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SEASONAL CORRECTION FACTORS FOR THE BIOTIC INDEX[1]

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ABSTRACT

For evaluation of streams with the biotic index (BI), samples of arthropods should be collected in the spring before degree day accumulations of mean air temperatures above 4.5°C reach 440° in warm-water streams, and before they reach 1050° in cold-water streams that remain below 20°C. Sampling in the fall may be resumed 60 days after the 440 degree day accumulation in warm-water streams and 45 days after the 1050 degree day accumulation in cold-water streams. Stream temperature had no effect on the BI, except as it affected seasonal differences. Current had less effect on the BI than anticipated, but currents below 0.3 m/sec should be avoided.

The arthropod biotic index (BI) was developed to evaluate organic and nutrient pollution, which causes depletion of oxygen in streams and alters their fauna (Hilsenhoff 1977, 1982a, 1987). Dissolved oxygen levels often determine which species of arthropods are able to live in a stream, with current and water temperature being important related factors. Rapid currents transport more oxygen past insects making dissolved oxygen more available, while higher temperatures increase metabolism and the need for oxygen. In summer, dissolved oxygen in streams reaches its lowest levels because warm water holds less oxygen, nocturnal plant respiration reaches a maximum, and aerobic decomposition of organic matter is also at its maximum. To avoid summer stress from low dissolved oxygen, higher summer metabolic rates, and often low water levels, many insects have resistant eggs or nymphs that pass the summer in diapause. Arthropods that are collected in summer tend to be more tolerant of low dissolved oxygen and have higher tolerance values, causing BI values to be higher in the summer (Hilsenhoff 1982a, 1987). In 1984 I began a study to develop seasonal correction factors and to evaluate possible effects of current and temperature.

MATERIALS AND METHODS

Seasonal Correction Factors. Six streams in southern Wisconsin were chosen for study. Two were unpolluted second order streams, Otter Creek being a spring-fed woodland stream and Trout Creek flowing through open country and having a large inflow of spring water about 0.5 km above the sampling site. The Sugar River and Narrows Creek are third order streams that were polluted to different degrees by pasturing of cattle. Badfish Creek is a third order stream that receives the effluent of the Madison Metropolitan Sewerage District, and the West Branch of the Pecatonica River is a second order stream, with my sampling site being 2 km downstream from the Cobb sewage

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treatment plant and 50 m downstream from an area where both hogs and cattle have access to the stream. All except this last sampling site were described previously (Hilsenhoff 1977, 1982b).

Samples of 100+ arthropods were collected from each of three riffles in each stream at 2-week intervals from 18 April to 23 November 1984 and 16 April to 13 November 1985. Some intervals exceeded 2 weeks in 1984 because storms or high water prevented sampling on intended sampling dates. Samples were collected and processed, and the BI calculated as outlined by Hilsenhoff (1987).

Effects of Temperature. Samples were collected from each of three riffles in Sidney Creek on 20 June, 1 August, and 18 October 1984 and less than one hour later from each of three riffles 7 km downstream in the North Branch of the Pike River. Sidney Creek is a cold, second order stream that joins with Macintire Creek to form the North Branch of the Pike River in a relatively uninhabited area of Marinette County, Wisconsin. Both sampling sites had similar substrate and current, but there was a 7°C difference in summer water temperature due to warming in two small impoundments between the sampling sites.

Effects of Current. The BI of four replicate samples from riffles with a current of 0.50 m/sec were compared with four replicates with a current of 0.25 m/sec in collections 23 October 1985 from two central Wisconsin streams, the Mecan River in Waushara County and the Poplar River in Clark County. Similar replicate samples 7 November 1985 from two northern Wisconsin streams, the Little Jump River in Price County and the North Branch of the Pike River were also compared. The current was measured 10 cm above the substrate with a pygmy current meter. On 18 September 1985, during low flow, current was measured in each of three riffles sampled in six study streams being evaluated for seasonal correction factors. The BI at each riffle was compared on the last five sampling dates in 1985.

RESULTS AND DISCUSSION

Seasonal Correction Factors. Developmental rates for most stream arthropods are related to temperature and food, with temperature influencing the production of food and being the factor that varies most from year to year. Temperature influences dates of emergence of most insects, especially in spring, and may also determine hatching dates of eggs in spring. Since seasonal succession of stream arthropods in spring is mostly related to changing temperature, and since these changes in community structure are reflected in the BI, correction factors must be tied to changes in stream temperature, or air temperature, which is directly related to stream temperature. In autumn, daylength is likely the most important factor in determining when the diapause of eggs or nymphs is broken, although temperature may also be a factor (Tauber et al. 1986).

Because mean daily air temperatures are readily available in all areas, BI values of the six study streams were compared with degree day accumulations of daily mean air temperatures at Madison, which is within 100 km of all of the streams. A base temperature of 4.5°C (40°F) was chosen arbitrarily. This is somewhat lower than the base temperature used for predicting development of most terrestrial species that are agricultural pests, but the results differed very little from results achieved when a base of 10°C was used. Some insects, such as species of Capniidae and Taeniopterygidae (Plecoptera) and *Prosimulium* (Diptera: Simuliidae) grow rapidly at much lower temperatures, but most aquatic arthropods tend to feed and develop only after water temperatures have warmed in the spring. Temperature and other factors influencing life history patterns of aquatic insects were reviewed by Sweeney (1984).

In 1984, degree day accumulations were very nearly normal (Fig. 1). BI values for each of the four warm-water streams increased sharply in early June, declined to normal levels in early August, and rose again in late October and November as summarized in Figure 1. In the two cold-water streams, which had summer maximum temperatures below 20°C, BI values were higher from mid-July through August, and then declined steadily (Fig. 1).

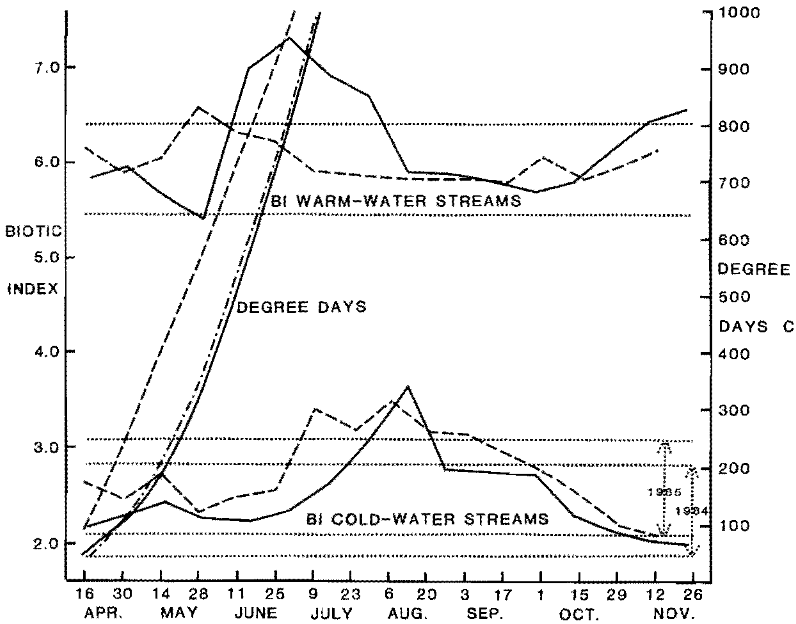

Figure 1. Mean biotic index values of four warm-water streams and two cold-water streams in 1984 (solid lines) and 1985 (dashed lines), with 95% confidence limits (dotted lines) for the mean of the lowest 75% of biotic index values. Comparison of degree day accumulations of mean air temperatures above 4.5°C in 1984 (solid line) and 1985 (dashed line) with 1951–1980 average (dot-dash line).

In the spring of 1985, temperatures were much above normal and degree day accumulations were about 3 weeks ahead of 1984 in May and about 2 weeks ahead in June (Fig. 1). In warm-water streams the impact on the BI was much less than in 1984 and occurred about 3 weeks earlier, while the effect on the BI of cold-water streams was similar to 1984 and also occurred about 3 weeks earlier (Fig. 1). Examination of the data suggests that differences between 1984 and 1985 in warm-water streams were due to differences in emergence and recruitment times of arthropods, with the warm weather in 1985 accelerating emergence and recruitment more in some species than in others. A mean BI that is believed to be representative of the BI during most of the year was calculated from the 12 lowest spring and fall samples each year for the four warm streams and the two cold streams, the four summer samples with abnormally high BI values not being used. Based on a standard deviation of 0.25 for all replicates, it was determined during which period of the year the BI exceeded the 95% confidence limits ($\pm$ 0.48) of these mean BI's (Fig. 1). The mean BI for warm streams was 5.92 in both years, but in the cold streams it was 2.34 in 1984 and 2.59 in 1985. The higher value in 1985 was due to elevated BI values for Trout Creek from late August to mid October, a phenomenon that was never observed during a previous 5-year study of this stream (Hilsenhoff 1982b) and which I believe was due to recent pollution upstream.

Because of the disparity of the data in the two study years it is not possible to formulate a correction factor that will work well in both years. The best solution is to use the BI to evaluate streams only in the spring and fall of the year. In spring, samples should be collected from warm-water streams before 440 degree days C have accumulated using 4.5°C as the threshold mean temperature (800 degree days F using 40°F). Samples may

Table 1. Analysis of variance of biotic index values of arthropod samples collected from Sidney Creek and the North Branch of the Pike River, Marinette County, Wisconsin, in 1984.

	Mean Biotic Index			
Date	Sidney Cr.	N. Br. Pike R.	SD	F
June 20	2.97	2.35	0.17	19.67[a]
Aug. 1	2.04	3.04	0.14	74.38[a]
Oct. 18	2.50	2.11	0.41	1.38

[a] $p = 0.05$

Table 2. Analysis of variance of biotic index values of arthropod samples from currents of 0.25 m/sec and 0.50 m/sec in four Wisconsin Streams.

	Mean biotic Index			
Stream	0.50 m/sec	0.25 m/sec	SD	F
Mecan R.	2.00	3.03	0.25	34.84[a]
Poplar R.	3.81	4.31	0.30	5.45
N. Br. Pike R.	2.42	2.78	0.38	1.69
Little Jump R.	3.52	3.56	0.27	0.06

[a] $p = 0.01$

be collected from cold-water streams until degree day accumulations reach 1050°C (1900° above 40°F), with cold-water streams being defined as streams in which afternoon water temperatures in summer remain below 20°C. Sampling may be resumed in the fall 60 days after the 440 degree days C have been reached in warm-water streams and 45 days after the 1050 degree days C have been reached in cold-water streams. This procedure should avoid exceeding the 95% confidence limits for the BI. Sampling after 1 November should probably also be avoided because BI values of warm-water streams tend to be abnormally high, and those of cold-water streams abnormally low. If samples must be collected during periods when BI values are abnormally high, subtracting 0.50 will not reduce the BI value below the lower confidence limit and will bring BI values more in line with those that would be obtained during the recommended sampling period. These recommendations are based on studies in an area where most streams freeze in winter, and may not be applicable farther south.

Effects of Temperature. The 7°C difference in temperature caused a significant difference in the BI of the two streams in June and August, but not in October (Table 1), with the BI of Sidney Creek being lower than that of the North Branch of the Pike River in June and higher in August. This was probably due to the normal seasonal variation in the BI, which causes cold streams (Sidney Creek) to have elevated BI values in late July and August, and warm streams (North Branch of the Pike River) to have elevated values in June and July. Stream temperature does not appear to affect the BI, except for its influence on seasonal differences.

Effects of Current. Mean BI values were always higher at currents of 0.25 m/sec than at 0.50 m/sec, but the differences were statistically significant only in the Mecan River (Table 2). Differences in mean BI values of the Little Jump River and North Branch of the Pike River were less than 0.36, probably because samples were taken when water temperatures were at 0°C, dissolved oxygen levels were at saturation, and most arthropods had probably ceased feeding and moved to overwintering sites.

In four of the six streams studied for seasonal correction, there was a significant

Table 3. Analysis of variance of biotic index values of arthropod samples from three riffles with varying currents at low flow in six Wisconsin streams at 2-week intervals from 18 September to 13 November 1985.

	Current m/sec			Mean BI				
Stream	1	2	3	1	2	3	SD	F
Otter Cr.	0.42	0.53	0.75	2.08	1.83	2.06	0.27	1.37
Trout Cr.	0.87	0.81	0.59	3.83	3.33	2.73	0.46	7.23[a]
Sugar R.	0.47	0.38	0.56	5.27	5.62	5.19	0.24	4.49[a]
Pecatonica R.	0.68	0.61	0.65	5.41	5.92	5.82	0.16	14.68[b]
Badfish Cr.	0.48	0.64	0.66	7.11	6.87	7.08	0.17	3.12
Narrows Cr.	0.81	0.81	0.71	7.85	7.41	7.13	0.32	6.36[a]

[a] $p = 0.05$
[b] $p = 0.01$

difference in BI values of the three riffles that were compared from September through November 1985, but these differences appeared to be related to differences in the microhabitats of each riffle rather than current, with the slowest current having the highest BI in two streams and the lowest in the other two (Table 3). Proximity of macrophytes to one or two riffles was likely a factor in two of the streams. Current appears to have less influence on the BI than previously thought, but sampling in currents of less than 0.3 m/sec is not recommended, and could result in erroneously high BI values.

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