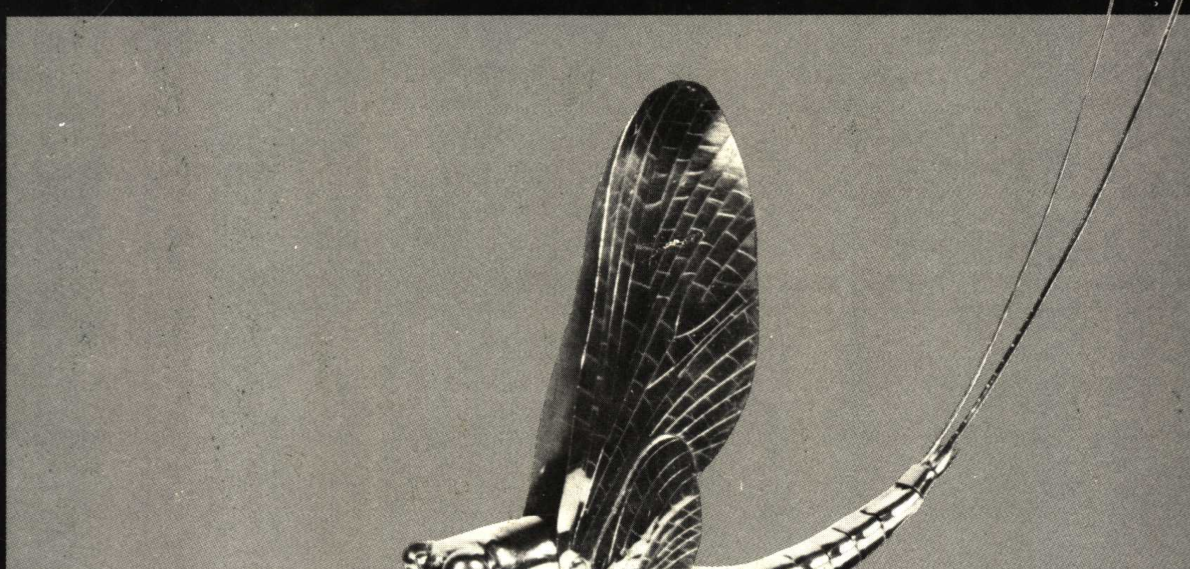
Advances in Ephemeroptera Biology



Edited by John F. Flannagan and K. Eric Marshall

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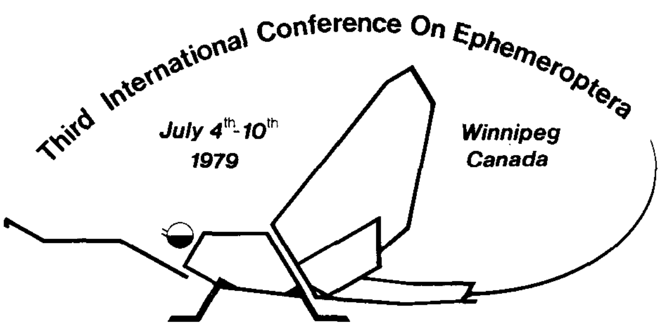

Proceedings of the Third International Conference on Ephemeroptera, held in Winnipeg, Manitoba, Canada, July 4–10, 1979.

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Preface

Following the first Conference in Florida, U.S.A. (1970) and the second in Krakow, Poland (1975), the Third International Conference on Ephemeroptera was held in Winnipeg, Manitoba, Canada from the fourth to the tenth of July, 1979, at the invitation of the International Permanent Committee on Ephemeroptera. (W.L. Peters, U.S.A. (Chairman); I. Müller-Liebenau, West Germany; H.J. Schoonbee, South Africa; G.F. Edmunds, Jr., U.S.A.; E.F. Riek, Australia; R. Sowa, Poland). The Conference was hosted by the Freshwater Institute (Department of Fisheries and Oceans, Canada) and the University of Manitoba and sponsored by the International Union of Biological Science. Sixty delegates from 11 countries attended.

Registration for the Conference took place on July 4th, and in the evening the delegates got acquainted, or renewed old acquaintances, at an informal gathering in the Hospitality Room at Mary Speechly Hall, the University residence which accomodated most of the delegates. Next morning, in the Fletcher-Argue theatre, the Conference was opened by the Honorary Chairman, Dr. F.P. Ide, who welcomed the delegates, then introduced the guest speakers: G.H. Lawler, Director-General of the Western Region of the Canada Department of Fisheries and Oceans; P. Jarvis, Deputy Minister, Manitoba Department of Mines, Natural Resources and Environment, and D.R. Campbell, President, University of Manitoba, who on behalf of their various organizations, welcomed the delegates to Canada and Manitoba, and extended good wishes for the success of the Conference. Following this, and commencing the scientific program, D. Dudley Williams gave the Invitational Lecture - Applied Aspects of Mayfly Biology - which is reproduced as the first paper in the Proceedings.

All but two of the papers presented at the Conference are reproduced here. The papers have been grouped together under broad subject headings. The editors would like to point out that these groupings had to be carried out in a rather arbitrary fashion, since many papers cross the subject boundaries.

We have not appended a discussion or question section to each paper since each paper was reviewed by a delegate, or member of the editorial committee during the Conference and each author had an opportunity during the Conference to adjust his or her paper in light of the questions asked after review and presentation. These adjustments have, in some cases, resulted in minor changes to the titles (and authorship) of some of the papers compared with those given in the Program. In addition, a number of small changes have been made during the editorial process. If these changes have affected the meaning or intent of the paper the editors accept responsibility, since, in some cases, the authors have not seen the final copy.

The submitted papers presented at the Conference have been, as stated above, grouped into seven sections. Within each section we have attempted to arrange the papers in either an historical or a general to specific sequence. The seven sections: Phylogeny and Systematics, Faunistics, Biology and Ecology, Behaviour, Methods, Environmental Impact and Toxicology, and Reviews and Historical Aspects of Mayfly Biology, are indicative of the wide range of topics covered at the Conference, almost every facet of Mayfly Biology being expanded on and/or reviewed. This volume therefore represents the state-of-the-art of Ephemeroptera biology at this point in time.

At the end of the volume are three indexes, prepared by K.E.M. The first is an index to the authors contributing papers to this volume. The Taxonomic Index provides a key to the major references in the text to families, subfamilies, genera and species. The Subject Index lists the main topics covered by the papers. This index is by no means exhaustive but hopefully provides a useful aid for the reader in locating pertinent information which cannot be located using the list of contents.

Dr. Bill Peters, on behalf of the Permanent Committee, and Dr. Fred Ide, the Honorary Chairman, closed the Conference by thanking the organizers and reviewing the achievements, both scientific and social, of this Third Conference.

The Convenor would like to thank the following individuals and organizations for their assistance in organizing, running and funding the Conference:

Contributing individuals:

W. Brown, W. Burton, S. Bubbs, P. Chang, D. Cobb, I. Davies, G. Decterow, M. Friesen, F. Frittaion, F.W.I. Women's Committee (chaired by D. Marshall), T. Galloway, J. Gee, D. Iredale, H. Klause, A. Kooyman, P. Laufersweiler, S. Lawrence, M. Layton, S. Leonhard, D. Malley, B. de March, E. Marshall, J. Mathias, G. McRae, A. Olivier, K. Patalas, D. Rosenberg, A. Salki, E. Scherer, L. Taite, B. Townsend, F. Ward, A. Wiens, H. Welch, R. Wickstrom, R. York, S. Zettler and M. Ziprick.

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John F. Flannagan
K. Eric Marshall

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BEHAVIOUR

METHODS

APPLIED ASPECTS OF MAYFLY BIOLOGY

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ABSTRACT

Mayflies have been of interest to man for centuries. This paper will trace the history of this interest from its earliest beginnings in crude piscatorial entomology, through more recent application of the group as water quality indicators and research tools to present and future uses in modern aquatic technology.

Frost and Brown (1967) state that the use of artificial baits to catch trout by means of rod and line dates back to twelfth century Europe, although Leonard and Leonard (1962) report that it was practised by the ancient Greeks. Documentation of this occurred first in 1496 in the form of "The Treatyse of Fysshynge wyth an Angle" by Dame Juliana Berners. Doubtless, tempting fish with freshly caught aquatic insects would have preceded this, but the delicate nature of insect bodies would probably soon have led to the making of more robust imitations from a variety of readily available materials such as fur, feathers and wool. Presumably, the more realistic the artificial insect, the more successful its user would be. This fact alone probably led to a more careful scrutiny of lake or riverside insects and their habits, bringing the first aquatic entomologists into being.

A considerable literature on this topic, in both scientific journals and the popular press, now exists. I do not propose to review the state of the art of angling here, but to summarize some of the basic good descriptive entomology that has led to the refinement of fly fishing as illustrated by the Ephemeroptera. Figure 1 shows the stages in the life cycle of a typical mayfly (left) and the artificial flies that are meant to imitate these stages (right). The aquatic nymphs is fished as a wet fly beneath the water surface. Dominant features of the nymph, such as the cerci, segmented abdomen, legs and darkened, pre-emergent wingpads are all duplicated in the fly. The emerging subimago is also fished as a wet fly, though just below the surface; most mayflies emerge at or near the water surface (Needham *et al.* 1935). The characteristic rumpled wings are simulated on the artificial fly by a small portion of feather. The fully emerged subimago, now a terrestrial stage, is represented by a dry fly fished on the water surface. The subimago is similar in appearance to the adult, but has duller colours, the legs and cerci are shorter, and heavy pigmentation along the veins may produce a dark pattern on the wings (Leonard and Leonard 1962). The latter rarely persists in the imago but is faithfully copied in the fly (called a dun) by use of a mottled feather. The features of the imago are seen in its counterpart - the spinner - which is again fished on the water surface. The colours in this lure are brighter than in the dun, and the wings are made from a non-mottled feather. Segmentation in the abdomen is duplicated by a silk thread binding. Many hundreds of patterns are known for this fly depending on the species of mayflies occurring in local waters. The final stage of mimicry is that of the prostrate, spent female floating on the water surface. This change in posture is again reflected in the dry fly counterpart.

Why should the art of deceiving fish have developed to such a high degree? Tebo and Hasler (1963) state that availability and not abundance is the most important factor determining what foods are eaten by trout. The Ephemeroptera are most easily accessible as prey at emergence (Frost 1939). This accounts for the findings of Frost and Went (1940) that young atlantic salmon stomachs (*Salmo salar* L.) contained larger numbers of *Baetis* spp. than *Ephemerella* spp. even though their densities in the benthos were almost identical; *Baetis* has a longer emergence period than *Ephemerella*. A certain amount of selectivity while feeding therefore appears evident. Bryan and Larkin (1972) reached a similar conclusion for brook trout (*Salvelinus fontinalis* (Mitchill)), cutthroat trout (*Salmo clarki* Richardson) and rainbow trout (*Salmo gairdneri* Richardson). This specialization is more evident in fish with full stomachs than in those with only a few items in their guts where feeding is more random (Allen 1941). Food constancy is of advantage to a fish in that it enables it to temporarily set its feeding behaviour for a transient but abundant supply of identical organisms (Frost and Brown 1967). This promotes efficiency in foraging, with a considerable safety benefit and has parallels in flower selection constancy documented for worker honeybees (Michener 1974). A fish may reset its feeding for successively available insect species (Williams and Coad 1979 have shown this for cyprinids).

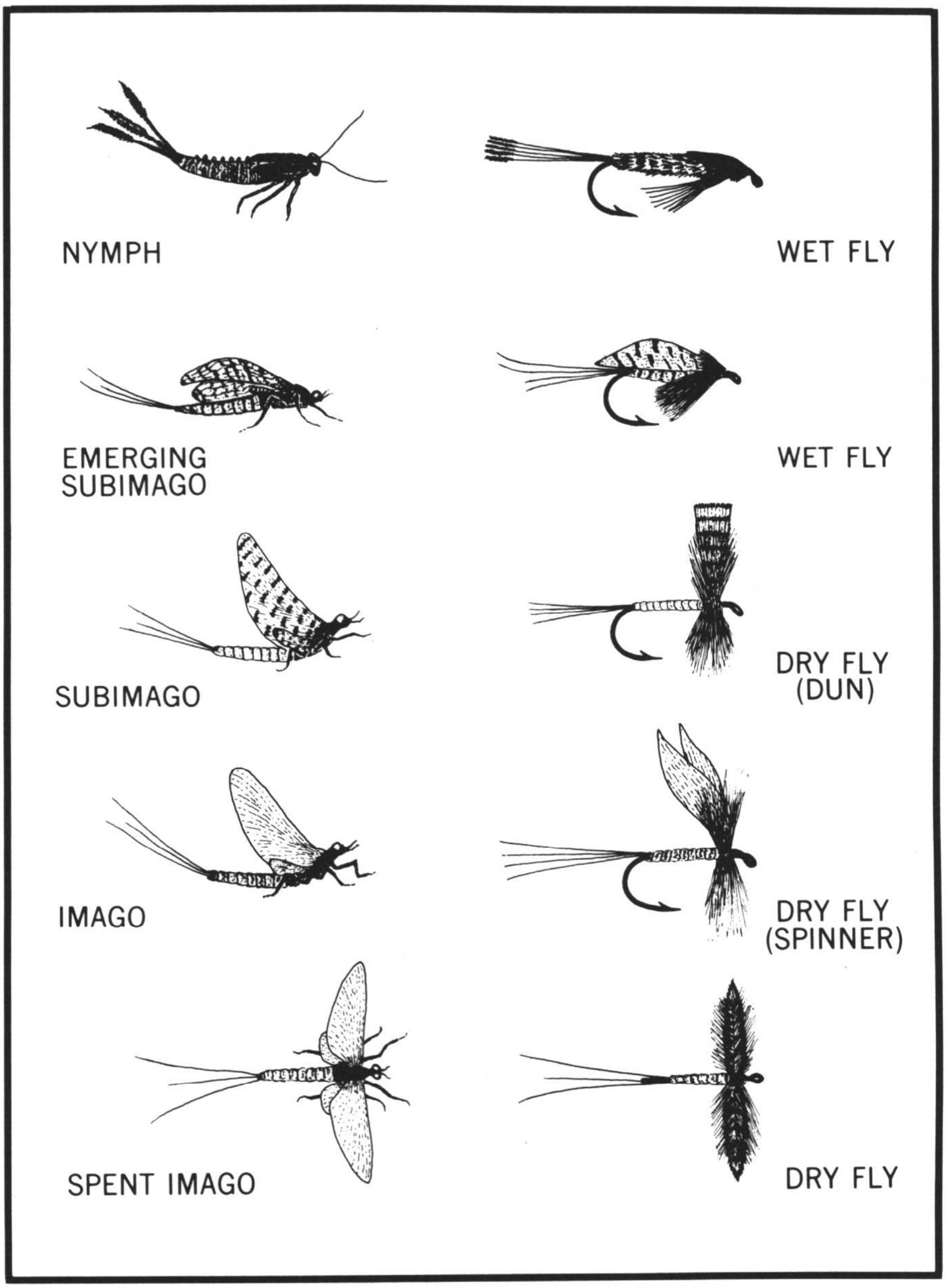

Figure 1. Comparison of the stages in the life cycle of a mayfly and the artificial flies that imitate them.

The angler takes advantage of this fact by presenting a suitable imitation of a particular mayfly during the time when the fish's feeding behaviour is set for that species; the so-called technique of "matching the hatch".

More recently, mayflies, along with other benthic macroinvertebrates, have been looked to as possible indicators of aquatic pollution (e.g. Britt 1975). Studies have shown that many pollutants have a marked affect on mayfly abundance and this can readily be detected. Table 1 cites some examples of mayfly abundance above and below various sources of pollution. It shows different degrees of of response by nymphs of different families. Even the same genus, *Baetis*, responded differently to organic pollution in the Rivers Dee and Tees. This could well have been due to a difference in species or in the exact nature of the pollutant, however. In one case, that of *Tricorythodes* in Deer Creek, a build up of quarry stonedust on a riffle resulted in an increase in density. This is perhaps not surprising as the genus typically prefers a silty substrate (Burks 1953). Other studies have found species apparently preferentially selecting polluted conditions. Snow and Rosenberg (1975), for example, in an experimental study of colonization of artificial substrates coated with crude oil, found Baetidae only in oily substrates. These examples clearly indicate that mayflies do respond to environmental change, but because of insufficient identification the conclusions are somewhat limited, in application, to the individual studies. Although mayflies are generally considered to be very sensitive to pollutants, particularly those of organic origin, Roback (1974) provided data to show that this, as a generality, is not so. He cites examples of common genera, like *Stenonema*, that may occasionally be found in extreme conditions, and concludes that although there may be differences at the species level, nymphal taxonomy is not sufficiently advanced, at present, to allow reliable prognostications to be made. Resh and Unzicker (1975) similarly point out the importance of species identification in the meaningful biological assessment of water quality.

Roback's argument, would, therefore, seem to preclude widespread application of mayflies as biological indicators in North America at present. However, where the nymphs of certain nearctic genera are separable, e.g., *Stenonema*, *Cloeon*, *Heterocloeon*, *Ephemerella*, *Neoephemera*, and *Hexagenia* (Edmunds *et al.* 1976), or where keys to local species are available (e.g., Flowers and Hilsenhoff 1975) then the group becomes valuable as a biotic index. Hilsenhoff (1977), for example, used a modified version of Chutter's (1972) empirical biotic index to evaluate the water quality of Wisconsin's streams. Familiarity with the local fauna allowed him to assign values to species, many of them mayflies. These values ranged between 0 and 5, with 0 assigned to species collected only in streams of very high water quality, and 5 assigned to species collected in badly polluted streams. Table 2 gives some examples

Table 1. Examples of mayfly abundance above and below various sources of stream pollution.

Taxon	Number/sample upstream pollution(x)	Number/sample immediately downstream of pollution (y)	Type of Pollutant	Location	Data source
Ephemeridae	237	188	Sewage	Red Cedar River	Leonard (1962)
Baetidae	16	2.5	"	Michigan, U.S.A	"
Heptageniidae	2.6	0	"	"	"
Baetis	5	4	"	River Tees	Butcher *et al.* (1937)
Ephemerella	3	4	"	England	"
Ecdyonurus	18	7	"	"	"
Rhithrogena	33	4	"	"	"
Baetis	205	36	Mild organic pollution	River Dee Wales	Hynes(1960)
Ecdyonurus venosus	5	4			"
Rhithrogena semicolorata	13	0	"	"	"
Heptagenia sulphurea	8	2	"	"	"
Stenonema frontale	195	0	Acid mine waste	Margaret Creek /Sandy Run, Ohio, U.S.A.	Napier and Hummon (1976)
Baetisca callosa	35	0			
Caenis	y/x ratio =	0.1	Deposited quarry stonedust	Deer Creek	Gammon (1970)
Baetis		0.7		Indiana, U.S.A.	"
Tricorythodes		1.7	"	"	"

of the values he assigned to the mayflies. The biotic index was calculated according to the formula:

$$B.I. = \frac{\Sigma n_i a_i}{N}$$

where n_i is the number of individuals in each species, a_i is its assigned value, and N is the total number of individuals in the sample. The biotic index for a given stream was then compared with a standard scale of values calculated for Wisconsin streams. Values of less than 1.75 indicated excellent water quality, characterizing clean, undisturbed streams; values of between 2.25 and 3.00 indicated fair quality, associated with moderate enrichment or disturbance; and greater than 3.75 indicated very poor water quality with gross enrichment or disturbance. Not only can mayflies be used to detect and categorize pollution, but, as Edmunds *et al.* (1976) have suggested, they may help to remove some of the organic material by incorporating it into their body tissues which may later decompose on land.

An increasing nymber of laboratory studies are being reported in the literature in which mayfly nymphs are used as experimental animals. For example, Fremling and Schoening (1973) advocated the use of the burrowing nymphs of *Hexagenia* for the study of behaviour and for bioassay work, and designed a special artificial substrate for these purposes. Mayflies may have considerable potential in this kind of research, particularly as many species are easy to collect and maintain in the laboratory. These facts may also make them useful educational material in the classroom (Needham *et al.* 1935).

Mayflies provide an important food source for a great many predators, in both aquatic and terrestrial environments. Some, such as fish, are immediately obvious, others are perhaps not so obvious. For example, Leonard and Leonard (1962) cite adult dragonflies, hornets and spiders as well as a variety of birds, bats and other mammals, many of which are attracted to areas of mass emergence. In the aquatic phase, mayfly nymphs are eaten by waterfowl and may be an important component of the diet of their young (Krull and Boyer 1976). By far the most studied aspect of the food potential of the Ephemeroptera is that for fish, and salmonids in particular. New ideas are presently opening up in this area and attempts are being made to apply principles of stream ecology to increasing salmonid stocks.

As part of the Canadian Federal Government's Pacific Salmon Enhancement Programme, Mundie (1974) proposed the feasibility of raising salmon smolts (primarily coho salmon, *Oncorhynchus kisutch* (Walbaum)) in high density in seminatural streams. The approach was to combine some of the desirable features of rivers with the