Burrowing Mayflies (*Hexagenia*) as Indicators of Ecosystem Health

Thomas A. Edsall and Carol C. Edsall, U. S. Geological Survey, Great Lakes Science Center, 1451 Green Rd., Ann Arbor, MI 48105, *thomas_edsall@usgs.gov*

ADULT

NYMPH

Hexagenia limbata

BACKGROUND

USEPA and Environment Canada have hosted three State-of-the-Lake Ecosystem Conferences (SOLEC) since 1996 to encourage the development of indicators of ecosystem health.

SOLEC indicators will be used to report to the International Joint Commission and the public on progress made in restoring the chemical, physical, and biological integrity of the Great Lakes, as called for in the Great Lakes Water Quality Agreement.

CHOOSING A SOLEC INDICATOR

We selected *Hexagenia* because it:

- was historically abundant in major Great Lakes mesotrophic environments,
- is intolerant of and was extirpated by pollution in most of those environments in the 1940s-50s,
- has recovered in one of those environments following pollution abatement,
- is ecologically important as a trophic indicator, linking detrital energy resources directly to the many fishes that feed on *Hexagenia*, and
- has highly visible mating swarms that can tell an informed public that the water body supporting the nymphal population is healthy.

CHOOSING AN INDICATOR METRIC

We chose mean annual biomass (B) and annual production (P) as the primary metrics for indicator development because:

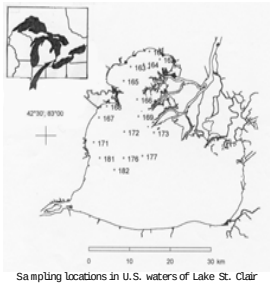
- B can be used directly as an indicator and because it is used to estimate P,
- P integrates recruitment, growth, mortality, and
- when P is considered with B, it provides a measure of turnover (P/B), which can be substantial in *Hexagenia* populations.

USE OF THE SIZE-FREQUENCY METHOD FOR ESTIMATING B AND P

We used the size-frequency method for estimating P because:

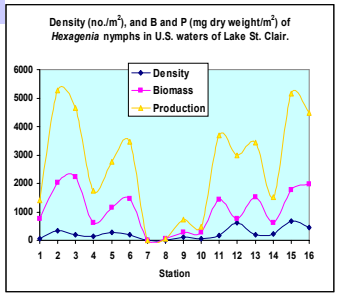
- it is widely used for that purpose and permits direct comparison of results with most other studies.
- does not require the identification of cohorts to produce reliable results, and
- can be applied to samples containing more than one *Hexagenia* species, if they have the same life span and maximum body size.

A study conducted in the U. S. waters of Lake St. Clair illustrates the use of the size frequency approach for estimating B and P in *Hexagenia*. Lakebed sediments were sampled with a Ponar grab at 16 stations monthly during the ice-free portion of one 12-month period.



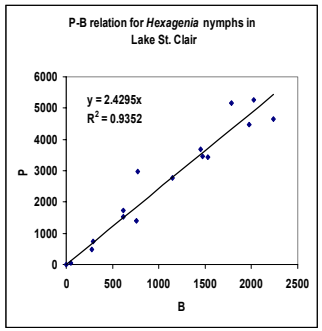
Sampling locations in U.S. waters of Lake St. Clair

Each sample was washed on a fine-mesh (0.65-mm) sieve. Nymphs and extraneous particulate material (detritus and sediment) retained on the sieve were placed in a sample jar with formalin and taken to the laboratory for further processing. Nymphs were extracted manually and measured (total length to nearest 0.5 mm). Lengths were converted to dry weights using equations from the literature. Annual production (P) and its variance were estimated with the size-frequency method of Hynes, as modified by Hamilton (1969), and a cohort production interval (Benke 1979) consistent with a 2-year life cycle (365 * 2 = 730). Study results are shown in the next figure.

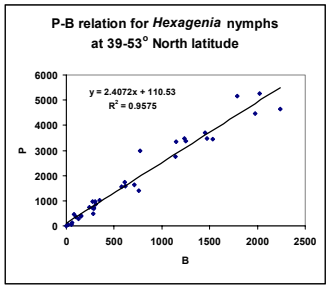


The absence of nymphs at stations 7 (167) and 8 (168) was due to pollution by metals, oil, and sewage from a major tributary. Low density (D), B, and P at stations 9 (169) and 10 (171) were due to unfavorable sediment type.

The high D, B, and P values at the other stations reflect a healthy environment. D was weakly correlated with B and P (R^2s = 0.25 and 0.49, respectively). P and B were strongly correlated (R^2 = 0.94) as shown in the next figure.



Adding the P and B data for other North American populations of *Hexagenia* at 39-53° North latitude improved the fit slightly to R^2 = 0.96, indicating the relation could be applied broadly to estimate P in North America (see Edsall et.al. 2001. J. Great Lakes Res. 27:449-456, for data sources).



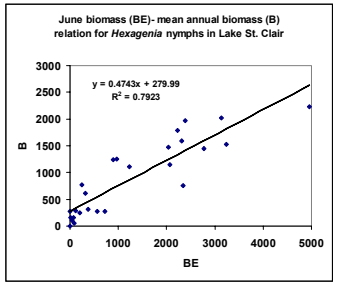
A PROBLEM WITH THE SIZE-FREQUENCY APPROACH

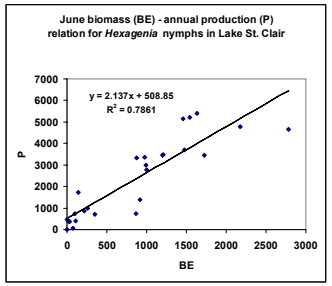
Sample collection and processing are labor intensive because:

- monthly sampling is needed for the ice-free portion of a 12-month period,
- the fine-mesh sieve collects extraneous material, which prolongs sample washing and impedes extraction of smaller nymphs, and
- measuring large numbers of small nymphs is time consuming.

A SIMPLIFIED, COHORT-BASED METHOD FOR ESTIMATING P AND B

Regression analysis of the size-frequency data from Lake St. Clair showed that the biomass in June of the emergent cohort (BE; nymphs > 18 mm, total length) could be used to estimate B and P (R^2 = 0.79), as shown in the two following figures.

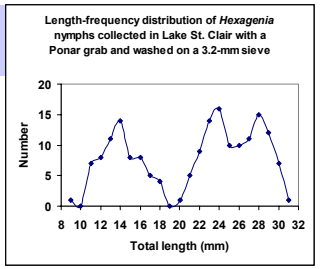




To verify this cohort-based approach, we collected 25 sediment samples with a Ponar grab at one location in Lake St. Clair in June and washed them on a coarse (3.2-mm) sieve (standard one-eighth inch hardware cloth). We selected the coarser sieve to eliminate the small nymphs and extraneous particulate material while retaining the nymphs of the emerging cohort.

The 3.2-mm sieve test results showed:

- small nymphs and extraneous material passed quickly through the sieve, and
- the sieve retained all of the nymphs of the 1998 cohort that were about to emerge (nymphs > 19 mm, total length) and also many of the nymphs (9-18 mm, total length) of the cohort that would have emerged the following year (see following figure).



Thus, washing the samples on the 3.2-mm sieve:

- yielded samples that could be used with confidence to estimate B and P, and
- substantially reduced the sample processing time in the field and laboratory as detailed in the following table.

Location & task	Size-frequency method	Cohort-based method
Field	(0.65-mm sieve)	(3.2-mm sieve)
Wash and preserve sample	Up to 10 mins	<5 mins (includes extracting nymphs)
Laboratory		
Extract nymphs	Up to 2 days	Done in field
Measure nymphs	Up to 1 hour	<5 mins
Get dry weight of sample	Calculated from length data	Direct weighing; about 5 mins
Data entry	1 value/nymph	1 value/sample

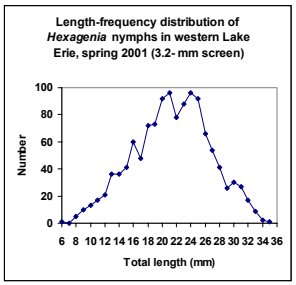
USE OF THE COHORT-BASED APPROACH

We used the cohort-based approach in spring 2001 to monitor *Hexagenia* populations in western Lake Erie. We established a sampling grid with 8-km-square cells as shown in the following figure.

Sampling grid, western Lake Erie

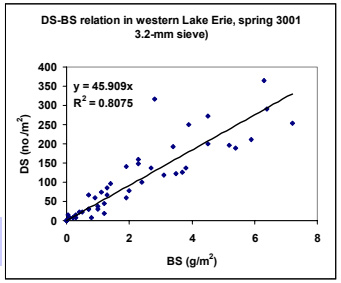
One sampling station was located in each of 49 cells where the cell area was >50% water and the substrate was mud or mud and fine sand, the substrate preferred by *Hexagenia*. We collected the samples with a Ponar grab, washed them on a 3.2-mm sieve and took the nymphs to the laboratory for further processing.

Problem: As shown in the following figure the length-frequency data for the nymphs did not let us separate the emerging cohort from the cohort that would emerge the following year.



Solution: We used all of the nymphs in the sample (both cohorts combined) to develop the metric.

Result: Regression analysis showed that spring density (DS) and spring biomass (BS) for the two cohorts combined described a straight line with an R^2 of 0.81 (see next figure)



SUMMARY AND CONCLUSIONS

The size-frequency method provides reliable estimates of B and P, but is labor intensive and would be expensive to use in routine monitoring.

The cohort-based method can provide rapid, reliable estimates of B and P, if the cohorts can be easily and reliably separated. However, if cohort separation is not feasible, either DS or BS can be used as the monitoring metric for reporting on population status and trends.

If DS is used the nymphs on the screen can simply be counted and recorded in the field and the sample discarded without further processing, thus greatly reducing sample processing time.