABMP.

CWS protocols for sampling wetlands are not suitable for the ABMP as they do not include collection of biological data. However, use of remote sensing data to track changes in wetland distribution and status, similar to that used by the PHJV, may be suitable for the ABMP. I recommend that several landscape-scale parameters, such as wetland density and distance to nearest wetland from a sampling point, be derived from remotely sensed data. Recommended landscape-scale parameters are provided in the protocols for sampling aquatic habitats below.

3.11 Fisheries and Oceans Canada

The role of Fisheries and Oceans Canada in Alberta is primarily policy enforcement. Therefore, this federal department samples fish populations in reaction to specific events (e.g. chemical spills or leaks into a lake or river) or when building an enforcement case (Bruce McCulloch, personal communication). Fisheries and Oceans personnel will sometimes assist other agencies (e.g. Alberta Conservation Association, Sustainable Resource Development) in their fish sampling programs, but do not run any large-scale sampling programs of their own.

4 BACKGROUND OF AQUATIC PROTOCOL DEVELOPMENT IN THE ALBERTA BIODIVERSITY MONITORING PROGRAM

Sampling aquatic elements within the ABMP has been challenging. Repeated attempts to identify sampling protocols for aquatic systems that would work across the entire province of Alberta have proven frustrating (Schieck et al. 2002) given the natural heterogeneity of aquatic systems across the province. For example, wetlands are the predominant aquatic habitat on the prairies, where most flowing water is confined to irrigation canals. In contrast, many streams exist in the mountainous areas of the province, but wetlands are relatively scarce. The boreal plains contain both streams and wetlands, but most streams have been transformed into a series of ponds by the activities of beavers.

Initial aquatic sampling protocols were developed for running (Scrimgeour and Kendall 1999) and standing (Boss et al. 2002) water habitats in Alberta. Potential protocols provided for running water were very general, and did not contain details of sampling methods, but rather a general treatment of the usefulness of various biotic and abiotic elements in a biodiversity monitoring program. Potential elements included biotic and abiotic instream elements (microbes, algae, macrophytes, macroinvertebrates, amphibians, fish, stream morphology, bankfull attributes, substrate, hydrology, stream elevation, water physiochemistry, light attenuation, and crown closure), and biotic and abiotic watershed elements (watershed and riparian vegetation, soil communities, animal communities, watershed attributes, bedrock and soil chemistry, hydrology, and degree of industrial development). Of these diverse elements, Scrimgeour and Kendall (1999) recommended that the ABMP monitor benthic algae, benthic macroinvertebrates, amphibians, and fish communities in streams.

Potential sampling elements for standing water habitats were also assessed for inclusion in the ABMP (Boss et al. 2002). This document was more complete than that for running water, and included details on plot establishment and sampling methods for a variety of biotic and abiotic elements, and estimates of equipment, cost, and time commitments needed for sampling. Elements included phytoplankton, zooplankton, benthic invertebrates, amphibians, fish, and aquatic birds; some discussion of remote sensing and GIS techniques was also included.

Many of the suggested sampling protocols for standing and running water habitats were incorporated into a pilot test of the protocols in 2002 (Schieck et al. 2002). Protocols for site selection called for sampling of standing water >0.5 m deep where it occurred within 300 m of a terrestrial sampling point (Shank et al. 2002). For flowing water, the first order stream closest to each terrestrial sampling point would be sampled (Shank et al. 2002). Elements recommended for sampling included basin characteristics and substrate, water physiochemistry, benthic macroinvertebrates, zooplankton, phytoplankton, and fish for standing water. For running water stream channel characteristics and substrate, water physiochemistry, downed woody material, benthic algae, benthic macroinvertebrates, amphibians, and fish were recommended.

The results of the 2002 test of aquatic sampling protocols were mixed (see Schieck et al. 2002). Many of the protocols could be performed within the time initially estimated for their completion. However, numerous problems occurred with site selection. For standing water habitats, three terrestrial sites with associated standing water in were initially identified, but the water at these locations proved to be too shallow (<0.25 m) for sampling. As a result, a moderately-sized lake was identified and standing water protocols were tested at this site; most of the protocols worked well, but the fish sampling was largely unsuccessful due to the shallowness of the lake, and the presence of abundant rooted aquatic vegetation.

Tests for flowing water habitats in 2002 were done at three streams chosen from a pool of 12 possible sampling sites. Two of the streams were unobstructed, and one was dammed by beaver. Testing at the beaver dam site was incomplete because some of the protocols (e.g. sampling macroinvertebrates with a corer) did not work behind the beaver dam. Some of the protocols worked as expected (e.g. downed woody material, benthic algae), but there were problems associated with others (e.g. fish, benthic macroinvertebrates). The corer used to sample benthic macroinvertebrates did not work well in either soft or coarse sediment. Electroshocking to sample fish did not work well: the water behind the beaver dam at one site was too deep to sample, and abundant vegetation at the other streams reduced the effectiveness of the shocker, so few fish were captured.

No aquatic work occurred in the 2003 field season. In January 2004, work on revising the existing aquatic protocols began. The focus was on standing and flowing water habitats, but the range of potential aquatic habitat types to be sampled was reduced, and site selection criteria changed. In addition, the number of elements to sample was reduced, and the layout of sampling plots at a sampling site was simplified to save time in the field. Field tests in the summer of 2004 had three objectives: (1) to determine if the modified protocols worked in the field as expected, and if they could be done in the time allotted; (2) to determine the time and effort necessary to verify the suitability of lake and stream sites chosen in the lab using GIS; (3) test the ability of field crews to haul sampling gear into these sites.

Four small lakes (20 – 500 ha in surface area, at least 3 m deep) and four streams (had to have flowing water and be unimpounded by beaver for the sampling reach) were sampled in 2004. Elements sampled at lakes included fish, amphibians, zooplankton, basin characteristics,

and water physiochemistry. Elements sampled at streams included benthic macroinvertebrates, water physiochemistry, downed woody material, and channel characteristics.

Tests in 2004 showed that the sampling protocols could be followed using the available equipment, and in the estimated time at suitable sites, but finding suitable sampling sites was a challenge. In addition to the lakes actually sampled, four additional lakes were assessed but were found to be too shallow. Eight additional streams were assessed but were impounded by beaver. The amount of gear needed to sample lakes was also a problem during access of remote sites, and efforts were made to reduce the mass of the equipment (e.g. fluke anchors were replaced with cannonball anchors, which require less space).

Below I present revised protocols for sampling aquatic habitats as part of the ABMP. This includes a discussion of the overall habitat types to be sampled, the elements to be sampled within each habitat type, how this sampling will be achieved, detailed protocols for each element, and issues related to variance and taxonomic resolution within the monitored elements.

5 ELEMENTS TO BE SAMPLED WITHIN THE ALBERTA BIODIVERSITY MONITORING PROGRAM

I suggest that aquatic sampling in the ABMP be conducted at two scales. Large lakes and rivers should be sampled at provincial scales, while wetlands and streams should be sampled at regional scales. Large lakes and rivers are important to the public for sport, recreation, and as a connection with nature. These water bodies often contain sport fish, a group with high public appeal. Inclusion of lakes and rivers in the ABMP therefore tracks changes in aquatic habitats that are ecologically important and have a high public profile. Sampling lakes and rivers requires a substantial investment in time and equipment, making it difficult to sample these habitats at a regional scale (e.g. at the same scale as the terrestrial sites within the ABMP). Therefore I suggest that approximately 100 lakes and 100 rivers be sampled across Alberta to provide provincial-scale tracking of changes in the biodiversity of these habitats. At this sampling intensity, 20 lakes and 20 rivers would be sampled each year. In addition, after the first year of the program 20% of the sample (4 lakes and 4 rivers) from the previous year would be re-sampled to provide statistical connectivity between years.

It is important to sample wetlands and streams to provide data on biodiversity change in physically smaller habitat types which are likely more vulnerable to anthropogenic impacts than larger entities. I suggest sampling streams in the mountains and foothills, where they are usually the dominant small aquatic habitat. I suggest sampling wetlands in the remaining ecoregions of Alberta as they are abundant in the northern portion of the province, and are a focus of much public concern and research in the south.

One of the stated objectives of the ABMP is measuring the status and temporal changes in selected biodiversity measures at provincial and regional scales (Shank et al. 2002). The approach outlined here fulfills this objective at the provincial scale by collecting sufficient data on fish populations to provide province-wide trends in status within this group. It also provides data on other groups (e.g. invertebrates) at both provincial and regional scales. Sampling physically smaller elements such as streams and wetlands at intensities similar to that of large lakes and rivers would not be tenable, as these aquatic habitats are more variable: being more strongly affected by natural factors such as drought and potentially by anthropogenic factors as well. In addition, the form that wetlands and streams take varies widely across the province (e.g.

prairie pothole wetlands in the south vs. treed fens in the north); larger habitats are not as variable in form across the province.

5.1 Provincial scale elements

At a provincial scale about 100 lakes and 100 reaches in large rivers will be sampled. This approach is suggested for several reasons: (1) fish are an important group to sample, as they have a high public profile, (2) fish assemblages are more speciose in larger lakes and rivers, (3) smaller lakes often contain only small-bodied fish or are fishless, and (4) large lakes and rivers are ecologically, economically, and socially important.

Although the sampling of only 100 lakes and rivers in Alberta precludes regional-scale assessments of change for fish, this sample size should track changes in these important biota at a provincial scale. A sample of 100 of the largest 500 lakes within the province, for instance, would probably include a high proportion of the approximately 800 Alberta lakes that contain native game fish populations (Alberta Environment 2002). Information on biodiversity trends of various biological groups in these lakes (in addition to fish) and the chemical state of the lake should be attractive to fisheries and lake managers, as well as the public; the same holds true for large rivers.

I suggest the following elements be sampled at large lakes: fish, zooplankton, phytoplankton, water physiochemistry, basin characteristics, and landscape variables. Basin characteristics and water physiochemistry provide important background data on the lake habitat, which may have explanatory power when investigating differences in biological elements over time and space. Phytoplankton, zooplankton, and fish are all important members of the lake ecosystem, and each of these groups is known to respond to perturbations within and outside (e.g. in the watershed) the lake. Landscape variables provide context for changes in aquatic habitats and biota, which may be related to human activity in the watershed (e.g. increasing urbanization).

At large rivers, channel and habitat characteristics, fish populations, benthic algae, benthic macroinvertebrates, water physiochemistry, and landscape variable should be sampled. As for lakes, physical, chemical, habitat, and landscape characteristics may be important for understanding patterns in other groups (in this case, fish) and landscape-level data provides context for these patterns. Fish have a long history of use as biological indicators in flowing water as they are mobile, feed at a variety of trophic levels, provide an integrated signal about the condition of the aquatic habitat, and can usually be identified in the field (Plafkin et al. 1989; Karr 1991). Benthic macroinvertebrates and benthic algae are responsive to a variety of environmental perturbations. Although it can be difficult to identify these groups, consultants are available to accomplish this task, and the additional information supplied by sampling these groups is important for obtaining a more complete picture of change in river biodiversity over time and space.

5.2 Regional scale elements

I suggest that wetlands and streams be sampled at regional scales within the ABMP, and that sample locations be distributed across the landscape at the same density as the terrestrial sampling plots (e.g. on a 20 x 20 km grid). Wetlands are a commonly occurring habitat in Alberta, where 21% of the land is covered in wetlands. Wetlands will be sampled in all ecoregions in the province except for the montane and foothill ecoregions, where streams will be sampled. Ecoregions within Alberta do not begin and end abruptly, but grade from one type into another across an area of transition known as an ecotone. Within this ecotone, conditions

common to the two adjacent ecoregions will blend together. Therefore, the types of habitats and the organisms that will be encountered within the ecotone will share characteristics with both ecoregions. Within the ABMP, although the existence of ecotones is acknowledged, when determining what habitats to sample across the province, the ecoregions will be taken as separate entities with hard boundaries. Thus, if an area falls within the foothills ecoregion, streams will be sampled there, no matter how similar the area appears to be to the nearby boreal forest ecoregions. This approach is adopted for practical and logistic reasons: (1) the width of an ecotone varies over space, making it difficult to apply rules related to ecotones consistently, and (2) if ecotones represent transitions from one ecoregion to another, it might be important to sample both wetlands and streams within the ecotone; this would lead to increased sampling and increased cost, without providing increased geographic coverage. Therefore, although the use of ecoregions to determine which habitats to sample in a given area is somewhat artificial, application of this rule is consistent, maintains the same density of sampling points for smaller aquatic entities (e.g. streams and wetlands) across the province, and is a cost-effective approach to determining selection of habitats to sample.

Wetlands were chosen for sampling in the boreal forest and Canadian Shield ecoregions because they are a predominant aquatic habitat in the northern part of the province. In the grassland and parkland ecoregions to the south wetlands are important for waterfowl and other aquatic-dependant organisms (e.g. amphibians). Wetlands in the south are currently a focus for research, reclamation, and regulatory activity (e.g. wetland mitigation bank) because of extensive wetland loss in the area in the recent past. Over 60% of the wetlands in the aspen parkland have been drained for agriculture (Alberta Water Resources Commission 1990) and more than 90% of wetlands occurring in the prairie and parkland have been modified by agriculture (Turner et al. 1987).

Wetlands are defined as "*land that is saturated with water long enough to promote wetland or aquatic processes as indicated by poorly drained soil, hydophytic vegetation and various kinds of biological activity which are adapted to a wet environment*" (National Wetlands Working Group 1988). The Canadian Wetland Classification System currently recognizes 49 wetland forms and 72 subforms (Warner and Rubec 1997); these are broadly subdivided into organic wetlands and mineral wetlands. Wetlands are important as reservoirs of biodiversity in many landscapes, and many endangered and threatened species are associated with wetlands. For these reasons, as well as their common occurrence on the landscape, wetlands should be included in the ABMP sampling protocols.

I suggest the following wetland elements be sampled: wetland characteristics, water physiochemistry, wetland plants, aquatic invertebrates, and landscape variables. Wetland characteristics and water physiochemistry provide background data on the status of the wetland. Wetland plants exhibit high diversity, especially when submergent, floating-leaved, emergent, and wet meadow plants are included. Wetland plants often persist when there is no standing water in the wetland, so some data may be collected even in years when the water table is low. Aquatic invertebrates are an important group in wetlands, and are often the dominant predators. Many invertebrate groups are able to rapidly colonize wetlands after they become rehydrated following a drought period. Landscape characteristics, such as wetland area, watershed area, distance to nearest wetland, and landuse near the wetland are important as background information for understanding biodiversity data collected at a site. A larger wetland, for instance, might be expected to have higher biodiversity.

Streams were chosen as sampling units for the montane and foothill regions as streams in these areas of high relief are lower order, are not impacted by beavers with the same intensity as those on the boreal plains, and stream benthic macroinvertebrates are known to respond to a variety of environmental perturbations. In addition, wetland density in the mountains and foothills is relatively low. I suggest the following stream elements be sampled: channel/habitat characteristics, water physiochemistry, downed woody material, benthic algae, and benthic macroinvertebrates. Habitat, channel, physiochemistry, and downed woody material are important as both background for the patterns in benthic macroinvertebrate species richness, community structure, and abundance, and as direct indicators of environmental quality and anthropogenic impacts. Benthic algae and benthic macroinvertebrates are responsive to a variety of environmental perturbations. Landscape characteristics, such as stream slope, watershed area, and number of stream crossings provide a context for understanding change in biodiversity over time.

Table 3 provides a general summary of the elements recommended for sampling in different aquatic habitats within Alberta.

Table 3. Parameters recommended for sampling in the Alberta Biodiversity Monitoring Program

Parameter	**Lakes**	**Rivers**	**Wetlands**	**Streams**
Fish	√	√		
Benthic macroinvertebrates		√		√
Aquatic invertebrates			√	
Benthic algae		√		√
Vascular plants			√	
Zooplankton	√			
Phytoplankton	√			
Water physiochemistry	√	√	√	√
Channel/basin characteristics	√	√	√	√
Downed woody material				√
Landscape factors	√	√	√	√

6 General Considerations When Sampling Aquatic Habitats

6.1 Safety

Safety of crews is of prime concern during any fieldwork. Aquatic field crews must maintain safe practices when moving to and from sampling sites by helicopter, truck, quad, or on foot, and must also ensure all possible safety measures are taken when working on or in the water. In no case should field personnel enter a situation that is considered to pose an unnecessary risk. Safe operating procedures need to be developed and field crews should be trained to make safe choices. If crews choose not to sample at a specific time, they should record the reasons behind this decision (e.g. "river in flood; dangerously strong flow").

There are specific hazards inherent in sampling each type of aquatic habitat. Lakes may be dangerous when periods of high winds produce large waves, or during thunder and lightening storms. When working on a lake watch for submerged or floating objects such as rocks or logs, and always be aware of other boaters in the area.

In wetlands, the bottom of many water bodies that look shallow often consists of a thick layer of unconsolidated material that can be difficult to move through. Many wetlands have floating vegetation mats that must be crossed before reaching open water, and it is possible to break through these mats; a PFD should always be worn when wading in wetlands.

Hazards associated with sampling rivers or streams include strong flows during flood periods, underwater obstructions that can be tripped over when wading or collided with when boating, and deep pools which can be dangerous when wading. Using electroshocking equipment to sample fish exposes workers to the chance of electrical shock. To minimize this hazard, all personnel must be informed of the dangers of receiving a shock, and must be taught all applicable methods to avoid receiving a shock. Neoprene waders and PFDs must be worn at all times when shocking. An experienced crew leader is required when electroshocking. All personnel must have First Aid and CPR training, and an Automatic External Defibrillator (AED) must be carried in the field and personnel must be trained in its use.

Dangerous animals such as bears or cougars may be encountered during any fieldwork. Bears may be attracted to the smell of equipment used to sample fish, and crews should be vigilant when working on foot near aquatic habitats. The sound of a stream or river may mask the noise of animals in the vicinity, or may mask the noise you make moving around an area, leading to potential encounters with bears. All personnel must take a bear awareness course and carry bear spray in the field at all times.

Listed here are different sets of equipment needed for fieldwork pertaining to aquatic sampling sites, and for accessing those sites.

Equipment

Boat / kayak

First aid kit ($100)
Waterproof pack (to hold safety equipment; $30)
Emergency strobe light ($15)
Waterproof flashlight ($30)
Rope throw bag ($60)
PFDs ($70.00 each; 2 per crew = total of $140)
Airhorn ($25)

Paddle for boat ($50 each; should have 2)
Paddle for kayak ($150 each; should have 2 per kayak = total of $300)
Anchor ($35)
Neoprene waders ($250)
Automatic External Defibrillator – for work on rivers when electroshocking ($4000)

On foot
Bear spray ($27 each; 2 per crew = total of $54)
Airhorn (use as bear deterrent; $25 each; 2 per crew = total of $50)
First aid kit ($21)
Knife (fixed blade; $45)

On quad
Helmet ($150 each; 2 per crew = total of $300)
Goggles ($50 each; 2 per crew = total of $100)
Gloves ($15 each pair; 2 per crew = $30)

6.2 Travel

The time required travelling to and from a sampling site from base camp should not exceed 4 hours in total; if it does, then helicopter access should be considered. The time to move around a sampling site is incorporated into the estimated times to complete the separate sampling protocols. An overall estimate of the time required to complete sampling for a single site (e.g. one lake) is provided at the end of each protocol section.

6.3 Site selection

Sites for all habitat types (see below) will initially be selected on the basis of maps and GIS coverages. Each site should be visited before the sampling session to ensure that it is suitable for sampling and is accessible to the field crews. This could be done early in the same season as the sampling, or a year before the sites are to be sampled. Note that this is only necessary once for each sample site in the program. I suggest a separate crew or crews be used to evaluate sites each year, working on a schedule that keeps them ahead of the sampling crews. This approach ensures that the most recent information on site access is available. Multiple crews may be necessary. There will be additional challenges to access in some parts of the province, as some citizens will not permit access to their land.

When site selection crews have completed their site selection for the season, they can be used to pick invertebrate samples, or for other functions within the ABMP. Once the first complete round of sampling is finished (e.g. after five years), site selection crews will no longer be necessary.

6.4 Sampling windows

Many groups of organisms exhibit seasonality in abundance and species composition. Aquatic invertebrates, for example, vary across the active season in terms of what species may be found at a

particular site at a particular time. In detailed studies designed to determine the species composition of a site or sites, therefore, sampling is often done periodically (weekly to monthly). Within the ABMP logistic and monetary constraints prevent repeated sampling of a site within a year. Therefore, to reduce the variation introduced by sampling a site in different parts of the field season in different years, I just that each particular site should be sampled at approximately the same time of year each time it is sampled. I suggest that resampling of a site take place within 10 Julian days of the date the site was originally sampled; therefore, a site originally sampled on June 17th in the initial sampling session should be resampled between June 7th and June 27th in the next sampling session. This represents a compromise between controlling for seasonal variation between years and the impossibility of returning to each site on exactly the same Julian day every sampling session. This approach can be applied to macroinvertebrates in all aquatic habitats. In some cases it may not be possible to revisit a site within the 20-day window. In this case the site should not be sampled in that session, but will be sampled in the next session scheduled for that particular site.

7 SAMPLING PROVINCIAL SCALE ELEMENTS

7.1 Large Lakes

The ABMP will sample 100 large lakes distributed across Alberta. Although the ABMP will not necessarily sample lakes currently sampled by government agencies, the data collected at ABMP sites will provide useful data to groups such as Alberta Environment and other entities charged with monitoring natural resources.

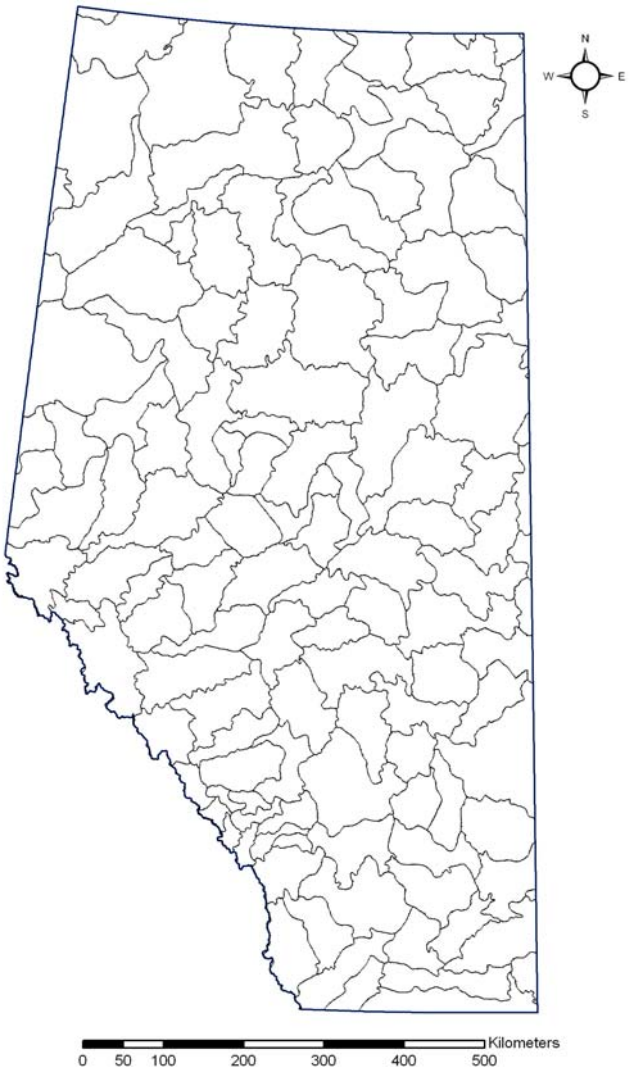

Figure 4. Watersheds in Alberta.

7.2 Large lake sampling protocols

7.2.1 Lake Sampling Window

Lakes in Alberta are often sampled in July and August when assessing fish communities (William Tonn, personal communication). Within the ABMP August is reserved for processing samples collected during the summer, so lake sampling should occur in July. As 20 lakes (+ 4 re-sampled lakes) should be sampled every year, and sampling each lake will take three days, three crews dedicated to lake work should be able to sample all 24 lakes in approximately one month.

7.2.2 Lake Selection

A GIS coverage of watersheds in Alberta (Figure 4) should be used to distribute sampling lakes across the province. Smaller watersheds should be amalgamated until 100

watersheds of approximately equivalent size remain. The distribution of lakes ≥ 300 ha within Alberta should be overlaid on the watershed map, and a lake within each watershed be randomly chosen.

Using GIS coverages, satellite images, and topographic maps in the lab potential, determine potential access routes to each chosen lake. Create and print maps with these routes, the lake, and important topographic and road information. Field staff will record information on the ground that will help other crews reach the field sites (e.g. landmarks, locations of roads and trails); add this information to site maps in the lab for future reference. Mark foot trails with flagging tape. Mark the access point to the lake with a 2 m orange steel bar driven into the ground.

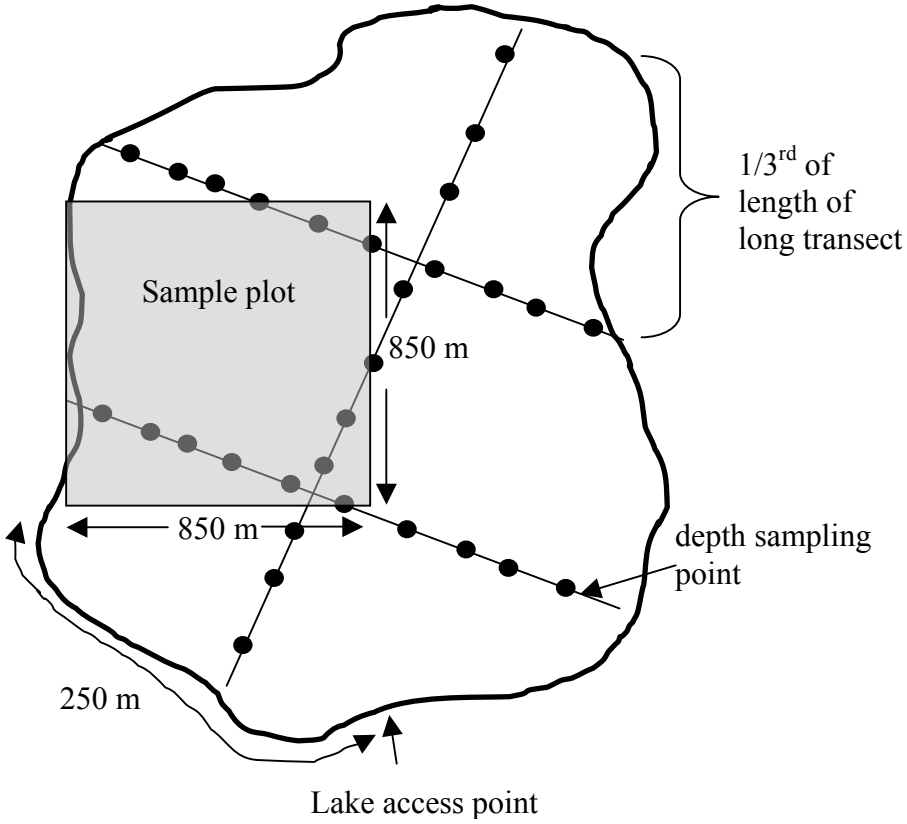

Figure 5. Location of sampling plot and depth transects on a lake. The sample plot should always include the shoreline.

Site location will be one of the biggest challenges for lake work during the first round of sampling. Finding potential lakes using GIS is not difficult, but travelling to each lake to determine depth is time-consuming. Depth must be determined for each potential sample lake, unless such data are available for that lake. The Atlas of Alberta Lakes (Mitchell and Prepas 1990) contains mean and maximum depth for 100 lakes. Bathymetric maps are available for 111 Alberta lakes from The Angler's Atlas website (http://www.anglersatlas.com/freemaps/alberta/index.php). Local fisheries officers and provincial and national parks staff may provide data on the depth of some lakes. As large lakes will be targeted by the ABMP, few are likely to be shallower than 3 m. In addition, many large lakes are accessible by road or trail

because they support game fish populations, so getting to and from these sites will not be as difficult as for remote sites. However, some lakes will only be accessible by air.

In each lake, a plot 850 x 850 m will be used for sampling (Figure 5); this is the maximum size that can be sampled well for fish using the recommended sampling effort of four gillnets and 10 minnow traps used over 2 nights. The sampling plot will be offset 250 m clockwise from the lake access point. If a lake is accessed by air, the sampling plot will be offset 250 m clockwise from where the shore is first reached after leaving the helicopter or plane.

Depth transects (see below) should be done on the first visit to all sampling lakes to gather data for production of bathymetric maps and locate the deepest point of the sampling plot. On subsequent visits the depth at the deepest point of the plot can be reassessed to document changes in lake level.

Equipment

Lab
GIS coverages (obtained from Sustainable Resource Development)
Topographic maps ($10)

Field
Steel bar ($5)
Flagging tape ($5)
Mallet ($20)
Sonar depth finder ($300)
Truck / quad / helicopter (variable; depends on distance to travel)
Boat (inflatable for remote sites: $5000; aluminum for truck-accessible: $2000)
Boat motor (5 horsepower, 4 stroke: $2000)

Time required

The average time to locate and map potential lakes will be 2.0 hours. This will include determining the area of potential sampling lakes, and possible access routes from GIS coverages and satellite images. The average amount of time to find and test potential sampling lakes for depth will be 5 hours per lake (4 for travel to and from the lake, 1 hour to determine depth); multiple attempts may be necessary before a suitable lake is found. Verification of lake depth will be necessary only during the first round of lake sampling; on subsequent rounds access routes and approximate depths will be known. Actual depth at the deepest part of the plot can be taken at each visit to determine lake level fluctuations. The average amount of time required to enter and manage the data from one lake will be 15 minutes.

7.2.3 Depth Transects

Before going in the field, delineate three depth transects on the map of a potential sampling lake using GIS. One transect will be on the longitudinal axis of lake and the other two perpendicular to, and equally spaced, along the first axis (Figure 5). Depth will be measured in the field at 10 equal intervals along each transect. Measure the total length of each transect using GIS and divide by 11 to determine the interval for the sampling points. Create a series of waypoints marking the sampling points in GIS and export these waypoints to a GPS unit. These waypoints will be used to locate sampling points in the field.

On the lake, start the transect from the water's edge and proceed to the first waypoint. Use the sonar depth finder to estimate depth at this point, and all other points on the transect. These

data will be used to create a bathymetric map of the site. While moving across the lake taking depth samples, note deep spots in the lake. Although only a 72 ha plot will be sampled in the lake, the size and depth of the lake will influence biotic diversity within the lake.

Equipment

Lab

GIS coverages (obtained from Sustainable Resource Development)
Topographic maps ($10)

Field

Sonar depth finder ($300)
GPS unit ($400 x 2 = $800)
Truck / quad / helicopter (variable; depends on distance to travel)
Boat (inflatable for remote sites: $5000; aluminum for truck-accessible: $2000)
Boat motor (5 horsepower, 4 stroke: $2000)

Time required

The average time required to complete depth transects will be 1.5 hours per lake. The average amount of time required to enter and manage the data from one lake, and generate bathymetric maps, will be 2 hours.

7.2.4 Plot Location

Establish a sampling plot at each lake; this plot is 850 m x 850 m, and always includes the shoreline (Figure 5). Mark the locations of the sampling plot corners temporarily with buoys; the location of the plot corners should be recorded using a GPS unit and marked on the site map. The marker buoys can be removed when sampling is completed. Criss-cross the sampling plot to determine the deepest point within the plot; this will be the first deep-water sampling site; vertical depth profiles and gillnetting is done here (see below). Locate a second deep-water sampling site 100 m from the first along the long axis of the lake so that the second plot is as far as possible from emergent vegetation, but stays within the sample plot; a second gillnet is placed at this point (Figure 6). Water, phytoplankton, and zooplankton samples are also collected at these sites, as well as at a third site located halfway between the two deep water gillnetting sites (Figure 6).

Ten shallow water sites are used when placing minnow traps. The first shallow water site is located 25 m clockwise around the lake from edge of the plot nearest the lake access point (Figure 6). Another nine sites should be established in a clockwise direction around the lake at intervals of 25 m. Two gillnets are deployed close to these sites (see gillnet protocols, below).

Sample fish for two nights at each site. After processing nets and traps after the first night, redeploy the gear within the lake for the second night of sampling. Establish two new deep-water plots perpendicular to the line between the initial two deep-water plots, and 100 m to either side from the centre of this line (Figure 6); place a gillnet at each of these sites, parallel to the long axis of the lake. Establish 10 new shallow water sites at 25 m intervals counter clockwise around the lake, starting 25 m counter clockwise from the edge of the plot nearest the lake access point (Figure 6). Deploy two gillnets close to these sites (see gillnet protocols, below).

Use a GPS unit to record the location of each sampling site and draw their approximate locations on the site map. Also draw the access point on the site map and record any relevant observations pertaining to the site.

Equipment

Lab

GIS coverages to produce map of lake (obtained from Sustainable Resource Development)

Field

Sonar depth finder ($300)
GPS unit ($400 x 2 = $800)
Bouys (inflatable marker buoys: $30 each x 4 = $120).
Truck / quad / helicopter (variable; depends on distance to travel)
Boat (inflatable for remote sites: $5000; aluminum for truck-accessible: $2000)
Boat motor (5 horsepower, 4 stroke: $2000)

Time required

Setting out and removing corner markers for the sampling plot will require approximately 15 minutes. The average time required to set out the plot locations will be 1.0 hour. The average time to enter and manage the data will be 15 minutes per site.

7.2.5 Water Physiochemistry

At the deepest point within the plot take vertical profiles for water temperature, pH, conductivity, and dissolved oxygen using the multiprobe meter; record these measurements at 10 intervals from water's surface to the bottom of the lake. To do this, divide the total depth (determined by the sonar depth-finder) by 10 and record the relevant data at the mid-point of each interval.

Take the Secchi depth at the deep-water plot. Working over the shaded side of the boat, without sunglasses on, lower the Secchi disk until it disappears; record the depth. Raise the disk again until it reappears and record the depth. The average of the two depths is the Secchi depth.

Collect water for a composite sample at the deepest point in the plot and at two other locations (see Figure 6 for locations); record each location using a GPS unit. Before taking the first water sample at a lake, rinse the sample tube and sample bottle three times with lake water, discarding the water after each rinse. Take water samples using a clear polyethylene tube (2.54 cm inside diameter, with a one-way foot valve and an attached lead weight). Extend the tube from the water's surface to the bottom of the euphotic zone (> 1% of ambient surface light, or approximately twice the Secchi depth) or to 1 m above the bottom of the lake (whichever is less). Wear powder-free latex or nitrile gloves during collection of water samples; do not place your hands inside, or on the lip of, the water sampler or sample bottles.

Empty each sample into a 10 L carboy placed inside a clean black garbage bag (to prevent photosynthesis from occurring within the carboy). Ensure that the bottom of the collection tube does not come any closer than 1 m to the substrate. If there is any evidence of sediment contamination of the water sample, discard the sample, rinse the tube 10 times with lake water, and take another sample. If sediment gets into the carboy, it must be emptied and rinsed 10 times with fresh lake water, and water sampling must be started all over again.

A total of at least 5 L of water should be collected. Therefore, if a lake is relatively shallow, multiple samples may be necessary at each water collection site. If this is the case, take

the same number of samples at each water collection site. If the euphotic zone is deeper than 15 m, only sample the top 15 m.

After water collection has been completed, mix the water sample by shaking the carboy vigorously and collect a 250 mL subsample in a dark plastic bottle; store this sample in a cooler until it can be refrigerated. Each water sample bottle will have a unique alphanumeric code written on it in permanent marker. Ensure that this number is recorded on the lake sample datasheet. Water samples can be held for 10 days at 4° C before analysis. However, they should be shipped to the water analysis lab as soon as possible (at the end of each shift in the field would be the most efficient approach) for analysis of total nitrogen, total phosphorus, and dissolved organic carbon.

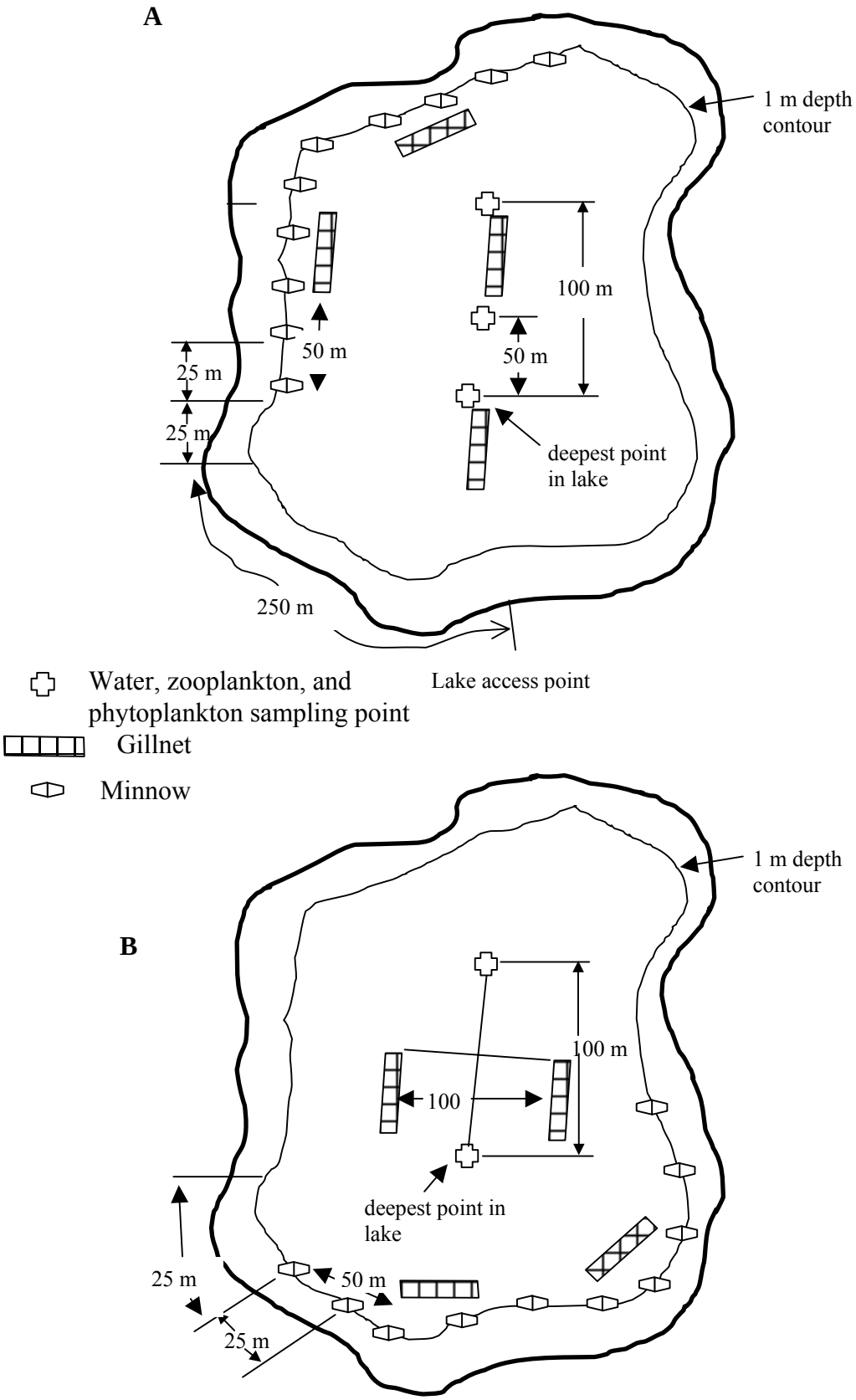

Figure 6. Location of sampling points at lakes, including those for fish, zooplankton, water and physiochemistry on (A) day 1 at the lake and (B) day 2. The sampling plot is not shown in this figure to retain clarity.

Equipment

Lab

Water samples should be sent to a certified lab for analysis. Costs for doing total nitrogen (TN), total phosphorus (TP), and dissolved organic carbon (DOC) approximately $67 / sample for all three parameters

Laboratory equipment necessary to perform the analysis for TN, TC, and DOC would cost in excess of $10,000, plus the cost of calibrating, operating, and maintaining the equipment.

Field

Multiprobe meter (approximately $5500)

Secchi disk ($90)

clear polyethylene tube (2.54 cm inside diameter, with a one-way foot valve and an attached lead weight; should have a short one [5 m long] and a long one [15 m]; total cost: $100)

10 L Nalgene carboy with spigot ($100)

Cooler ($50)

Dark plastic bottles (usually supplied by water analysis lab; if not, cost approximately $2.50 per 250 mL dark Nalgene bottle)

Time required

The average time to do a vertical profile for temperature, conductivity, dissolved oxygen, and pH, and take the Secchi depth will be 0.5 hours, though this may increase at deeper lakes. The average time required to collect and subsample the water samples will be approximately 0.5 hours. The time required to enter and manage the data for one site will be 0.25 hours.

7.2.6 Phytoplankton

Collect 1 L of water from the carboy filled when collecting water for chemical analysis. Use an opaque polyethylene bottle to collect and store the sample. Immediately after collection add 10 mL of Lugol's solution (recipe: 100 g iodine, 200 g potassium iodine, 200 mL glacial acetic acid, and 2000 mL distilled water) to the sample, followed immediately by 20 mL of FAA (recipe: equal volumes of formaldehyde [37%] and glacial acetic acid). Store the sample bottle in the dark.

Equipment

Field

Opaque plastic bottles ($4.00 per 1 L amber polypropylene bottle)

Chemicals ($1.00)

Time required

The average time required to sample to collect and preserve phytoplankton samples at a single site will be 0.25 hours. The time required to identify phytoplankton from one site would vary substantially with the training and experience of the taxonomist; a contract will be established to identify the specimens. Time required to enter and manage the data from a site will be 0.5 hours.

7.2.7 Zooplankton

Collect three vertical hauls for zooplankton (one at the deepest point in the lake / plot, and the other two at the same stations where additional water samples are taken; see Figure 6) in each lake. Collect the samples using a Wisconsin-style net 75 cm long with an opening of 13 cm and a detachable straining bucket. Mesh size of the net will be 63 μm. Soak the net in the lake for 2 minutes before use. Before taking the zooplankton haul, fill a Nalgene squeeze bottle with water filtered through the net. Lower the net vertically to within 0.5 m of the bottom (don't forget to account for the length of the net), or 15 m, whichever is less. Retrieve the net at a rate of approximately 0.5 m/s so that fast-swimming zooplankton cannot avoid the net. Upon completing the haul, pull the rim of the net above the surface of the lake and splash water onto the outside of the net (not into the net) to wash the zooplankton down into the sample bucket. When this is done, remove the sample bucket from the net, hold the tube at the bottom over a sample bottle, open the tube and allow the sample to drain into the bottle. Use the squeeze bottle you previously filled to rinse the entire sample down into the bottle. Add Eno or Alka-Seltzer to narcotize the zooplankton, then add buffered formalin in sufficient quantity (about 5% of the total volume of the sample) to preserve the sample. Make sure the depth of water sampled at each site is recorded. Pool the samples taken at the three sites before subsampling and sending the zooplankton to an expert consultant for identification.

I have suggested that three zooplankton sles be collected so ABMP sampling provides a good index of zooplankton biodiversity in lakes. Single samples may not provide good estimates of zooplankton species richness in a lake; additional samples improve estimates of the annual species pool (Arnott et al. 1998).

During the protocol outlined here, different amounts of water are sampled in lakes of different depths. Because the accumulation of species is not linear with effort, sampling should be standardized. This can be accomplished by only sampling to a given depth of water (e.g. 2 m) in all lakes, but this approach would miss many species that might occur at greater depths. Therefore, sampling will be done to near the bottom of the lake, so that most species occurring in the lake are available to be sampled during the subsampling step. Subsample by filtering the zooplankton from the preservative and adding the sample to 1 L of water in an Imhoff cone. Remove a given volume of water from the cone. This volume is based on a ratio of 1:10 sample to original depth of lake for a lake 10 m deep, so that 100 mL would be withdrawn from the cone if a depth of 10 m of water were originally sampled. For depths of less than 10 m, a greater volume of water is withdrawn from the Imhoff cone to achieve the same relative sampling effort. Send the zooplankton subsample to a consultant for identification. Zooplankton samples are further subsampled during identification, if the samples contain high numbers of individuals.

Equipment

Lab

Imhoff cone ($125)

Filtering equipment ($5)

Chemicals ($1)

Microscope, sample splitter, taxonomic keys (recommendation is that the samples be sent to consultants for processing, so this equipment will be unnecessary)

Field

Zooplankton net (Wisconsin-style net 75 cm long with an opening of 13 cm and a detachable straining bucket; mesh size of the net should be 63 µm: $500)
Sample bottles ($5)
Narcotizing agent (Eno, Alka-Seltzer, etc.: $0.25)
Squeeze bottle (1 L; $8)
Chemicals ($1)

Time required

The average time to collect each zooplankton sample will be 0.25 hours (0.75 hours total for all samples). The average time to prepare each sample for shipping to the consultants for species identification will be approximately 0.5 hours per sample; this includes the time necessary to subsample using the Imhoff cone. The average amount of time to enter and manage the data from each site will be 0.25 hours.

7.2.8 Fish – minnow traps

Set ten unbaited minnow traps (standard Gee minnow traps with 6.35 m mesh) in each sample lake. Minnow traps are easy to use, quick to set and retrieve, and rarely produce mortalities. They stack to reduce their bulk, and are relatively light. Traps should be set on the bottom of the lake along the 1 m depth contour at intervals of 25 m clockwise around the lake, starting at 25 m from the lake access point (Figure 6); use a GPS unit to record the location of each trap. Traps are marked with lengths of pool noodle tied to the traps; pool noodles are light and take up less space than buoys. Traps are set during the afternoon and retrieved the following day. After they are checked, they are redeployed within the lake for a second night of sampling. Distribute the minnow traps at 25 m intervals counter clockwise around the lake, starting 250 m counter clockwise from the initial access point to the lake (Figure 6). Use a GPS unit to record the locations of the traps as they are redeployed.

When checking traps, haul them up one at a time and empty them into a live well (bucket with fresh lake water). Remove the fish from the live well in batches using a small net (e.g. aquarium net) and assign each individual to a species; additional information should be collected on up to 30 individuals of each fish species. See Appendix A for guidelines on fish handling, preservation, and disposal.

Equipment

Lab

Bottles (1 L; $15)
Isopropyl alcohol (70%; $10)

Field

Bottles (1 L; $15)
Isopropyl alcohol (70%; $10)
Portable electronic balance (10,000 g capacity, 1 g readability: $450)
Pelican case for balanace ($140)
30 cm fish measuring board ($75)
Live well (bucket or plastic bin; $25)

Net (aquarium net; $5)
Gee minnow traps (6.35 mm mesh; $200)
Pool noodles (for making floats; $5)
Tarred twine (for attaching floats to traps; $2)
Clove oil ($5)
Ethanol ($2)

Time required

The average time required to set 10 minnow traps will be approximately 0.5 hours. Checking traps will take approximately 0.25 hours when they are empty, and up to 2 hours when they contain numerous fish. Entering and managing the data from one site will require 0.5 hours.

7.2.9 Fish – gillnets

Set four gillnets in each sample lake. Gillnets are 30 m long and consist of 12 panels, each 2.5 long x 1.5 m high. Mesh sizes of the panels range from 5 to 55 mm (knot-to-knot measurement). Two nets are set in relatively deep water (up to 6 m deep), 100 m apart. The remaining two nets are set closer to shore, in water 1.5 to 2 m deep; these nets are set offshore of the minnow traps (Figure 6), with one gillnet approximately 50 m clockwise from the first minnow trap, and the second net set approximately 50 m counter clockwise from the last minnow trap (Figure 6).

The bottoms of the gill nets (the lead lines) are secured in position using anchors, while the tops (the float lines) are attached to buoys with orange flags (see "Regulations for marking nets and traps" below). Gillnets are set during the afternoon and retrieved the following day. Retrieve nets by starting at one end and pulling the net into the boat, removing fish as the net is brought in. It may be necessary to sedate live fish using a clove oil solution to make it easier to extricate them from the net. Assign each individual to a species; additional information should be collected on up to 30 individuals of each fish species. Ageing structures should be collected from dead game fish. See Appendix A for guidelines on fish handling, preservation, collection of ageing structures, and disposal.

After checking gillnets the first day, redeploy them within the lake for a second night of sampling. The two deep gillnets will be moved to sites located 100 m on either side of a line drawn between the two deep-water plots (Figure 6); the gillnets will be deployed parallel to the long axis of the lake. The two shallow gillnets are set in proximity to the minnow traps (after the minnow traps have been moved). One gillnet is set approximately 50 m clockwise from the first minnow trap, and the second is set approximately 50 m counter clockwise from the last minnow trap (Figure 6).

Multimesh gillnets require more gear to set up than minnow traps, and are themselves greater in bulk because they must be carried in plastic tubs. A competent boat operator is required when setting nets, to ensure they remain taut. Two anchors are required for each net; 5 – 10 lb cannon ball anchors require the least room for transport, compared other types of anchors. Each net also requires two buoys with flags (see fish sampling regulations, Appendix B), one at either end of the net. These buoys require a large amount of space for transport. In remote lakes it may be possible to use buoys without flags, which would require considerably less space; inflatable buoys are available, and these would be the optimal solution for remote work.

Equipment

Lab

Bottles (1 L; $15)
Isopropyl alcohol (70%; $10)
Coin envelopes ($3)
Scissors ($4)

Field

Bottles (1 L; $15)
Isopropyl alcohol (95% and 70%; $10)
Portable electronic balance (10,000 g capacity, 1 g readability: $450)
Pelican case for balance ($140)
30 cm fish measuring board ($75)
100 cm fish measuring board ($175)
Live well (bucket or plastic bin; $25 x 2 = $50)
Experimental gillnets (Nordic type; $825 x 4 = $3300)
Anchors ($15 x 8 = $120)
Buoys with attached flags ($60 X 8 = $240)
Plastic bags ($5)

Time required

The average time to set four gillnets will be 1 hour. The time necessary to check and process four gillnets will range from 1 hour when they are empty to 6 hours when they are full. The time to preserve and label fish samples will be 2 hours. Entering and managing the data from one site will require 4 hours.

7.2.10 Overall time required to sample lakes

The average overall time required to sample one lake will be 2 hours for site selection in the lab (generating maps), 4 hours for travel/day (2 hours each way to a site; this is probably a maximum value), 7.25 hours for sampling and setting nets and traps at the site on the first day, and 9.5 hours on the second and third days (this assumes maximum time for checking minnow traps and gillnets), 2.5 hours for sample processing in the lab, 8 hours for data entry and management, 1.5 hours/day for preparation for field work and for packing equipment away at the end of the day, and 1 hour for preparing materials for shipping to consultants (e.g. packaging). The total time commitment is therefore 56.25 hours per lake.

7.3 Landscape Elements – Lakes

The following landscape elements should be derived for sampled lakes. Some variables may be obtained from existing datasets (e.g. soil types, watershed area, mean slope of watershed), while others will need to be derived from remote sensing data periodically (e.g. landuse). The resolution needed to obtain the necessary information varies across elements. Following is a description of the different elements and why they are being measured.

- lake area – biodiversity is influenced by lake size; determine from attribute table for hydropoly layer for Alberta
- watershed area (from DEM) – area of the watershed for the lake; may influence the amount of water entering the lake and potential inputs (e.g. herbicides); determine using ArcMap and DEM for province; save watershed boundary as a coverage for use in determining other attributes of watershed
- watershed slope (from DEM) – influences movement of materials (e.g. sediments, chemicals) into lake; determine using ArcMap and DEM for watershed
- distance to nearest lake – an index of landscape connectivity; measure on hydropoly coverage for Alberta using ArcMap
- number and area of lakes in watershed – an index of lake density; use clip function in ArcMap to isolate lakes in a watershed, then use attribute table for hydropoly coverage to determine number, mean area, and total area of lakes
- soil types in the watershed – may influence lake water chemistry; clip soil coverages for Alberta to isolate watershed then determine percentage of watershed area in different soil classes
- number of inlets and outlets for the lake – influences connectivity across the landscape; use hydropoly, single line net, air photos, and DEM to determine the number of inlets and outlets
- vegetation – area of watershed in different vegetation categories, such as deciduous, coniferous, mixedwood, and percentage of the area within 100 m, 500 m, and 1000 m of the lake that falls into these categories; habitat type around lakes may influence nutrient availability, and other factors; this data can be derived from the latest Alberta Vegetation Inventory (AVI) coverages using the clip and buffering tools; can also be derived from medium grain (spatial resolution of 1 – 5 m) classified air photos or satellite imagery if this is available
- landuse – area of watershed in different landuse categories, and percentage of the area within 100 m , 500 m, and 1000 m of the lake that falls into these categories – categories include roads, well sites, seismic lines, right-of-ways, cut blocks, urban development (villages, towns), crops, pasture, and industrial areas; this data can be derived from the latest Alberta Vegetation Inventory (AVI) coverages using the clip and buffering tools; can also be derived from medium grain (spatial resolution of 1 – 5 m) classified air photos or satellite imagery if this is available.

7.4 Large Rivers

The ABMP will sample 100 reaches in large rivers distributed across Alberta. Although some rivers are currently being sampled by other agencies, the objectives of these agencies are different from those of the ABMP (e.g. sampling for chemical parameters such as heavy metals rather than biodiversity). Therefore, although sampling by the ABMP will not directly replace sampling done by other groups in rivers, information collected by the ABMP can help place changes documented by these agencies within the context of changes in biodiversity.

7.5 River Sampling Protocols

7.5.1 River Sampling Window

Sampling rivers within the ABMP should occur in June, as July is reserved for lake sampling, and August is reserved for processing samples collected during the summer. In this way equipment (e.g. sonar depth finders, boats) can be used to sample rivers first, and lakes later in the season. As 20 river reaches should be sampled every year, +4 river sites that are resampled from the previous year to provide statistical continuity, and sampling each river reach will take one day, two crews of three people each dedicated to river work should be able to sample all 24 river reaches within one month.

7.5.2 River Selection

A GIS coverage of watersheds within Alberta (Figure 4) should be used to distribute sampling river reaches across the province. Smaller watersheds should be amalgamated until 100 watersheds of approximately equivalent size remain. The distribution of large river reaches within Alberta should be overlain on the watershed map, and a river reach within each watershed be chosen randomly. Note that the distribution of large rivers is not uniform across Alberta (Figure 7), and current monitoring by the provincial government (Figure 3) is done to track levels of bacteria, flow rates, chemicals, and other parameters related largely to human activities.

Figure 7. Large river systems in Alberta.

Equipment

Lab

GIS coverages (obtained from Sustainable Resource Development)

Topographic maps ($10)

Time required

The average amount of time required to identify river sites and access routes using GIS and maps in the lab will be 1 hour.

7.5.3 Transect Location

At each river site establish six cross-section transects. Establish the first downstream transect 100 m upstream from the river access point or randomly

chosen point on the river (selected using GIS and some form of randomized selection procedure). The first plot should be identified with a steel bar driven into the ground next to the river and its location should be marked with flagging tape. Establish five more transects at 200 m intervals upstream of the first plot; mark the ends of each transect with flagging tape (Figure 8). Record the locations of both ends of each transect using a GPS unit.

Equipment

Field

50 m measuring tape ($60)
Steel bar ($5)
Flagging tape ($5)
Mallet ($20)

Time required

The average amount of time required to establish plots along rivers will be 1 hour. Note that plot establishment will be integrated with other activities, so that a plot will be located, marked with flagging tape, and then sampled; after sampling, the crew will move on to the next plot, sample it, and so on.

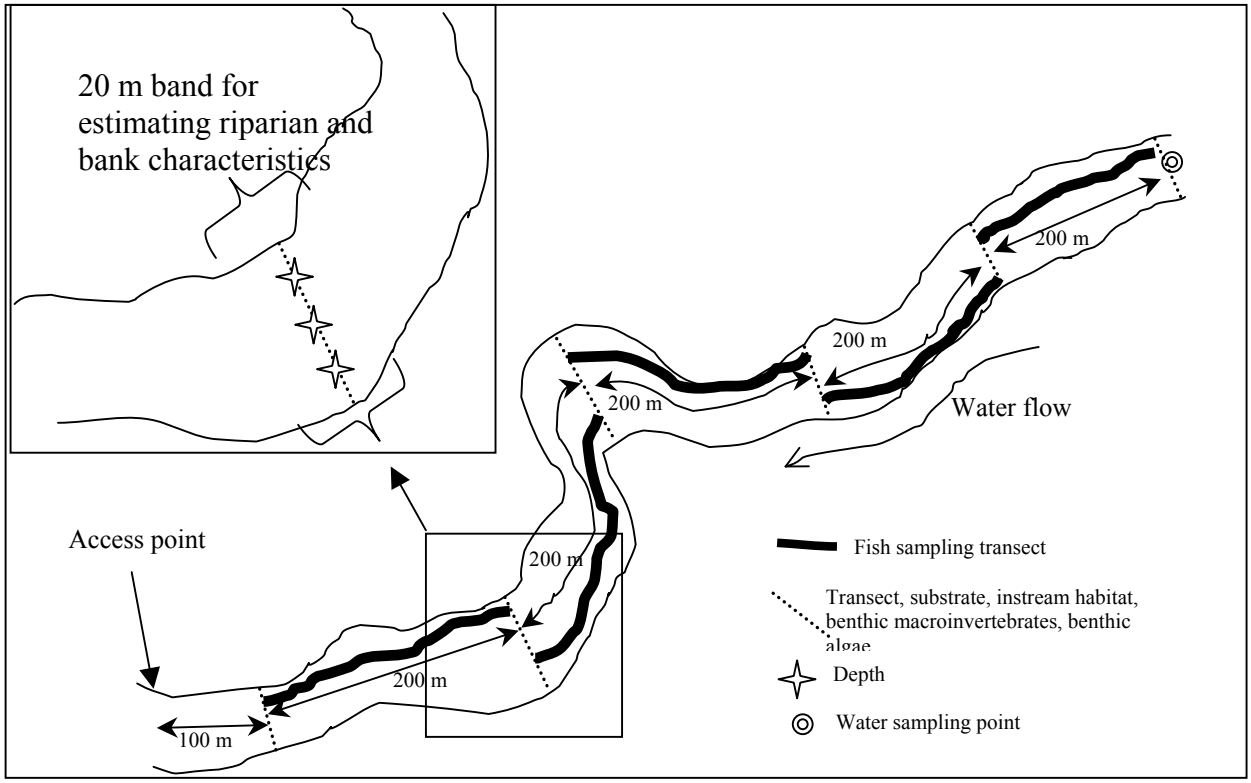

Figure 8. Schematic diagram of river sampling protocols.

7.5.4 Physical Characteristics of Rivers

At each transect measure the following parameters: using a laser range finder determine bankfull width (width of the channel at the point where over-bank flow begins during a flood event; may be discerned by the lower extent of perennial vegetation, and / or changes in slope or particle size of the stream bank), and wetted width (width of the channel presently containing water). Using a sonar depth finder determine maximum depth and depth at 25%, 50%, and 75% of the wetted width; use a tape measure or laser rangefinder to determine the distance from shore. Make a sketch of the channel between the first and last cross-section plot, including the location of the sample plots, concentrations of downed woody material (DWM), and the location and extent of riffle, run, glide, and pool habitats. The sketch can be made by standing on the bank at the cross-section farthest upstream and looking downstream and making the sketch, and then moving to the cross-section farthest downstream and looking upstream to verify the initial sketch. If bends in the river or vegetation prevent viewing the entire reach from the transect farthest upstream, sketch as much of the sample reach (upstream and downstream) as possible from each transect, and verify/continue the sketch at the next transect.

A number of elements should be estimated for a 20 m segment of bank centered at the end of each transect. Elements that should be estimated include river bank stability (see Table 4; make notes on the cause of any instability, such as road crossing, cattle watering, and undercutting), dominant riparian vegetation (vegetation within 5 m of river; categories = none [>50% of stream bank without vegetation], grass/sedge [>75% of riparian vegetation is grass or sedges], shrub [>25% of stream side vegetation is shrubs/willows], deciduous [>25% of stream side vegetation is deciduous trees], coniferous [>25% of stream side vegetation is coniferous trees], and mixedwood [>25% of stream side vegetation is a combination of deciduous and coniferous trees in approximately equal parts]), terrestrial canopy cover (living vegetation that projects over water surface; this can be any vegetation from grass to trees; categories = very low [0-5%], low [6-25%], moderate [26 – 50%], high [>50%]), and coarse woody material (woody vegetation found within the water or projects over the water and within 1 m of the water's surface; categories = very low [0 – 5% coarse woody material], low [6 – 25%], moderate [26 – 50%], and high [>50%]). A densiometer will be used to measure tree / shrub canopy cover when anchored in the middle of the river at each transect. The slope of the river reach sampled will be determined in the lab using a digital elevation model (DEM) in ArcMap.

Table 4. Categories for bank stability. Adapted from Johnson et al. (1998).

Category	Description
Stable	Banks well vegetated or covered with large boulders
Slightly unstable	>50% of bank vegetated or covered with rocks, and possibly some undercut banks
Moderately unstable	<50% of bank vegetated or covered with rocks, or lots of undercut banks
Unstable	Massive bank slumping, large silt deposition, exposed raw dirt

At each of the six cross-sections, visually estimate the proportion of the river that is represented by riffles (areas where water flows swiftly over obstructions that are completely or

partially submerged to create surface turbulence), runs (areas of slow moving, relatively shallow water with little or no surface turbulence), and pools (areas with reduced velocity and deeper water than surrounding areas) in a 5 m band across the stream, as well as the proportion of the substrate (if visible) in six fraction classes. The six fraction classes are bedrock (>4000 mm), boulders (>250 – 4000 mm), cobble (>64 – 250 mm), gravel (>2 – 64 mm), sand (>0.06 – 2 mm), and fines (<0.06 mm). If the substrate cannot be seen (due to turbidity, turbulence, or depth) estimate the proportion of the total transect area which is not visible, and estimate the percent of the remaining transect that falls into each fraction class. Estimate substrate embeddedness when characterizing substrate composition (categories = none [<25% of large substrate types covered in fines], low [26 – 50%], moderate [51-75%], and high [>75%]). Note that the status of the geomorphic channel units (riffle, run, pool) will change with changes in water depth (e.g. changes in run-off).

Equipment

Field

Laser rangefinder ($3000)
Sonar depth finder ($300)
Densiometer ($200)

Time required

The average time necessary to complete the surveys for physical characteristics of the river reach will be 3 hours. The time to enter and manage the data for one site will be 1 hour.

7.5.5 Water Physiochemistry

At the deepest point at the transect farthest upstream, measure water temperature, pH, dissolved O_2, conductivity (using a multiprobe meter), and water velocity (using a velocity meter) in the middle of the water column. At the same point collect a water sample for analysis of total nitrogen, total phosphorus, and dissolved organic carbon using a 1 L dark Nalgene bottle. Rinse the bottle three times with river water and collect water just below the surface of the river. Make sure to wear Nitrile gloves while collecting the water sample. Store water samples in a cooler until they can be refrigerated. Water samples can be held at 4º C for 10 days; samples should be submitted for analysis at the end of each field shift.

Equipment

Lab

Water samples should be sent to a certified lab for analysis. Costs for doing total nitrogen (TN), total phosphorus (TP), and dissolved organic carbon (DOC) is approximately $67 / sample for all three parameters

Laboratory equipment necessary to perform the analysis for TN, TC, and DOC would cost in excess of $10,000, plus the cost of calibrating, operating, and maintaining the equipment.

Field

Multiprobe meter ($5500)
Water velocity meter ($2500)
Cooler ($50)
Dark plastic bottles (usually supplied by water analysis lab; if not, cost approximately $6.00 per 1 L dark Nalgene bottle)

Time required

The average time required to complete the water physiochemistry protocol will be 0.5 hours. Time to enter and manage the data for one site will be 0.5 hours.

7.5.6 Fish sampling

One question related to sampling fish on rivers is the length of reach that must be sampled to obtain a good estimate of species richness. Many programs use sampling reaches of 40 – 100X channel width. Research has indicated that 30 – 40X the wetted channel width is sufficient to estimate species richness in some areas (Maret and Ott 2003), while longer lengths (100X channel width) are necessary to collect 95% of potential fish species in other areas (Hughes et al. 2002). Hughes et al. (2002) estimated that sampling an average of 300 channel widths was necessary to collect all fish species in a reach in the rivers they examined in Oregon. Within EMAP reach lengths are 40 or 100X channel width (Lazorchak et al. 2000). I suggest that using channel width to determine sampling reach not be used in the ABMP, but rather a fixed length of 1000 m be used. This length would encompass 40X channel widths for all reaches 25 m in wetted width or less, and make it easier to plan field sampling, as the length sampled would always be the same.

At each river reach fish will be sampled using a boat-mounted electroshocker. A 5 horsepower unit mounted on an inflatable boat is suitable for smaller rivers. For larger, deeper rivers an electrofishing boat is needed. For the relatively small number of reaches for which an electrofishing boat will be necessary, it is probably most efficient to hire a contractor with an electrofishing boat to assist in sampling the river reach.

When sampling a reach, start at the upper transect and move downstream, shocking along the shoreline on one side of the river; switch the bank being shocked between transects. One person will drive the boat, while a second will control the electroshocking equipment and net the stunned fish. A third person in an inflatable kayak will follow the boat and carry fish holding and processing gear. Only a single pass will be made with the electroschocker.

Stunned fish should be immediately placed in a live well, and held until the entire 1000 m reach has been shocked. When the reach has been sampled, fish should be identified to species and enumerated; additional information (fork length, weight, age class, sex, reproductive condition) should be collected on up to 30 individuals of each fish species. To reduce stress on individual fish, and increase the ease with which they can be handled, clove oil should be used to sedate fish before handling. Ageing structures should be collected from dead game fish. See Appendix A for guidelines on fish handling, preservation, collection of ageing structures, and disposal.

Equipment

Lab

Bottles (1 L; $15)
Isopropyl alcohol (95%; $10)
Coin envelopes ($3)
Scissors ($4)

Field

Inflatable boat ($5000)
Boat motor (5 horsepower, 4 stroke; $2000)
Inflatable kayak ($2000)
Electroschocker (for inflatable boat; $25000)
Electrofishing boat (for deep sites; will need to borrow or rent)
Bottles (1 L; $15)
Isopropyl alcohol (70%; $10)
Portable electronic balance (10,000 g capacity, 1 g readability: $450)
Pelican case for balanace ($140)
30 cm fish measuring board ($75)
100 cm fish measuring board ($175)
Live well (bucket or plastic bin; $25 x 2 = $50)
Plastic bags ($5)
Clove oil ($5)
Ethanol ($2)

Time required

The average amount of time required to electrofish a river reach, including processing fish in the field, will be 4 hours. The amount of time necessary to process mortalities (e.g. removing aging structures) will be 1 hour. The amount of time to enter and manage data per site will be 1 hour.

7.5.7 Benthic Macroinvertebrates

In rivers, only sample for benthic macroinvertebrates on the margins of the river where water is <1 m deep. Use a D-frame kick net and sample the river bed by walking back and forth across portion of the sampling transect < 1 m deep, disturbing the substrate and sweeping the net through the disturbed material at a rate that covers approximately 10 m of transect over a period of three minutes. This may require multiple trips back and forth across the transect that is < 1 m deep; record the length of the transect sampled. Sweep the kick net both vertically and horizontally through the water so that invertebrates kicked up from the bottom into the water column are captured in the net; vigorously disturb the substrate to a depth of about 5 cm. In flowing water keep the net downstream and close to the area being disturbed. A good sweeping motion is particularly important in areas of low flow. Switch the edge of the river (right vs. left) on which the benthic macroinvertebrate sample is being taken with each transect. Sample benthic macroinvertebrates at the five transects farthest downstream so the data can be compared to that collected in streams, where only five transects are used.

Combine benthic macroinvertebrate samples from five transects at a site into a single sample. This sample should be placed into a sample bottle (or bottles if the sample is large) and preserved for analysis in 95% ethanol. A label including date, site, collectors, collection gear, and transect / sample plot data are written in pencil on a piece of paper and included inside the bottle and another label with the same information should be affixed to the outside of the bottle; if more than one bottle was used at a site ensure that the label contains the words "Bottle 1 of *x*".

Process macroinvertebrate samples from rivers in the same way as those from wetlands (see wetland section below). I suggest that summer staff spend August picking samples collected during the summer, and that these be analyzed to the lowest taxonomic level possible for most groups by consultants. Chironomids, although a speciose group, are costly and difficult to identify to the species level. Therefore, I suggest the chironomids be taken only to the subfamily level. Samples should be archived following identification, so if the decision is made to go to species level with the chironomids in the future, these samples could be taken to species retroactively.

Note that for some species, the adult forms necessary for identification to species, or even genus, may not be available during the sampling period. Because the ABMP is built on single visits to the river sites, this is an unavoidable artifact of the sampling design. Immature invertebrates will be identified to as fine a resolution as possible. If a river is sampled at approximately the same time of the season every time it is sampled, then variance in biodiversity estimates due to phenological responses by macroinvertebrates should be minimized.

Equipment

Lab

Sample bottles ($10)
Ethanol ($3)
Microscope ($6000)
Counting equipment (forceps, petri dishes; $20)
Marchant box ($400)
Sieves ($90 x 3 different sizes = $270)

Field

Sweep net (modified D ring, with 500 µm net; $680.00)
Sample bottles ($10)
Ethanol ($3)

Time required

The average time required to collect and preserve benthic macroinvertebrate samples at a single site will be 2 hours. The time required to pick a sample from one site will be 8 hours. Sorting the invertebrates into broad taxonomic groups (e.g. family), which may result in savings at the identification step, will take approximately 2 additional hours per site. The time required to identify invertebrates from one site would vary substantially with the training and experience of the taxonomist; a contract will be established to identify the specimens. Time required to enter and manage the data from a site will be 2 hours.

7.5.8 Benthic Algae

Collect a sample of benthic algae at each river transect. On the same side of the river as the benthic macroinvertebrate sample is taken, find a point where the water depth is between 25 and 50 cm deep; if such a location cannot be found, sample benthic algae at a site with water depth as close to this range as possible. Within 0.5 m of the sample point, choose a rock or other hard substance; use a knife to scrape the benthic algae from an area of 25 cm^2. Place the sample in a 100 mL bottle. At each sample location also carefully lift some fine sediment with a trowel, trying not to disturb the surface of the sediment. Using a second trowel, skim off an area of 25 cm^2 from the surface of the sediment; place this material in the 100 mL bottle with the material scrapped from the rock. If only one type of substrate is available at the sample location, then collect two 25 cm^2 samples from that substrate type; record the substrate types and water depth where the sample was collected on the field data sheet.

Collect material from the five downstream river transects in the same manner, placing all material in the same bottle to form one composite sample for the site. After sample collection is complete, fill the sample bottle with 4% formaldehyde. Make sure the bottle is labelled clearly. Send the sample to a qualified consultant for identification and enumeration of species.

Equipment

Field

Sample bottles ($5)
Formaldehyde ($3)
Two trowels ($15)
Scalpel ($5)

Time required

The average time required to collect and preserve benthic algae samples at a single site will be 1 hour. A contract will be established to identify the specimens. Time required to enter and manage the data from a site will be 1 hour.

7.5.9 Overall time required to sample rivers

The average overall time required to sample one river will be 1 hour for site selection in the lab (generating maps), 4 hours for travel (2 hours each way to a site; this is probably a maximum value), 11.5 hours for sampling at the site, 11 hours for sample processing in the lab, 6 hours for data entry and management, 1.5 hours/day for preparation for field work and for packing equipment away at the end of the day, and 1 hour for preparing materials for shipping to consultants (e.g. packaging). The total time commitment is therefore 36 hours per river reach.

7.6 Landscape Elements – Rivers

The following landscape elements should be derived for sampled river reaches. Some variables may be obtained from existing datasets (e.g. soil types, watershed area, mean slope of watershed), while others will need to be derived from remote sensing data periodically (e.g. landuse, stream crossings). The resolution needed to obtain the necessary information varies across elements. Following is a description of the different elements and why they are being measured.

- Strahler order – the Strahler order of the river reach sampled; provides an indication of river size and allows comparison with other rivers of similar order; Strahler order can be derived from single line coverages in ArcMap
- sinuosity – a measure of how "bendy" a river is, reflecting the degree to which it is meandering across its floodplain; measured as the ratio of the length of a river reach to the straight-line distance between the start and end of the reach; this data can be derived from single line coverages in ArcMap
- soil types in the watershed – may influence river chemistry; clip soil coverages for Alberta to isolate watershed then determine percentage of watershed area in different soil classes
- watershed area – (from DEM); area of the watershed for the river; may influence the amount of water entering the river, potential amount of inputs into the river (e.g. herbicides); determine using ArcMap and DEM for province; save watershed boundary as a coverage for use in determining other attributes of watershed
- watershed slope (from DEM) – influences movement of materials (e.g. sediments, chemicals) into river; determine using ArcMap and DEM for watershed
- number of beaver dams above sample reach – may influence water levels and sedimentation rates; determine using medium grain (spatial resolution of 1 – 5 m) air photos or satellite imagery if this is available; examine the images to determine the number of intact beaver dams within 1, 10, and 20 km above the sample reach
- number and type of crossings (e.g. bridge, road with culvert, trail) within 1, 10, and 100 km above sample reach – the number and type of crossings above the sample reach may influence sedimentation patterns in the river, which may impact fish populations. Also, chemicals associated with road maintenance and vehicular traffic may enter the river at crossings. This data can be derived from road coverages in ArcMap and medium grain (spatial resolution of 1 – 5 m) classified air photos or satellite imagery if this is available
- vegetation – area of watershed in different forest categories, such as deciduous, coniferous, and mixed wood, and percentage of the area within 100 m and 500 m of the river that falls into these categories; habitat type around streams may influence nutrient availability, stream temperature, cover; this data can be derived from the latest Alberta Vegetation Inventory (AVI) coverages using the clip and buffering tools; can also be derived from medium grain (spatial resolution of 1 – 5 m) classified air photos or satellite imagery if this is available
- landuse – area of watershed in different landuse categories, and percentage of the area within 100 m and 500 m of the river that falls into these categories – categories include roads, well sites, seismic lines, right-of-ways, cut blocks, urban development (villages, towns), crops, pasture, and industrial areas. This data can be derived from the latest Alberta Vegetation Inventory (AVI) coverages using the clip and buffering tools; can also be derived from medium grain (spatial resolution of 1 – 5 m) classified air photos or satellite imagery if this is available.

8 SAMPLING REGIONAL SCALE ELEMENTS

8.1 Wetland sampling protocols

8.1.1 Wetlands Sampling Window

Wetlands are more likely to contain water in the early part of the field season. Wetland sampling should therefore occur in late May to the end of July. Note that invertebrates found in wetlands will often exhibit seasonal fluctuations, both in abundance, species composition, and life history stages present for particular species. Life history stage may affect the taxonomic resolution that can be reached for some species (e.g. those for which adult forms are needed for identification to species). This problem, however, is unavoidable and can only be overcome by repeat visits to a site, or the use of traps that are in placed in a wetland for relatively long time periods and are checked periodically. Neither of these approaches is cost effective within the ABMP. If a wetland is sampled at approximately the same time of the season every time it is sampled, then variance in biodiversity estimates due to phenological responses by macroinvertebrates should be minimized. A subset of field crews should be dedicated to sampling wetlands during the summer season.

8.1.2 Site selection

Using GIS coverages, determine the site classified as a wetland that is closest to the target ABMP terrestrial point. Wetland types vary from region to region across Alberta (e.g. potholes in the grasslands and fens in the boreal). Selection of sampling sites based on the ABMP terrestrial point grid ensures the wetlands sampled reflect the actual wetland types present on the landscape within different ecoregions in the province. Wetlands should contain water on the first visit; note, however, that water levels in wetlands may fluctuate temporally, so water may not be present at the site in every sampling year. In cases where standing water does not occur, plants may still be sampled.

Wetlands can be very heterogeneous, with patches of water often interspersed with vegetation. Wetlands between 1 and 20 ha should be sampled as part of the ABMP. In extensive wetland complexes a plot of 20 ha should be established for sampling. This plot will always include a shoreline (e.g. transition zone to upland vegetation; Figure 9). If a wetland dries between sampling events, vegetation can still be sampled, as wetland plants often persist even if no water is visible on the surface, as long as the soil is wet enough. If wetlands are drained or altered (e.g. cultivated) between sampling events, this should be noted, and the wetland should be monitored to determine if it returns to a "wetland" state.

Equipment

Lab

GIS coverages (obtained from Sustainable Resource Development)

Topographic maps ($10)

Time required

The average time required to locate and map potential wetland sites near terrestrial sampling points will be 1.0 hour. This will include determining the area of the potential sampling wetland, and determining possible access routes from GIS coverages and satellite images. The average amount of time to find and assess potential wetland sampling sites for the presence of water will be 2 hours per wetland; it may take multiple attempts before a suitable wetland is found.

Remember that this will only need to be done during the first round of lake sampling; on subsequent rounds access routes and approximate depths will be known. The average amount of time required to enter and manage the data from one wetland will be 0.5 hours. Note that the time taken to assess wetlands will increase if interacting with landowners to gain access is included in the time estimate. I suggest that gaining agreements from landowners for access to wetlands be a separate activity from wetland sampling, and that the ABMP have someone dedicated to procuring access agreements with landowners, leaving the monitoring crews to concentrate on sampling. Potential wetland sites that are not sampled because access is denied should be recorded. If the number of access-denied sites is a large proportion of the population of potential sites, land use around access-denied sites, and their spatial distribution, should be compared to sampled sites to ensure there is no systematic bias in site selection.

8.1.3 Depth Transects

Before going in the field, delineate three depth transects on the map of the wetland using GIS. One transect will be on the longitudinal axis of wetland (or plot) and the other two perpendicular to, and equally spaced, along the first axis (similar to the approach taken in lakes; see Figure 5). Measure depth at 10 equal intervals along each transect using a folding 2 m measuring stick or an extendable pole from the inflatable kayak. To determine the interval for the sampling points, the total length of each transect is estimated using the scale on the field map (this map was produced from the GIS coverages for the wetland) and the total length of the transect is divided by 11 to determine the interval between sampling points.

On the wetland, start the transect from the water's edge and estimate the distance between sampling points. Sketch the depths and transects on a field sheet to get an idea of where the deeper parts of the wetland are. Use the GPS unit to record the location for each sampling point (also record the accuracy of the GPS for that point). These data will be used to create a bathymetric map of the site. The deepest spot found should be noted, as it will be used for the vertical depth profile for temperature, pH, dissolved oxygen, and conductivity.

Equipment

Lab
GIS coverages (obtained from Sustainable Resource Development)
Topographic maps ($10)

Field
2 m folding measuring stick ($30)
7.5 m fiberglass telescoping height pole ($400)
GPS unit ($400 x 2 = $800)
Truck / quad / helicopter (variable; depends on distance to travel)
Inflatable kayak ($2000)

Time required

The average time required to complete depth transects will be 1 hour per wetland. The average amount of time required to enter and manage the data from one wetland, and generate bathymetric maps, will be 2 hours.

8.1.4 Plot Location

Mark the point where the wetland was accessed with a steel bar driven into the ground. Establish a deep plot at the deepest point in the wetland, if it lies within the 20 ha sampling plot; this plot is approximately 450 m x 450 m, and always includes the shoreline (Figure 9). Mark the location of the 20 ha plot corners temporarily with buoys or stake flags (if the wetland is shallow or contains no water). Record the location of the plot corners using a GPS unit and draw them on a map of the wetland. The marker buoys can be removed when sampling is completed. If the deepest point in the wetland is not within the plot, use the deepest point within the plot as the first deep-water sampling site. Invertebrates and water physiochemistry are sampled at this location (Figure 9).

Additional plots are located as indicated in individual protocols described below. Figure 9 provides a summary of these plots.

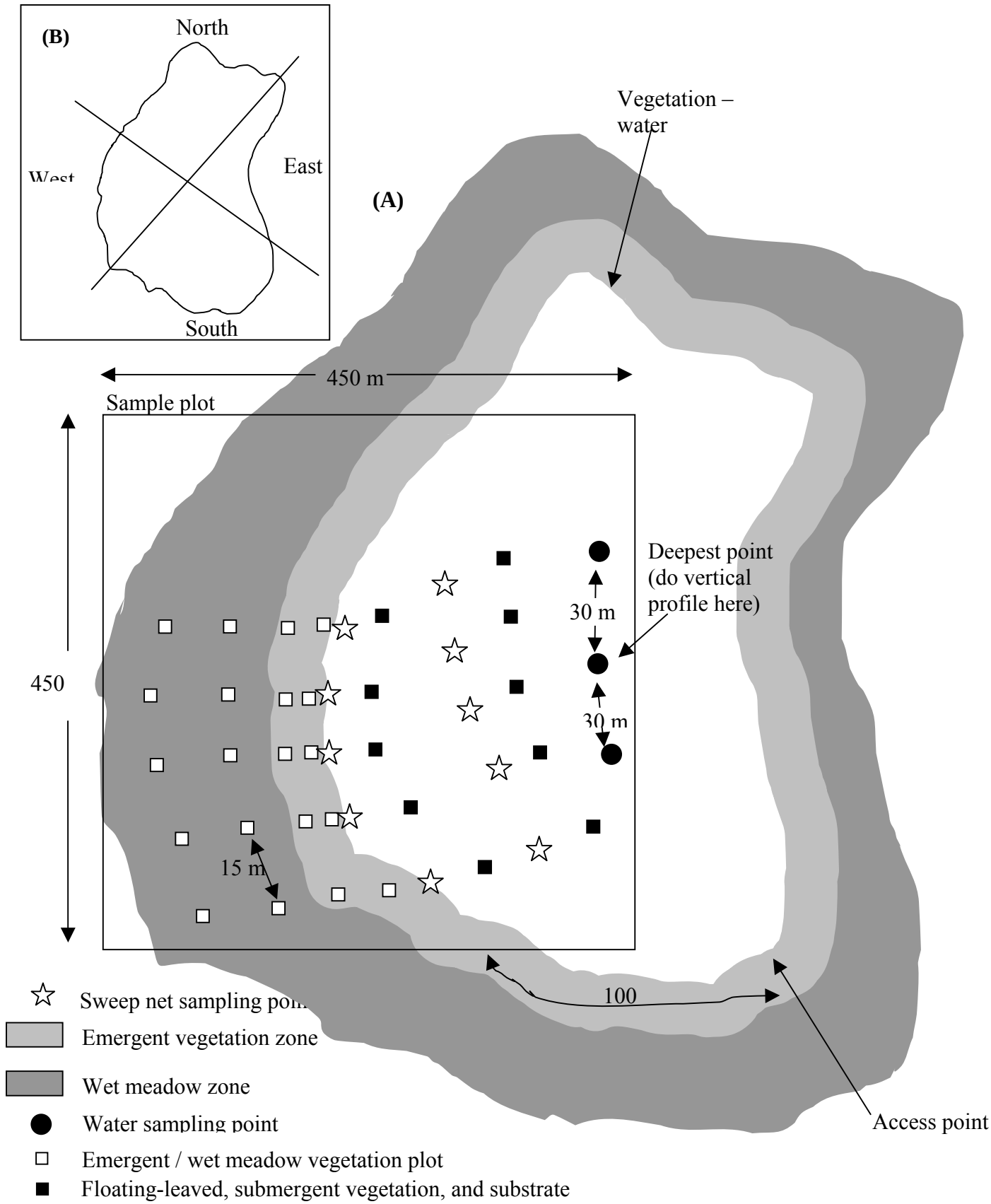

Figure 9. (A) Location of sample plot on a wetland and schematic diagram of sampling points for invertebrates, plants, and water in wetlands. The sample plot should always include the shoreline. (B - inset) Schematic diagram of quadrants for sampling riparian vegetation and bank erosion.

Equipment

Lab

GIS coverages to produce map of lake (obtained from Sustainable Resource Development)

Field

GPS unit ($400 x 2 = $800)
Steel bar ($5)
Mallet ($20)
Buoys (inflatable marker buoys: $30 each x 4 = $120).
Truck / quad / helicopter (variable; depends on distance to travel)
Inflatable kayak ($2000)

Time required

Setting out and removing corner markers for the 20 ha sampling plot will require approximately 0.25 hours. The average time required to set out the plot locations will be 1.0 hour, but much of this will be incorporated in the individual protocols. The average time to enter and manage the data will be 0.25 hours per site.

8.1.5 Water physiochemistry

Do a vertical profile of temperature, pH, conductivity, and dissolved oxygen at the deepest point of the wetland or wetland plot (before collecting the sweep net sample at this site; see below) using a multiprobe meter. Record measurements at five intervals from water's surface to the bottom of the wetland. To do this, divide the total depth by five and record the relevant data at the mid-point of each of these intervals. When collecting measurements, there should be at least 10 cm between the mid-point of each depth interval. If the water is not deep enough to collect five measurements, do as many as possible while maintaining the minimum distance between sample depths. It is possible to collect measurements as long as the water is deep enough to fully immerse the probe.

Collect a grab water sample for total phosphorus (TP), total nitrogen (TN), and dissolved organic carbon (DOC) using a 1 L Nalgene bottle. Rinse the bottle three times with water from the wetland before taking the first sample and be sure not to disturb the bottom of the wetland in any way before taking the sample. Pour the water into a 5 L carboy placed inside a black plastic garbage bag. Collect water samples at two additional sites (use the same sites as used for collecting invertebrate samples; see below) using the same method. These sites are located 30 m away on either side of the deepest plot along the long axis of the wetland or plot edge (see Figure 9). Mix the water sample vigorously and collect a 1 L subsample in a dark plastic bottle. Wear Nitrile gloves while collecting water samples. Store water samples in a cooler until they can be refrigerated; samples should be stored at 4° C for up to 10 days before analysis. Samples should be submitted to the water lab at then end of each field shift.

Equipment

Lab

Water samples should be sent to a certified lab for analysis. Costs for doing total nitrogen (TN), total phosphorus (TP), and dissolved organic carbon (DOC) approximately $67 / sample for all three parameters

Laboratory equipment necessary to perform the analysis for TN, TC, and DOC would cost in excess of $10,000, plus the cost of calibrating, operating, and maintaining the equipment.

Field
Multiprobe meter (approximately $5500)
5 L Nalgene carboy with spigot ($100)
Cooler ($50)
Dark plastic bottles (usually supplied by water analysis lab; if not, cost approximately $6.00 per 1 L dark Nalgene bottle)

Time required
The average time required to complete the water physiochemistry protocol will be 1 hour. Time required to enter and manage the data for one site will be 0.5 hours.

8.1.6 Wetland characteristics
Divide the wetland into four equal quadrants, each of which will be centred on a cardinal compass point (north, east, south, west; Figure 9). For each quadrant use a clinometer to estimate the average height of the riparian vegetation (vegetation within 5 m of the water's edge) and the % composition of the vegetation in the following classes: herbs, grasses, shrubs, deciduous trees, and coniferous trees. Estimate the total % of the wetland bank that exhibits erosion (eroded areas do not need to be continuous with one another), and whether this erosion is natural or anthropogenic (estimate % caused by each). Erosion includes disturbance by cattle, foot or vehicular traffic, overland flow channels, and bank slumping; other types of erosion noted in the field should be described on the data sheet. Make note of any anthropogenic activity on the shore of the wetland (e.g. cattle, quad activity), and the presence of animal activity (e.g. beaver dam or lodge). Sketch the general shape of the wetland, identifying areas of open water and those of vegetation, islands, and other important physical structures. If the wetland is too large and one or more of the banks of the wetland cannot be reached or readily observed, record this information on the field sheet.

Equipment
Field
Clinometer ($150)

Time required
Characterizing the wetland will require approximately 0.5 hours. The average time to enter and manage the data will be 0.5 hours per site.

8.1.7 Sampling aquatic invertebrates
For quick assessments of wetland aquatic invertebrate communities, using a sweep-net is one of the best methods (Lisette Ross, personal communication). This can be accomplished by carefully placing the mouth of the net on the bottom of the wetland, with the handle of the net held at an angle to the body. Draw the net rapidly up through the water column to the surface; record the water depth where the sample was taken. If the water is more than 1 m deep, only sample the top 1 m of water. Place the collected invertebrates in a jar and preserve with 70% ethanol; invertebrate samples will be picked and pooled in the lab, before sending them to consultants for identification.

In each wetland, five sweep net samples should be collected in open water (e.g. where there is no emergent vegetation, though there may be submerged or floating-leaved vegetation), and five along the vegetation – water interface (Figure 9). The open water samples should be taken about halfway between the centre of the wetland and plots established at the vegetation – water interface, ensuring that open water sampling sites are 15 m apart from one another (Figure 9). The five samples taken at the vegetation – water interface should be spaced at 15 m intervals around the edge of the wetland (Figure 9), with the first sample taken 10 m counter clockwise from the edge of the wetland sampling plot, or the access point (for wetlands smaller than 20 ha). The location of each sampling point should be sketched on the field sheet. Using a laser range finder or tape measure and a compass, measure the distance and bearing of each sampling point from the stake marking the wetland access point.

Combine all the macroinvertebrate samples into a single composite sample. This sample should be placed in a sample bottle (or bottles if the sample is large) and preserved for analysis in 95% ethanol. A label including date, site, collectors, and collection gear is written in pencil on a piece of paper and included inside the bottle, while another label, with the same information, is affixed to the outside of the bottle. If more than one bottle is used at a site ensure that the label contains the words "Bottle 1 of *x*".

In the lab the invertebrates are picked from the other material in the sample (e.g. plant fragments and other debris). Pass the sample through a series of sieves to extract progressively smaller invertebrates; use dissecting microscopes to remove invertebrates from the debris in the sample. Picked samples are placed in sample bottles with the original labels (or hand-written copies of the labels if the invertebrates are sorted into broad taxonomic groups during the picking process) until identification can be done. Samples should be shipped to a consultant for identification.

Use a Marchant box, which is divided into 100 separate cells and randomly chose cells until 500 specimens are counted (Rosenburg et al. *undated*). Studies suggest that the number of taxa in a sample approaches an asymptote as subsample counts approach 300 individuals (Ostermiller and Hawkins 2004). King and Richardson (2002) found that bioassessment using benthic macroinvertebrates in wetlands improved most when at least 200 individuals were included in a subsample. Inclusion of large / rare assessments, in which the entire sample is scanned for 15 minutes to pick out large and/or rare taxa, may also be important (Vinson and Hawkins 1996; King and Richardson 2002), and should be used in the ABMP. Large/rare assessments are done after subsampling is complete.

Equipment

Lab

Sample bottles ($10)
Ethanol ($3)
Microscope ($6000)
Counting equipment (forceps, petri dishes; $20)
Sieves ($90 x 3 different sizes = $270)

Field

Compass ($70)
Laser rangefinder ($3000)
50 m measuring tape ($60)
Sweep net (modified D ring, with 500 µm net; $680.00)

Sample bottles ($10)
Ethanol ($3)

Time required

The average time required to collect and preserve macroinvertebrate samples at a single site will be 2 hours. The time required to pick a sample from one site will be 8 hours. Sorting the invertebrates into broad taxonomic groups (e.g. family), which may result in savings at the identification step, will take approximately 2 additional hours per site. The time required to identify invertebrates from one site would vary substantially with the training and experience of the taxonomist; a contract will be established to identify the specimens. Time required to enter and manage data from one site will be 1 hour.

8.1.8 Vascular plants

Four different groups of vascular plants will be sampled: wet meadow, emergents, floating-leaved, and submergents. Although terrestrial vascular plants are already being sampled as part of the ABMP terrestrial protocols, wetland-related plants are largely a different suite of species from that encountered in upland settings. In addition, plants may be the only biotic group available for sampling in wetlands in years when the water table is low.

Plants will be sampled by establishing a series of sampling plots within each different vegetation zone (wet meadow, emergent, submergent/floating leaved) in the wetland. Within each zone ten 1 x 1 m plots will be established; plots will be arranged in five pairs, with the two plots within each pair distributed equidistant from the edges of the vegetation zone and from each other (Figure 9). There will be 15 m between sets of plots with a vegetation zone (Figure 9). Plots for submergent/floating-leaved plants will be located equidistant from the shore and the edge of the plot closest to the centre of the wetland, or the centre of the wetland itself, if the wetland is less than 20 ha in size (Figure 9). The first set of plots in each zone should be 10 m from edge of the plot closest to the access point to the wetland. The approach outlined here should provide a good estimate of the species richness and relative abundance of plants associated with each wetland (Richard Grosshans, personal communication).

Sketch the location of each plant-sampling plot on the field sheet. Using a laser range finder or tape measure and a compass, measure the distance and bearing of each sampling point from the stake marking the wetland access point. If a vegetation zone is narrower than 5 m wide, find the centre point of the transect in the zone and place plots two metres from this point on either side of the transect within that vegetation zone. If the water has receded between sampling sessions, establish plant sampling plots as if the wetland had not been sampled before, but starting at the same access point so the sampling plots are placing in roughly the same area of the wetland as before. Although moving the plots this was means that the exact same locations are not sampled each time, it does ensure that all the vegetation zones found in the wetland are sampled each time. Moving plots may reduce statistical power, but would introduce less variance than sampling all vegetation zones in one session, and then only a reduced number of zones (e.g. only wet meadow) at the next session if the standing water at a site recedes. If there is no water in a wetland at the time of sampling, still sample all the plots (including those that would have been in the submergent/floating-leaved zone); plot locations will be the same as those used in the previous visit in this situation. Sampling a wetland that has dried will provide an indication of colonization of the former wetland by non-aquatic plant species.

Within each plot, visually estimate the percent cover to the nearest 1% for each species; identify species in the field where possible. Collect voucher specimens for species that could not be identified on site. Collect voucher specimens of the same species as occur in the plot from at least 2 m outside the plot to avoid changing the species composition of the plot. Sample floating-leaved plants using a floating 1 m x 1 m plot frame made of white PVC pipe; anchor the plot frame and visually estimate the cover of each species; identify the species in the field where possible, and collect voucher specimens when necessary; measure water depth at the centre of the plot. Sample submergent plants by looking through the floating plot frame and visually estimating a 1 x 1 m plot on the bottom of the wetland; estimate the percent cover. Again, remove samples of each species from outside the plot area for identification, if necessary. If possible, this can be done by hand; use a garden rake to retrieve samples if necessary. Characterize the substrate within each plot for submergent plants as fines, sand, gravel, cobble, boulder, or bedrock (use the same size criteria as in streams), and note any downed woody material present within the plot.

Plant samples collected in the field should be placed in bags with appropriate labels and placed in a plant press as soon as possible. Summer staff will identify as many specimens as possible in the lab during August. Remaining samples (those the summer staff are unable to identify) will be sent to experts for identification.

Time required

Establishing and sampling wetland vegetation plots will take approximately 5 hours. Identifying plants in the lab will take approximately 4 hours per site. Entering and managing data will require 1 hour per site.

Equipment

Lab

Microscope ($6000)
Plant press ($50)
Identification of plants by experts ($70)

Field

Vascular plant guides ($100)
Plot frames ($25)
Bags ($5)
Rake ($20)

8.1.10 Overall time required to sample wetlands

The average overall time required to sample one wetland will be 1 hour for site selection in the lab (generating maps), 4 hours for travel (2 hours each way to a site; this is probably a maximum value), 8.75 hours for sampling at the site (this assumes that field personnel will work separately when doing the vegetation plots), 14 hours for sample processing in the lab, 5.75 hours for data entry and management, 1.5 hours/day for preparation for field work and for packing equipment away at the end of the day, and 1 hour for preparing materials for shipping to consultants (e.g. packaging). The total time commitment is therefore 36 hours per wetland.

8.2 Landscape Elements – Wetlands

The following landscape elements should be derived for sampled wetlands. Some variables may be obtained from existing datasets (e.g. soil types, watershed area, mean slope of watershed), while others will need to be derived from remote sensing data periodically (e.g. landuse). The resolution needed to obtain the necessary information varies across elements. Following is a description of the different elements and why they are being measured.

- wetland area – biodiversity is influenced by wetland size; determine from attribute table for hydropoly layer for Alberta; can also be derived from medium grain (spatial resolution of 1 – 5 m) classified air photos or satellite imagery if this is available
- watershed slope - influences movement of materials (e.g. sediments, chemicals) into wetland; determine using ArcMap and DEM for watershed
- percent watershed which is wetland – an index of wetland density; use clip function in ArcMap to isolate wetlands in a watershed from AVI coverages, then use attribute table for to determine number, mean area, and total area of wetlands
- distance to nearest wetland – an index of landscape connectivity (important for organisms such as amphibians); measure on hydropoly or AVI coverage for Alberta using ArcMap
- soil types in the watershed – may influence wetland water chemistry; clip soil coverages for Alberta to isolate watershed then determine percentage of watershed area in different soil classes
- watershed area – area of the watershed for the wetland; may influence the amount of water entering the wetland and potential inputs (e.g. herbicides); determine using ArcMap and DEM for province; save watershed boundary as a coverage for use in determining other attributes of watershed
- vegetation – area of watershed in different forest categories, such as deciduous, coniferous, and percentage of the area within 100 m and 500 m of the wetland that falls into these categories; habitat type around wetlands may influence nutrient availability, and other factors; this data can be derived from the latest Alberta Vegetation Inventory (AVI) coverages using the clip and buffering tools; can also be derived from medium grain (spatial resolution of 1 – 5 m) classified air photos or satellite imagery if this is available
- landuse – area of watershed in different landuse categories, and percentage of the area within 100 m and 500 m of the wetland that falls into these categories – categories include roads, well sites, seismic lines, right-of-ways, cut blocks, urban development (villages, towns), crops, pasture, and industrial areas; this data can be derived from the latest Alberta Vegetation Inventory (AVI) coverages using the clip and buffering tools; can also be derived from medium grain (spatial resolution of 1 – 5 m) classified air photos or satellite imagery if this is available.

8.3 Stream Sampling Protocols

8.3.1 Stream Sampling Window

Streams can be sampled at almost any time of the summer, but they are more likely to contain water in the early, rather than the late, part of the field season. Stream sampling should therefore

occur in late May to the end of July. Note that invertebrates found in streams will often exhibit seasonal fluctuations in abundance, species composition, and life history stages present for particular species. Emergence dates for some groups may vary temporally as well in response to extrinsic factors such as climate (Briers et al. 2004). Life history stage may affect the taxonomic resolution that can be reached for some species (e.g. those for which adult forms are needed for identification to species). This problem, however, is unavoidable and can only be overcome repeat visits to a site. This is not cost effective for the ABMP. If a stream is sampled at approximately the same time of the season every time it is sampled, then variance in biodiversity estimates due to phenological responses by benthic macroinvertebrates should be minimized. A subset of field crews should be dedicated to sampling streams during the summer season.

8.3.2 Stream Selection

Identify potential streams reaches closest to an ABMP terrestrial sampling point within the Rocky Mountain and foothills ecoregions using GIS and air photos; visit these streams to verify that they are acceptable sampling sites. Locating acceptable sites (streams with a depth of at least 25 cm, but no more than 1.5 m; width of at least 1 m; containing flowing water) will not be possible using only GIS and air photos; visits to verify the acceptability of the site are necessary. Beavers can be avoided by choosing low-order, high gradient streams; in the foothills of Alberta the beaver pond abundance peaks in third order streams with low gradient (Cameron Stevens, personal communication).

Equipment

Lab

GIS coverages (obtained from Sustainable Resource Development)

Topographic maps ($10)

Field

Folding 2 m measuring stick ($20)

50 m measuring tape ($60)

Truck / quad / helicopter (variable; depends on distance to travel)

Time required

The average amount of time required to identify possible stream sites and access routes using GIS and maps in the lab will be 2 hours. Average time to reach and check each potential site in the field will be 4 hours.

8.3.3 Transect Location

At each stream site, five cross-section transects are established. The first downstream transect is established 25 m upstream from where the team first reached the stream; this first plot should be identified with a steel bar driven into the ground next to the stream and it's location should be marked with flagging tape. Four more transects are established at 50 m intervals upstream of the

first plot and marked with flagging tape (Figure 10). The locations of both ends of each transect are recorded using a GPS unit.

Equipment

Field

50 m measuring tape ($60)
Steel bar ($5)
Flagging tape ($5)
Mallet ($20)

Time required

The average amount of time required to establish plots along streams will be 0.5 hours. Note that plot establishment will be integrated with other activities, so that a plot will be located, marked with flagging tape, and then sampled; after sampling, the crew will move on to the next plot, sample it, and so on.

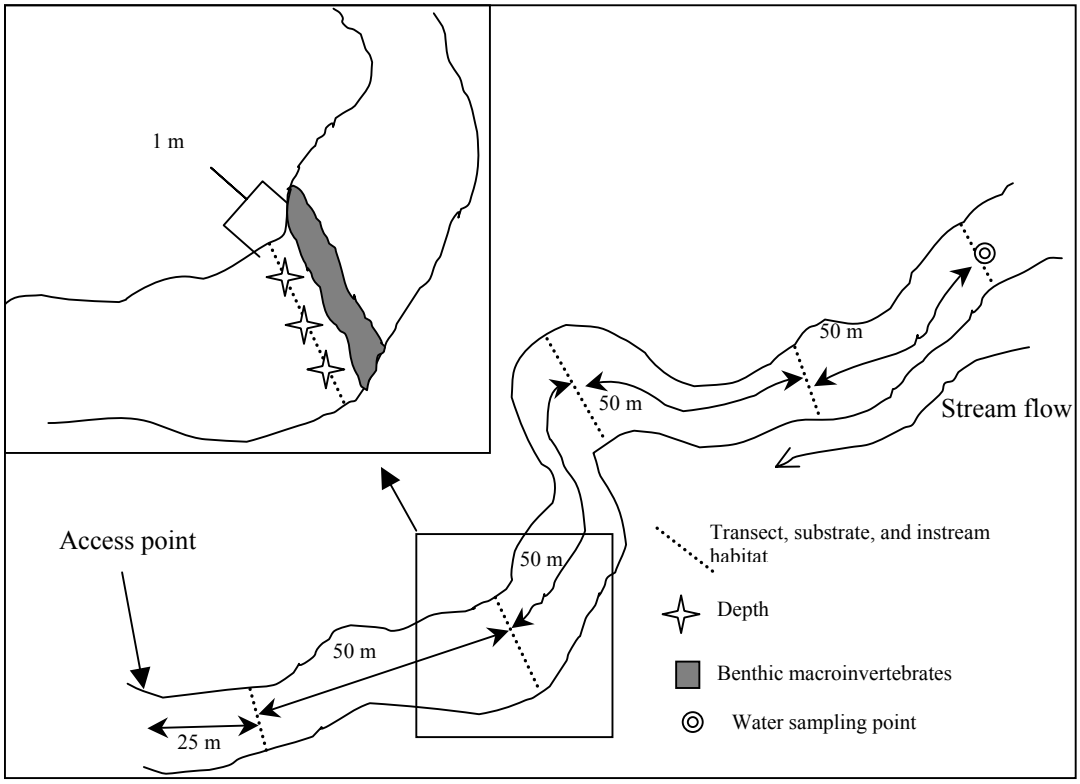

Figure 10. Schematic diagram of stream sampling protocols.

8.3.4 Physical Characteristics of Streams

At each transect measure the following parameters: (a) bankfull width (width of the channel at the point where over-bank flow begins during a flood event; may be discerned by the lower extent of perennial vegetation, and / or changes in slope or particle size of the stream bank), (b) wetted width (width of the channel presently containing water), (c) maximum depth (if the water

is too deep to wade a section, then record that the water is deeper than *x* [e.g. 1.5 m]), and (d) depth at 25%, 50%, and 75% of the wetted width. Make a sketch of the channel between the first and last cross-section plot, including the location of the sample plots, concentrations of downed woody material (DWM), and the location and extent of riffle, run, and pool habitats. Riffles are areas of swiftly flowing water with surface turbulence, run are areas of water flowing at relatively low velocity with little or no surface turbulence, and pools are relatively deep areas in the stream with reduced velocity. The sketch can be made by standing on the bank at the cross-section farthest upstream and looking downstream and making the sketch, and then moving to the cross-section farthest downstream and looking upstream to verify the initial sketch. If bends in the stream or riparian vegetation make it difficult to sketch the entire sampling reach from one point, complete the sketch in stages as you move from one transect to the next.

A number of elements should be estimated for a 20 m segment of bank centered at the end of each transect. Elements that should be estimated include stream bank stability (see Table 4; make notes on the cause of any instability, such as road crossing, cattle watering, or undercutting), dominant riparian vegetation (vegetation within 5 m of stream; categories = none, grass/sedge, shrub, deciduous, coniferous, and mixedwood), and terrestrial canopy cover (living vegetation that projects over water surface; this can be any vegetation from grass to trees; categories = none, low, moderate, high). A densiometer will be used to measure tree / shrub canopy cover when standing in the middle of the stream at each transect. The slope of the stream reach sampled will be determined in the lab using a digital elevation model (DEM) in ArcMap.

At each of the five cross-sections, visually estimate the proportion of the stream that is represented by riffles, runs, and pools in a 5 m band across the stream, as well as the proportion of the substrate in six fraction classes (Figure 13). The six fraction classes are bedrock (>4000 mm), boulders (>250 – 4000 mm), cobble (>64 – 250 mm), gravel (>2 – 64 mm), sand (>0.06 – 2 mm), and fines (<0.06 mm). Where the substrate cannot be seen (due to turbidity or turbulence) substrate size will by assessed by feel with hands or feet. Estimate substrate embeddedness when characterizing substrate composition (categories = none [<25% of large substrate types covered in fines], low [26 – 50%], moderate [51-75%], and high [>75%]).

Measure downed woody material (DWM) along the entire length of the sampling reach. Count and record the length and diameter at the midpoint of all pieces of DWM > 10 cm long and > 1 cm wide.

Equipment

Field
50 m measuring tape ($60)
Aluminum 24 inch DBH calipers ($225)
Densitometer ($200)

Time required

The average time necessary to complete the surveys for physical characteristics of the stream reach, DWM and substrate will be 3 hours. The time to enter and manage the data for one site will be 1 hour.

8.3.5 Water Physiochemistry

In the middle of the water column at the deepest point on the transect farthest upstream, measure water temperature, pH, dissolved O_2, and conductivity using a multiprobe meter, and water velocity using a water velocity meter. At the same point collect a water sample for analysis of total nitrogen, total phosphorus, and dissolved organic carbon using a 1 L dark Nalgene bottle. Rinse the bottle three times with stream water and collect water just below the surface of the stream. Make sure to wear Nitrile gloves while collecting the water sample. Store water samples in a cooler until they can be refrigerated. Water samples can be held at 4º C for 10 days; samples should be submitted for analysis at the end of each field shift.

Equipment

Lab

Water samples should be sent to a certified lab for analysis. Costs for doing total nitrogen (TN), total phosphorus (TP), and dissolved organic carbon (DOC) approximately $67 / sample for all three parameters

Laboratory equipment necessary to perform the analysis for TN, TC, and DOC would cost in excess of $10,000, plus the cost of calibrating, operating, and maintaining the equipment.

Field

Multiprobe meter ($5500)
Water velocity meter ($2500)
Cooler ($50)
Dark plastic bottles (usually supplied by water analysis lab; if not, cost approximately $6.00 per 1 L dark Nalgene bottle)

Time required

The average time required to complete the water physiochemistry protocol will be 1.5 hours. Time to enter and manage the data for one site will be 0.5 hours.

8.3.6 Benthic Macroinvertebrates

Use a D-frame kick net and sample the stream bed by walking back and forth across the sampling transect disturbing the substrate and sweeping the net through the disturbed material at a rate that covers approximately 10 m of transect over a period of three minutes. In small streams this may require multiple trips back and forth across the stream. Sweep the kick net both vertically and horizontally through the water so that invertebrates kicked up from the bottom into the water column are captured in the net; vigorously disturb the substrate to a depth of about 5 cm. In flowing water keep the net downstream and close to the area being disturbed. A good sweeping motion is particularly important in areas of low flow. This approach is less quantitative than using a Neill sampler, but offers the advantages of being useful in many kinds of substrate, under different flow conditions (as the flowing of the water is not relied upon to move the invertebrates into the net), and the fact that the kick net is more portable than the Neill sampler.

Benthic macroinvertebrate diversity and abundance is usually highest in riffles within a stream (Grubaugh et al. 1996), and some monitoring programs target this habitat type

specifically. However, not all stream reaches will necessarily have riffle habitats, and a multiple-habitat method is suggested here, with the sampling transect dictated by distance from the stream access point. This means that the establishment of sampling transects does not rely on the judgement of field crews, which will vary from person-to-person. Some studies have indicated that little within-stream variation is associated with habitat type, transect position, or water flow rate, but that sampling effort had a large impact on taxon richness (Li et al. 2001). Therefore, sampling will take place along the transects already established, but approximately 1 m upstream of the transects to avoid areas disturbed during substrate characterization and other activities (Figure 10). If a section of the transect is too deep to sample safely because of the presence of deep poles, record the percent of the transect this portion represents, and complete the three minutes of sampling in the remaining parts of the transect.

Benthic macroinvertebrate samples from all five transects at a stream site should be pooled into a single sample. This sample should be placed into a sample bottle (or bottles if the sample is large) and preserved for analysis in 95% ethanol. A label including date, site, collectors, collection gear, and transect / sample plot data are written in pencil on a piece of paper and included inside the bottle and another label with the same information should be affixed to the outside of the bottle; if more than one bottle was used at a site ensure that the label contains the words "Bottle 1 of *x*".

Process macroinvertebrate samples from streams in the same way as those from wetlands (see wetland section above). I suggest that summer staff spend August picking samples collected during the summer, and that these be analyzed to the lowest taxonomic level possible for most groups by consultants. Chironomids, although a speciose group, are costly and difficult to identify to the species level. Therefore, I suggest the chironomids be taken only to the subfamily level. Samples should be archived following identification, so if the decision is made to go to species level with the chironomids in the future, these samples could be taken to species retroactively.

Note that for some species, the adult forms necessary for identification to species, or even genus, may not be available during the sampling period. Because the ABMP is built on single visits to the stream sites, this is an unavoidable artifact of the sampling design. Immature invertebrates will be identified to as fine a resolution as possible. If a stream is sampled at approximately the same time of the season every time it is sampled, then variance in biodiversity estimates due to phenological responses by macroinvertebrates should be minimized.

Equipment

Lab

Sample bottles ($10)
Ethanol ($3)
Microscope ($6000)
Counting equipment (forceps, petri dishes; $20)
Marchant box ($400)
Sieves ($90 x 3 different sizes = $270)

Field

Sweep net (modified D ring, with 500 µm net; $680.00)
Sample bottles ($10)
Ethanol ($3)

Time required

The average time required to collect and preserve benthic macroinvertebrate samples at a single site will be 1.5 hours. The time required to pick a sample from one site will be 8 hours. Sorting the invertebrates into broad taxonomic groups (e.g. family), which may result in savings at the identification step, will take approximately 2 additional hours per site. The time required to identify invertebrates from one site would vary substantially with the training and experience of the taxonomist; a contract will be established to identify the specimens. Time required to enter and manage the data from a site will be 1 hour.

8.3.7 Benthic Algae

Collect a sample of benthic algae at each stream transect. If the water depth is <50 cm at the centre of the transect, then collect the sample at this location. If the water at the centre of the transect is >50 cm, collect the sample at the point on the transect nearest to the centre where the water depth is <50 cm. Within 0.5 m of this point, choose a rock or other hard substance; use a knife to scrape the benthic algae from an area of 25 cm^2. Place the sample in a 100 mL bottle. At each sample location also carefully lift some fine sediment with a trowel, trying not to disturb the surface of the sediment. Using a second trowel, skim off an area of 25 cm^2 from the surface of the sediment; place this material in the 100 mL bottle with the material scrapped from the rock. If only one type of substrate is available at the sample location, then collect two 25 cm^2 samples from that substrate type; record the substrate types on the field data sheet.

Collect material at all five stream transects in the same manner, placing all material in the same bottle to form one composite sample for the site. After sample collection is complete, fill the sample bottle with 4% formaldehyde. Make sure the bottle is labelled clearly. Send the sample to a qualified consultant for identification and enumeration of species.

Equipment

Field

Sample bottles ($5)
Formaldehyde ($3)
Two trowels ($15)
Scalpel ($5)

Time required

The average time required to collect and preserve benthic algae samples at a single site will be 1 hour. A contract will be established to identify the specimens. Time required to enter and manage the data from a site will be 1 hour.

8.3.8 Overall time required to sample streams

The average overall time required to sample one stream reach will be 2 hours for site selection in the lab (generating maps), 4 hours for travel (2 hours each way to a site; this is probably a maximum value), 7.5 hours for sampling at the site, 10 hours for sample processing in the lab, 3.5 hours for data entry and management, 1.5 hours/day for preparation for field work and for packing equipment away at the end of the day, and 1 hour for preparing materials for shipping to consultants (e.g. packaging). The total time commitment is therefore 29.5 hours per stream.

8.4 Landscape Elements – Streams

The following landscape elements should be derived for sampled stream reaches. Some variables may be obtained from existing datasets (e.g. soil types, watershed area, mean slope of watershed), while others will need to be derived from remote sensing data periodically (e.g. landuse, stream crossings). The resolution needed to obtain the necessary information varies across elements. Following is a description of the different elements and why they are being measured.

- watershed area - area of the watershed for the stream; may influence the amount of water entering the stream, potential amount of inputs into the stream (e.g. herbicides); determine using ArcMap and DEM for the area; save watershed boundary as a coverage for use in determining other attributes of watershed
- watershed slope - influences movement of materials (e.g. sediments, chemicals) into river; determine using ArcMap and DEM for watershed
- Strahler order – the Strahler order of the stream reach sampled; provides an indication of stream size, and allows comparison with other streams of similar order; Strahler order can be derived from single line coverages in ArcMap
- sinuosity – a measure of how "bendy" a stream is, reflecting the degree to which it is meandering across its floodplain; measured as the ratio of the length of a stream reach to the straight-line distance between the start and end of the reach; this data can be derived from single line coverages in ArcMap
- soil types in the watershed – may influence stream chemistry; clip soil coverages for Alberta to isolate watershed then determine percentage of watershed area in different soil classes
- watershed area – area of the watershed for the stream; may influence the amount of water entering the stream, potential amount of inputs into the stream (e.g. herbicides)
- number and type of stream crossing (e.g. bridge, road with culvert, trail) above sample reach – the number and type of stream crossings 1, 10, and 20 km above the sample reach may influence sedimentation patterns in the stream, which would influence the suitability of the substrate habitat for benthic macroinvertebrates, as well as impacting stream fish populations. Also, chemicals associated with road maintenance and vehicular traffic may enter the stream at crossings. This data can be derived from road coverages in ArcMap and medium grain (spatial resolution of 1 – 5 m) classified air photos or satellite imagery if this is available
- vegetation – area of watershed in different forest categories, such as deciduous, coniferous, and percentage of the area within 100 m and 500 m of the stream that falls into these categories; habitat type around streams may influence nutrient availability, stream temperature, and cover; this data can be derived from the latest Alberta Vegetation Inventory (AVI) coverages using the clip and buffering tools; can also be derived from medium grain (spatial resolution of 1 – 5 m) classified air photos or satellite imagery if this is available
- landuse – area of watershed in different landuse categories, and percentage of the area within 100 m and 500 m of the stream that falls into these categories – categories include roads, well sites, seismic lines, right-of-ways, cut blocks, urban development (villages, towns), crops, pasture, and industrial areas. This data can be derived from the latest Alberta Vegetation Inventory (AVI) coverages using the clip and buffering

tools; can also be derived from medium grain (spatial resolution of 1 – 5 m) classified air photos or satellite imagery if this is available.

9 FIELD TESTING PROTOCOLS IN 2005

The protocols outlined here must be field tested before they are incorporated in the overall ABMP. Tests in 2005 will determine if time and cost estimates are accurate, address potential issues with the amount of gear required and transportation of this equipment, and ensure that the protocols are clear and detailed enough for field crews to use them in a consistent manner in the future. Appendix C provides an overview of the protocol tests proposed for 2005.

10 CONCLUSION

The Alberta Biodiversity Monitoring Program has tremendous potential to generate data about the condition of ecosystems within Alberta, and to provide early warning of biodiversity change within the province. Aquatic habitats are important elements of the ecosystems in Alberta, and aquatic ecosystem health is an issue of increasing concern. The aquatic monitoring protocols outlined in this document can be used to assess and track biodiversity and physical, chemical, and structural elements in a variety of aquatic habitats, including running and standing water, and ranging from small ephemeral to large permanent entities.

Within the aquatic sampling program described in this document a variety of different biotic groups are sampled. These range from invertebrates (zooplankton, benthic macroinvertebrates, wetland invertebrates) to vertebrates (fish, amphibians), and from microscopic plants (phytoplankton) to larger wetland plants. Given the diversity of sizes, forms, life history patterns, and distributions within these groups, there is a high probability that one or more groups will respond to environmental or habitat change. This is the strength of the ABMP: no assumptions are made about cause and effect, but enough elements are monitored in a consistent way that biotic responses related to change will be discernible. Aquatic elements should respond to a variety of environmental perturbations and are critical for the proper functioning of our ecosystems and our society.

REFERENCES

Alberta Environment. 2002. Focus on Fisheries Management. Publication No. I/761. Alberta Environment / Alberta Sustainable Resource Development, Edmonton, Alberta.

Alberta Water Resources Commission. 1990. Wetlands: values and opinions – a draft policy for the management of wetlands in the settled areas of Alberta. Alberta Water Resources Commission, Edmonton, Alberta. 7 pp.

Arnott, S. E., J. J. Magnuson, and N. D. Yan. 1998. Crustacean zooplankton species richness: single- and multiple-year estimates. Canadian Journal of Fisheries and Aquatic Sciences 55: 1573-1582.

Boss, S., Scrimgeour, G., Paszkowski, C., Tonn, W., and Kendall, S. 2002. Developing monitoring protocols for aquatic ecosystems in forested regions of Alberta. Report prepared for Alberta Sustainable Resource Development. *available at:* http://www.abmp.arc.ab.ca/Chapter17.pdf. 95 pages.

Briers, R. A., J. H. R. Gee, and R. Geoghegan. 2004. Effects of the North Atlantic Oscillation on growth and phenology of stream insects. Ecography 27: 811-817.

Crump M.L., Scott N.J. Jr. 1994. Visual encounter surveys. pp. 84-91 In W.R. Heyer, M.A. Donnelly, R.W. McDiarmid, L.C. Hayek and M.S. Foster (Editors). Measuring and monitoring biological diversity. Standard methods for amphibians. Smithsonian Institution Press, Washington, USA.

Fitch, L. and Adams, B.W. 1998. Can cows and fish co-exist? Canadian Journal of Plant Science **78:** 191-198.

Gibbs, J. P. 1995. Software for estimating the statistical power of population monitoring programs, Version 6.3. *available at:* http://www.mp1-pwrc.usgs.gov/powcase/monitor.html.

Gibbs, J. P. 2000. Monitoring populations. Pages 213-252 *in* Boitani, L., and T. K. Fuller (eds). Research Techniques in Animal Ecology. Columbia University Press, New York.

Gingras, B., C. Paszkowski, G. Scrimgeour, and S. Kendall. 1999. Comparison of sampling techniques to monitor stream amphibian communities in forested regions of Alberta. Report prepared for the Alberta Biodiversity Monitoring Program. *available at:* http://www.abmp.arc.ab.ca/Chapter11.pdf.

Grubaugh, J. W., J. B. Wallace, and E. S. Houston. 1996. Longitudinal changes of macroinvertebrate communities along an Appalachian stream continuum. Canadian Journal of Fisheries and Aquatic Sciences 53: 896-909.

Hughes, D., and C. Brady. 2003. A comparison of Nordic Netting, SLIN and NSCIN on Koshlong and Dickey Lakes. FAU Network Report No. 2003-02. Ontario Ministry of Natural Resouces. 6 pages.

Hughes, R. M., S. G. Paulsen, and J. L. Stoddard. 2000. EMAP-Surface Waters: a multiassemblage, probability survey of ecological integrity in the U.S.A. Hydrobiologia 422/423: 429-443.

Hughes, R. M., P. R. Kaufmann, A. T. Herlihy, S. S. Intelmann, S. C. Corbett, M. C. Arbogast, and R> C. Hjort. 2002. Electrofishing distance needed to estimate fish species richness in raftable Oregon rivers. North American Journal of Fisheries Management. 22: 1229-1240.

Irwin, R. J. 2004. Draft Part B of Aquatic Habitat Park Service guidance for Park Service Vital Signs Monitoring. Planning Process Steps: issues to consider and then to document in a detailed study plan that includes a quality assurance project plan (QAPP) and monitoring

"protocols" (Standard Operating Procedures). *available at:* http://science.nature.nps.gov/im/monitor/protocols/wqPartB.doc. 180 pages.

Johnson, C. F., P. Jones, and S. Spencer. 1998. A guide to classifying selected fish habitat parameters in lotic systems of west central Alberta. Foothills Model Forest, Hinton, Alberta. 15 pages.

Jones, C., K. M. Somers, B. Craig, and T. Reynoldson. 2004. Ontario Benthos Biomonitoring Network Protocol Manual. Ontario Ministry of Environment, Environmental Monitoring and Reporting Branch, Dorset, Ontario. 107 pages.

Karr, J. R. 1991. Biological integrity: a long neglected aspect of water resource management. Ecological Applications 1: 66-84.

Keene, J. L., D. L. G. Noakes, R. D. Moccia, and C. G. Soto. 1998. The efficacy of clove oil as an anaesthetic for rainbow trout, *Oncorhynchus mykiss* (Walbaum). Aquaculture Research 29: 89-101.

King, R. S., and C. J. Richardson. 2002. Evaluating subsampling approaches and macroinvertebrate taxonomic resolution for wetland bioassessment. Journal of the North American Benthological Society 21: 150-171.

Lazorchak, J. M., B. H. Hill, D. K. Averill, D. V. Peck, and D. J. Klemm (editors). 2000. Environmental Monitoring and Assessment Program – Surface Waters: field operations and methods for measuring the ecological condition of non-wadeable rivers and streams. U.S. Environmental Protection Agency, Cincinnati, Ohio.

Li, J., A. Herlihy, W. Gerth, P. Kaufmann, S. Gregory, S. Urquhart, and D. P. Larsen. 2001. Variability in stream macroinvertebrates at multiple spatial scales. Freshwater Biology 46: 87-97.

MacKay, W. C., G. R. Ash, and H. J. Norris (eds.). 1990. Fish ageing methods for Alberta. R. L. & L. Environmental Services Ltd. in association with Alberta Fish and Wildlife Division and University of Alberta, Edmonton. 113 pp.

Manley, P.N., Zielinski, W.J., Schlesinger, M.D., and Mori, S.R. 2004. Evaluation of a multiple-species approach to monitoring species at the ecoregional scale. Ecological Applications **14:** 296-310.

Maret, T. R., and D. S. Ott. 2003. Assessment of fish assemblages and minimum sampling effort required to determine biotic integrity of large rivers in southern Idaho, 2002. Water-Resources Investigations Report 03-4272.

McDonald, M. E., S. Paulsen, R. Blair, J. Dlugosz, S. Hale, S. Hedtke, D. Heggem, L. Jackson, K. B. Jones, B. Levinson, A. Olsen, J. Stoddard, K. Summers, and G. Veith. 2002. Research Strategy: Environmental Monitoring and Assessment Program. EPA/620/R-02/002. U.S. Environmental Protection Agency, Washington D.C.

Mitchell, P. and E. E. Prepas. 1990. Atlas of Alberta Lakes. University of Alberta Press, Edmonton, Alberta. 675 pages.

National Wetlands Working Group. 1988. Wetlands of Canada. Ecological Land Classification Series, No. 24. Environment Canada and Polyscience Publications Inc. Ottawa, Ontario. 452 pp.

Ostermiller, J. D., and C. P. Hawkins. 2004. Effects of sampling error on bioassessments of stream ecosystems: application to RIVPACS-type models. Journal of the North American Benthological Society 23: 363-382.

Patalas, K. 1990. Diversity of the zooplankton communities in Canadian lakes as a function of climate. Verhandlungen der Internationalen Vereinigung fur theoretische und angewandte Limnologie 24: 360-368.

Peterson S.A., N. S. Urquhart, E. B. Welch. 1999. Sample representativeness: A must for reliable regional lake condition estimates. Environmental Science & Technology 33: 1559-65.

Plafkin, J. L., M. T. Barbour, K. D. Porter, S. K. Gross, and R. M. Hughes. 1989. Rapid bioassessment protocols for use in streams and rivers: benthic macroinvertebrates and fish. EPA/440/4-89/001. U. S. Environmental Protection Agency, Washington, D.C.

Rosenberg, D. M., I. J. Davies, D. G. Cobb, and A. P. Wiens. undated. Protocols for Measuring Biodiversity: Benthic Macroinvertebrates in Fresh Waters. Ecological Monitoring and Assessment Network. Document available at ***http://www.eman-rese.ca/eman/ecotools/protocols/freshwater/benthics/intro.html***.

Russell, A. P., and A. M. Bauer. 2000. The amphibians and reptiles of Alberta. University of Calgary Press, Calgary. 2nd edition.

Schieck, J. 2002. Statistical power in the Alberta Forest Biodiversity Monitoring Program. Report prepared for Alberta Forest Biodiversity Monitoring Program. 28 pages.

Schieck, J., McKinnon, D., Stroebel, K., and Kendall, S. 2002. The Alberta Forest Biodiversity Monitoring Program: summary of the 2002 pilot. Report to the Alberta Research Council. Document available at http://www.abmp.arc.ab.ca/ PilotSpSumTest.pdf. 75 pages.

Schindler, D. W. 2001. The cumulative effects of climate warming and other human stresses on Canadian freshwaters in the new millennium. Canadian Journal of Fisheries and Aquatic Sciences 58: 18-29.

Scrimgeour, G. and Kendall, S. 1999. Forest ecosystem monitoring in Saskatchewan and Alberta: identification of aquatic elements and sampling protocols. Report prepared for Alberta Forest Biodiversity Monitoring Program. Obtainable at: http://www.abmp.arc.ab.ca/Chapter10.pdf. 100 pages.

Shank, C., J. Schieck, and D. Farr. 2002. The Alberta Forest Biodiversity Monitoring Program: technical integration. Report to the Foothills Model Forest. Available at http://www.abmp.arc.ab.ca/Chapter18.pdf. 61 pages.

Stevens, D. L., Jr., and A. R. Olsen. 1999. Spatially restricted surveys over time for aquatic resources. Journal of Agricultural, Biological, and Environmental Statistics 4: 415-428.

Stevens, D. L., Jr., and A. R. Olsen. 2004. Spatially balanced sampling of natural resources. Journal of the American Statistical Association 99: 262-278.

Tegler, B., M. Sharp, and M. A. Johnson. 2001. Ecological Monitoring and Assessment Network's proposed core monitoring variables: an early warning of environmental change. Environmental Monitoring and Assessment 67: 29-56.

Turner, B. C., G. S. Hochbaum, and F. D. Caswell. 1987. Agricultural impacts on wetland habitats on the Canadian prairies, 1981-85. Trans. N. A. Wildl. Nat. Res. Conf. 52: 206-216.

Urquhart, N. S., S. G. Paulsen, and D. P. Larsen. 1998. Monitoring for policy-relevant regional trends over time. Ecological Applications 8: 246-257

U. S. National Parks Service: Inventory and Monitoring. *undated.* Natural Resource Monitoring - Program Administration and Organizational Framework. Available at: http://science.nature.nps.gov/im/monitor/vsmAdmin.htm.

Vinson, M. R., and C. P. Hawkins. 1996. Effects of sampling area and subsampling procedure on comparisons of taxa richness among streams. Journal of the North American Benthological Society 15: 392-399.

Wagner, G.N., T. D. Singer, and R. S. McKinley. 2003. The ability of clove oil and MS-222 to minimize handling stress in rainbow trout (*Oncorhynchus mykiss* Walbaum). Aquacuture Research 34: 1139-1146.

Warner, B. G., and C. D. A. Rubec (eds.) 1997. The Canadian Wetland Classification System. Wetlands Research Centre, University of Waterloo, Waterloo, Ontario. 68 pages.

Watmough, M. D., D. W. Ingstrup, D. C. Duncan, and H. J. Schinke. 2002. Prairie Habitat Joint Venture Habitat Monitoring Program Phase 1: recent habitat trends in NAWMP targeted landscapes. Technical Report Series Number 391. Canadian Wildlife Service, Edmonton, Alberta, Canada.

PERSONAL COMMUNICATIONS

Norine Ambrose, Program Manager, Cows and Fish, Alberta Riparian Habitat Management Society, Lethbridge, AB

Ken Bodden, Provincial Commercial / Domestic Fisheries Specialist, Sustainable Resource Development, Alberta Environment, Edmonton, AB

Richard Grosshans, Wetland Ecologist, Ducks Unlimited Canada, Oak Hammock Marsh, Manitoba

Bruce McCulloch, Impact Assessment Biologist, Fisheries and Oceans Canada, Edmonton District Office, Edmonton, AB

Darcy McDonald, Water Quality Specialist, Environmental Monitoring and Evaluation Branch, Alberta Environment, Edmonton, AB

Lisette Ross, Aquatic Ecologist, Ducks Unlimited Canada, Oak Hammock Marsh, Manitoba

Garry Scrimgeour, Manager of Science and Research, Alberta Conservation Association, Edmonton, AB

Michael Sullivan, Provincial Fisheries Science Specialist, Sustainable Resource Development, Alberta Environment, Edmonton, AB

Cameron Stevens, Ph.D. candidate, Department of Biological Sciences, University of Alberta, Edmonton, AB

William Tonn, Professor, Department of Biological Sciences, University of Alberta, Edmonton, AB

Michael Watmough, Wetland Biologist, Habitat Conservation and Assessment Division, Canadian Wildlife Service, Environmental Conservation Branch, Edmonton, AB

Ron Zurawell, Limnologist/Water Quality Specialist, Environmental Monitoring and Evaluation Branch, Alberta Environment, Edmonton, AB

APPENDIX A. HANDLING, PRESERVATION, AND DISPOSAL OF FISH.

Fish anaesthesia

Clove oil should be used to sedate fish before handling to reduce stress on individual fish and make handling easier. Dissolve clove oil in ethanol at a ratio of 1:10 (clove oil : ethanol), then use this solution to create an anaesthetic bath of 40 - 60 mg / L (Keene et al. 1998; Wagner et al. 2003). Place the solution in an amber bottle to limit photodegradation. Immerse fish in the bath until fully anaesthetized (1 – 5 minutes), and then proceed with fish processing (e.g. measuring length). When processing is complete, place the fish in a live well with fresh water and allow them to recover. This will probably take about 10 minutes (Keene et al. 1998; Wagner et al. 2003).

Fish processing, preservation, and disposal

The first 30 fish of each species collected should be processed; if extra time is available at a site, additional specimens may be processed. Measure fork length (to nearest 0.5 cm) for each fish with a measuring board and weigh them using a portable electronic balance. Determine the species, sex, and age class (adult, juvenile, or young-of-the-year) of each fish, if possible, and note any injuries or deformities. If it is not possible to determine the species, save at least five voucher specimens of the species for later identification.

Small fish that are being retained as specimens can be placed on ice in the field and frozen once appropriate facilities are reached, or they can be placed in appropriate bottles in the field and preserved with 70% isopropyl alcohol. Specimens should be weighed before preservation, if possible. Large fish should be placed in plastic bags and placed in coolers with ice, and either processed as soon as an appropriate site is reached (e.g. lake shore, base camp), or frozen as soon as possible. For all specimens that are being saved, ensure that collection date, location (including UTM coordinates and the lake name, if known), collectors, gear used (e.g. gillnet), and storage medium (e.g. 70% isopropyl alcohol) is recorded in pencil on a piece of paper or Tyvek material. Include this label in the bag or bottle with the fish.

Some fish will die during sampling and handling procedures. Ageing structures should be collected from up to 30 specimens of each species of game fish; see Table A1 for a list of ageing structures to collect. Assign a code to each specimen; this code will be used to link the data collected from each individual to the aging structures collected from the same individual fish. Place the aging structures in a coin envelope and write the code on the envelope in pencil; ensure that the envelopes are spread out somewhere so the structures may dry out. Collection of aging structures and biological data is a condition of the fish research permit that is issued by Alberta Fish and Wildlife; aging structures will not be analyzed as part of the Alberta Biodiversity Monitoring Program but will be submitted to Fish and Wildlife.

If dead fish are not being saved, return them to the lake of origin (puncture their swim bladders with a knife first) or bag and disposed of them in a sanitary landfill. The former option can only be used in remote sites that are not frequented by people.

Table A1. Ageing structures that can be collected from game fish in Alberta. A preferred and secondary structure is suggested for each species; see MacKay et al. (1990) for details.

Common Name	Scientific Name	Ageing structures to collect (L = lethal, NL = non-lethal)	
		Preferred	**Secondary**
Family Acipenseridae - sturgeons			
Lake Sturgeon	*Acipenser fulvescens*	pectoral fin ray (NL)	otoliths (L)
Family Salmonidae - trouts			
Lake Whitefish	*Coregonus clupeaformis*	sagittal otoliths (L) / scales (NL)	sagittal otoliths (L), pelvic fin rays (NL)
Cutthroat Trout	*Oncorhynchus clarki*	otoliths (L)	scales (NL)
Rainbow Trout	*Oncorhynchus mykiss*	sagittal otoliths (L) / scales (NL)	none
Golden Trout	*Oncorhynchus mykiss aguabonita*	otoliths (L)	none
Mountain Whitefish	*Prosopium williamsoni*	scales (NL)	sagittal otoliths (L)
Brown Trout	*Salmo trutta*	otoliths (L)	scales (NL)
Bull Trout	*Salvelinus confluentus*	otoliths (lethal)	none
Brook Trout	*Salvelinus fontinalis*	otoliths (lethal)	scales (NL)
Lake Trout	*Salvelinus namaycush*	pelvic fin rays (NL); sagittal otoliths (L)	scales (NL)
Arctic Grayling	*Thymallus arcticus*	scales (NL)	pectoral fin rays (NL), sagittal otoliths (L)
Family Esocidae - pikes			
Northern Pike	*Esox lucius*		
Family Hiodontidae - mooneyes			
Goldeye	*Hiodon alosoides*	operculum (L)	pectoral fin rays (NL); scales (NL)
Gadidae - cods			
Burbot	*Lota lota*	sagittal otolith (L)	opercular bones (L), cleithra (L), pectoral fin rays (NL)
Family Percidae - perches			
Yellow Perch	*Perca flavescens*	pelvic spine and first 2 fin rays (NL) or anal spines (NL)	opercular bone (L)
Sauger	*Stizostedion canadense*	pelvic spine and first 2 fin rays (NL)	dorsal spines (NL), otoliths (L), opercular bones (L)

Walleye	*Stizostedion vitreum*	pelvic spine and first 2 fin rays (NL)	dorsal spines (NL), otoliths (L), opercular bones (L)

APPENDIX B. REGULATIONS FOR MARKING NETS AND TRAPS.

Provincial regulations stipulate that fishing gear must be marked to ensure public safety, and to provide information for individuals encountering the gear. Adequate marking of gear is especially important in lakes with public access, where the number of boaters can be expected to be higher than in more remote locations.

Each end of a gillnet must be marked with a spar buoy, the top of which is at least 1 m above the surface of the water. The buoy must be clearly marked in letters at least 20 mm high with the fish research license number and the name of the research license holder. Each buoy must be marked with a blaze orange or red flag at least 20 x 20 cm in size. The location of minnow traps must be clearly marked using a buoy or other device (e.g. lengths of pool noodle). A weather proof tag at least 5 x 10 cm in size must be affixed to the trap itself; this tag must bear the fish research license number and the name of the license holder, in letters at least 20 mm high. Although pool noodles are adequate for marking the locations of minnow traps, because they lie horizontally in the water they can be difficult to see when waves are present on the water's surface.

APPENDIX C. PROPOSED PROTOCOL TESTS FOR THE 2005 FIELD SEASON

A number of the protocols outlined in this document have not yet been tested within the context of the ABMP, and others have been modified from earlier versions. These protocols need to be assessed in the field to determine if the timing estimates are reasonable, and identify areas where protocols must be changed for logistic or technical reasons. Protocols for large lakes, large rivers, wetlands, and streams would all benefit from testing. Testing should include all aspects of the protocols from site selection using GIS coverages and maps, through access and collection of data, to specimen processing (though submitting samples to experts for identification may not be necessary at this stage, as long as the potential costs of this stage are known) and data entry.

One critical area that must be addressed for the aquatic sampling program is the amount of gear that must be used. Minimizing the weight and bulk of this gear will be critical to the success of moving aquatic sampling into remote sites. To this end, new inflatable watercraft (a boat and a kayak) should be purchased and evaluated in 2005 to determine if they are suitable for the ABMP.

Another aspect of the aquatic sampling protocols that must be investigated is the time requirements for both identifying vascular wetland plants, and picking and sorting invertebrate samples. A great deal of money can be saved by picking invertebrate samples before submitting them to taxonomic experts for identification.

Partnerships with other agencies monitoring aquatic habitats in Alberta should be pursued before the 2005 season. If some preliminary cooperative work could be conducted in 2005 it could go a great way toward mutual understanding of the data needs of the different agencies involved. It would be especially beneficial to form partnerships with organizations with the personnel and gear to sample fish populations, especially those in rivers.

Table C1 outlines a work plan for a crew of two summer staff to test ABMP aquatic protocols. In addition to these two persons, I would spend much time in the field ensuring that protocols are working as originally conceived. The cost related to these activities is outlined in Table C2; this table does not included equipment we already own or can borrow. The total cost for 2 summer students for 4 months, plus equipment, is approximately $46,000.

The work outlined here should prove a good test of the aquatic portion of the ABMP, and will help refine the sampling approaches that will be used in the future.

Table C1. Time budget for testing aquatic protocols for the ABMP, based on a single crew of two people.

	Number of days	Number of people	Person days	Total person days remaining	Activities
Total days available	84	2	168	168	
Training	12	2	24	144	Quad, truck, boat, first aid, bear awareness
Lakes	16	2	32	112	two 8 day trips to sample two lakes on each trip; total = 4 lakes sampled for 2 nights each
Rivers	10	2	20	92	one 10 day trips to sample 4 river reaches; this may depend on the availability of an electroshocker
Wetlands	10	2	20	72	one 10 day trip to sample 6 wetlands (may sample more depending on how easy access proves to be)
Streams	10	2	20	52	one 10 day trip to sample 6 stream reaches (may sample more depending on how easy access proves to be)
Taxonomy	20	2	40	12	one month of identification of vascular plants and picking bugs
Total extra days				12	number of extra days that can be used as rain days, etc.

Table C2. Preliminary budget for testing aquatic ABMP protocols in 2005.

Item	Unit cost ($)	Number of units	Total
Field crew	12,500	2	$25,000
Truck (cost per km)	0.40	20000	$8,000
Quads (cost per month)	200	9	$1,800
Trailer	600	1	$600
Food ($40 / day)	34	160	$5,440
Zooplankton net	500	1	$500
8 lb Cannon ball anchors	16	5	$80
Fish measuring board (100 cm)	175	1	$175
Fish measuring board (30 cm)	75	1	$75
Waders	500	3	$1,500
PFDs	70	2	$140
Kayak paddle	150	2	$300
Bear spray	27	3	$81
Goggles	50	3	$150
Gloves	15	3	$45
Flagging tape	2	5	$10
Mallet	20	1	$20
Inflatable kayak	1,500	1	$1,500.00
plant press	50	4	$200.00
clear polyethylene tube	55	1	$55.00
Miscellaneous	50	3	$100.00
Plot frame	25	2	$50.00
Rake	20	1	$20.00
Grand total			**$45,591.00**