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Effect of a Total Solar Eclipse on Invertebrate Drift in Snobs Creek, Victoria

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Abstract

The effect of the total solar eclipse of 23 October 1976 on invertebrate drift in Snobs Creek, Victoria, was investigated by taking hourly drift samples in two drift nets between 1300 and 2000 h (Eastern Standard Time) on 22, 23 and 24 October. *Paramoera fontana* (Amphipoda) and terrestrial arthropods exhibited no pattern in their occurrences in the drift. Nymphs of Baetidae (Ephemeroptera) and *Trinotoperla* (Plecoptera) were rarely found in the drift except after sunset, but exhibited no increase related to the eclipse. Four taxa, namely helodid (Coleoptera) larvae, the larvae of two species of Leptoceridae and one species of *Conoesucus* (Trichoptera), were more abundant in the drift after sunset and also exhibited an eclipse-related increase in abundance in the drift. *Cricotopus* (Diptera) larvae were less abundant in the drift after sunset and also exhibited an eclipse-related decrease in abundance in the drift. The results suggest that light intensity has an effect on the occurrence in the drift not only of dark-active invertebrates but also of some light-active invertebrates.

Introduction

In this paper we describe an investigation that was conducted to determine the effect of the total solar eclipse of 23 October 1976 on the drift of stream invertebrates. The investigation was carried out in Snobs Creek about 9 km north of the approximate central line of the eclipse (Department of Crown Lands and Survey, Victoria, 1976) and about 2 km upstream of the Snobs Creek Freshwater Fisheries Research Station and Hatchery (37°16′S., 145°52′E.). In this area the time between the first and fourth contacts of the sun and moon was about 2 h 6 min and the period of totality was computed to be 2 min 55·6 s (Fiala and Duncombe 1975). At Snobs Creek the total eclipse began just before 1642 h Eastern Standard Time (EST) and was accompanied by a pre-totality dusk (rapidly decreasing light intensity) of approximately 15 min and a post-totality dawn (rapidly increasing light intensity) of approximately 15 min.

The Study Area

Snobs Creek is about 26 km long and has a catchment area of about 130 km^2 (Affleck 1952). It arises over Upper Devonian acid igneous rocks (Thomas 1947) and descends 762 m through wet sclerophyll forest before passing over alluvial flats to join the Goulburn River at a point about 200 m above sea level. The drift sampling site was situated at the downstream end of a 6·5-m long riffle, where the creek was 7 m wide and had a substrate of gravel and boulders. Vegetation around the sampling area consisted mainly of eurabbie, *Eucalyptus st-johnii* (Baker); hazel pomaderris,

Pomaderris aspera Sieber ex de Candolle; blackwood wattle, *Acacia melanoxylon* Brown; mountain tea tree, *Leptospermum grandifolium* Smith; and soft tree-fern, *Dicksonia antarctica* Labillardière.

Hourly discharges in Snobs Creek for the experimental periods (1300–2000 h on 22, 23 and 24 October) were calculated from data supplied by the State Rivers and Water Supply Commission of Victoria. On 22 October hourly discharge fell steadily from 87 to 81 Ml/day, on 23 October it fell steadily from 78 to 75 Ml/day, and on 24 October it remained constant at 75 Ml/day. Affleck (1952) recorded the typical pH of Snobs Creek as 6·8; the same value was recorded by hatchery staff at the hatchery take-off point on Snobs Creek on 22, 23 and 24 October. A water sample taken at the drift sampling site on 24 October indicated that turbidity was 5 JTU,* hardness (as $CaCO_3$) was 36 mg/l and total alkalinity (as $CaCO_3$) was 9·6 mg/l (State Rivers and Water Supply Commission, personal communication).

Methods

Drift was sampled hourly between 1300 and 2000 h EST on 22, 23 and 24 October 1976. Two drift nets each with a rectangular opening, a mesh size of 0·5 mm, and fitted with a removable collecting jar, were used concurrently. The opening of net 1 was 100 mm wide and 0·5 m high and tapered into a collecting jar having a diameter of 50 mm and a capacity of 195 ml; the opening of net 2 was 45 mm wide and 0·5 m high and tapered into a collecting jar having a diameter of 45 mm and a capacity of 195 ml. Water depth at net 1 was 0·4 m and at net 2 was 0·55 m. The nets were positioned 4 m apart, one on each side of the midline of the creek. They were held in position on the creek bed by means of cords attached to the front and sides of the frame supporting the opening of each net. The nets were left in position for the 3 days of the experiment, but the collecting jars were fitted into position only during the sampling periods. The contents of the collecting jars were emptied hourly after the nets had been shaken in an attempt to dislodge any organisms clinging to the inside surfaces of the nets. Any debris was removed from the drift nets and their supporting cords before the collecting jars were re-positioned. The same procedure was followed throughout the sampling periods, with the jar from net 1 being emptied and replaced before the jar from net 2. Maximum and minimum air and water temperatures were recorded hourly at the drift sampling site as soon as the collecting jars had been emptied.

The hourly drift samples from each net were preserved in 10% formalin and sorted at a later date under a low-power ($< \times 100$) microscope.

Results

The minimum air temperature dropped markedly during the hour in which the eclipse occurred, but water temperature did not appear to be affected (Fig. 1).

The numbers of most of the drifting organisms taken in the nets are shown in Table 1; these numbers represent 94% of all animals taken in net 1, and 87% of all animals taken in net 2. Some of the taxa which occurred in the drift in relatively large numbers, such as *Paramoera fontana* and terrestrial arthropods, showed no pattern in their occurrence in the drift. Other groups, such as the nymphs of Baetidae and *Trinotoperla*, were never abundant and were rarely present except after sunset. They exhibited no increase associated with the eclipse. Four groups, namely helodid larvae, the larvae of two species of Leptoceridae and one species of *Conoesucus*, were more abundant in the drift after sunset and also occurred in increased numbers in the samples taken between 1700 and 1800 h on the day of the eclipse. On the other hand, *Cricotopus* larvae were less abundant in the drift after sunset and were present in reduced numbers in the samples taken between 1700 and 1800 h on the day of the

* Jackson turbidity units.

eclipse. The changes in the percentage occurrence in the drift of the five taxa whose drift patterns were affected by the eclipse are indicated in Fig. 2.

Discussion

Exogenous light conditions have usually been found to have a marked effect on the occurrence of dark-active invertebrates in the drift and it is generally considered that if an endogenous rhythm exists at all in circadian drift cycles then it is very weak and strongly influenced by environmental light conditions (Elliott 1965, 1967; Müller 1965; Holt and Waters 1967; Chaston 1968, 1969; Bishop 1969; Waters 1969, 1972). In the present study, the eclipse-related increase in the occurrence of the

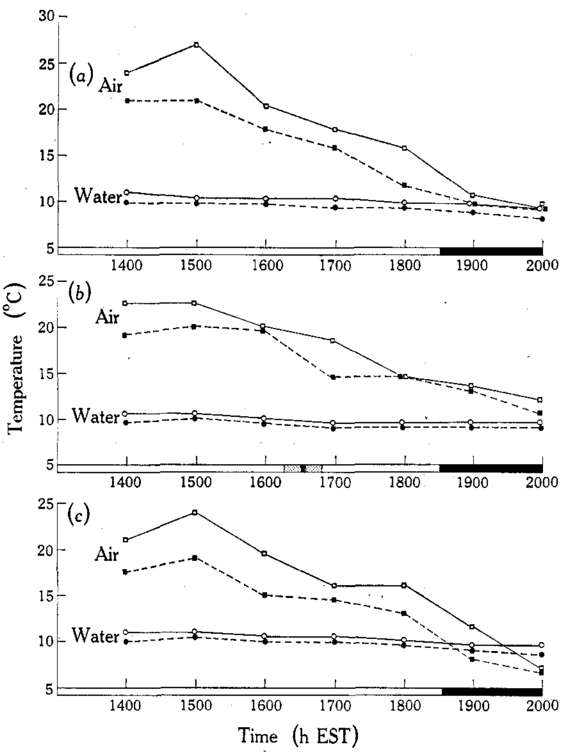

Fig. 1. Hourly maximum and minimum air and water temperatures recorded at the drift-sampling site on (*a*) 22, (*b*) 23 and (*c*) 24 October 1976. At the base of each graph the black horizontal bar indicates the post-sunset period; the black vertical line indicates the period of totality, and the stippled areas the pre-totality dusk and post-totality dawn.

dark-active helodid, leptocerid and *Conoesucus* larvae in the drift suggests that light intensity has an effect on their occurrence in the drift. The occurrence of day-active invertebrates in the drift is usually related to water temperature, light intensity apparently having no effect on their occurrence in the drift (Waters 1968; Cadwallader 1975). However, the reduction in numbers of *Cricotopus* larvae in the drift samples taken immediately following the eclipse and the subsequent increase in their numbers in the 1800–1900 h samples suggests that light intensity may play a role in controlling the activity of these day-active dipterans.

McLay (1968) found a time lapse of 0·5–1 h between the time of sunset and the occurrence of peak drift of invertebrates in a New Zealand river. In the present study, a similar delay after sunset occurred for the dark-active invertebrates (including the nymphs of Baetidae and *Trinotoperla*). In addition, the eclipse-related increase in abundance of the dark-active helodid, leptocerid and *Conoesucus* larvae in the drift

Table 1. Numbers of the major drifting organisms taken in each sampling period on 22, 23 and 24 October 1976

Period 1, 1300–1400 h; period 2, 1400–1500 h; period 3, 1500–1600 h; period 4, 1600–1700 h; period 5, 1700–1800 h; period 6, 1800–1900 h; period 7, 1900–2000 h. N, nymphs; A, adults; L, larvae. Sunset on 22, 23 and 24 October was at 1842, 1842 and 1843 h EST respectively

Taxon	22 October							23 October							24 October						
Period:	1	2	3	4	5	6	7	1	2	3	4[A]	5	6	7	1	2	3	4	5	6	7
(*a*) Net 1																					
Insecta																					
Ephemeroptera																					
Baetidae (N)	0	0	1	0	0	0	5	0	0	0	0	0	0	6	0	0	0	0	0	2	6
Leptophlebiidae (N)	0	0	2	0	2	0	2	0	0	0	0	0	0	8	0	0	0	2	0	0	3
Plecoptera																					
Gripopterygidae (N)																					
Trinotoperla sp.	0	0	0	0	2	0	11	1	0	0	0	0	0	9	0	0	0	0	0	0	9
Coleoptera																					
Elminthidae (A)	0	0	2	0	1	1	2	2	1	0	0	1	1	4	1	1	1	0	0	0	3
Elminthidae (L)	1	1	1	0	0	1	5	0	0	0	0	0	0	1	0	1	1	0	0	0	0
Helodidae (L)	0	0	0	0	0	0	11	0	0	0	0	6	0	8	0	0	0	0	0	0	14
Diptera																					
Chironomidae																					
Adults	0	2	1	0	3	3	0	0	0	2	0	1	1	5	3	3	1	3	5	3	6
Pupae	0	0	0	1	0	0	2	1	1	3	1	0	1	0	1	3	1	3	0	2	1
Larvae																					
Chironomus sp.	1	0	0	0	0	1	1	1	1	2	0	0	0	1	0	3	0	1	0	0	1
Cricotopus spp.	14	11	16	9	14	8	1	7	13	14	3	1	5	1	14	21	17	15	18	6	0
Trichoptera																					
Tasimiidae (L)	0	0	3	0	0	1	2	0	0	0	1	0	0	2	1	0	0	0	1	1	0
Leptoceridae (L)[B]																					
Species A	4	6	3	3	7	7	46	6	4	4	2	12	4	42	5	3	4	7	4	8	43
Species B	4	4	3	7	3	4	17	2	5	4	1	10	1	22	2	1	5	2	3	3	27
Conoesucidae (L)																					
Conoesucus sp.	4	3	3	2	4	5	25	1	1	2	2	7	4	16	3	2	5	3	3	5	31
Crustacea																					
Amphipoda																					
Paramoera fontana (Sayce)	3	1	5	2	4	4	6	1	2	6	1	0	0	3	0	2	0	4	0	2	0
Terrestrial arthropods	0	3	17	3	11	6	6	4	10	4	1	7	1	3	9	6	6	7	5	6	11

(*b*) Net 2

Insecta																					
Ephemeroptera																					
Baetidae (N)	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0
Leptophlebiidae (N)	1	0	1	0	1	0	6	0	2	1	0	3	0	4	1	0	0	0	0	0	3
Plecoptera																					
Gripopterygidae (N)																					
Trinotoperla sp.	0	0	1	0	0	1	2	0	1	1	0	0	0	3	1	0	0	0	1	0	5
Coleoptera																					
Elminthidae (A)	0	0	0	2	1	0	2	3	0	1	0	0	0	2	0	1	1	0	1	1	5
Elminthidae (L)	0	0	0	0	0	1	1	0	0	0	0	1	0	1	0	0	0	1	1	1	4
Helodidae (L)	0	0	0	0	0	0	6	0	0	0	0	5	0	9	0	0	0	0	0	2	12
Diptera																					
Chironomidae																					
Adults	0	0	0	0	0	0	0	0	1	0	0	0	0	3	0	0	0	0	0	1	0
Pupae	1	2	0	0	1	0	0	0	1	0	0	2	0	3	0	2	1	4	2	0	1
Larvae																					
Chironomus sp.	0	0	0	0	1	0	1	0	2	0	0	0	1	0	1	1	0	1	0	0	0
Cricotopus spp.	5	8	7	9	9	5	1	10	15	12	16	2	12	5	7	10	8	7	14	3	0
Trichoptera																					
Tasimiidae (L)	1	0	1	1	0	0	5	0	0	0	0	0	0	0	0	0	0	1	2	1	0
Leptoceridae (L)[B]																					
Species A	2	2	4	2	6	5	40	4	10	8	6	21	6	38	7	5	7	13	8	13	46
Species B	3	1	2	0	2	3	15	0	2	4	1	12	2	20	6	4	5	3	4	6	22
Conoesucidae (L)																					
Conoesucus sp.	1	0	1	1	1	4	6	1	0	0	1	4	0	8	1	1	2	4	1	3	16
Crustacea																					
Amphipoda																					
Paramoera fontana (Sayce)	1	4	2	1	1	1	5	0	4	2	3	2	0	4	1	0	1	1	2	2	0
Terrestrial arthropods	6	9	3	8	2	3	0	7	4	14	5	14	4	7	10	8	6	9	5	2	1

[A] The total solar eclipse began at 1642 h EST.

[B] Two leptocerid species were recognized, but since their taxonomic positions are uncertain they are here referred to as species A and species B; species A belongs to either *Leptorussa* or *Triaenodes* and species B belongs to either *Notalina* or *Triplectides* (A. Neboiss, National Museum of Victoria, personal communication).

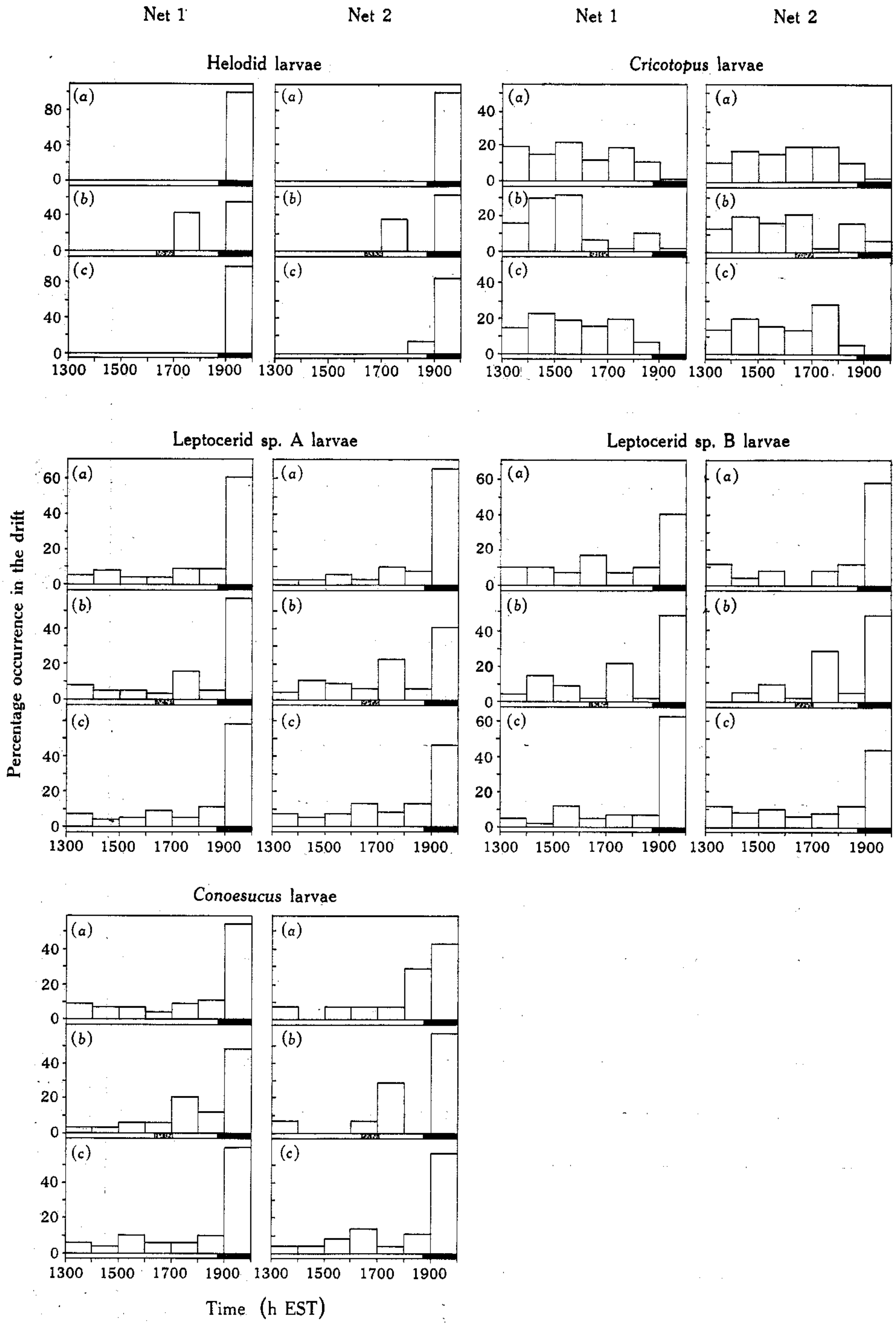

Fig. 2. Occurrence in the drift on (*a*) 22, (*b*) 23 and (*c*) 24 October 1976 of each of the five taxa whose drift patterns were affected by the eclipse. Each histogram indicates the hourly occurrence in the drift as a percentage of the total number of individuals of each taxon taken between 1300 and 2000 h EST (see Table 1 for numbers of organisms). At the base of each histogram the black horizontal bar indicates the post-sunset period; the black vertical line indicates the period of totality, and the stippled areas on each side of it indicate the pre-totality dusk and post-totality dawn.

occurred in the 1700–1800 h samples and not in the samples taken between 1600 and 1700 h when the eclipse occurred. These delays in response time are in contrast to the rapid increases and decreases in the occurrence of nymphs of *Baetis vagans* McDunnough in the drift recorded in experimental light–dark situations by Holt and Waters (1967). Apart from specific differences in the behaviour of benthic invertebrates which become part of the drift, these apparent differences in response time may reflect differences in experimental design, particularly with regard to the length of the sampling period and the proximity of the collecting nets to the source of drifting invertebrates.

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References

Affleck, R. J. (1952). Zinc poisoning in a trout hatchery. *Aust. J. Mar. Freshwater Res.* **3**, 142–69.

Bishop, J. E. (1969). Light control of aquatic insect activity and drift. *Ecology* **50**, 371–80.

Cadwallader, P. L. (1975). Feeding habits of two fish species in relation to invertebrate drift in a New Zealand river. *N.Z. J. Mar. Freshwater Res.* **9**, 11–26.

Chaston, I. (1968). Endogenous activity as a factor in invertebrate drift. *Arch. Hydrobiol.* **64**, 324–34.

Chaston, I. (1969). A comparison of the activity patterns of the aquatic larvae *Protonemura meyeri* (Plecoptera) and *Chaoborus punctipennis* (Diptera). *Am. Midl. Nat.* **82**, 302–7.

Department of Crown Lands and Survey, Victoria (1976). Map 'Path of Total Solar Eclipse, Saturday, 23 October 1976'. (Government Printer: Melbourne.)

Elliott, J. M. (1965). Daily fluctuations of drift invertebrates in a Dartmoor stream. *Nature (London)* **205**, 1127–9.

Elliott, J. M. (1967). Invertebrate drift in a Dartmoor stream. *Arch. Hydrobiol.* **63**, 202–37.

Fiala, A. D., and Duncombe, J. S. (1975). Total solar eclipse of 23 October 1976. *U.S. Nav. Observ. Circ.* **152**, 1–23.

Holt, C. S., and Waters, T. F. (1967). Effect of light intensity on the drift of stream invertebrates. *Ecology* **48**, 225–34.

McLay, C. L. (1968). A study of drift in the Kakanui River, New Zealand. *Aust. J. Mar. Freshwater Res.* **19**, 139–49.

Müller, K. (1965). Field experiments on periodicity of freshwater invertebrates. In 'Circadian Clocks'. (Ed. J. Aschoff.) (North-Holland: Amsterdam.)

Thomas, D. E. (1947). The geology of the Eildon Dam project. *Mem. Geol. Surv. Victoria*, 1947, 1–57.

Waters, T. F. (1968). Diurnal periodicity in the drift of a day-active stream invertebrate. *Ecology* **49**, 152–3.

Waters, T. F. (1969). Invertebrate drift-ecology and significance to stream fishes. In 'Symposium on Salmon and Trout in Streams'. (Ed. T. G. Northcote.) (University of British Columbia: Vancouver.)

Waters, T. F. (1972). The drift of stream insects. *Annu. Rev. Entomol.* **17**, 253–72.

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