Testing Alaska's macroinvertebrate- and diatom-based stream condition indices in select urbanized streams

Daniel Rinella and Daniel Bogan

Environment and Natural Resources Institute and Alaska Natural Heritage Program
University of Alaska Anchorage

Report prepared for Alaska Department of Environmental Conservation
Anchorage, Alaska

INTRODUCTION

The U.S. Environmental Protection Agency encourages states and tribes to use biological techniques for the monitoring and assessment of ecological condition in surface waters (USEPA 2002, 2003), and macroinvertebrates and diatoms are two of the primary biological communities used for this purpose (Barbour et al. 1999). Biological endpoints are the ultimate indicators of ecological condition because they integrate chemical, physical, and habitat conditions at a given site (Karr and Chu 1999). Environmental assessments based on multiple assemblages are particularly good at detecting disturbances because different assemblages are sensitive to different types of environmental stressors (Karr and Chu 1999, Hughes et al. 2000).

Over the past 12 years, researchers at the University of Alaska Anchorage's Environment and Natural Resources Institute (ENRI) have collected extensive field data for use in the calibration of biological assessment indices. From these data, we have calibrated a macroinvertebrate-based biological monitoring index for wadeable streams in the Alexander Archipelago ecoregion (southeast Alaska; Rinella et al. 2005) and both diatom- and macroinvertebrate-based indices for wadeable streams in the Cook Inlet Basin ecoregion (southcentral Alaska;. Rinella and Bogan 2007). These indices combine information from separate constituent metrics, each indicative of different aspects of environmental condition, into a single multimetric index score.

The performance of these indices was tested at the time of development, to the extent that the data sets permitted. The Alexander Archipelago macroinvertebrate index (Rinella et al. 2005) consistently detected urbanization impacts: urbanized streams (n=6) consistently scored below the 25th percentile of reference sites (n = 64), for a discrimination efficiency of 100%. This index, however, was not effective for detecting ecological impacts associated with timber harvest. Precision of the index was high; the coefficient of variation (CV) for metrics calculated from simultaneously-collected quality assurance replicate samples was 6.7% and from annually-replicated samples was 15.3%.

Discrimination efficiency for the Cook Inlet macroinvertebrate index (Rinella and Bogan 2007) was 79% (i.e., 11 of 14 Class 2 sites scored lower than the 25th percentile of Reference sites). A validation data set showed the same trends as the calibration data (i.e., Reference > Class 1 > Class 2), giving an independent confirmation of index reliability. Quality assurance replicates (i.e., separate samples collected in the same stream on the same day) differed by an average of 6 index points (based on 41 pairwise comparisons). Year-to-year variation in index scores, based on Reference sites sampled over multiple years, averaged 8 index points (based on 7 pairwise comparisons).

Discrimination efficiency for the Cook Inlet diatom index (Rinella and Bogan 2007) was 100% (i.e., all 17 Class 2 sites scored below the 25th percentile of reference sites). Quality assurance replicates (n=2) varied by a median of 4 index points, and sites sampled on different years differed by a median of 9 index points (based on 9 comparisons).

The objective of the current study is to further test the effectiveness of the biological monitoring indices on selected urbanized streams in the Mat-Su Valley and in Juneau's Mendenhall Valley.

METHODS

This study focused on Duck and Juneau creeks in the Juneau area (Alexander Archipelago ecoregion) and Meadow, Wasilla, and Willow creeks in the Mat-Su Valley (Cook Inlet Basin ecoregion). All of these streams are listed by ADEC as high priority water bodies and have had previous biological and water chemistry monitoring. Additionally, Duck Creek is listed as an impaired water body by ADEC for low dissolved oxygen, debris, iron, fecal coliform bacteria, and turbidity due to urban runoff (including landfill and roads) and land development. Jordan Creek is listed for debris, sediment, and low dissolved oxygen due to land development and road runoff.

We sampled these streams during the spring of 2010, processed and identified the samples according to ENRI protocols, and used the resulting biological data to calculate multimetric macroinvertebrate and diatom index scores (Rinella et al. 2005, Rinella and Bogan 2007). All data are stored in ENRI's biological database. We did not calculate index scores for the Juneau-area sites since a diatom-based index has not yet been developed for this ecoregion. We then compared the 2010 index scores and selected water chemistry parameters to existing data from these same sites and to ecoregion-specific reference sites (see Rinella et al. 2005, Rinella and Bogan 2007). Reference sites in both ecoregions were defined by a lack of detectable human disturbance (e.g., roads, buildings, timber harvest, etc.) within the watershed upstream of the sampling reach. For water quality parameters, we chose to examine specific conductance and dissolved oxygen concentration because our experience suggests that (of the parameters that can be readily measured in-situ) these are the most sensitive indicators of anthropogenic water quality impairment. Specific conductance reflects the concentration of inorganic dissolved solids and is often elevated in streams receiving urban runoff, while dissolved oxygen is often diminished in streams that receive organic pollutants or nutrient enrichment.

RESULTS AND DISCUSSION

Biological assessments

Macroinvertebrate assemblages from Duck and Jordan creeks indicated consistent and substantial biological impairment at these Juneau-area sites, where multimetric index scores from all years were substantially lower than reference site scores (Figure 1A). At these sites, index scores in 2010 were generally similar to those collected in previous years (Table 1). The 2010 Duck Creek sample scored 19 while previous samples from that stream ranged from 14 to 17. The 2010 Jordan Creek sample scored 28, while that from 2003, the only previous sample, scored 32.

In the Mat-Su Valley, macroinvertebrate data show consistent biological impairment at Meadow Creek, where scores from current and previous samples were at or below the 5th percentile of reference site scores (Figure 2A). Samples from Wasilla Creek were more variable and indicated little or no biological impairment (Figure 2A). Index scores from 2010 were consistent with prior samples for both Meadow and Wasilla creeks (Table 2). Meadow Creek scored 33 in 2010 while previous scores ranged from 24 to 34. Wasilla Creek scored 63 in 2010 while previous scores ranged from 39 to 66.

Samples from Willow Creek were variable, ranging from a low of 49 in 2010 to a high of 89 in 2000 (Table 2). While the current and previous data indicate no obvious biological impairment (Figure 2A), index scores are too variable to draw conclusions about biological condition. This stream is too deep and swift to sample effectively under the wadeable stream protocol used for this study, particularly during the spring index period when biological samples are collected. For example, macroinvertebrate samples in 2010 could only be collected from the stream margins, leaving all mid-channel habitats unsampled. The lack of representative samples might have contributed to the temporal variation, and we recommend that any further sampling on this stream be conducted under a non-wadeable protocol and that the resulting data be compared to a set of non-wadeable reference sites.

Of the two sites sampled for diatoms in 2010, only Wasilla Creek had previously been sampled for diatoms. The current and previous (2005) scores were similar (Table 3), and both were lower than the 5th percentile of reference site scores (Figure 2D). Thus the diatom data for Wasilla Creek appear to indicate some ecological impairment, and examination of the constituent metrics points to a likely cause. Values for two metrics – organic nitrogen tolerance and trophic state – were well above the ranges observed within the reference site data (see Rinella and Bogan 2007), indicating high tolerances for organic nitrogen pollution and eutrophic conditions among the Wasilla Creek diatom assemblage. Similar high tolerances have been documented in disturbed streams in many other geographical settings (Fore and Graff 2002, and references therein). The Meadow Creek diatom score, by contrast, was near the median value for reference sites (Figure 2D), indicating a lack of impairment to the diatom assemblage. Willow Creek diatoms were not sampled because high water levels prohibited adherence to the sampling protocol, which calls for sampling transects across stream riffles.

<u>Correspondence between water chemistry and biological assessments</u>

While biological assessments are generally regarded as comprehensive and integrative indicators of ecological condition (Karr and Chu 1999), physical and chemical data are regularly collected as complements (USEPA 2006). This is because physical and chemical data can be very helpful in the interpretation of patterns observed in the biological data. Here, we examine the extent to which assessments based on biological and chemical data correspond, and the extent to which assessments would have differed if based solely on chemical data. We will focus mainly on macroinvertebrate assemblages since we have relatively few diatom data.

Based on water chemistry alone (i.e., specific conductance and dissolved oxygen), Duck and Meadow creeks are clearly the most impaired of the streams of those sampled in 2010. For both of these streams, specific conductance is elevated (Figures 1B, 2B) and dissolved oxygen is depressed (Figures 2C, 3C) relative to reference sites. In the case of these two streams, macroinvertebrate indices actually show clearer separation between reference and test sites than do the water chemistry measures (Figures 1 and 2), making them a better indicator of ecological impairment at these sites with obvious chemical impairment.

Based on water chemistry alone, Jordan Creek shows relatively mild impairment. Specific conductance is elevated above the 75th percentile of reference sites (Figure 1B), but dissolved oxygen is nearly within the interquartile range of the reference site data (Figure 1C). The macroinvertebrate assemblage, by contrast, clearly shows substantial impairment relative to reference sites (Figure 1A). Given the ability of macroinvertebrate communities to integrate ecological conditions over time, as opposed to one-time chemical readings which do not, the macroinvertebrate assemblage is likely reflecting impaired ecological conditions that were not obvious from the chemical data.

Chemically, the situation at Wasilla Creek is similar to that just described for Jordan Creek. Specific conductance is clearly elevated (i.e., all readings were above the 75th percentile of reference site readings; Figure 2B) yet dissolved oxygen is within the range observed at reference sites (Figure 2C). The biological data here are inconclusive, with two samples greater than and three samples less than the reference site median (Figure 2A). Thus the macroinvertebrate data do not conclusively reflect the elevated conductivity observed over time at this site, suggesting the possibility that water quality impairment is not substantial enough to have measurable impact on the macroinvertebrate assemblage. The diatom index score, however, does suggest impairment at this site (Figure 2D), but further data will be needed to assess this conclusively.

Lastly, chemical conditions at Willow Creek indicated no water quality impairment (Figures 2B and 2C). Despite our concerns regarding lack of sample representativeness at this relatively large stream, the macroinvertebrate data generally support this conclusion (Figure 2A).

General conclusions and recommendations

Biological index scores from samples collected in 2010 are generally in line with the values from samples collected in years past, suggesting relatively consistent ecological condition across these sites. One exception is Willow Creek, but we expect the high level of variation observed in these samples relate to our inability to adequately sample this relatively large stream using a wadeable stream protocol (see above).

It is interesting to note that the macroinvertebrate assemblage in Meadow Creek indicated impairment while the diatom assemblage did not. The opposite pattern was observed in Wasilla Creek. These results support the importance of using multiple biological assemblages to characterize biological condition in aquatic systems. More diatom data will be needed to assess the relative sensitivities of this assemblage relative to water chemistry and the macroinvertebrate assemblage.

This analysis clearly demonstrates the utility of biological assessments, used in concert with water chemistry, for tracking ecological condition in Alaska's streams. At the most impaired sites -- Duck and Meadow creeks -- macroinvertebrates showed clearer impairment than did water chemistry parameters. At Jordan Creek, macroinvertebrates indicated impairment that was not readily apparent in the chemical data. As an added benefit, the reference site macroinvertebrate data represent the most biologically relevant restoration goal available for these streams. Restoration of these sites can be considered a success when their biological assemblages begin to approximate that found at the reference sites.

Table 1. Macroinvertebrate multimetric index scores, including scores for constituent metrics, from Juneau-area streams sampled in 2010. Scores from previous samples collected at these sites are included for reference. Samples with a 1 in the replicate number column indicate repeat samples collected for quality assurance. EPT indicates the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies).

Station ID	Waterbody name	Date	Replicate number	Number of insect taxa	% Noninsect taxa	% EPT	Number of scraper taxa	Number of clinger taxa	% Intolerant taxa	Multimetric index score
juduc01	Duck Cr.	5/8/2002	0	6	50	1	1	1	17	14
juduc01	Duck Cr.	5/8/2002	1	9	40	1	0	2	7	16
juduc01	Duck Cr.	5/13/2004	0	6	57	2	3	1	21	17
juduc01	Duck Cr.	5/6/2010	0	7	36	1	1	1	18	19
jujor01	Jordan Cr.	5/13/2003	0	10	33	17	1	3	40	32
jujor01	Jordan Cr.	5/6/2010	0	12	33	12	1	2	22	28

Table 2. Macroinvertebrate multimetric index scores, including scores for constituent metrics, from Mat-Su-area streams sampled in 2010. Scores from previous samples collected at these sites are included for reference. Samples with a 1 in the replicate number column indicate repeat samples collected for quality assurance. EPT indicates the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies).

Station ID	Waterbody name	Date	Replicate number	Number of EPT taxa	Number of mayfly taxa	% Mayflies	% Scrapers	Shannon's diversity	% Non-insects	Multimetric index score
msmea01	Meadow Cr.	5/15/1998	0	6	1	1	2	0.5	6	24
msmea01	Meadow Cr.	6/15/2000	1	5	2	2	8	1.4	20	34
msmea01	Meadow Cr.	6/15/2000	0	6	2	3	0	1.1	12	27
msmea01	Meadow Cr.	6/15/2001	0	4	2	2	1	0.5	2	26
msmea01	Meadow Cr.	6/4/2010	0	7	1	5	1	1.8	18	33
mswas01	Wasilla Cr.	5/11/1998	0	9	3	10	3	1.3	2	49
mswas01	Wasilla Cr.	5/11/1998	1	9	3	10	2	1.1	1	47
mswas01	Wasilla Cr.	6/13/2000	0	6	2	12	3	1.1	3	39
mswas01	Wasilla Cr.	6/18/2001	0	10	3	33	3	1.9	2	66
mswas01	Wasilla Cr.	6/23/2005	0	11	4	3	1	1.5	11	49
mswas01	Wasilla Cr.	6/2/2010	0	11	4	11	3	2.0	4	63
mswil04	Willow Cr.	5/13/1998	0	11	4	9	0	1.5	3	55
mswil04	Willow Cr.	7/13/2000	0	14	6	32	15	1.6	0	89
mswil04	Willow Cr.	6/4/2010	0	10	4	3	1	1.2	2	49

Table 3. Diatom multimetric index scores, including scores for constituent metrics, from Mat-Su-area streams sampled in 2010. Scores from previous samples collected at these sites are included for reference. N denotes nitrogen.

Station ID	Waterbody name	Date	Replicate	Percent motile	Organic N tolerance	Saprobity	Species richness	Trophic state	Multimetric index score
mswas01	Wasilla Cr.	6/23/2005	0	1	2.0	2.2	34	6.5	44
mswas01	Wasilla Cr.	6/2/2010	0	1	2.0	2.4	12	6.8	47
msmea01	Meadow Cr.	6/4/2010	0	0	1.7	2.0	16	5.7	66

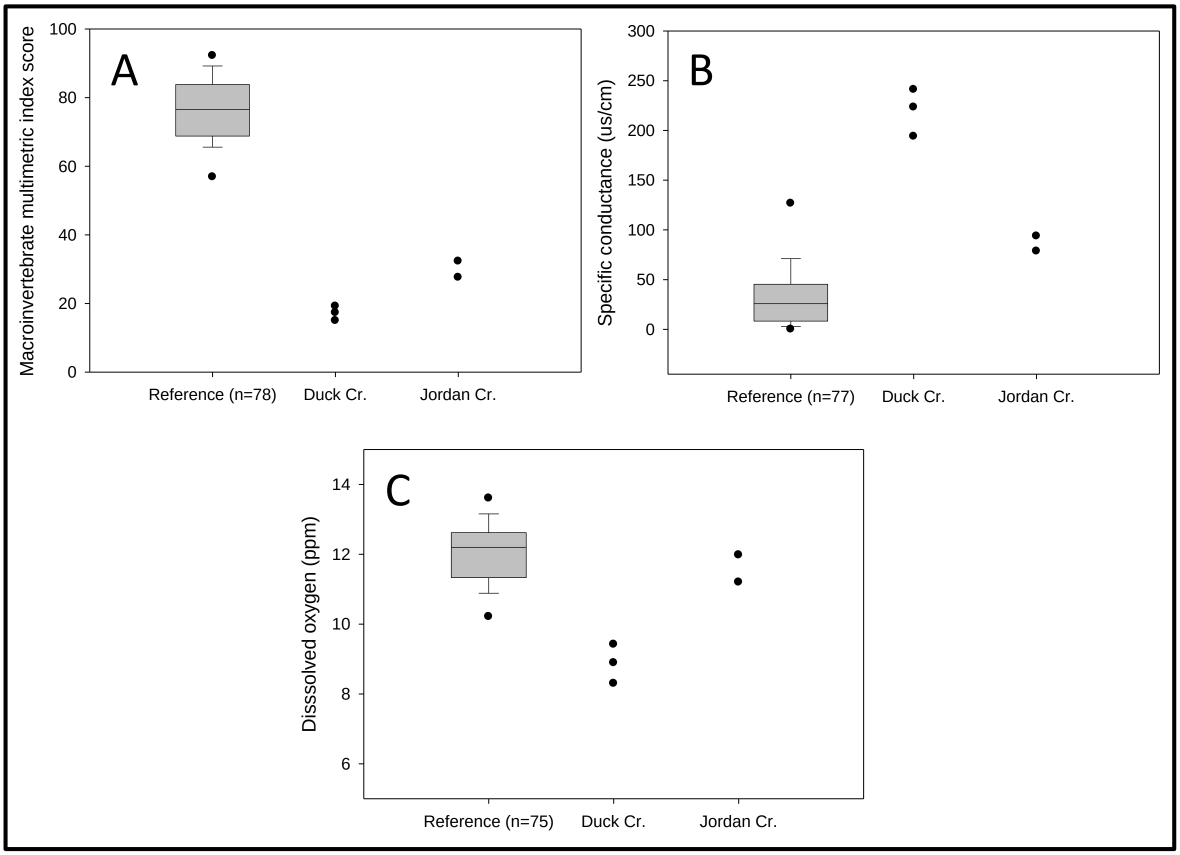

Figure 1. Current and previous macroinvertebrate multimetric index scores (A), specific conductance (B), and dissolved oxygen concentration (C) for Juneau-area sites sampled in 2010. Box and whisker plots represent the distribution of all reference site samples previously collected in the Alexander Archipelago ecoregion (2002 through 2004); the horizontal line indicates the median, the box indicates the 25th and 75th percentiles, the whiskers indicate the 10th and 90th percentiles, and the dots indicate the 5th and 95th percentiles. The 2002 Duck Creek macroinvertebrate samples replicated for quality assurance are averaged for this figure.

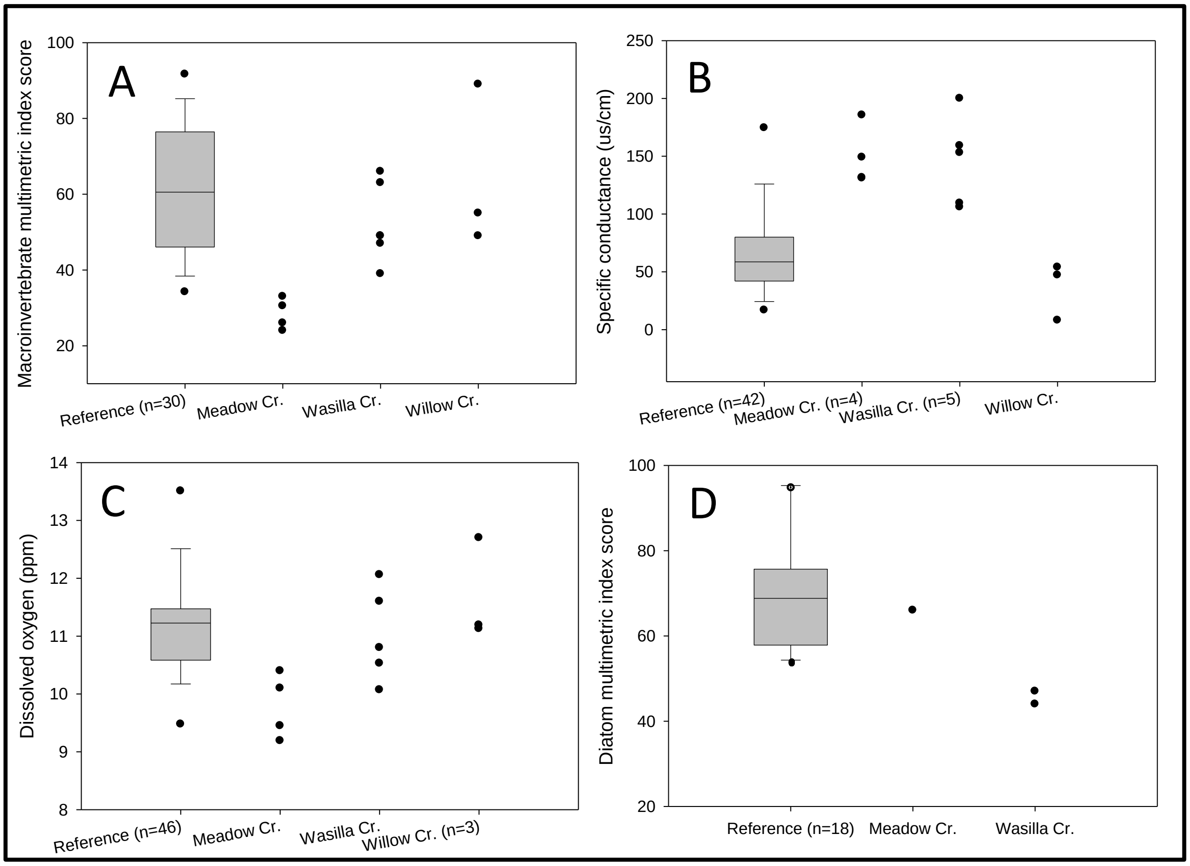

Figure 2. Current and previous macroinvertebrate multimetric index scores (A), specific conductance (B), dissolved oxygen concentration (C), and diatom multimetric index scores (D) for Mat-Su-area sites sampled in 2010. Box and whisker plots represent the distribution of all reference site samples previously collected in the Cook Inlet Basin ecoregion (1998 through 2006); the horizontal line indicates the median, the box indicates the 25th and 75th percentiles, the whiskers indicate the 10th and 90th percentiles, and the dots indicate the 5th and 95th percentiles. The 2000 Meadow Creek and the 1998 Wasilla Creek macroinvertebrate samples replicated for quality assurance are averaged for this figure.

LITERATURE CITED

Barbour, MT, J Gerritsen, BD Snyder, and JB Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish. U.S. Environmental Agency, Office of Water, Washington, DC. EPA 841-B-99-002.

Fore, L.S., and C. Grafe. 2002. Using diatoms to assess the biological condition of large rivers in Idaho (U.S.A.). Freshwater Biology 47: 2015-2037.

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: 429-433.

Karr, J.R., and E.W. Chu. 1999. Restoring life in running waters: better biological monitoring. Island Press.

Rinella, D.J., D.L. Bogan, K. Kishaba, B. Jessup, C. Hill, and S. Moegenburg. 2005. Development of a Macroinvertebrate Biological Assessment Index for Alexander Archipelago Streams – Final Report. Prepared for the Alaska Department of Environmental Conservation.

Rinella, D.J. and D.L. Bogan. 2007. Development of Macroinvertebrate and Diatom Biological Assessment Indices for Cook Inlet Basin Streams – Final Report. Prepared for the Alaska Department of Environmental Conservation.

USEPA. 2002. Biological assessments and criteria: crucial components of water quality programs. U.S. Environmental Agency, Office of Water, Washington, DC. EPA 822-F-02-006.

USEPA. 2003. Elements of a state water monitoring and assessment program. U.S. Environmental Protection Agency, Office of Wetlands, Oceans, and Watershed, Washington, DC. EPA 841-B-03-003.

USEPA. 2006. Wadeable streams assessment: a collaborative survey of the Nation’s streams. U.S. Environmental Protection Agency, Office of Research and Development, Office of Water, Washington, DC. EPA 841-B-06-002.