DIURNAL VARIATIONS IN THE ACTIVITY OF *MIRAWARA PURPUREA* RIEK (EPHEMEROPTERA, SIPHLONURIDAE) IN THE ABERFELDY RIVER, VICTORIA AUSTRALIA

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ABSTRACT

Although *Mirawara* is a widespread genus in eastern Australia, the nymphs are frequently under-represented in benthic samples. Evidence is presented which indicates that *Mirawara* nymphs descend into the substrate during the day, returning to the surface at night to feed. Relatively large numbers of nymphs can be collected at night. Light intensity is probably the factor which controls the movements of the nymphs. The significance of these results for ecological studies is discussed.

INTRODUCTION

Although species of the genus *Mirawara* Harker are widespread in eastern Australia (Fig. 1), the nymphs are not common in conventional stream macroinvertebrate samples. Smith *et al.* (1977) recorded *Mirawara* from the Mitta Mitta valley, but collected only a few specimens. Macmillan (1975) did not collect the genus from the Acheron River, although, from the river bed characteristics and the location of the river, it would be expected to occur there; and no specimens were reported in a study of the Thomson River (M.M.B.W. 1975), only 2 km from the site of the present study in a similar river with similar substrate. Dean (cited in M.M.B.W. 1975) collected nymphs from

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Figure 1. Map of Australia with the known distribution of *Mirawara* indicated by shading. The top of the figure is north.

the Aberfeldy River in 1974, but Jackson (1978), in a study on the Aberfeldy at a site approximately 10 km upstream of the present study, also failed to record the presence of the genus.

The nymphs would not be readily overlooked in collections, since full grown specimens are about 30 mm long, and moderately large nymphs may be collected at all times of the year. Their characteristic head shape and unique gill structure make it unlikely that they would be misidentified. In the case of three of the studies cited, those of Smith *et al.*, Macmillan and Jackson, I have been able to examine the material collected and confirm the identifications.

The genus *Mirawara* was first erected by Harker (1954) for the single species *Mirawara aapta*. The material on which the description was based was collected by Tillyard in 1936 from the Murrumbidgee River at Adaminaby in southern New South Wales. In his revision of the Australian siphlonurids, Riek (1955) described two further species: *M. purpurea*, from the Australian Alps south of Canberra (the same general area as *M. aapta*) and *M. megaloprepia*, from Queensland. He records *M. megaloprepia* from as far north as Mackay, and I have collected *Mirawara* nymphs from the Atherton Tableland near Cairns. The genus does not occur in Tasmania.

Two species of the genus occur in Victoria: *Mirawara aapta* Harker and *M. purpurea* Riek. Of these, *M. purpurea* is the most common. In 1977 I commenced a study of the taxonomy, life histories and distributions of siphlonurids in southeastern Australia and found that nymphs of *M. purpurea*, although not abundant during the day, could be collected readily at night. Samples collected from the Aberfeldy River at 1730, 1930 and 2130 h (before, at and after dusk) on 24th February, 1978, showed a marked increase in the number of nymphs collected from a 4 m^2 area as the light faded, mean numbers being 1.8 at 1730, 2.0 at 1930 (dusk) and 14.3 after dark at 2130. The experiments described here were initiated to investigate this phenomenon.

THE STUDY AREA

The site selected for the study is a section of the Aberfeldy River, which is a tributary of the Thomson River, about 150 km east of Melbourne (Fig. 2). The Aberfeldy flows about 48 km in a southerly course draining a steep, forested catchment of 308 km^2. Although the river was the scene of considerable mining activity as a result of the discovery of gold in the area in 1861, there has been little human activity in the catchment since 1914, apart from some logging operations. The areas damaged by mining are now largely revegetated. The catchment is vegetated by open forest dominated by *Eucalyptus obliqua* and *E. radiata*. More detailed discussions of the vegetation and topography of the catchment can be found in L.C.C. (1973) and M.M.B.W. (1975).

The stretch of river studied is located at Beardmore's (37° 51.5'S, 146°26'E), about 150 m upstream from a Victorian State Rivers and Water Supply Commission gauging station. The mean annual flow at this point is 64.7 ML and the mean salinity is 45 ppm (Bibra and Riggs 1971). The substrate is predominately shingle: a mixture of small (< 30 cm diameter) stones and coarse sandy gravel. The river ranges from 3 m to 20 m wide and is mostly shallow, with a maximum depth of 60 cm.

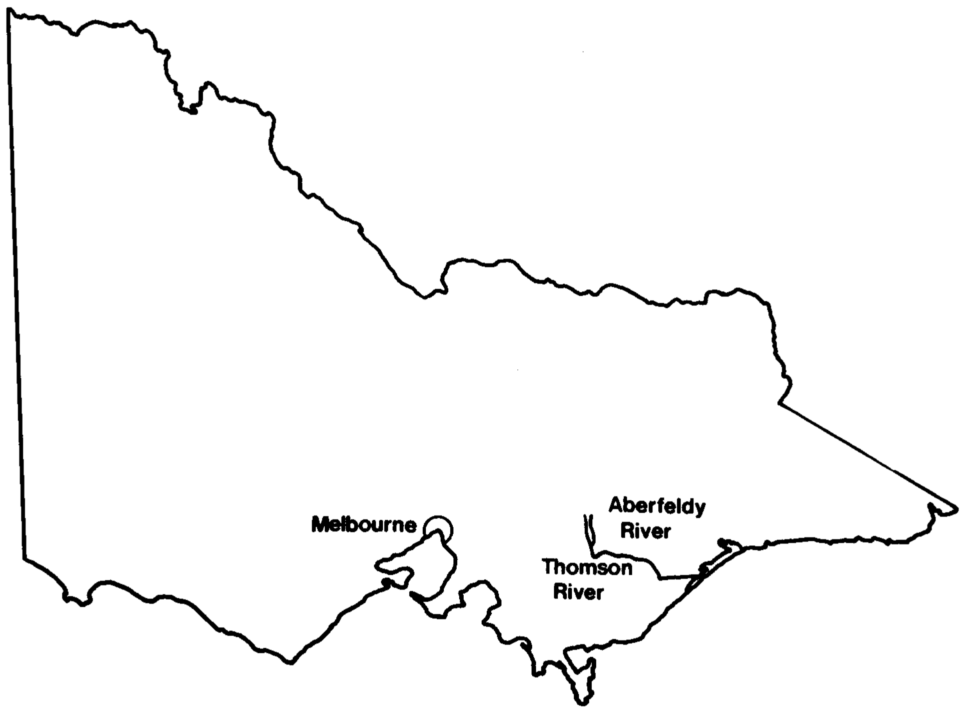

Figure 2. Map of Victoria indicating the location of the Aberfeldy River. The top of the figure is north.

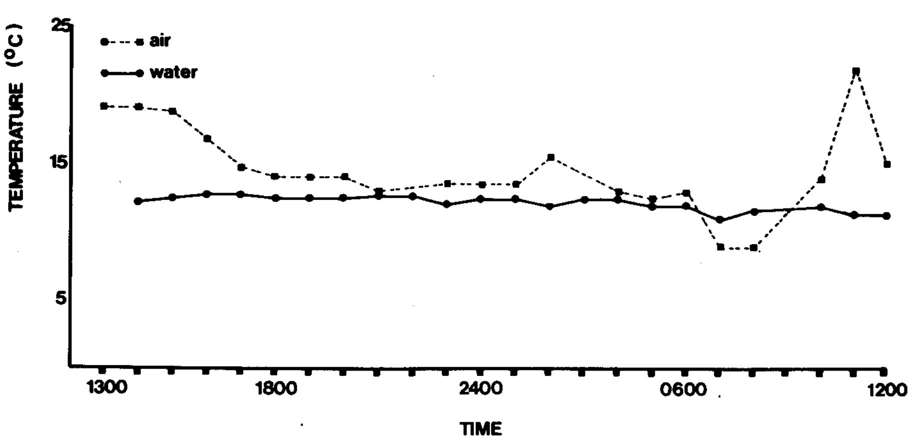

Figure 3. Air and water temperatures taken at hourly intervals from 1300 h on 22nd to 1200 h on 23rd April 1978.

METHODS

Samples were collected on two occasions: on the 22nd and 23rd of April, 1978, and again from 30th March to 1st April, 1979. On each occasion a grid was marked out, using string stretched across the river, defining metre square quadrats. The grid was constructed such that the water in each quadrat was no more than 35 cm and no less than 10 cm deep. The current on the grid varied from 0.08 to 0.50 m/sec in 1978, and from 0.05 to 0.29 m/sec in 1979. In 1978 one group of 18 quadrats were 50 m downstream of the rest, but in 1979 all of the quadrats were located in the one section of stream. The quadrats to be sampled at each time interval were chosen using random number tables. In 1978 six quadrats were sampled each hour for 24 hours, whilst in 1979 six were sampled every 2 hours for 48 hours. Each quadrat was sampled only once.

The sampling apparatus consisted of a wooden frame 1 m^2 and 40 cm high with the sides covered in 300 μm nylon mesh. The frame was pushed firmly against the substrate to obtain as good a seal as possible. The water inside the frame was then vigorously agitated and repeated swept with a 300 μ mesh FBA net for 2 minutes. The contents of the net were emptied into 1 L plastic jars and preserved with Kahle's solution. In the laboratory the samples were sorted by hand under a binocular microscope.

At the same time as each set of six samples were collected, air and water temperatures were recorded using a pair of mercury thermometers. Water velocity was recorded with a stopclock and an orange tied to a 1 m length of string.

From 2030 h on the second evening (31st March, 1979) until 0500 h the following morning the grid was illuminated with four 2.5 kva floodlights, to test the effect of illumination on the number of animals collected.

RESULTS

The water and air temperature data for the 1978 sampling are presented in Figure 3 and for 1979 in Figure 4. The mean numbers of *Mirawara* nymphs found in the six samples collected at each interval are presented in Figure 5 (1978) and Figure 6 (1979).

DISCUSSION

The number of animals collected in the 1978 samples was fairly small. Nineteen samples contained no *Mirawara*, and the largest number in any of the samples was 22. The low overall numbers of nymphs collected on this occasion probably accounts for the somewhat

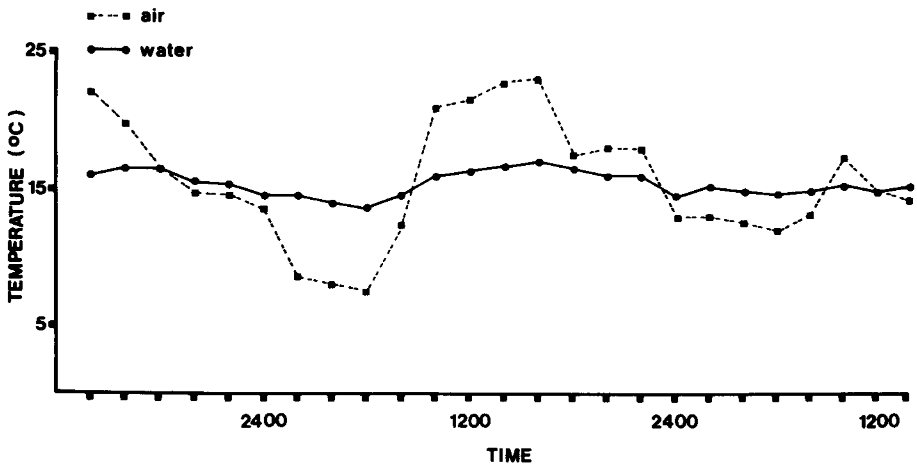

Figure 4. Air and water temperatures taken at two hourly intervals from 1400 h on 30th March to 1400 h on 1st April 1979.

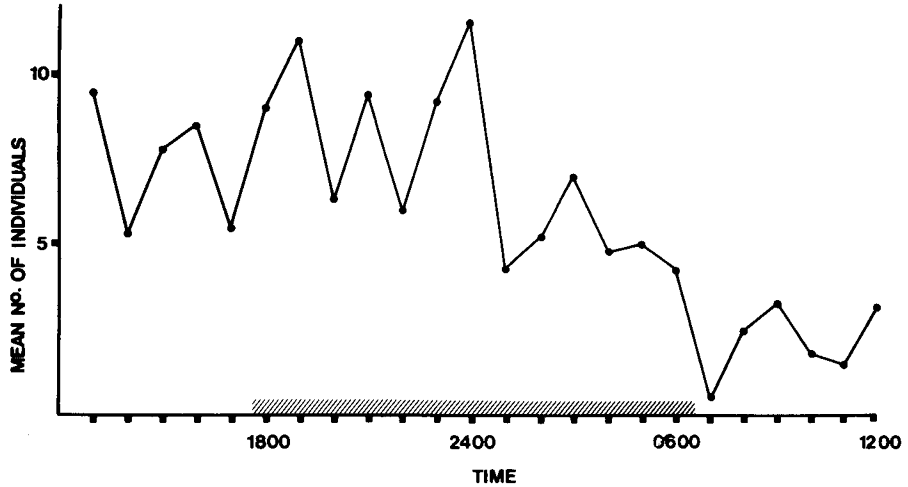

Figure 5. Mean numbers of *Mirawara* nymphs collected per sample in sets of six samples taken hourly from 1300 h on 22nd to 1200 h on 23rd of April 1978. The dark period is indicated by the shading.

erratic form of Figure 5; however, there is a fairly clear peak at 1900 h, just after dusk, and another at midnight with a drop between the two. A second very marked drop in numbers occurred after midnight, the numbers being relatively depressed until dawn, when there was a further marked decrease. The drop between midnight and 0100 h may have been due to the overcast sky clearing, allowing bright moonlight to illuminate the grid. Anderson (1966), Waters (1962) and Bishop and Hynes (1969) have all shown that bright moonlight is sufficient to depress drift activity of stream insects. The further drop in mean numbers of *Mirawara* collected per sample, which occurred between 0600 and 0700 h, was presumed to be a response to daylight.

The daylight results on the first day are markedly higher than those on the second day. This difference was tested using the median test for two independent samples (Siegel 1956) and found to be significant at the 0.005 level. The first day of the study was overcast and the second clear and sunny, and the difference in natural illumination is probably at least partially responsible for the difference in the number of nymphs collected.

Because of this difference between the two sets of light results, the dark results were tested against each of them separately, again using the median test. The difference between the dark results

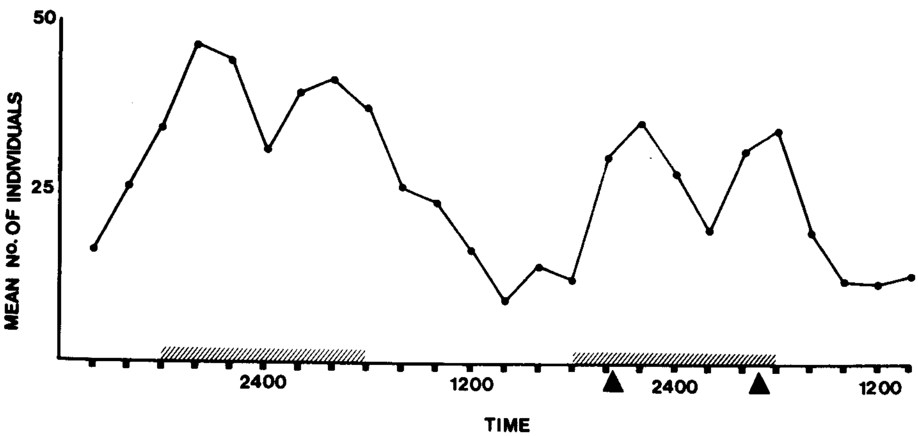

Figure 6. Mean numbers of *Mirawara* nymphs per sample in sets of six samples taken every two hours from 1400 h on 30th March to 1400 h on 1st April 1979. The dark period is indicated by shading, and the two arrows indicate the period during which the stream was illuminated.

and the light results on April 23rd was found to be significant at the 0.001 level, but no significant difference was found between the results of the light period on April 22nd and the dark period.

In 1979 the experiment was repeated over a longer time interval, with the intention of using floodlighting to test whether changes in illumination could influence the activity pattern noted in 1978. On this occasion, surprisingly large numbers of animals were collected. Only one sample contained no *Mirawara* and the highest number collected in any single sample was 74, an extremely high density for a carnivorous insect. The reasons for this large increase in numbers between 1978 and 1979 are not known; however, an extremely large flood, which occurred in September 1978, moved large amounts of substrate and, although the distribution and apparent composition of substrate was largely unchanged, subtle changes may have made the habitat more suitable for *Mirawara*.

The 1979 results show very clear dusk and dawn peaks with reduced numbers occurring at, or shortly after, midnight. The peaks were lower on the second night when the grid was illuminated, and this difference, when tested with the median test, was significant at the 0.005 level.

The sampling technique collects insects on top of stones in the quadrat and also those sheltering under any loose stones, since these were turned over by the vigorous swirling of the water. I believe that the difference between the night and day samples can be attributed to the movement of nymphs into the substrate during light periods, and up to the surface again at night. *Mirawara* nymphs are always found in streams with a loosely packed shingle or cobble substrate which has abundant, large interstices into which the insects can move. The presence of large numbers of insects and other aquatic invertebrates in, and their movement into and out of, the hyporheic environment is well established (e.g. Bishop 1973, Williams and Hynes 1974, Stanford and Gaufin 1974).

A number of the features of *Mirawara* nymphs could be interpreted as adaptations to hyporheic life. Included amongst these are dorsoventral flattening, which is uncharacteristic of siphlonurids, the decided wedge shape of the head and the presence of both gill filaments and plates. The presence of gill filaments and plates is not shared by the related genus, *Ameletopsis* Phillips, which has only gill plates, although these are more highly ramified than those of *Mirawara* (Phillips 1930). The presence of filaments provides a large respiratory surface whilst the plates are used to create a water current over the respiratory surfaces.

The obvious difference in numbers of *Mirawara purpurea* collected during dark and light periods in both experiments, together with the significant depression of the numbers collected during the period in which the stream was illuminated in 1979, may be interpreted, therefore, as evidence of a negative phototaxis combined with nocturnal activity peaks probably associated with feeding behaviour. A number of studies have been carried out on the influence of light on the behavioural patterns of ephemeropterans. Moon (1940) showed that nymphs of *Ecdyonurus* and *Baetis* are more active during the night than the day. Harker (1953), in a series of laboratory experiments on *Ecdyonurus torrentis* Kimmins, *Heptagenia lateralis* (Curtis) and *Baetis rhodani* (Pictet) showed distinct diurnal rhythmicity of activity which, once established in the early instars, was not directly affected by the light regime. However, Harker's experiments were carried out using animals obtained from running water but observed in still water, and Elliott (1968) later showed that quite different results are obtained under flowing water conditions. He found that both activity and position on stones were directly contolled by light intensity for five species of Ephemeropterans: *Baetis rhodani* (Pictet), *Ephemerella ignita* (Poda), *Ecdyonurus venosus* (Fabricus), *Rhithrogena semicolorata* (Curtis) and *Heptagenia lateralis* (Curtis). Under laboratory conditions, significantly more individuals of all of these species were present on the top of a stone in an artificial stream during dark than light periods. Field counts of the numbers of *B. rhodani* present on the tops of stones in a stream in light and dark periods indicated that the same phenomenon also occurs under natural conditions. These results are in general agreement with those of the present study, although Elliott recorded a single nocturnal maximum in both activity and numbers of animals on top of stones, rather than a pair of maxima as was found here.

A considerable amount has been published on the relationships between light intensity, diurnal activity and drift of aquatic insects and other invertebrates. The literature on drift has been reviewed by Hynes (1970), Waters (1972) and Müller (1974). A common pattern is for maximal numbers of drifting animals to occur shortly after dusk and again shortly before dawn, with a slight decrease around midnight and minimal numbers during the day.

It has been widely suggested that these peaks correspond to activity peaks of the animals, which, in turn, are controlled by light intensity (e.g. Elliott 1967, Chaston 1968, Bishop 1969, Bishop and Hynes 1969), although this interpretation is disputed by Corkum (1978). The activity cycles found by the authors previously mentioned are consistent with the results of the present study, with the dawn and dusk drift and activity peaks corresponding to the periods in which *Mirawara* moves to the surface of the substrate to actively seek food.

Clifford (1972) compared two sets of Surber samples collected from the Bigoray River (Alberta, Canada) during the day and night and concluded that there were no significant differences between them with respect to total numbers, total number of taxa and total volume-biomass. The results presented here indicate that the time at which benthic samples are collected from eastern Australian streams could have a marked effect on the composition of the sample, and lead to a significant underestimate of the proportion and absolute numbers of insect carnivores.

CONCLUSIONS

Significantly higher numbers of *Mirawara purpurea* nymphs were found in samples collected at night than in samples taken during the day. This is probably due to a negative phototaxis, and the animals probably move down into the substrate during the day and ascend to the surface again to feed at night. Negative phototaxes and nocturnal activity peaks are common amongst ephemeropterans.

Results of this study indicate that samples of stream benthos collected during the day may significantly underestimate the numbers of *Mirawara* nymphs present in the stream or fail to collect them altogether. This may be the reason why a number of studies of Australian stream benthos found only small numbers of *Mirawara* nymphs or collected none at all.

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RESUME

Bien que *Mirawara* soit un genre extrêmement répandu en Australie orientale, bien souvent les larves se trouvent en nombre inférieur dans les échantillons de faune benthique. L'auteur démontre, à l' aide de certains indices, que les larves *Mirawara* descendent sous terre pendant le jour et remontent le soir à la surface pour se nourrir. On peut alors en prendre d'assez grandes quantités. L' intensité de la lumière est problement le facteur qui règle le mouvement des larves. L'auteur montre enfin l'importance de ces découvertes dans le domaine des études écologiques.

ZUSSAMENFASSUNG

Obwohl *Mirawara* eine weitverbreitete Gattung im östlichen Australien ist, treten die Nymphen oft nur in geringen Mengen in benthischen Proben auf. Hier soll nun ein Nachweis erbracht werden, der zeigt, daß *Mirawara* Nymphen während des Tages tiefer in das Substrat hinabsteigen und nachts an die Oberfläche zurückkehren, um Nahrung zu erwerben. Verhältnismäßig große Zahlen von Nymphen können daher in der Nacht gesammelt werden. Wahrscheinlich ist die Lichtintensität der Faktor, der die Bewegungen der Nymphen kontrolliert. Die Bedeutung dieser Ergebnisse für ökologische Studien wird in der vorliegenden Arbeit erörtert.

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