THE IMPORTANCE OF IDENTIFYING NATURAL VARIATION IN AQUATIC COMMUNITIES: THE THOMPSON CREEK MOLYBDENUM MINE EXAMPLE[1]

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Abstract: The monitoring of aquatic communities is a common way to assess impacts of human activities in a watershed. However, aquatic communities can show substantial temporal variability as the result of natural processes. A well designed monitoring program is necessary in order to identify the difference between potential impacts and natural variation. The Thompson Creek Molybdenum Mine is located in the Thompson Creek and Squaw Creek watershed in central Idaho. The monitoring program for the mine included upstream reference sites, and the sampling of multiple organisms with quantitative techniques over many years. Fish and macroinvertebrate data have been collected for these streams upstream and downstream of the mine site since 1980, which includes the period prior to construction through operation to present. Using this long-term data set and the Idaho Department of Environmental Quality (IDEQ) Water Body Assessment Guidance Document, the natural variation at study sites upstream of any potential mining impacts was compared to the variation at study sites downstream of the mining activities. For macroinvertebrate data, the IDEQ index varied from very good to poor among the various years in Thompson and Squaw creeks. The range of variability was similar at upstream reference sites and sites downstream of the mine. This analysis points out the importance of monitoring both reference sites and potentially impacted sites for long periods of time. Changes in the macroinvertebrate community which might have been attributed to the mine were likely the result of natural variation.

Additional Key Words: temporal variability, reference sites, Idaho, fish assemblage, macroinvertebrate assemblage, biological monitoring

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Introduction

In order to better meet the goals of the Clean Water Act of 1972, an effort has been made to incorporate the status of biological communities when assessing water quality. Chemical parameters have been measured by standard techniques for water quality monitoring for decades, but the more difficult task of preserving biological integrity has lagged behind. This has lead to a move by the U.S. Environmental Protection Agency (USEPA) to implement biological criteria to supplement standard water quality monitoring. ABiological criteria are numeric values or narrative expressions that describe the preferred biological condition of aquatic communities based on designated reference sites@ (Gibson *et al.*, 1996). Reference sites are sites where Aleast-impacted@ conditions exist and can be used as a benchmark to guide restoration and protection programs (Davis and Simon, 1995; Hughes, 1995). While the development and implementation of biological criteria programs has been slow, most states have developed biological assessment programs to measure biological integrity of water bodies, and the monitoring of aquatic communities is a common way to assess impacts as a result of human activities in a watershed.

The Idaho Department of Environmental Quality (IDEQ) has developed such biological assessment guidance to evaluate biological data to determine beneficial use support in Idaho waters (Grafe, *et al.*, 2002). One major concern of using multimetric biological assessment programs is how well the assessment programs deal with the substantial temporal variability in most aquatic systems associated with natural processes. The purpose of this paper is to present an assessment of how the IDEQ biological assessment program performed in the context of natural variability and what type of monitoring program is necessary to separate natural variability from actual impacts of anthropogenic stress based on annual biological monitoring data collected by Chadwick Ecological Consultants, Inc. since 1980 on Thompson Creek and Squaw Creek, tributaries to the Salmon River in central Idaho at both potentially impacted and reference sites.

Study Area

The Thompson Creek Molybdenum Mine is located in the Thompson Creek and Squaw Creek watersheds (Fig. 1). The open pit mine and the waste rock deposit areas are near the upstream reaches of Buckskin Creek and Pat Hughes Creek, tributaries to Thompson Creek. Buckskin Creek is a first-order tributary to Thompson Creek. Permitted Outfall 001 from the mine potentially could discharge into Buckskin Creek. Pat Hughes Creek is a first-order stream also flowing into Thompson Creek. Pat Hughes Creek could potentially receive Permitted Outfall 002 from the mine. Buckskin and Pat Hughes creeks do not directly receive active discharge from the mine. However, they do receive runoff associated with stormwater conveyance and drainage from the waste rock piles. Sediment control ponds are located on Bruno Creek downstream of the tailings impoundment.

Thompson Creek in the study area is a second-order stream, with a drainage area of approximately 75 km^2 and an average gradient of 2.5%. Its average width and depth are 4 m and 19 cm, respectively. The stream flows through a relatively narrow canyon in the study area, with an abundant riparian zone of willows and alders, providing shade and abundant leaf litter input.

Squaw Creek is also a second-order stream in the study area, with a drainage area of approximately 205 km^2 and an average gradient of 1.3%. It has an average width and depth in the study area of 6 m and 14 cm, respectively. Willows and alders are the predominant woody vegetation, but are not as abundant as the riparian area of Thompson Creek.

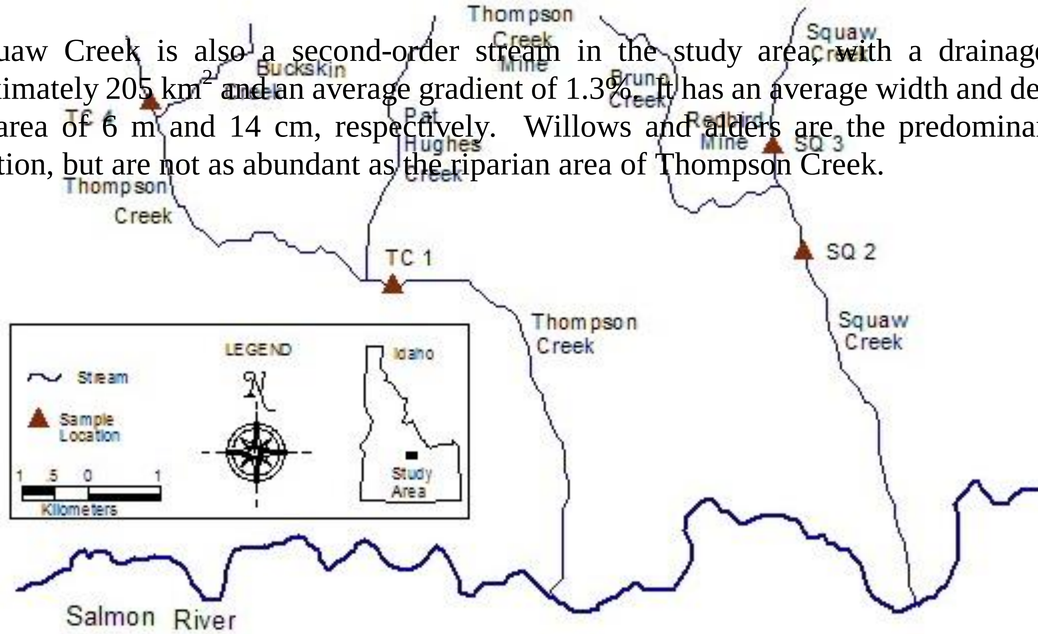

Figure 1: Locations of sampling sites on Thompson Creek and Squaw Creek, Idaho.

Two sampling sites are located on Thompson Creek as part of the long term monitoring program. The upstream site, TC-4, is located upstream of the confluence with Buckskin Creek (Fig. 1) at an elevation of 1,923 m, and serves as an upstream reference site to monitor natural variation in the aquatic community unaffected by Thompson Creek=s mining activities. The downstream site, TC-1, is located 4.5 km downstream of Site TC-4, and downstream of the confluence with Pat Hughes Creek (Fig. 1) at an elevation of 1,809 m. The site is located to monitor potential effects of drainage from the mine on aquatic biological populations in Thompson Creek.

Two sampling sites are located on Squaw Creek. The upstream reference site, SQ-3, is located adjacent to the inactive Redbird Mine at an elevation of 1,777 m, upstream of Bruno Creek and upstream of drainage from the mine (Fig. 1). The downstream site, SQ-2, is located downstream of Bruno Creek, and 2.4 km downstream of Site SQ-3 at an elevation of 1,740 m. This site serves to monitor potential effects of mining activity on aquatic biological populations in Squaw Creek.

Methods

Benthic macroinvertebrate data were obtained from annual biological monitoring which has been conducted seasonally at these four sites since 1980. Only summer data were used to match IDEQ protocol. Field methods used by CEC to collect macroinvertebrates are the same as IDEQ methods, so metrics could be calculated directly from raw CEC data. Benthic macroinvertebrates from Thompson Creek and Squaw Creek were sampled by taking three replicate samples from riffle habitat at each site using a modified Hess sampler with a mesh size of 500 µm (Canton and Chadwick, 1984). In the laboratory, organisms were sorted from debris, identified, and counted. Identifications were made to lowest practical taxonomic level using available keys.

Each of the nine macroinvertebrate metrics (Table 1) from the IDEQ stream macroinvertebrate index (SMI) was calculated individually for all years and summed to produce and index score based on the metric equations for the central and southern mountains ecoregion (Jessup and Gerritsen, 2002). In order to calculate total index scores, each individual metric was converted to an index score that ranged from zero to 100 (Table 1). The metric scores where then added together and divided by nine to get an overall SMI score that also ranged from zero to 100. The final score was then used to rate the site from very good to very poor (Table 2). Data were pooled for all metrics and years for each of the four sites to compare the distribution of the Thompson Creek and Squaw Creek reference sites with the potentially impacted sites.

Fish population data were obtained from biological monitoring which has been conducted at these four sites for 14 years between 1980 and 2000. The protocol developed by IDEQ requires single pass electrofishing data with a record of all fish species captured, length data for sculpins and salmonids, and electrofishing effort (duration in seconds). Not all years of data for Thompson and Squaw Creek met all of these requirements. Specifically, length data were not always recorded for salmonids and sculpins throughout the early years of the biological monitoring program. Additionally, effort was often recorded by distance and not by time. In order to calculate metric values for these years, missing values were estimated based on years when the data were recorded. For years missing the number of age classes of salmonids or sculpins, the final IDEQ stream fish index (SFI) score was calculated using values observed in other years in order to calculate a SFI score. For years missing catch per unit effort measured by time, a simple linear regression equation was calculated to estimate this value, based on years in which both time and distance measurements were available. These data were estimated to obtain a reasonable estimation of the variability associated with the sites, not to estimate a true representation of the biological integrity of these sites in years that had missing data.

Each of the six SFI metrics (Table 3) were calculated for all years and summed to produce an SFI score based on criteria from the mountain stream SFI developed for second-order streams in Idaho (Mebane 2002). The SFI was first evaluated by examining each metric individually. The distribution of each individual metric was compared between Thompson Creek and Squaw Creek reference sites and potentially impacted sites. In order to calculate total SFI scores, each individual metric was converted to an index score that range from zero to one. The metric scores were then added together, divided by six, and multiplied by 100 to get an final SFI index score that ranged from zero to 100.

TABLE 1: Metric scoring formulas for SMI metrics from central and southern mountain ecoregions. The 5th and 95th percentiles are based on the combined data from least impacted and stressed sites. Any scores that exceed 100 were reset to 100 (from Jessup and Gerritsen 2002).

Metric	Metric Scoring Formula	5th or 95th Percentiles
Total taxa	100 (ATotal taxa@/95th	40
Ephemeroptera taxa	100 (AEphemeroptera taxa@/95th	11
Plecoptera taxa	100 (APlecoptera taxa@/95th	9
Trichoptera taxa	100 (ATrichoptera taxa@/95th	10
% Plecoptera	100 (A% Plecoptera@/95th	25
Hilsenhoff Biotic Index	100 ((10 - AHBI@)/(10 - 5th)	2
% 5 Dominant taxa	100 ((100 - A% 5 Dominant taxa)/(100 - 5th)	53
Scraper taxa	100 (AScraper taxa@/95th	9
Clinger taxa	100 (AClinger taxa@/95th	21

TABLE 2: Rating categories for SMI are based on 25th percentiles of least impacted index scores (from Jessup and Gerritsen 2002).

	Central and Southern Mountains
Rating	SMI Range
Very Good (midpoint between 25th percentile and maximum index score to maximum score)	79 - 100
Good (25th percentile to midpoint between 25th percentile and maximum score)	58 – 78
Fair (upper trisect of minimum score to 25th percentile)	39 – 57
Poor (middle trisect of minimum score to 25th percentile)	19 – 38
Very Poor (lower trisect of minimum score to 25th percentile)	0 – 18

TABLE 3: Stream Fish Index metrics for small mountain streams (#2nd order) in the central and southern mountains ecoregion of Idaho (Mebane 2002).

Metric
1. Number of coldwater native species.
2. Percent as sensitive native individuals.
3. Number of salmonid age classes.
4. Number of sculpin age classes.
5. Percent as coldwater individuals.
6. Catch per unit effort (# of coldwater individuals/minute electrofishing).

Results

Macroinvertebrates

The SMI score incorporates all nine individual metrics into a final rating, which is used to determine if the benthic community is stressed. For the 20 years of macroinvertebrate data used in this analysis, total SMI scores ranged from a median value of 58.5 at Site SQ-3 to 72.7 at Site TC-4 (Fig. 2). These values are all within the Agood@ category as defined by the IDEQ (Table 2). Distributions of SMI scores were very similar for the two sites on Thompson Creek. Site TC-4, the upstream reference site has a higher median value but also had greater variation. For Squaw Creek, Site SQ-3, the upstream reference site actually had a lower median SMI score, but Site SQ-2 had greater variability.

Total SMI scores for Thompson Creek have varied between Afair@ and Avery good@ over the years for both Sites TC-4 and TC-1 (Fig. 2). Site TC-4 is upstream of any influence of mining activities. Therefore, this variation must be due to natural phenomenon (drought conditions, magnitude of spring runoff, floods, etc.) or disturbances in the watershed unrelated to the mine. Site SQ-2 has ranged from being rated as Avery good@ to Apoor@ over the years while Site SQ-3 upstream of mining activities has been less variable and been rated between Agood@ to Afair@ (Fig. 2).

Generally, the lowest SMI ratings occurred between 1988 and 1992 (Fig. 2) during low water flows for both reference and potentially impacted sites on both Thompson and Squaw creeks (CEC 2001). This suggests the SMI may not be able to discriminate subtle natural and anthropogenic disturbances to the aquatic community. If a site appears to be impaired based on SMI scores, it cannot be assumed that human induced disturbance is responsible for the low rating. The two sites on each stream did not seem to respond consistently with each other and demonstrated considerable variation between sites on a given stream. This points out the considerable variation associated with benthic communities in mountain streams and demonstrates the uncertainty associated with numeric biological criteria.

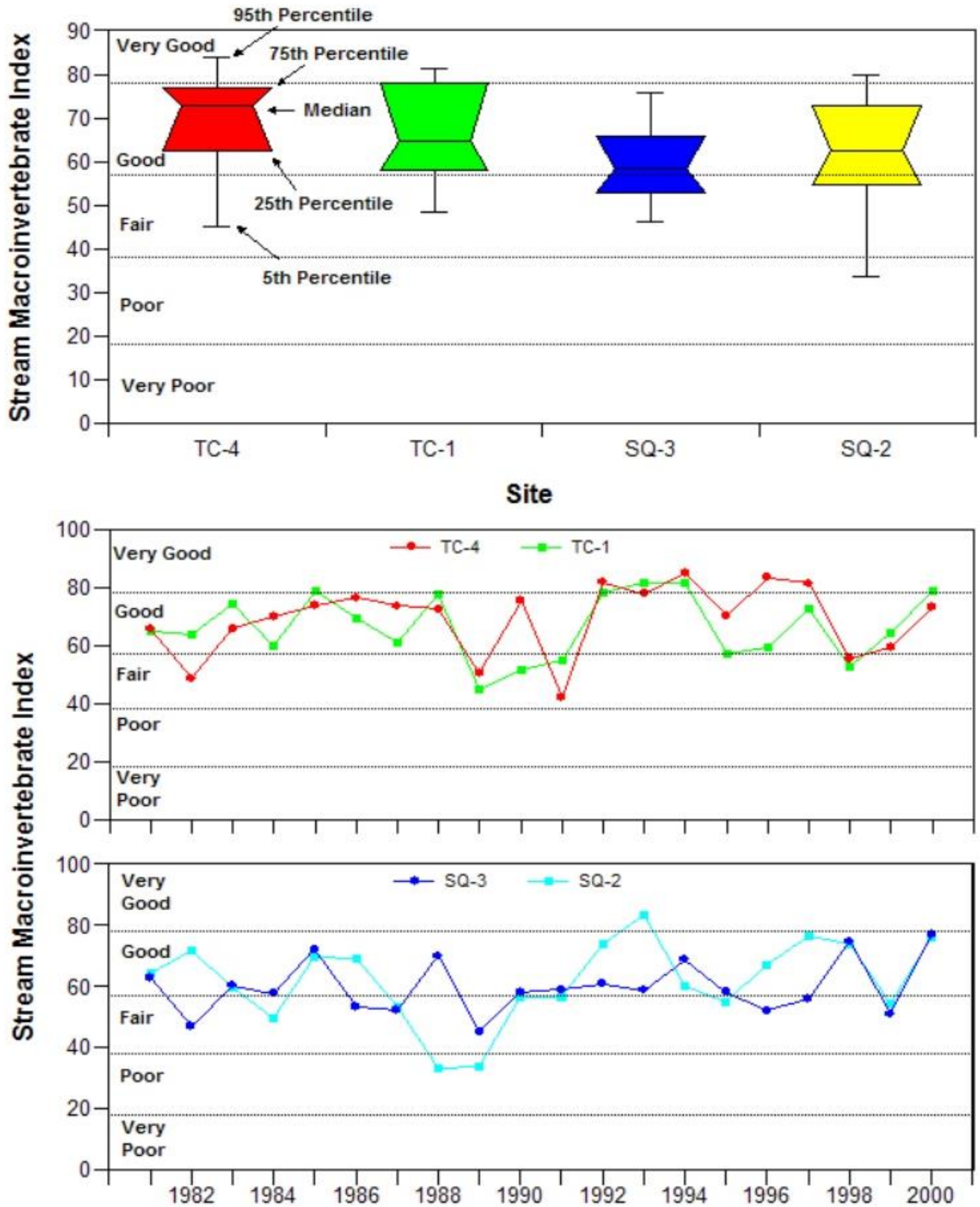

Figure 2: Top: Box Plots showing median and percentiles for the Stream Macroinvertebrate Index (SMI) from study sites on Thompson Creek and Squaw Creek. Middle and Bottom: Total SMI scores from study sites on Thompson Creek and Squaw Creek from 1981 to 2000.

Fish

The SFI score incorporates all six individual metrics into a final rating, which is used to determine if the fish community is impacted. For the 14 years of fisheries data used in this analysis, total SFI scores ranged from a median value of 91.7 at Site TC-4 to 95.8 at Site SQ-3 (Fig. 3). The lowest index score was 81.2 at Site TC-1. Distributions of SFI scores were very similar for all four sites (Fig. 3).

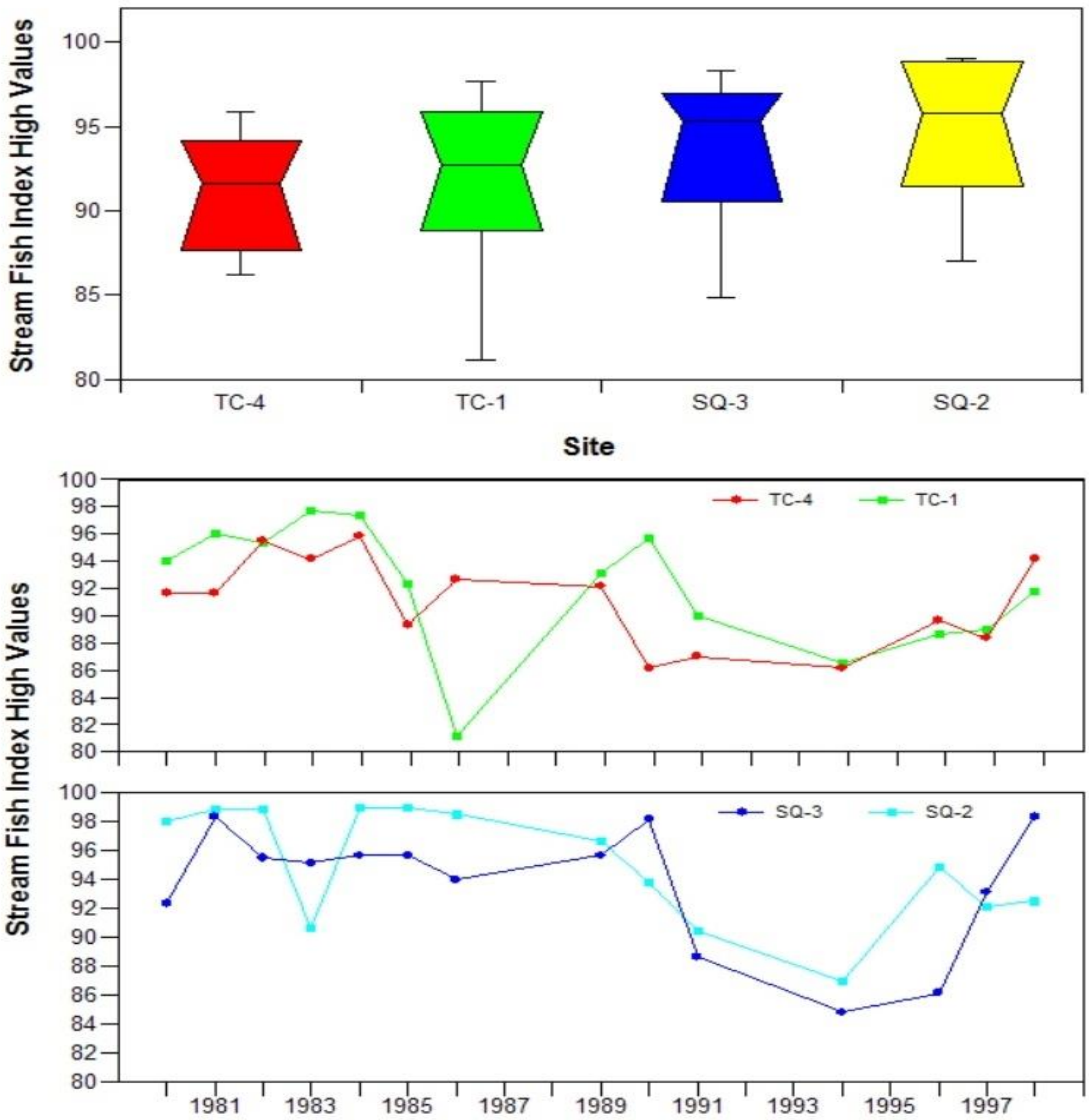

Figure 3: Top: Box Plots showing median and percentiles for the Stream Fish Index (SFI) from study sites on Thompson Creek and Squaw Creek. Middle and Bottom: Total SFI scores from study sites on Thompson Creek and Squaw Creek from 1980 to 1998.

Total SFI scores have varied little over time on Thompson Creek or Squaw Creek. Site SQ-2 showed a sharp decline in 1983 (Fig. 3), and both Squaw Creek sites showed a general decline in 1990 and 1991 and remained lower in 1994. Site TC-4 showed a decline in 1985 and values were once again lower for 1990, 1991, and 1994 (Fig. 3). The site downstream of mining activities, Site TC-1, showed a sharp decline in SFI scores in 1985 and 1986. The magnitude of these changes in total SFI scores was minimal as no score at any site in any year ever decreased below 80. These very high SFI scores seen at all sites for all years on Thompson and Squaw Creek indicate that these streams have shown no indications of impacts over the monitoring period.

Conclusions

It is apparent from the analysis of the SMI that all of the sites on Thompson Creek and Squaw Creek resembled data from least-impacted sites around the state of Idaho based on the high scores seen at all sites over most years. Interestingly, median values for most SMI metrics were generally lower at both sites on Squaw Creek compared to the sites on Thompson Creek. In addition, only half the time did the reference sites score higher than potentially impacted sites for both streams. Often times, a site changed categories (good to fair to good) from one year to the next. This occurred both at reference sites and potentially impacted sites, indicating that natural variation alone is sufficient to cause a site to change categories through time.

For the SFI, very high scores were seen at all sites for all years on Thompson Creek and Squaw Creek. These data indicate that the SMI is more susceptible to natural variation than the SFI. The purpose of this paper is not to endorse nor criticize the IDEQ biological assessment procedures. Rather, we simply point out that such multimetric assessments can be misleading if not put in the proper context of natural variability. In order to correctly use the results of multimetric assessments, proper placement of reference sites and sufficient long-term data must be collected.

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