Minnesota’s Lake Superior Coastal Program

Developing a Diagnostic Tool for Assessing Excessive Sediment Harm to Stream Communities

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Introduction

Excess sediment is a top cause of impairment in U.S. rivers and streams. A number of streams on the north shore of Lake Superior's western arm are on the Minnesota Pollution Control Agency's impaired waters list due to turbidity problems. The underlying geology of the north shore, in addition to the steep slopes of the Lake Superior escarpment, forms a stream base vulnerable to erosion and excessive sediment deposition in streams. This vulnerability is created, at least in part, by an area of clay loam soil that many north shore stream channels intersect as they come down the escarpment to the shore of Lake Superior. The steep slopes cause high stream velocities which, combined with the high erodability of this soil layer, create high erosion potentials, particularly on outside channel bends.

The increased fine sediments traveling through and accumulating in stream substrates potentially presents several problems for aquatic biota. Excess sediment deposits reduce habitat space for aquatic macroinvertebrates, which are vital components of the food web. In addition to potentially decreasing food sources for fish, the excess sediment deposits can bury fish spawning habitats. Even if the fish can clean off nesting areas, they will expend extra energy doing so.

There are many stream condition indicators using stream fish or macroinvertebrates, but none address excess sediment specifically. In many areas of the country there are any number of human-caused stressors affecting stream condition, including agricultural runoff, high stormwater discharges, loss of stream shoreline habitat, deforestation, development, and industrial discharges. When there are many stressors impacting streams, it is hard to differentiate among them to determine which stressors are creating which problems for stream biota. While some north shore streams have non-turbidity impairments, there are considerably fewer than in other parts of the country. The dominance of erosion-based impairments provided the opportunity to develop an indicator diagnostic of excessive sediment deposition in stream substrate as the cause of biotic impairment in north shore streams.

We selected stream macroinvertebrates for indicator development for several reasons. They are less mobile than fish, meaning that they have limited ability to escape from disturbance, and even more limited ability to return after a disturbance ceases (at least until the next generation begins). Macroinvertebrates are easy to collect, are present in relatively high abundances, and have high morphological diversity. For all of these reasons, macroinvertebrates are commonly used in stream condition assessments, and their use is ubiquitous across the US and across agencies. Because most agencies collect stream macroinvertebrate information already, their use to create a diagnostic indicator could allow agencies and managers to get more information out of data they already have, without the need for additional sampling.

The goal of this project was to develop a suite of stream macroinvertebrate metrics diagnostic of invertebrate community impairment caused by excessive fine sediment deposition in stream substrate; in other words, burial or partial burial of streambed rocks by sand, silt, and clay. Such a diagnostic tool would aid managers in their stream assessment work. While similar projects have been previously attempted (and failed) in other parts of the country, most have been in areas suffering from a number of stressors, making development of an indicator diagnostic of just sediment impairment more difficult. Our hope in attempting such work using north shore streams was that the relative lack of other stressors in northeastern Minnesota would make the development of such an indicator more possible. Having such an indicator should help agencies make a stronger connection between the Total Maximum Daily Load (TMDL) turbidity measurements and sediment deposition presumed to be causing harm to stream biota.

Work Completed

Site Selection

The Natural Resources Research Institute's historical datasets were extensively used to aid this project. Because NRRI has stream data going back 25 years, we were able to use these datasets to identify potential stream study sites. Stream sediment data were used to select sites expected to cover a range of sediment conditions, from very little fine sediments embedding (burying) rocks, to quite a bit of embedment.

Sites for this project were selected using GIS parameters such as stream size, site accessibility, watershed size, and historical stream sediment measurements. Using these parameters, 100 potential sites were identified. Final site selection was based on an initial site visit that evaluated these parameters on the ground (rather than via GIS), resulting in 22 sites on 16 north shore streams (Appendix 1).

We had originally proposed 8 study sites due to budget constraints. However, our statistician advised tripling the site number, if possible, to ensure adequate statistical power. Procurement of additional funding from several sources allowed sampling of more sites.

During the field season, it became clear that summer 2010 was going to be wetter than average and this rainfall (and subsequently higher streamflow) was reducing the amount of sediment settling out in the stream substrate. We subsequently verified that rainfall during the summer 2010 was higher than the five year average using data from three National Weather Service rain gauges near the stream sites. The data from these three gauges were pooled and averaged. The average rainfall per week for the years 1995-2010 and the average weekly rainfall from 2010 is shown in Figure 1. There were several weeks in 2010 with much higher than average rainfall, as was the season overall.

Erosion was probably as high or higher than other years, but greater stream flows meant that the sediment was getting washed through the streams and out into Lake Superior, rather than settling out and embedding stream rocks. We presume that macroinvertebrates were experiencing harsh conditions during storms as fine sediment was washed downstream, but the sediment evidence to prove this was difficult to document after the water levels returned to normal. Thus we also used the NRRI historical macroinvertebrate datasets, in addition to the project data, to aid in metric and indicator creation. To ensure that we were actually covering enough of the excessive sediment range, we also used some western Lake Superior south shore streams that were in the historic database. Adding the historic datasets gave us data from sites with much higher stream sediment amounts than we were able to sample during this project and, in theory, streams and invertebrates experiencing more stress due to sediment accumulation. Adding additional sites also increased statistical power.

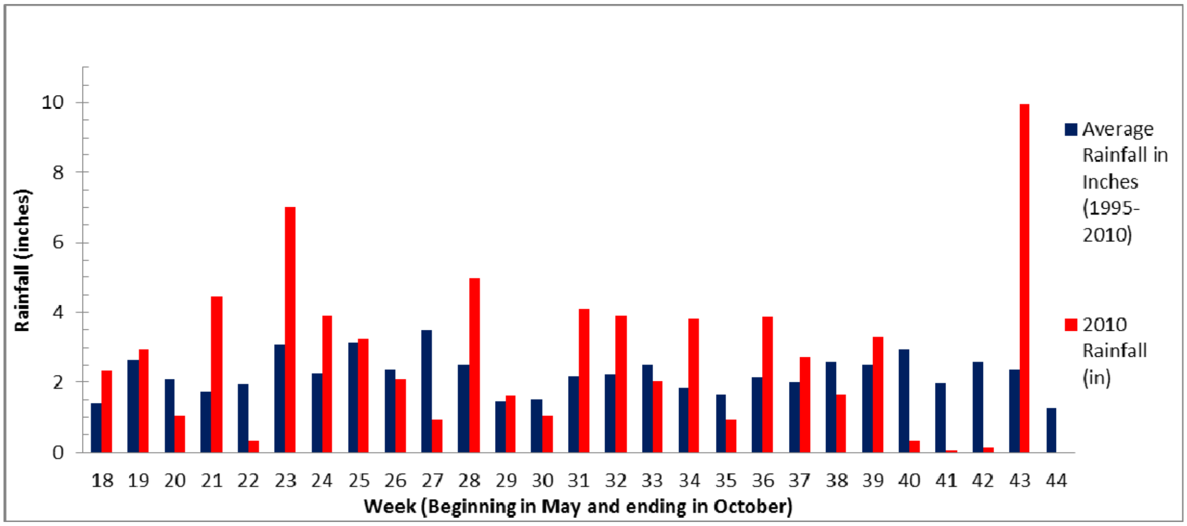

Figure 1. Data from three NWS rain gauges pooled and averaged, then summed to get weekly rainfall totals for the summers of years 1995-2010; also shown are the weekly rainfall totals from 2010. Week 18 is the first week of May and week 44 is the last week in October.

Stream Sampling

For this project, each stream site was sampled for sediment in the stream substrate five times during the summer along permanently-marked cross-sectional transects, one transect per site. Intensive sediment data collection included using 4 methods to assess sediment: Wolman pebble count (Wolman 1954), substrate percent composition, percent embeddedness (burial of rocky substrate), and particle size fractionation of fine sediment. The original goal was to sample each site every two weeks throughout the field season and to sample shortly after rainfall. This strategy proved unworkable for two reasons. First, frequent rainfall throughout the field season caused the streams to have high, flashy flow conditions, during which sampling could not be accomplished both due to safety concerns and because it was not possible to properly collect the sediment data under these conditions. Beyond making the streams unsafe, the frequent rainfall limited the total number of days available for sampling. Therefore, each site was sampled approximately once a month.

On each sampling date, water quality and sediment parameters were measured at each site. Water clarity was measured using a transparency tube. Basic water quality measurements of pH, dissolved oxygen, temperature, and conductivity were collected using a YSI 85 multiprobe meter. These standard stream water chemical and physical parameters were collected to double-check that all parameters were within normal ranges. Water velocity was measured several times across the transect to get an estimate of flow conditions.

Stream substrate and sediment were intensively measured, as listed above. The Wolman pebble count consisted of measuring the size of 100 pieces of substrate across the entire transect. Each rock, pebble, or gravel was taken from the stream bottom and the intermediate axis is measured. The intermediate axis is the axis of intermediate length between the longest axis and the shortest. Fine substrates (sand, silt, and clay) are listed and the median of their defined size range is used as their measurement. Defined size ranges and medians were determined using Fetter (1988). Once all 100 pieces were measured, a median particle size was calculated. Other substrate and sediment measurements were made within 0.5 sq. m quadrats placed across the stream along the transect. One quadrat was placed at the midpoint of every 25% length of the transect, with an additional quadrat taken in the thalweg (fastest-flowing part of the channel). Substrate percent composition categorizes stream substrate by size within the quadrat. We used standard size classes (Fetter 1988) of bedrock, boulder, cobble, gravel, sand, silt, and clay. Embeddedness within each quadrat was also recorded and measures the burial of rocky substrates (boulder, cobble, and gravel) by fine substrates (sand, silt and clay). Fine sediment depth was measured by inserting a stiff plastic rod down into the softest sediment in each quadrat and measuring the greatest depth that the rod reached before hitting hard substrate. Lastly, a sediment sample was taken from wherever we could find enough deposited sediment near the transect. This sample was processed at the laboratory to measure fine particle sizes. Sediment samples were dried, ashed (to burn off organic matter), and run through a standard sieve series to get sand sizes and silt/ clay proportions (silt cannot be separated from clay with the sieve sizes we have). Additional habitat measurements were made once at the end of the summer for each reach and included bankfull width and depth, stream shading, riparian vegetative cover, and size of the largest trees along the banks.

Aquatic macroinvertebrates were sampled at the end of the field season, as is typical for north shore streams. Most agencies collect aquatic macroinvertebrate samples between mid-August and mid-September. Three quantitative macroinvertebrate samples were collected from riffles at each site using Hess, Surber, or Portable Invertebrate Box (PIB) samplers, which are standard stream invertebrate sampling gear. Stream substrate type and depth determined which sampler was used. The Hess sampler is considered the most standard gear and was used whenever it could be worked into the substrate deep enough to get flow through the gear and collect invertebrates. If the stream was too shallow, the Surber sampler was used. If the stream had too much large rock or bedrock and was relatively deep (20 – 75 cm), the PIB sampler was used. All three samplers allow quantitative collection of invertebrates from approximately a 0.1 sq. m area of stream bottom. Operative mesh size on all gear was 0.25 mm.

Invertebrate samples were sorted under 5x magnification and identified to lowest practical taxonomic unit under at least 10x magnification. Most aquatic insects were identified to genus, including a subset of the Diptera: Chironomidae.

Trait Identification and Metric Development

Determining potential traits of aquatic macroinvertebrates that might be sensitive to excessive sediments was begun through searches of the peer-reviewed scientific literature. The list of potential vulnerable traits included types of gills (filamentous and fragile gills were assumed to be vulnerable to excessive sediments), whether or not gills had protective coverings (assumed to provide protection from sediment and abrasion), presence and type of cases (which could provide protection), burrowing ability (and thus adaptation for movement in excessive sediments), and body integument (a hard shell, case, or exoskeleton would provide more protection against sediment abrasion). A complete list of traits is provided in the results section. After potential traits were identified, the NRRI macroinvertebrate traits database was updated for each invertebrate taxon collected from north shore streams. Information from scientific journals and taxonomy textbooks was used for this task (e.g., Merritt *et al*. 2008).

Traits and taxonomic metrics were screened for use as potential sediment indicator metrics by plotting them against a combined sediment stress axis to see if there was a relationship between each potential metric and the amount of sediment stress each site received. The sediment stress index was created by combining the measurements of embeddedness, depth of fine sediments (sand, silt, and clay), and total proportion of fine sediments comprising the riffle substrate at each site. These three variables were each normalized, then standardized and finally were added together to create a combined sediment index that ranged from 0 to 3. Both embeddedness and total percentage of fine sediments are proportion measurements, and therefore the arcsin square root transformation was used to normalize the values (this is the standard transformation for proportion values). The depth of fine sediments data were normalized using a natural log transformation. The natural log was chosen for transformation because it provided the best normalization of the data. The natural log transformation is one of the preferred transformations and commonly used in biological datasets. Standardization was achieved using the same method for all three sediment stress measurements. The standardization step transformed the data so that the data range for each sediment variable fell between 0 and 1. Standardizing each sediment variable to the same scale kept any one sediment measurement from dominating the combined sediment axis. The combined sediment axis was created by simply adding up the three transformed, standardized individual sediment measurements (data shown in Appendix 2). Therefore, the combined sediment axis had a theoretical range of 0 (no measurable sediment stress) to 3 (maximum possible sediment stress). Regressing the three variables separately against the combined Sediment Stress Index showed high r-squared values for each, indicating that the index does well at capturing the information in all three variables (Table 1).

Table 1. Results of regression between the combined Sediment Stress Index and the individual variables that comprise it.

Sediment Variable	**R squared**
Arcsin sq root of Embeddedness	0.882
Ln of Depth of Fines	0.796
Arcsin sq root of Total Fines	0.647

Potential metrics that showed a strong relationship with the sediment stress axis or one of its components were identified as candidates for inclusion in the indicator. These metrics were then carefully compared to one another to ensure that their inclusion would not create excessive redundancy. For example, aquatic worms (oligochaetes) and midge larvae (Diptera: Chironomidae) are two of the primary groups in streams classified as burrowers. Thus, if worms, midge larvae and proportion burrowers all increase as the amount of sediment increases, only proportion burrowers should be included as a metric in the indicator; worms and midge larvae would be redundant. However, we found that some redundancy was necessary to have enough metrics for the indicator to work.

Indicator Development

Indicator development generally followed the strategy popularized by Karr, beginning with stream fish IBIs and then moving to stream macroinvertebrate ICIs (e.g., Karr and Chu 1999). Potential metrics were evaluated visually by plotting each metric against the combined sediment stress axis. Those graphs that showed a strong relationship were divided into sections corresponding to impact not detectable, moderate impact, and strong impact by excessive fine sediments. Metric ranges in the not detectable section of the graph were given a score of 5, ranges in the moderate impact section of the graph were given a score of 3, and metric ranges in the strong impact section of the graph were given a score of 1. Metric values (1, 3, or 5) were then added up to create the indicator, which has a potential range of 10 (best) to 50 (worst). Although this is a continuous score, we divided the range into 3 equal sections for assessment. Streams with indicators above 37 are considered to be strongly affected by fine sediments, while those with scores below 23 are considered to have undetectable effects. Those with scores between 37 and 23 are considered to be moderately affected.

We are in the process of publicizing our results. A preliminary poster was presented at the International Association for Great lakes Research annual meeting, held in Duluth in 2011 (and partly sponsored by the Coastal Program). The project received positive reviews from scientists at the meeting. The project was presented to the NOAA Great Lakes Environmental Research Laboratory in Ann Arbor and the macroinvertebrate laboratory at Utah State University. There are several other outreach activities planned including a presentation at the Twin Ports Freshwater Folk meeting on April 3rd, 2013. An abstract has been submitted to the Society of Wetland Scientists annual meeting, to be held in Duluth the first week of June, 2013.

Results and Discussion

The summer of 2010 proved to be an unfortunate summer for the execution of this research project. The summer was unusually wet (Figure 1), much wetter than any of the previous five years, making deposited sediment measurements difficult and fewer than we had planned due to high stream flows. Even using all sediment measurements together in a combined sediment index as our stress (x) axis, our Coastal Program stream data for this project showed few sites with very high values (green dots in Figure 2). Because the year was unusually wet and high stream flows were likely washing the sediment downstream instead of letting it settle out, as it would in a more normal year, we decided to use the historic macroinvertebrate dataset that NRRI has been collecting for the past 20 years. Adding in the north shore stream historic data added more sites toward the higher end of the sediment stress index (blue dots in Figure 2). When south shore stream historic data were added in, this extended the sediment stress index range far enough (brown dots in Figure 2) for us to see relationships between this index and potential macroinvertebrate metrics of an invertebrate response to stream sediment.

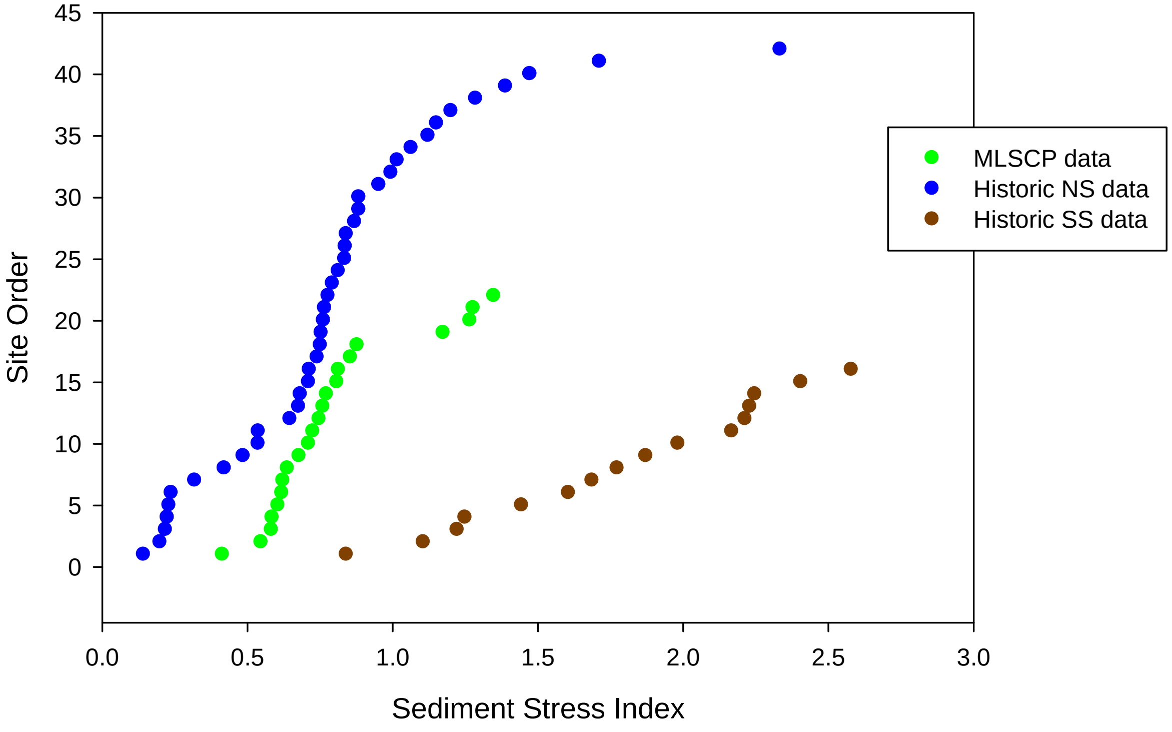

Figure 2. Sediment stress index scores for the three datasets used to create the index. The data collected for this project (MLSCP data, green) had the smallest range of stress index scores. The historic NS data (blue) had a greater range of sediment stress index scores. However, the historic SS dataset (brown) had more sites on the high end of the stress index.

We individually graphed and visually examined a large number of potential macroinvertebrate metrics that we expected might respond to excess stream sediment (Table 2). Graphs of metrics that showed a visual relationship with the combined sediment stress index were visually divided into sections representing unaffected (score 1), moderately affected (score 3), and strongly affected (score 5) by in-stream fine sediments (example in Figure 3).

Table 2. List of metrics evaluated for inclusion in the indicator of harm by excessive fine sediments, along with the final list of metrics chosen.

Potential Taxonomic Richness Traits	**Potential Proportional Abundance Traits**	**Final Metrics**
Burrower Richness	Proportion Burrower	
Case-maker Richness	Proportion Case-maker	
Clinger Richness	Proportion Clingers	
Coleoptera richness	Proportion Coleoptera	**Proportion Coleoptera**
Depositional Pref. Richness	Proportion Depositional Pref.	
Diptera Richness	Proportion Diptera	
Ephemeroptera Richness	Proportion Ephemeroptera	**Ephemeroptera Richness**
EPT Richness	Proportion EPT	**EPT Richness**
Erosional Pref. Richness	Proportion Pref. Erosional	
External Gill Richness	Proportion External Gills	
Filamentous Gill Richness	Proportion Filamentous Gills	**Filamentous Gill Richness**
Filterer Richness	Proportion Filterers	
Gastropod Richness	Proportion Gastropods	
Hard exoskel. Richness	Proportion Hard exoskel.	
Hydropsyche Richness	Proportion Hydropsyche	
Insect Richness	Proportion Insects	
Acari Richness	Proportion Acari	**Proportion Acari**
Nematod Richness	Proportion Nematods	
Odonata Richness	Proportion Odonates	
Oligochaeta Richness	Proportion Oligochaetes	
Plecoptera Richness	Proportion Plecoptera	**Plecoptera Richness**
Predator Richness	Proportion Predator	**Predator Richness & Prop. Predators**
Protected Gill Richness	Proportion Protected Gills	
Scraper Richness	Proportion Scrapers	
Sprawler Richness	Proportion Sprawlers	**Sprawler Richness**
Trichoptera Richness	Proportion Trichoptera	
Taxa Richness	Total Number per square meter	**Taxa Richness**

From the 15 to 18 metrics that showed a reasonably strong relationship with the combined sediment stress index, we selected ten metrics for inclusion in the final indicator. A reduction in the number of metrics was necessary to ensure that we did not incorporate undue redundancy in the final indicator. This final list of ten metrics (Table 3), when added together, creates a macroinvertebrate indicator of potential sediment stress that ranges from 10 (impact not detectable) to 50 (strong impact). We divided the graph into 3 equal portions to create cutoffs for site evaluation. Sites with scores above 37 may be strongly affected by fine sediments, while those with scores below 23 have undetectable effects. Those with scores between 37 and 23 are considered to be moderately affected. Appendix 3 shows metric values and scores and indicator scores for sites. The formal explanation of how to calculate and score each metric, add up the metric scores to get an indicator score for a site, and then interpret that score is shown in Appendix 4.

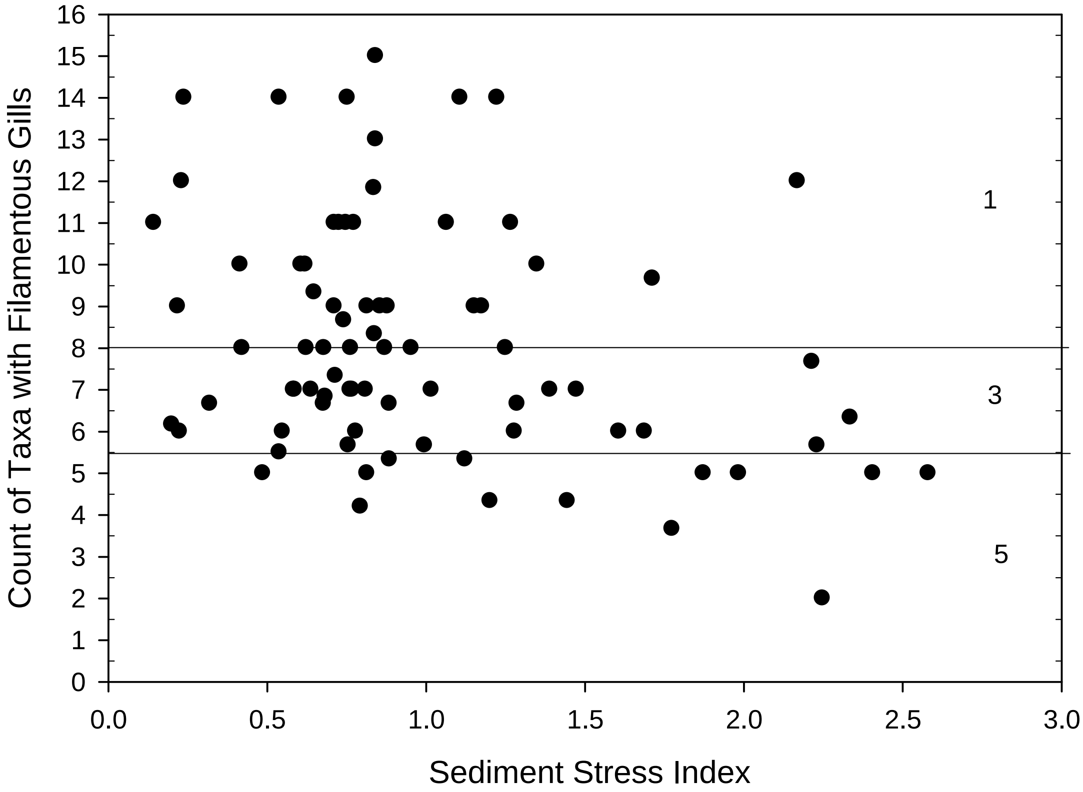

Figure 3. Graph illustrating creation of a metric with scores for the indicator of excessive stream sediment. This metric is the number of taxa with filamentous gills found at each site. Filamentous gills are hypothesized to be susceptible to damage by fine sediments washing downstream through riffle areas. Fewer of these taxa are found at sites with higher sediment stress index scores.

We calculated the metrics scores and indicator score for all sites (Figure 4), but as anticipated, the site data collected with Coastal Program funding was bunched together with relatively good (low) indicator scores but also low sediment stress index scores (green O's in Figure 4). Adding in the NRRI historic north shore stream data greatly expanded the range of indicator scores, including some sites with quite high scores, indicating loss of sensitive macroinvertebrates (blue N's in Figure 4). However, most of these sites had low to moderate values on the sediment stress index (x-axis). Adding in the NRRI historic south shore stream data again added in some sites with high indicator scores, but in this case those sites also had high sediment stress scores (brown S's in Figure 4).

Table 3. Final list of metrics and scoring criteria for each metric.

	Score		
Metric Name	**1**	**3**	**5**
Richness Metrics			
EPT Richness	> 18	18 - 11	< 11
Sprawler Richness	> 6	6 - 2	< 2
Total Richness	> 37	37 - 23	< 23
Filamentous Gill Richness	> 8	8 - 5.5	< 5.5
Plecoptera Richness	> 3.6	3.6 - 1.8	< 1.8
Ephemeroptera Richness	> 5.5	5.5 - 3.5	< 3.5
Predator Richness	> 6.5	6.5 - 4	< 4
Proportion Abundance Metrics			
Predator Proportion	> 0.13	0.13 - 0.05	0.05
Acari Proportion	> 0.07	0.07 - 0.02	0.02
Coleoptera Proportion	< 0.05	0.05 - 0.14	> 0.14

Considering all of this information, we interpret these results to mean that the indicator does a good job of showing loss of sensitive macroinvertebrates from stream riffles. However, the indicator is relatively non-discriminatory for the cause of this loss. In an area (western south shore of Lake Superior) where there is very high sediment stress and erosion (many of the streams have quite a lot of sand, silt and clay), the indicator seems to accurately point out the impact to the stream macroinvertebrates (Figure 5).

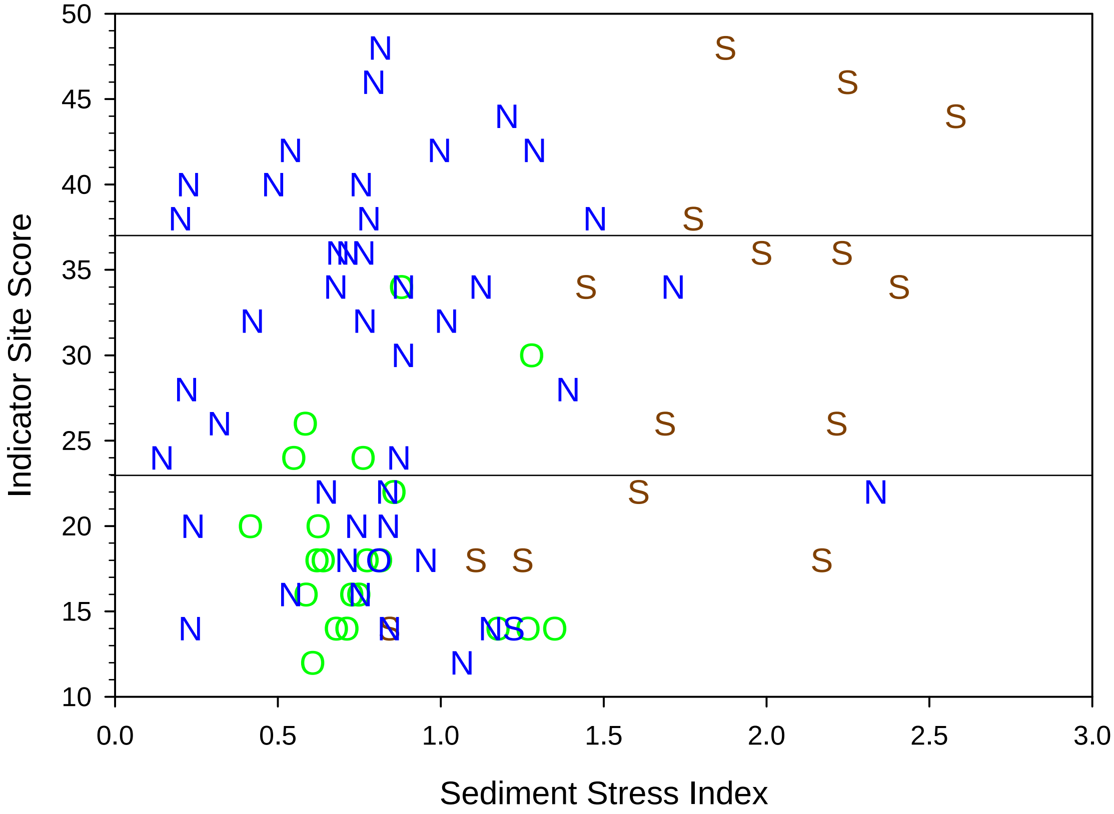

Figure 4. Indicator scores for all three datasets graphed against the Sediment Stress Index. Sites for this project are shown with green O's, sites from the historic north shore dataset are shown with a blue N, and sites from the historic south shore dataset are shown with a brown S. Horizontal lines show division of scores into macroinvertebrate condition, with lower scores meaning better condition.

Western Lake Superior north shore streams, especially those in the historic dataset, do seem to show stress to the macroinvertebrate community, but because the sediment and substrate data from these areas does not indicate high sediment stress, it is quite possible that there may be something else stressing the macroinvertebrates in these streams (Figure 6). It should be noted that substrate data collection was done at the time of macroinvertebrate data collection, and that these data were collected in a very similar manner to the Coastal Program-funded data collection. The difference is in a lack of Wolman pebble count, and that sediment/substrate data was collected only once, rather than many times, giving us somewhat less data to work with. The years of data collection for many of these streams had more normal or even low rainfall amounts, so we do not believe that most of these data suffer from the same substrate measurement problems as the Coastal Program-funded dataset.

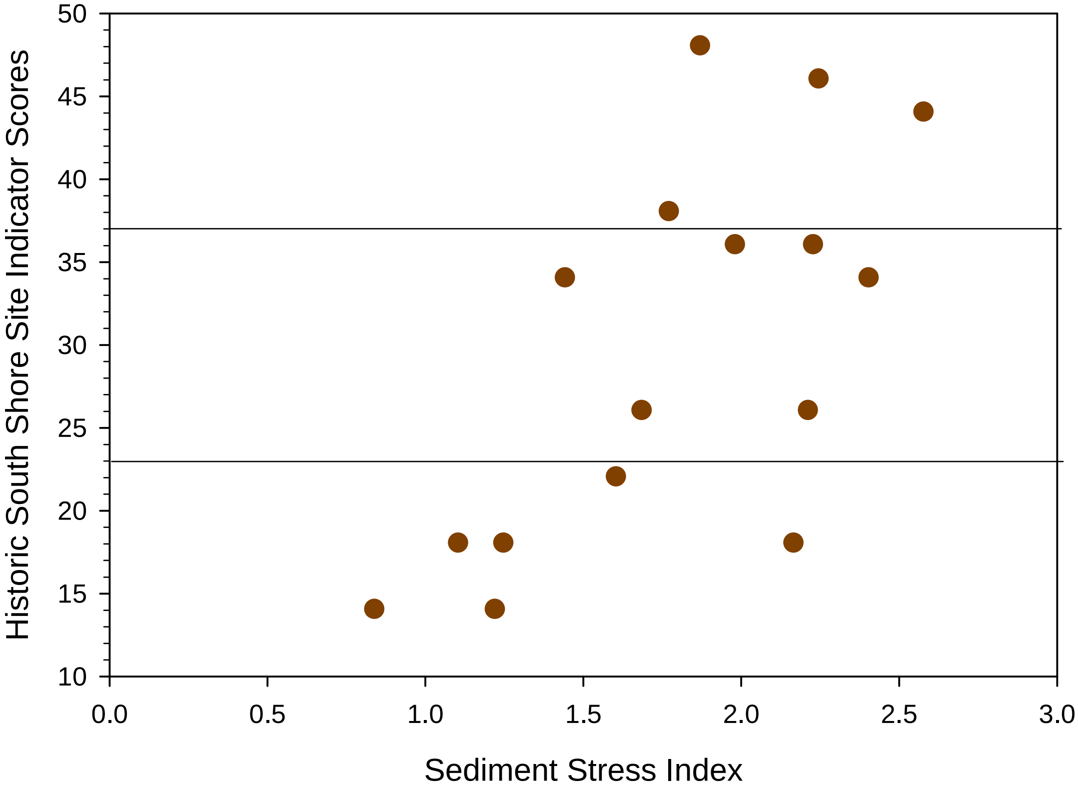

Figure 5. Indicator scores for the historic south shore dataset are shown plotted against the Sediment Stress Index. Horizontal lines show division of scores into macroinvertebrate condition, with lower scores meaning better condition. Many sites have moderate to high Sediment Stress Index Scores and corresponding moderate to high (poor) macroinvertebrate indicator scores, indicating loss of sensitive macroinvertebrates.

We are somewhat surprised by these results because the PI (Brady) has been under the impression that excessive fine sediments are the primary stressor affecting north shore streams, beyond the general harshness of the terrain. Other studies have found very few human-caused stressors for north shore streams.

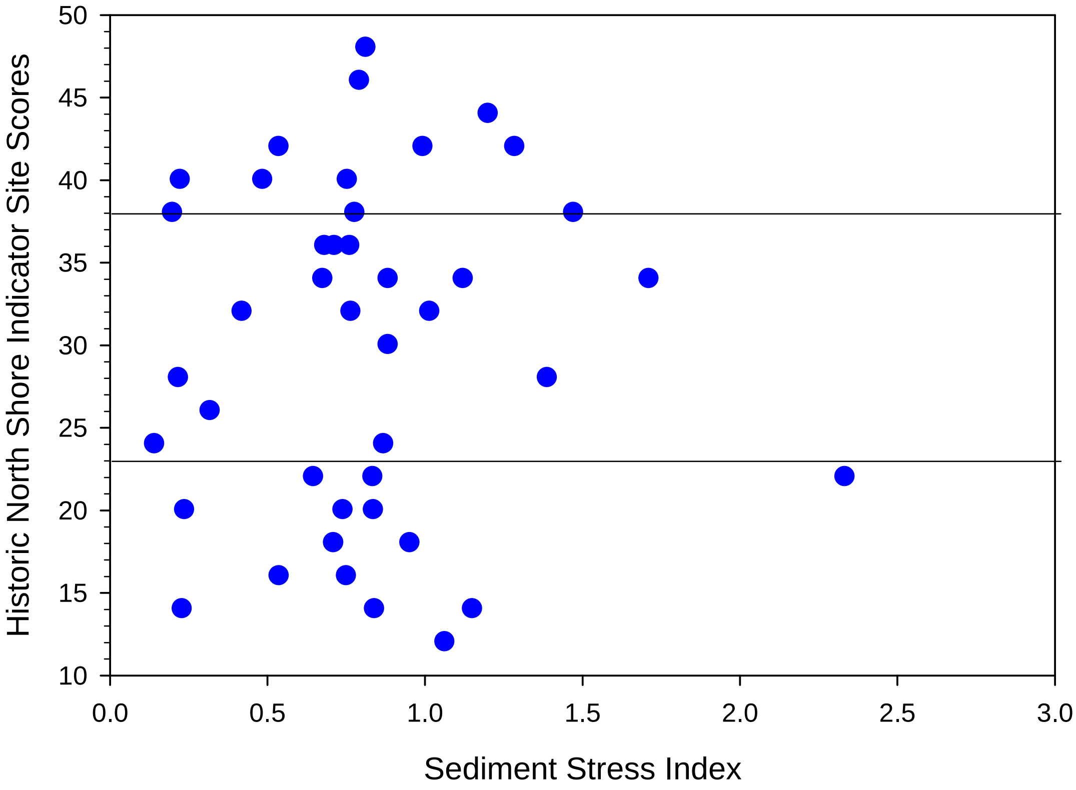

Figure 6. Indicator scores for the historic north shore dataset are shown plotted against the Sediment Stress Index. Horizontal lines show division of scores into macroinvertebrate condition, with lower scores meaning better condition. There is only a single site with a reasonably-high Sediment Stress Index score, but a number of sites have poor (high) macroinvertebrate indicator scores, indicating loss of sensitive macroinvertebrates.

Partnerships

None at present. We have been talking with Dr. David Barton, University of Waterloo, about using his dataset for testing of our indicator. However, his dataset does not have comprehensive sediment and substrate data, which we still need at this point in the process. Dr. Barton saw the graduate student's poster at the IAGLR 2011 conference in Duluth and was quite intrigued by our attempt, prompting him to discuss collaboration.

Leveraged Dollars

Several additional funding sources were secured by the graduate student, Larissa Herrera, that greatly benefitted this project and allowed it to be expanded to the scope that was needed to adequately attempt to address this issue. One additional funding source was the University of

Minnesota Water Resources Sciences Program that allowed this project to start at the beginning of the field season. This additional $5,000 graduate fellowship provided initial supplies and partially funded Herrera for the summer. Additionally, Herrera won a DOVE fellowship from the University of Minnesota, which supported her and provided health insurance through the end of the 2010 summer. The Coastal Program project was originally written to provide support for the graduate student during the 2010-2011 school year, but the project was not funded at the fully-requested level, leaving a funding gap to accomplish the full project objectives. Herrera also won a CILER long-term fellowship with a proposal based on this project. This fellowship allowed her to work half-time on the project without cost to it during the 2010-2011 year. These additional monies freed up project funding to allow many more sites to be sampled more often and for the full summer.

Summary and Conclusions

Lessons learned for this project include the need to include more than a single field season for a field project of this type due to the chance of having non-normal weather for enough of the field season to affect sampling and data collection. The funding period and timeline for Coastal Program projects are also out-of-synch for field work; funding typically does not start until the very end of the summer, and the short funding period means that field data collection cannot be put off until the second summer if there is to be time for sample processing and data analysis. More flexibility in project start date would be quite helpful for projects that cover summer activities.

To summarize our project results, despite an abnormally wet summer with high streamflow, we have succeeded in developing an indicator that shows loss of sensitive macroinvertebrates from riffle areas of streams, where many of these macroinvertebrates are typically found. However, the indicator does not appear to diagnostically indicate excessive fine sediments as the cause of the stress to stream invertebrates. While the indicator does work well in streams experiencing primarily quite high levels of excessive fine sediments, such as streams on the south shore of western Lake Superior, it is likely that it will also indicate high stress in streams that are experiencing other problems.

The most positive result to come out of this effort is that all north shore sites sampled for this project show relatively low amounts of stress to stream macroinvertebrates, which is an encouraging finding.

Future Plans

We are in the process of publicizing our results and seeking input and ideas from other stream researchers. We will be giving a presentation at the Twin Ports Freshwater Folk meeting on April 3rd, 2013. This seminar series is typically attended by at least two dozen local aquatic resource managers, researchers, natural resource nonprofits, and others. An abstract has been submitted to present a poster at the Society of Wetland Scientists annual meeting, to be held in Duluth the first week of June, 2013.

We will continue to analyze these data, search for other complementary datasets, and search for other opportunities to study north shore streams to better understand them so we can determine whether the macroinvertebrate impairments we see in north shore streams have a human cause or whether some are due to our north shore geology and soils.

Public Relations

None at present.

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Photos

Photo 1. Graduate student Larissa Herrera collecting sediment and substrate data from a quadrat along a transect in Amity Creek. Undergraduate field assistant Kelia Axler (in background) records the data.

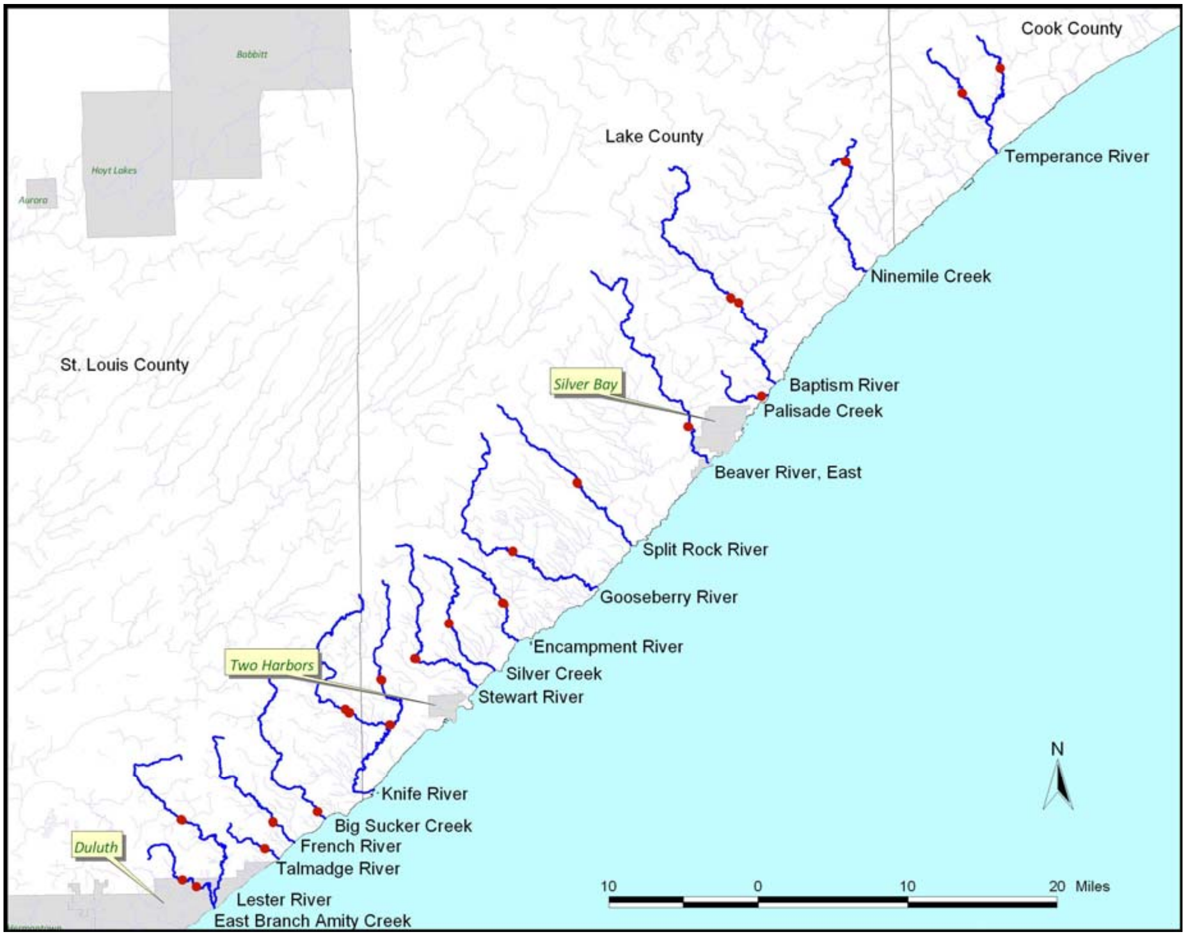
Photo 2. Graduate student Larissa Herrera collecting macroinvertebrates using a Hess sampler in Amity Creek.

Photo 3. Undergraduate field assistant Kelia Axler collecting macroinvertebrates using a Hess sampler.

Photo 4. PI Valerie Brady (left) and field assistants Kelia Axler and Cory Peterson wash macroinvertebrates out of a Hess sampler and into a collection basin in preparation for preservation. Site is Amity Creek.

Photo 5. Undergraduate field assistants Kelia Axler (left) and Cory Peterson water quality and transect data. Instrument in the water is a multimeter that measures pH, dissolved oxygen, temperature, and conductivity. Clear tube on the bank is a transparency tube for measuring water clarity. Site is French River.

Appendix 1. Site map and site list.



Map showing locations of Coastal Program stream sampling sites for this project. There were 22 sites on 16 streams. Sites were sampled during the summer of 2010.

Appendix 1. List and location of Coastal Program project sampling sites on north shore streams sampled during the summer of 2010.

Stream	Site Number	Decimal Degrees X Coordinate	Decimal Degrees Y Coordinate
Amity Bank	9	-92.0302	46.8572
Amity-Martin	2	-92.0487	46.8642
Blind Temperance	55	-90.8644	47.6354
E. Beaver	63	-91.3199	47.2957
Encampment	82	-91.5876	47.1273
French	5	-91.9210	46.9180
Gooseberry	75	-91.5755	47.1779
Hackamin	84	-91.2573	47.4182
Heartbreak	56	-90.9192	47.6120
Knife-Airport	68	-91.7636	47.0556
Knife-Stanley	79	-91.7517	47.0121
Lester	4	-92.0486	46.9217
Little Knife	10	-91.8117	47.0258
Moose	69	-91.0887	47.5500
Palisade	85	-91.2170	47.3220
Silver	77	-91.6673	47.1092
Split Rock	95	-91.4804	47.2424
Stewart	8	-91.7139	47.0747
Sucker	7	-91.8580	46.9290
Talmadge	6	-91.9341	46.8945
W. Baptism	90	-91.2451	47.4144
W. Knife	3	-91.8159	47.0277

Appendix 2. Sediment variable data.

Appendix 2. Sediment variables and transformed versions of the variables that were combined to form the Sediment Stress Index used as the x-axis to create the metrics and indicator. Sediment Stress Index values also shown. Data are for all Coastal Program sites sampled during 2010.

Site	Percent Embedded	Arcsin sq rt Embedded	Depth of Fines (m)	Ln of Depth of Fines	Total Fines (percent)	Arcsin sq rt Total Fines	Sediment Stress Index
Amity-Bank	12	0.3075	0.0308	0.3783	1	0.0759	0.7617
Amity-Martin	3.75	0.1694	0.0169	0.2669	5	0.1708	0.6071
Bl. Temperance	30	0.5039	0.0504	0.4843	6	0.1874	1.1756
E. Beaver	30	0.5039	0.0504	0.4843	14	0.2904	1.2786
Encampment	10	0.2797	0.028	0.3593	8	0.2172	0.8562
French	27.5	0.4799	0.048	0.4733	25	0.3965	1.3498
Gooseberry	2	0.1234	0.0123	0.2164	1	0.0759	0.4156
Hackamin	9.4	0.2709	0.0271	0.353	0	0	0.6239
Heartbreak	3.75	0.1694	0.0169	0.2669	3.75	0.1476	0.5839
Knife-Airport	6	0.2151	0.0215	0.3091	6	0.1874	0.7117
Knife-Stanley	30	0.5039	0.0504	0.4843	13	0.2794	1.2675
Lester	13	0.3207	0.0321	0.3869	2	0.1075	0.815
Little Knife	5	0.1961	0.0196	0.2923	3	0.1318	0.6202
Moose	15	0.3458	0.0346	0.4025	0	0	0.7482
Palisade	4.6	0.1879	0.0188	0.2848	1	0.0759	0.5486
Silver	8.75	0.2611	0.0261	0.3457	2.5	0.1203	0.7271
Split Rock	8	0.2493	0.0249	0.3368	6	0.1874	0.7735
Stewart	7	0.2328	0.0233	0.3238	2.6	0.1227	0.6792
Sucker	10	0.2797	0.028	0.3593	5	0.1708	0.8098
Talmadge	11.25	0.2974	0.0297	0.3715	7.5	0.2101	0.879
W. Baptism	10	0.2797	0.028	0.3593	0	0	0.639
W. Knife	5	0.1961	0.0196	0.2923	1.6667	0.098	0.5864

Appendix 3. Metric values and scores and indicator scores.

Appendix 3a. Metric values for each Coastal Program site sampled during summer 2010.

Site Name	Prop. Coleoptera	Prop. Acari	Prop. Predator	Predator Richness	Sprawler Richness	Filamentous Gill Richness	Plecoptera Richness	Ephemeroptera Richness	EPT Richness	Taxa Richness
Amity Bank	0.06	0.20	0.05	6	4	7	7	5	20	47
Amity-Martin	0.00	0.06	0.23	11	6	10	5	6	23	48
Blind Temperance	0.00	0.09	0.15	5	4	9	5	8	20	42
E. Beaver	0.13	0.03	0.10	6	2	6	4	4	16	33
Encampment	0.18	0.17	0.14	9	4	9	4	3	16	38
French	0.02	0.14	0.12	8	4	10	4	6	18	39
Gooseberry	0.01	0.04	0.33	7	5	10	3	6	16	36
Hackamin	0.04	0.12	0.12	11	4	8	5	3	17	43
Heartbreak	0.04	0.04	0.11	9	3	7	3	1	12	40
Knife-Airport	0.05	0.08	0.22	9	4	11	4	8	20	42
Knife-Stanley	0.05	0.08	0.18	12	8	11	6	5	19	34
Lester	0.03	0.08	0.09	9	4	9	3	6	15	37
Little Knife	0.08	0.16	0.17	10	2	10	4	6	16	44
Moose	0.04	0.06	0.17	9	5	11	6	5	18	44
Palisade	0.03	0.26	0.09	4	2	6	6	5	20	44
Silver	0.09	0.07	0.10	10	3	11	7	6	22	43
Split Rock	0.22	0.14	0.12	7	4	11	5	8	24	56
Stewart	0.02	0.11	0.17	5	3	8	8	6	20	49
Sucker	0.03	0.05	0.21	8	3	7	6	5	18	45
Talmadge	0.05	0.06	0.04	4	4	9	2	3	11	32
W. Baptism	0.01	0.07	0.12	7	5	7	4	7	18	42
W. Knife	0.04	0.08	0.08	10	3	7	6	8	26	46

Appendix 3b. Metric scores and final indicator score for each Coastal Program site sampled during summer 2010.

Site Name	Prop. Coleoptera	Prop. Acari	Prop. Predator	Predator Richness	Sprawler Richness	Filamentous Gill Richness	Plecoptera Richness	Ephem. Richness	EPT Richness	Taxa Richness	Indicator Score
Amity Bank	3	1	5	3	3	3	1	3	1	1	**24**
Amity-Martin Rd.	1	3	1	1	1	1	1	1	1	1	**12**
Blind Temperance	1	1	1	3	3	1	1	1	1	1	**14**
E. Beaver	3	3	3	3	5	3	1	3	3	3	**30**
Encampment	5	1	1	1	3	1	1	5	3	1	**22**
French	1	1	3	1	3	1	1	1	1	1	**14**
Gooseberry	1	3	1	1	3	1	3	1	3	3	**20**
Hackamin	1	1	3	1	3	1	1	5	3	1	**20**
Heartbreak	1	3	3	1	3	3	3	5	3	1	**26**
Knife-Airport	3	1	1	1	3	1	1	1	1	1	**14**
Knife-Stanley	1	1	1	1	1	1	1	3	1	3	**14**
Lester	1	1	3	1	3	1	3	1	3	1	**18**
Little Knife	3	1	1	1	5	1	1	1	3	1	**18**
Moose	1	3	1	1	3	1	1	3	1	1	**16**
Palisade	1	1	3	5	5	3	1	3	1	1	**24**
Silver	3	1	3	1	3	1	1	1	1	1	**16**
Split Rock	5	1	3	1	3	1	1	1	1	1	**18**
Stewart	1	1	1	3	3	1	1	1	1	1	**14**
Sucker	1	3	1	1	3	3	1	3	1	1	**18**
Talmadge	1	3	5	5	3	1	3	5	5	3	**34**
W. Baptism	1	3	3	1	3	3	1	1	1	1	**18**
W. Knife	1	1	3	1	3	3	1	1	1	1	**16**

Appendix 4.
Calculating a Macroinvertebrate Indicator of Excessive Stream Sediment

In development by
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This indicator is being developed to provide a diagnostic indication of whether or not excessive fine (clean) sediments are the cause of impairment to a stream macroinvertebtrate assemblage that is indicating some impairment. Most of the metrics that correlate with excessive clean sediments will also be sensitive to many other causes of stream impairment, and caution should be used in interpretation.

Metrics:

- *Ephemeroptera Richness:* Count of Ephemeroptera unique taxa at each site. Based on identification to genus for all possible individuals.
- *Plecoptera Richness:* Count of Plecoptera unique taxa at each site. Based on identification to genus for all possible individuals.
- *EPT Richness:* Count of Ephemeroptera, Plecoptera, and Trichoptera unique taxa at each site. Based on identification to genus for all possible individuals.
- *Total Richness:* Count of unique taxa at each site (excluding chironomid genera if these were identified beyond Chironomidae). Based on identification to genus for all insect taxa except Chironomidae.
- *Sprawler Richness:* Count of unique taxa classified behaviorally as “sprawlers” in Merritt et al. (2008). Chironomidae should not be included in this classification.
- *Predator Richness:* Count of unique taxa classified as predators in Merritt et al. (2008).
- *Filamentous Gill Richness:* Count of unique taxa which have filamentous or fragile gills. There are no ready sources for this information and it is recommended that notes be kept on taxa possessing this trait during sample identification.
- *Predator Proportion:* Proportion of the sample comprised of predatory invertebrates (as listed in Merritt et al. (2008)). Proportions should be calculated without inclusion of Chironomidae.
- *Acari Proportion:* Proportion of the sample comprised of aquatic mites (Acari).
- *Coleoptera Proportion:* Proportion of the sample comprised of aquatic beetles (Coleoptera).

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After calculating each metric for each site, score the metrics based on Table 1. Scores are then summed to get the final indicator score for each site. Score interpretations are shown in Table 2.

Table 1. Scoring criteria for metric for the Macroinvertebrate Indicator of Excessive Stream Sediment.

		Score	
Metric Name	**1**	**3**	**5**
Richness Metrics			
EPT Richness	> 18	18 - 11	< 11
Sprawler Richness	> 6	6 - 2	< 2
Total Richness	> 37	37 - 23	< 23
Filamentous Gill Richness	> 8	8 - 5.5	< 5.5
Plecoptera Richness	> 3.6	3.6 - 1.8	< 1.8
Ephemeroptera Richness	> 5.5	5.5 - 3.5	< 3.5
Predator Richness	> 6.5	6.5 - 4	< 4
Proportion Abundance Metrics			
Predator Proportion	> 0.13	0.13 - 0.05	0.05
Acari Proportion	> 0.07	0.07 - 0.02	0.02
Coleoptera Proportion	< 0.05	0.05 - 0.14	> 0.14

Table 2. Interpretation of Macroinvertebrate Indicator of Excessive Stream Sediment Score.

Indicator score	Assessment
10-22	No detectable effects
23-37	Moderately affected
37-50	Strongly affected

Important notes: This indicator was created using data from streams draining into the western arm of Lake Superior and has not been tested in other areas. Macroinvertebrate data were collected quantitatively from riffles and at least 25% of each sample was picked and identified to lowest practical taxonomic unit. Chironomidae, Oligochaeta, Nematoda, and Acari were not identified further. This indicator has not been tested on qualitative samples. This indicator is sensitive to anything that causes loss of sensitive taxa, particularly EPT taxa. Habitat assessments, surrounding land use, and potential water quality degradation should be carefully considered when attempting to interpret cause of loss of sensitive stream macroinvertebrates.

Citation

Merritt, R.W., K.W. Cummins, and M.B. Berg (eds). 2008. An introduction to aquatic insects of North America. 4th Edition. Kendall-Hunt, Dubuque, IA.