THE POSSIBILITIES OF MAYFLY FAUNISTICS TO INDICATE ENVIRONMENTAL CHANGES OF LARGE AREAS

Vladimír Landa and Tomás Soldán

Institute of Entomology,
Czechoslovak Academy of Sciences,
Branisovská 31, 370 05 Ceské Budějovicê,
Czechoslovakia

ABSTRACT

Based on extensive faunistic research carried out in the Elbe Basin, Czechoslovakia (about 50,000 km2) an attempt has been made to define trends and priorities in using mayflies to determine environmental changes. The following aspects are emphasized and discussed in detail: (i) selection of localities, and techniques and frequency of sampling; (ii) species and/or faunal components analysis; (iii) quantitative analysis and changes of dominant and subdominant species; and (iv) some possibilities of multivariate statistical analysis. Mayflies are shown to be a very reliable indicator of environmental changes provided that there is a really competent and long-term system of acquiring field data. Examples of environmental changes indicated by qualitative and quantitative shifts in mayflies in the Elbe Basin in 1950-1965 and 1970-1985 are presented. The possibilities of using mayfly entomofaunistics in some international research programs (e.g. IUBS, UNESCO-MAB, SCOPE or ICSU - Global Changes) are discussed.

DISCUSSION

The questions of environmental changes at both regional and global levels represent a priority interest of mankind. Their study requires perfect knowledge of the effects of toxic substances on organisms, populations and ecosystems and, on the other hand, a definition of measures restricting these undesirable tendencies. Numerous international programs are focused on the collecting of data with respect to the above intentions, for example, the IBP program organized by the IUBS in the 1960's, the MAB program of UNESCO carried out during the past 20 years and its new present orientation, or SCOPE projects specializing in the cycling of geobiogenic elements, heavy metals and others. The program of IIASA are aimed at investigating human impact on the environment using methods of system analysis and different scenarios. An extensive, comprehensive program is Global Changes by ICSU.

From all these projects and research programs ensue, of course, complex results. However, they definitely require knowledge at all levels: effects of toxic or - more precisely, biologically active substances on organisms, populations and communities. The Ephemeroptera and especially their larvae possess many advantages from this point of view: (i) they represent a phylogenetically very old and differentiated order; e.c. it contains many species of different body organization and different ecological requirements, which very sensitively reflect various conditions and environmental effects; (ii) mayflies as an order are relatively well known from the taxonomical, morphological and ecological points of view; (iii) nearly all species feed on detritus so that they are often affected even by very low doses of toxic substances entering the environment; (iv) their development is relatively long (especially in so-called "winter" species), so that mayflies can indicate really long-term changes; (v) mayflies are included and "indexed" in most of the biotic index systems, e.g., in the saprobial system (Zelinka & Marvan, 1961) and others which are usually very simple to use (cf. Sládecek, 1973), and (vi) mayflies live just in waters which are the most valuable from environmental and/or practical points of view (sources of drinking water).

The basic faunistics of mayflies represent the first step in their use for the monitoring of environmental changes in large areas. However, although the level of "normal" faunistics is very important for taxonomy or even biogeography this type of study cannot meet all the requirements of environmental monitoring. As concerns faunistics, whose data should be used for environmental studies, the following aspects should be carefully considered:

(i) Selection of localities. Localities should be numerous (optimal selection represents more than 20-25 % of 10 x 10 km squares of uniform grid system) and especially places with pronounced environmental changes (e.g., rhithron-potamon alternations) should be sampled at more collection sites. All types of aquatic biotopes (springs, streams, rivers, brooks, lakes etc.) and all the altitudinal zones must be investigated proportionally according to their quantitative presentation and actual area.

(ii) Collecting methods should be quantitative but simple and not time-consuming. The most effective ones seem to be the time-limited "kitching" technique or the use of benthometers.

(iii) In order to investigate all the seasonal aspects selected localities should be sampled at least 4-5 times a year.

During a long-term, extensive faunistic program on aquatic insects carried out in Czechoslovakia for more than the past thirty years we have collected samples of over 600,000 larvae from 2,087 localities (75.9 % of uniform grid system in Czechoslovakia). Of these, 150 localities of the Elbe Basin (about 50,000 km2) were investigated in two cycles (1950-1965 and 1970-1985) once a month (for details see Landa & Soldan, 1989).

The method of further study of the samples is the most important step in evaluating the faunistical result. We suggested that three groups of methods be used more or less independently:

(i) Species and/or faunal components analysis. Although classifications of species to faunistic elements are of limited use in the monitoring of large area changes, some elements (e.g., more vulnerable oreotundral and eremial species) seem to be much more useful indicators than species with large ranges or most of the arboreal species. Environmental changes can be evaluated according to pulsation of the area (restriction, extension, no or slight changes - for details see Landa & Soldan, 1985). On the other hand, just a simple comparison of the average number of species per locality can signalize serious environmental changes in a large area. For instance, with several exceptions (e.g., biotopes of the "roach" zone) these average numbers decreased rapidly during the second phase of our investigations (1970-1985) in Czechoslovakia: from 4.85 to 3.89 species per locality in the Elbe Basin, from 6.91 to 6.34 in the Danube Basin, and from 5.14 to 4.29 in Czechoslovakia generally. This decrease is apparently higher in lowland waters owing to cumulative pollution in all 17 faunistic districts (for details see Table 1).

(ii) Quantitative analysis should contain at least the following approaches: a) subgroup analysis of abundance according to an objectified scale; usually very few species are really common or dominant. In Czechoslovakia only 5 % of 110 species are really common (e.g., Baetis rhodani, Baetis vernus, Ephemerella ignita, and others), about 20 % of the species are abundant, about 35 % are moderate to scarcely distributed and the rest are of solitary occurrence;

b) subgroup analysis of quantitative representation at least of dominant and subdominant species. Table 2 presents an example of changes in 7 faunistic districts in the Elbe Basin in Czechoslovakia (note progressive increase in representation of dominant species and much smaller changes of species with representation up to 1-3 %);

c) the use of common general quantitative indexes and study of community composition. In Czechoslovakia (Elbe Basin with 150 selected localities) the Shanon-Weaver diversity index decreased at 150 localities in 1970-1985 in comparison with the period from 1950-1965. However, vertical changes of communities are usually correlated with indexes of diversity only at unpolluted localities. Polluted and strongly man-influenced localities exhibit a pronounced tendency in index diversity decrease and tendency to constitute azonal communities. A common and very informative quantitative index is the ratio Baetidae : Heptageniidae. This index usually decreases progressively with decreasing altitude of localities (cf. Devan & Mucina, 1985);

d) the use of specialized indexes, usually according to national standards. In Czechoslovakia we used the index of saprobity according to Pantle-Buck. Of the 150 selected localities, at least 53 showed permanent decrease of water quality (increase of the index of saprobity). Twenty to 30 profiles where pronounced shifts of saprobial index values have been ascertained can be assigned to heavily polluted ones, and further deterioration of water quality resulting in total elimination of mayfly fauna can be expected soon. Other examples of specialized indexes have been presented e.g. by Armitage *et al.* (1986); Frutiger (1985) and others.

(iii) Multivariate analysis. There are many appropriate methods and computer programs for these methods. We have used the following combinations: agglomerative hierarchic classification, divisive hierarchic classification, and ordination of localities and species. Detailed results have been published elsewhere (Leps *et al.*, 1989). Agglomerative hierarchic classification shows the most pronounced environmental change (shifts and fusions of clusters in dendrograms). Divisive hierarchic classification exhibits an apparent decrease in the number of indicatory species. Species ordination can be interpreted according to their indicatory values. However, ordination of localities shows the most pronounced changes at localities with a low diversity index and its interpretation seems to be rather difficult.

To conclude, the mayfly faunistics can be a very useful tool in the monitoring of environmental changes in large areas provided that the trends and priorities indicated above are taken into consideration. However, it is not possible to determine the factors causing changes in the environment. Consequently, further investigation into the mayfly indicatory capacity should be focused on the study of effects of the most important substances and factors on individual mayfly species (cumulation of pesticides, heavy metals, organic pollutants, fertilizers, changes of oxygen conditions, and others).

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Table 1.

Average number of species at localities of individual altitudinal zones

Faunistical district	Altitudinal zone (m)						
	to 200	201-500	501-750	751-1,000	1,001-1,500	above 1,500	total
I.	3.33 (2.26)*	5.09 (4.22)	5.61 (3.73)	3.45 (2.50)	1.50 (1.50)	-	4.77 (3.71)
	2.94	4.77	5.12	3.15	1.50		4.40
II.	3.61 (3.05)	4.46 (3.84)	3.12 (2.88)	1.13 (1.75)	2.00 (2.00)	-	3.91 (3.29)
	3.38	4.29	3.00	1.33	2.00		3.70
III.	5.10 (2.57)	4.89 (2.40)	3.67 (2.83)	5.00 (3.50)	-	-	4.66 (2.55)
	4.06	3.90	3.43	4.57			3.88
IV.	2.95 (5.43)	5.21 (3.87)	4.32 (4.00)	2.33 (3.86)	1.80 (1.75)	-	4.72 (3.99)
	4.25	4.46	4.23	3.40	1.78		4.33
V.	-	4.65 (4.43)	5.33 (4.13)	6.12 (4.75)	3.00 (2.50)	-	4.92 (4.37)
		4.52	4.87	5.55	2.71		4.62
VI.	-	5.77 (5.34)	6.79 (4.17)	4.41 (2.93)	2.46 (3.33)	-	5.31 (4.63)
		5.56	5.67	3.93	2.82		5.01
VII.	-	6.92 (4.06)	4.53 (2.78)	-	-	-	6.33 (3.91)
		5.39	3.96				5.13
XII.	-	7.72 (5.80)	9.13 (5.00)	7.38 (7.04)	3.94 (1.89)	1.50 (1.22)	7.01 (4.52)
		7.30	7.50	7.22	2.86	1.37	5.94
XVII.	6.10 (5.20)	7.36 (6.24)	2.00 (3.83)	0.00 (2.50)	-	-	6.68 (5.31)
	5.48	6.84	3.57	2.50			5.84

* Data on average numbers of species ascertained in the second period of investigation (1970-1985) in parentheses.

The third value means average number of species in both research period.

Table 2.

Relative presentation (%) of dominant and subdominant species in rhithron of individual faunistical districts I-VII. Values in parentheses concern the second phase of investigation (1970-1985).

Faunistical district/ /species	I		II		III		IV		V		VI		VII	
B. rhodani	16.67	(25.47)	21.94	(56.88)	11.69	(21.55)	14.66	(20.51)		(15.39)	11.90	(12.12)	23.50	(19.35)
B. alpinus	13.02	(2.60)	10.88	(5.31)	7.82	(5.52)	1.74	(1.06)	6.69	(1.81)	-	(12.78)	-	-
B. vernus	10.73	(7.80)	17.23	(9.04)	12.04	(29.83)	5.70	(7.33)	-	(6.37)	6.74	(10.06)	12.08	(21.62)
E. ignita	10.18	(15.99)	4.86	(1.25)	9.03	(8.84)	6.76	(9.71)	9.28	(5.34)	6.50	(4.46)	14.21	(15.23)
H. modesta	6.49	(3.96)	16.04	(2.54)	10.58	-	14.75	(4.76)	4.69	(3.94)	10.16	(3.81)	6.65	(2.87)
R. semicolorata	6.42	-	4.06	-	7.07	(2.76)	5.64	(11.30)	3.68	-	7.08	(7.68)	5.66	(6.11)
H. lauta	3.68	(2.76)	-	-	-	-	3.50	-	2.29	(3.81)	3.41	-	2.46	(5.27)
R. ferruginea	3.04	(2.60)	2.26	-	1.33	(6.63)	-	(1.07)	2.27	(6.77)	2.99	(2.34)	-	-
B. fuscatus	2.72	(1.73)	-	-	4.61	(4.42)	1.46	(1.34)	-	(2.54)	1.82	-	1.86	-
E. sylvicola	2.18	(2.38)	3.74	-	4.94	-	-	-	2.69	-	5.81	(4.58)	-	-
E. lateralis	1.94	-	-	-	-	-	2.86	(2.55)	-	-	-	-	-	(1.01)
B. muticus	1.60	(1.08)	3.54	-	2.56	-	3.06	(3.86)	-	(4.09)	2.86	-	-	-
R. iridina	1.54	-	-	-	-	-	-	-	-	-	1.06	-	-	-
H. fusca	1.42	-	-	-	2.01	-	-	-	-	-	-	-	-	-
C. luteolum	1.16	(3.36)	-	(2.87)	1.71	(1.66)	1.26	(4.27)	11.19	(14.58)	-	-	-	-
E. danica	-	(6.83)	4.64	-	3.34	(4.42)	9.92	(5.37)	5.57	(8.31)	4.20	(7.30)	8.23	(5.92)
E. dispar	-	(4.28)	-	-	2.13	-	-	-	-	(3.36)	2.81	-	-	(8.19)
C. dipterum	-	(3.52)	-	-	-	-	1.44	-	1.65	(2.19)	-	-	-	-
B. niger	-	(1.73)	-	(9.20)	-	-	-	-	-	-	-	-	-	-
E. venosus	-	(1.46)	1.98	-	-	-	-	-	3.13	-	3.74	-	-	-
E. mucronata	-	(1.36)	-	(3.15)	4.44	-	-	-	1.04	-	-	(3.86)	2.09	(3.15)
S. lacustris	-	-	2.51	-	-	-	-	-	-	-	-	(1.78)	-	-
P. submarginata	-	-	4.31	-	-	-	-	(3.33)	2.58	(1.46)	1.19	-	-	-
E. submontanus	-	-	-	-	-	(2.76)	-	-	-	-	1.99	-	-	-
C. macrura	-	-	-	-	-	-	-	(2.85)	1.94	(1.39)	-	-	-	-
L. marginata	-	-	-	-	-	-	-	(1.05)	3.14	(1.67)	-	-	-	-
E. torrentis	-	-	-	-	-	-	-	-	4.23	(2.74)	1.45	(3.60)	2.26	-