Project Report

Peterhead Inlet Invertebrate Inventory: Towards an Index of Biological Integrity for Small Arctic Streams

1. INTRODUCTION

Project Proponent:

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Project Background and Rationale:

The biological integrity[1] of freshwater systems such as streams and rivers can be impaired by a multitude of stressors (e.g. spills or releases of chemicals and oil, sewage outfalls, air pollution). However, assessing the extent of biological impairment in streams, and measuring the effectiveness of management efforts to restore or improve biological integrity in these systems is challenging. It is now widely accepted that assessing the health of living communities in streams requires direct measures of biological status in addition to the standard water quality measurements of physical, chemical and microbial conditions.

Benthic macroinvertebrates are widely considered excellent bioindicators of the health of rivers and streams (Lathrop and Markowitz 1995; Karr and Chu 1999). Aquatic invertebrates are relatively sessile (stationary), ubiquitous (found in diverse habitats), have a high species diversity, and a broad range of sensitivity to physical and chemical stressors - factors that make invertebrates very good indicators localized (site specific) perturbations in streams. An experienced biologist can detect degraded river conditions with only a cursory examination of the invertebrate assemblage (Resh 1995). Moreover, invertebrates are relatively simple and cheap to sample, making them an attractive option for cost effective long term monitoring. Monitoring agencies have developed a variety of methodologies to describe and rank the overall biological health status of streams simply be inventorying the local macroinvertebrate species (Karr et al. 1986, Kerans and Karr

[1] Biological integrity can be defined as "the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitat of the region" (Karr and Dudley 1981: 56).

1994, USEPA 1997A., Simon 1998). One such methodology, the *Benthic Index of Biological Integrity (IBI)*, evaluates the impact of human activities on streamsby integrating information from species, population, community and ecosystem levels into a single numerical value of stream health. The IBI serves as a yardstick to rank and compare sites according to their relative conditions, and makes it easier to interpret biological information in the management process (Karr and Chu 1999).

Due to their relative ease and low cost of sampling, macroinvertebrates are also one of the most common parameters sampled by citizen volunteer groups to assess local stream quality, and to promote stewardship and environmental awareness (Lathrop and Markowitz 1995). Several protocols have been developed to facilitate citizen-based stream invertebrate sampling and to aid volunteer groups in developing invertebrate IBIs for assessing local stream health (e.g. see USEPA 1997A.). The Canadian Aquatic Biomonitoring Network (CABIN) offers detailed protocols for collecting and evaluating stream invertebrate community data.

Despite their active utilization in southern jurisdictions, no invertebrate biomonitoring criteria have been developed or tested for community based stream monitoring in Arctic Canada. Baseline knowledge of the macroinvertebrate diversity in pristine and perturbed Arctic stream habitats is insufficient to develop biomonitoring criteria to assess biological integrity change in Arctic streams. However, it is known that small Arctic streams offer important habitat for juvenile char. The charr find protection in streams from larger piscivorous char, sue the streams to travel to and from marine and aquatic habitats, and actively feed on invertebrates and small fish (such as sticklebacks) that are associated with these small streams. Arctic streams are also sensitive ecosystems potentially affected by various stressors, and there is a need for cost-effective monitoring protocols to measure human impacts on stream health, and to provide early warning of impending biological impairment. The importance that local residents place on protecting charr habitat also underscores the need to develop monitoring protocols that can be applied broadly - by monitoring agencies and concerned Nunavut residents - to help assess biological integrity in Arctic streams.

Developing scientifically valid and reliable IBIs for Arctic stream fist requires pilot studies to describe and evaluate habitat variability in the macroinvertebrate fauna of undisturbed reference streams.

Project Objectives:

1) Appliying methods developed by the Canadian Aquatic Biomonitoring Network (CABIN), describe the benthic invertebrate diversity and physical-chemical characteristics in various microhabitats (pools and riffles) within a small Arctic stream, and develop a representative collection of invertebrate samples for scientific reference and educational purposes;
2) Evaluate the potential for developing a benthic index of biological integrity (B-IBI) to assess perturbations and change in small Arctic streams;

3) Build local monitoring capacity and promote stewardship of stream habitat by providing a local project technician with hands on experience in limnology field and laboratory methods

Methodology:

Field

The field sampling for 2003 took place during in late July base flow conditions. For the water chemistry data collection, a portable hydro lab, Quanta Water Quality Monitoring System, was used. A D frame kick net with an opening size of 30 x 30 cm and a mesh size of 500um was utilized for invertebrate sampling. The kick net was placed firmly on the substrate and the operator stood 12-14inches upstream of the opening. S/he then proceeded in a zigzag direction across the stream bed while shuffling his/her feet to ensure maximum substrate disturbance and invertebrate drift into the sampling net. In areas where the substratum contained larger cobble and boulders, the rock surfaces were disturbed by hands and feet and the kick net was raised and lowered down stream of the rock faces. In July 2003 four samples were taken at site PI -01-03, three samples at PI-02-03 and only one sample at PI-03-03. The duration of each sampling event was 3 minutes. The samples were preserved in 70% ethanol and transported to the Nunavut Research Center.

Field sampling for 2004 took place in late August, three samples were taken at sites PI-01-04 and PI-02-04; one using a kick method and two samples using the jab method. At site PI-03-04, only two samples were taken one kick and one jab method. The 2004 kick samples were taken using the same procedures as the 2003 kick net sampling. The 2004 sampling efforts also included a supplementary invertebrate sampling method called Jab Sampling. Jab sampling involved disturbing the substrate of a 1m x 1m area for 5-10 sec. upstream of the D frame net, removing the net from the water, then repeating the process a total of 10 separate times at different locations within a single sampling reach. In areas were boulders were present, the jab still followed the same procedure but the surfaces of the rocks were rubbed with the D frame net and with feet to free any invertebrates present.

Laboratory

The samples for 2003 were freed of the excessive debris and stored in 70% ethanol. The samples were then sorted for invertebrates using a four section grid divider and a hand held counter for organism enumeration. Using a dissecting microscope and various aquatic insect identification keys (Merritt et al., 1996 & McCafferty, 1998), the dipterans (Simuliidae and Tipulidae) were identified down to genus while the dipterans of the family Chironomidae were identified down to family level only. The May flies were identified down to species level and the water mites down to the sub cohort Hydracarina. The specimen of each species or family was put into vials with 70% ethanol. Pictures of the different taxa were taken and kept on the NRI computer database.

Sorting of the 2004 samples were done by floating the entire sample and removing the invertebrates from the sample using a 5x hand help magnifying lens. Organisms of the same type were grouped for further identification. Using a 1x to 6x powered stereoscopic microscope each organism was identified to family level with the aid of standard taxonomic keys. Where the numbers permitted, 5 individuals of each represented family were placed in vials containing 70% ethanol and labeled with site and family name. Pictures of the different aquatic insect family representatives and their diagnostic features were taken and stored on the NRI invertebrate computer database.

In light of the fact that the density of organisms in each sample was small, the quality assurance method as indicated in the CABIN manual could not be replicated in this case. To establish quality control in the sorting efficiency of the samples in 2004, 25% of three samples were randomly chosen and re-sorted. The number of organisms missed (OM) was counted and a % OM was calculated for each re-sorted sample (# org. missed/total # of org. found x 100). An average of the three values was taken to give a standard sorting efficiency. The % OM for sample PI-02-04 Jab was 6.85%; the % OM for sample PI-02-04 Kick was 10.8% and the % OM for sample PI-03-04 Jab was 3.42%. The average %OM was calculated to be 7% and thereby represents the standard sorting efficiency for the 2004 samples. Sorting efficiency was not determined for the 2003 samples.

2. DELIVERABLES

Tasks Completed

May 2003 – In collaboration with research advisor Dr. Terry Dick, University of Manitoba, identified a study stream, and developed a project proposal for the Peterhead Inlet Invertebrate Inventory. Submitted the proposal to Environment Canada for consideration for funding under the Environmental Damages Fund.

May 2003 – Applied for a multi-year research license from Department of Fisheries and Oceans, and Nunavut Research Institute, to undertake field activities as part of the Invertebrate Inventory Project.

June 2003 - Received DFO and NRI research licenses to conduct project field work.

June, 2003 – Hired a project technician to undertake field and lab. Worked with project technician, research advisory (Dr. Terry Dick), developed protocols for the collection and analysis of invertebrates and stream habitat descriptors. Ordered all necessary field and laboratory equipment and supplies for sample collection and analysis

July, 2003 – Signed a contribution agreement with Environment Canada authorizing the transfer of funds to Nunavut Research Institute to carry out various project activities
July 2003 – Project team (leader, technician, research advisor, and volunteers) collected replicate samples of invertebrates, and record water chemistry, and physical descriptors from three locations representing distinct stream microhabitats in the Peterhead river.

The standard three minute kick-sample method was employed. Specimens were preserved in alcohol on-site.

August 2003 – Invertebrate specimens were sorted, identified, photographed, and archived at the Nunavut Research Institute for later analysis.

August 2004 - Project team (leader, technician, research advisor, and volunteers) collected replicate samples of invertebrates, and record water chemistry, and physical descriptors from the same three locations on the Peterhead river visited in 2003. The standard three minute kick-sample method used in 2003 was applied in 2004. Additional invertebrate samples were collected using a "jab" method developed by Dr. Dick. Specimens were preserved in alcohol on-site, and transported to the NRI laboratory for storage.

January 2004 – A project technician was hired to identify, photograph, and enumerate the 2004 invertebrate samples. NRI staff are currently completing a final project report that will: describe the physical and chemical characteristics and invertebrate fauna of the sampling locations; compare invertebrate sampling results between sites and years with respect to measures of species richness, diversity, evenness. The report will document reference conditions in a relatively pristine, undisturbed stream. These data are intended to serve as a benchmark for assessing change over time in the health of the study stream, and to help measure stream invertebrate response to environmental stressors (e.g. pollution, sedimentation or disturbance) in perturbed streams. A digital photogallery of invertebrates is also being developed for educational purposes.

Preliminary Results:

In 2003 the total invertebrate samples (all sites) comprised 636 individuals representing three orders; Diptera (true flies), Ephemeroptera (May flies) and Water Mites (Hydracarina). There were 33 Simuliidae (black flies), 203 Chironomidae (midge flies), 7 Tipulidae (crane flies), 385 Baetidae (May flies) and 8 specimen of Hydracarina (water mites). There were 7 different insect families present in the samples from riffle (rapids) sites (PI-01-03 & PI-03-03) while only 3 families from the pool samples (PI-02-03). Baetidae (Mayflies) were common in the riffle sites but the pool sites were dominated by the Chironomidae (midge flies). The Chironomidae (midge flies) were more widespread than the Baetidae (May flies) and were noted in both pool and riffle sites.

The 2004 samples produced 683 individuals representing 4 orders and 6 families of aquatic insects. The Dipterans comprised 523 specimens of Chironomidae (midge flies), 55 Tipulidae (crane flies), and 8 Simuliidae (black flies). The Ephemeroptera were represented by the family Baetidae with 60 individuals and the Trichoptera order was represented by 4 individuals of the Limnephilidae family. Also present in the 2004 samples were 33 specimen of Hydracarina. Chironomidae (midge flies) were abundant in each sample regardless of site characteristic (riffle or pool, boulders or no boulders) or method of sampling (kick or jab). Site PI-02-04, a pool/run sampling site, was noted to

consist of 98% Chironomidae with only 1 adult Simuliidae present and 4 Tipulidae larvae which both came from the sampling efforts using the kick method at this site. Of particular interest is the fact that site PI-03-04, a pool area, was the only sample that contained a specimen of the Trichoptera (caddis fly) order with 4 individuals of the Limnephilidae family. It should be noted that the site location of PI-03-04 (pool) is different than the pool site of 2003. The 2003 sampling sites did include a pool area but no Trichoptera were identified. Perhaps the presence of Trichoptera in the 2004 pool site could be attributed to the timing of the sampling in 2004 (Aug. rather than July).

Samples were taken at sites PI-01 and PI-02 in both 2003 and 2004, allowing certain comparisons between years and sites. In both years, PI-01 (riffle) had the most diverse invertebrate community with 4 families represented, regardless of sampling method. There were more representatives from the Simuliidae (black fly) family in 2003 (6% of all individuals as apposed to 3% in 2004). The percentage of individuals from the Baetis (mayfly) family declined from 75% in 2003 to 33% in 2004. Conversely the percentage of individuals from the Chironomidae (midge fly) family increased from 18% in 2003, while in 2004 63% in 2004.

PI-02 (pool/run) was dominated by the Chironomidae (midge fly) family in both years (99% in 2003 and 98% in 2004), and in both years, samples form this site yielded a relatively low diversity of invertebrates.

It appears that despite the different sampling methods used between the two years and change in between years in personal involved in sorting and identification of the invertebrates, the data for the two sites at the same location over the two years present very similar assemblages of the invertebrate communities. Factors that should be considered when looking at the assemblages of family representatives from both years data is the different time of year that the sampling took place, the life cycles and the many developmental stages as well as the physiological tolerances and requirements of the aquatic insect groups.

The introduction of the Jab method in 2004 in bouldered and non bouldered regions of the sampling sites was to decipher whether or not any notable differences would be apparent. At site PI-01-04 (riffle) in an area with no boulders saw a total of 22 invertebrates; 21 individuals of the Chironomidae family 2 of which were adults and only 1 individual of the Baetidae family which also happened to an adult. In an area with boulders, the jab method retrieved a total of 42 invertebrates. Two specimen of Hydracarina, 28 Chironomidae (midge flies), 3 Baetidae (may fly) larvae, 2 Simuliidae (black fly) adults, 4 Chironomidae (midge fly) adults and 3 Baetidae (may fly) adults were identified. From the data, it can be said that the jab method in the areas where boulders were present produced a more diverse assemblage of invertebrates. However, one must consider the substrate present at the site as well as the physiological requirements of the identified species.

In examining the efficiency of the Jab method verses the traditional standard kick method, it was noted that the kick method retrieved a greater density of invertebrates in

the riffle (PI-01-04) site but fewer in the pool (PI-03-04) and pool/run (PI-02-04) sites. In the riffle site (PI-01-04), the jab method seemed to be biased towards the Chironomidae (midge fly) family, producing 53 individuals from both boulder and non boulder regions and only 7 individuals of the Baetidae (may fly) family. The kick method at the same sight area produced 53 Baetidae (may fly) and 61 Chironomidae (midge fly). The jab method at the pool/run site (PI-02-04) resulted in only individuals of the Chironomidae (midge fly) family while the kick method did produced predominately individuals of the Chironomidae (midge fly) family it also retrieve 1 Simuliidae (black fly) and 4 Tipulidae (crane fly). The sampling methods in the deep pool site of PI-03-04 resulted in the opposite pattern. The Jab method produced more total invertebrates and had more families represented, 63 Chironomidae (midge fly), 46 Tipulidae (crane flies), 31 Hydracarina (water mites) and 4 Limnephilidae (caddis flies). The kick method produced 111 Chironomidae (midge flies) and only 1 Tipulidae (crane flies) and no Hydracarina or caddis flies.

It could be argued that the Jab method is site dependent and can askew the actual assessment of the invertebrate assemblage in a community. However further research is needed to explore this hypothesis.

Shannon Wiener Diversity

The diversity of taxa within a given community can be an indicator of the status of that aquatic ecosystem. However, aquatic ecosystems with low diversity are not necessarily polluted. There are a number of naturally occurring contributing factors that can limit the biodiversity of an ecosystem. Tundra streams for instance are commonly known to be naturally acidic due to the low nutrient inputs of the surrounding bedrock and landscape. This low nutrient input along with the physiological tolerance and requirements of the different invertebrate species can limit the diversity in an ecosystem. The climate, latitude and other geographical elements as well as anthropogenic impact can also play a role in the diversity of aquatic benthic invertebrates in an ecosystem.

The Shannon Wiener diversity takes into account relative abundance of each species present at a site. The larger the value of H the more uncertainty there is in knowing which species the next individual drawn from the sample will belong to (Hartley, 2005). The diversity, H values, will be 0 for a community with a single species while higher H values indicate higher diversity.

The sample sites in the riffle areas (PI-01-03 & 04 and PI-03-03) were the communities with the most diversity. In 2003 site PI-03-03 had the greatest diversity with an H value of 0.927. Site PI-01 in 2003 had an H value of 0.740 and in the summer of 2004 this same site had an H value of 0.843. Site PI-02 a pool/run area had very low diversity in 2003 and 2004, with an H value of 0.065, and 0.107 respectively. The deep pool site of 2004 (PI-03-04) resulted in an H value that fell in between the maximum and minimum observed over the two summers samples, with a value of 0.635.

Pielou's Evenness Index

Evenness is the measure of similarity in the abundance of individuals from different species in a community. Communities with highly dominant species exhibit a low degree of evenness. As theories concerning dominance and diversity indicate, as a community becomes more diverse, the evenness should increase. Evenness will vary for 0 to 1, 1 being an index of more evenness in the relative abundance of species (Hartley, 2005).

Site PI-03-03 (riffle) exhibited the most evenness of all sample sites, E value of 0.668, followed closely by the riffle site of PI-01 which had evenness indexes for 2003 and 2004 of 0.534 and 0.609 respectively. The pool/run site (PI-02) showed the least amount of species evenness in both 2003 (E=0.094) and 2004 (E=0.097). The deep pool site of 2004 (PI-03-04) exhibited an evenness of 0.458.

It can be concluded that the sites in the riffle locations exhibited the greater species evenness, where no one species was dominant. Any decrease in species evenness over time may be an indication of environmental stress. However, species evenness may also be affected by seasonal patterns of species abundance (Turner, 2001)

Hilsenhoff Family Biotic Index

Using the family biotic index adapted from Hilsenhoff 1988 presented in the CABIN laboratory manual, the calculated family biotic index of each sample taken at all sites from both summers samples falls within the range of 0.00-3.75 which evaluates the stream's condition as excellent.

As a reference station, the Peter Head Inlet River has minimal disturbance levels and represents typical attributes of a small-medium sized Arctic stream. The resulting diversity indices of the Peter Head Inlet River invertebrate communities can be used to monitor the changes in the site over time or compare assessment results of invertebrate communities from different rivers with similar physical characteristics in the same ecoregion.

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