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THE INFLUENCE OF WATER-LEVEL FLUCTUATION ON THE DRIFT OF *SIMULIUM CHUTTERI* LEWIS, 1965 (DIPTERA, NEMATOCERA) IN THE ORANGE RIVER, SOUTH AFRICA

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ABSTRACT

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In July 1982, the invertebrate drift at Marksdrift comprised 98,7% *Simulium chutteri;* 0,75% Chironomidae; 0,3% Ephemeroptera; 0,15% Copepoda, and 0,1% Trichoptera. Simuliid eggs were found in only 6 out of 75 samples.

A single water-level reduction of 57 cm (54%) resulted in a more than sixfold increase of *S. chutteri* larvae in the drift and a more than 50% decrease of 1st and 2nd instar larvae in the drift after the water had returned to its original level. Larvae found lying in pools after the water-level had dropped belonged mainly to instars 5–7, 70% of them showing symptoms of starvation after 3 days when the river had risen again.

The drift of simuliid head capsules decreased when the larval drift increased, as fewer simuliid larvae moulted when they had been disturbed.

The low drift of eggs and the presence of very few pupae and adults indicated that most of the *S. chutteri* population was in the larval stage and that July was therefore an ideal month for water-level manipulation. Its main effect was achieved by irritating larger larvae and thus preventing them from resettling.

INTRODUCTION

Invertebrate drift in rivers is subject to a recurrent temporal pattern of activity within a 24-hour period, called "diel periodicity" (Elliott, 1970). Fluctuations in drift density are determined by various factors, including the density of invertebrates in the benthos, the stage in their life history, their activity and behaviour and the current velocity to which they are exposed (Elliott, 1967). According to Chutter (1975), Waters (1969) defines "constant drift" as occuring at any time, "behavioural drift" as having a diel pattern with greater nocturnal activity, and "catastrophic drift" as being associated with physical disturbances of the benthos.

A catastrophic increase of invertebrate drift in response to a decrease in stream flow was observed in a small river in Idaho, United States, by Minshall & Winger (1968) and in South Africa in the Vaal River by De Moor (1982 b). Since 1978, the Veterinary Research Institute, Onderstepoort, in co-operation with the Directorate of Water Affairs, has performed trials to reduce the population of Simuliidae by desiccating the aquatic habitat of larvae and pupae through water-level manipulation (Howell, Begemann, Muir & Louw, 1981). This led to a gradual decrease of the adult population of Simuliidae so that, according to the various writers' observations, *S. chutteri* lost its pest status in regions of the river affected by water-level manipulation.

The aim of the present study was to evaluate the influence of a single decrease of water flow on invertebrate drift.

METHODS

Invertebrate drift was collected in the Orange River at Marksdrift, near Douglas in the Cape, 160 km below the P. K. le Roux Dam, using a water-wheel drift sampler (Pearson & Kramer, 1969) modified by Chutter (1975) (Fig. 1). A sampling point was selected in a rapid 100 m below the Marksdrift gauging weir. At 11h00 on 16 July 1982 the sluices of the P. K. le Roux Dam were closed. Forty-nine hours later, at 12h00 on 18 July the water flow began to fall at Marksdrift. Samples of drift were taken at hourly intervals from 16–22 July 1982 during 4 separate sampling periods.

Sampling period I lasted 26 hours, from 16–17 July, during normal water flow. Sampling period II lasted 25 hours, from 19–20 July, during a falling water-level. Sampling period III lasted 18 hours on 21 July and was separated from sampling period IV (6 hours on 22 July) by a sudden increase in water flow to the original level seen in sampling period I (Fig. 2).

FIG. 1 Water-wheel drift sampler in the Orange River 100 m below the Marksdrift gauging weir

As there was no constant outflow from the P. K. le Roux Dam, the water-level at Marksdrift fluctuated continuously. To obtain accurate results a maximum of only 15 minutes in every hour could be used for sampling drift. The water-wheel was calibrated before and after each sample was taken by measuring the amount of water filtered during 3 revolutions of the wheel as measured with a revolution counter. Drift was filtered through silk nets with a pore size of 92 μm, which was small enough to retain simuliid eggs.

Water temperatures, conductivity and pH were measured at various times throughout the study period. By moving the sampler slightly, a current speed of ± 1,2 m/s, measured from a drifting object, was maintained throughout all sampling periods. Polythene strips 100 cm in length and 2,5 cm in width were used as artificial substrates to observe the settling rate of drifting simuliid larvae (De Moor, 1982 b). Two of the strips were fixed in the current immediately below the drift sampler 48 hours before the water-level was reduced, and a further 2, also for 48 hours, when the water-level was falling.

Bottom samples were obtained by scraping simuliid larvae from rocks at the site where drift samples were taken later. Water was deviated by holding a plank in the current above the rock from which larvae were to be collected and a net was held behind the rock to catch the specimens. Samples were taken at 5 points and a random sample of 500 larvae was measured to determine their instar distribution.

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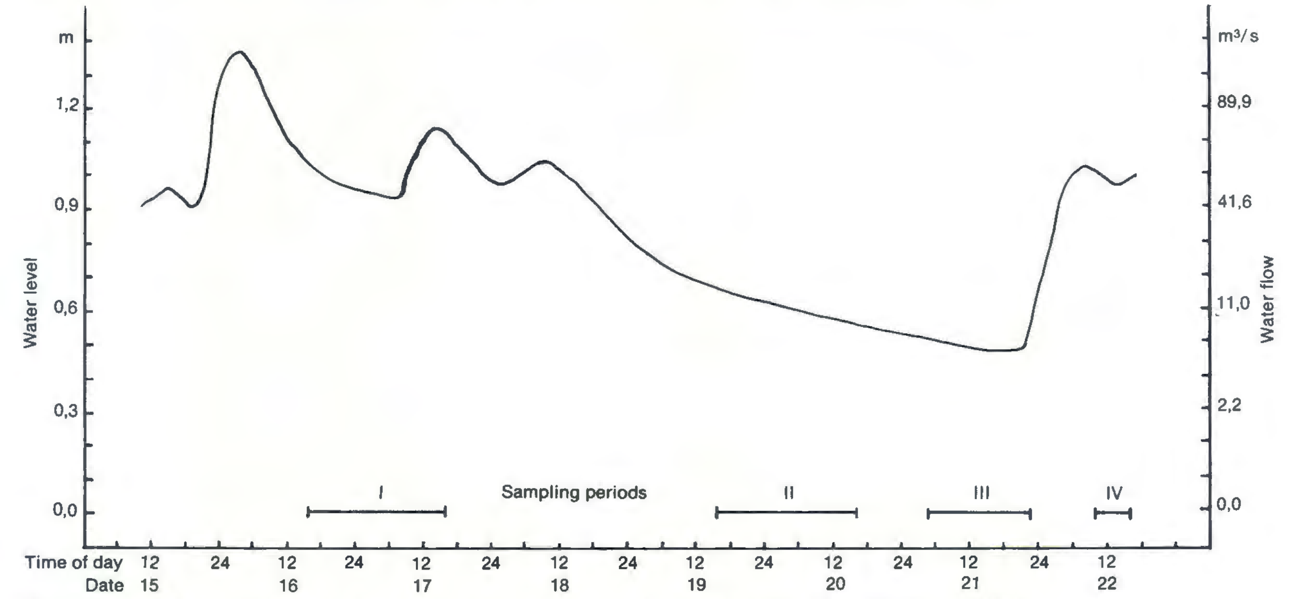

FIG. 2 Water-level, water flow and drift sampling periods at Marksdrift, Orange River, from 15–22 July 1982

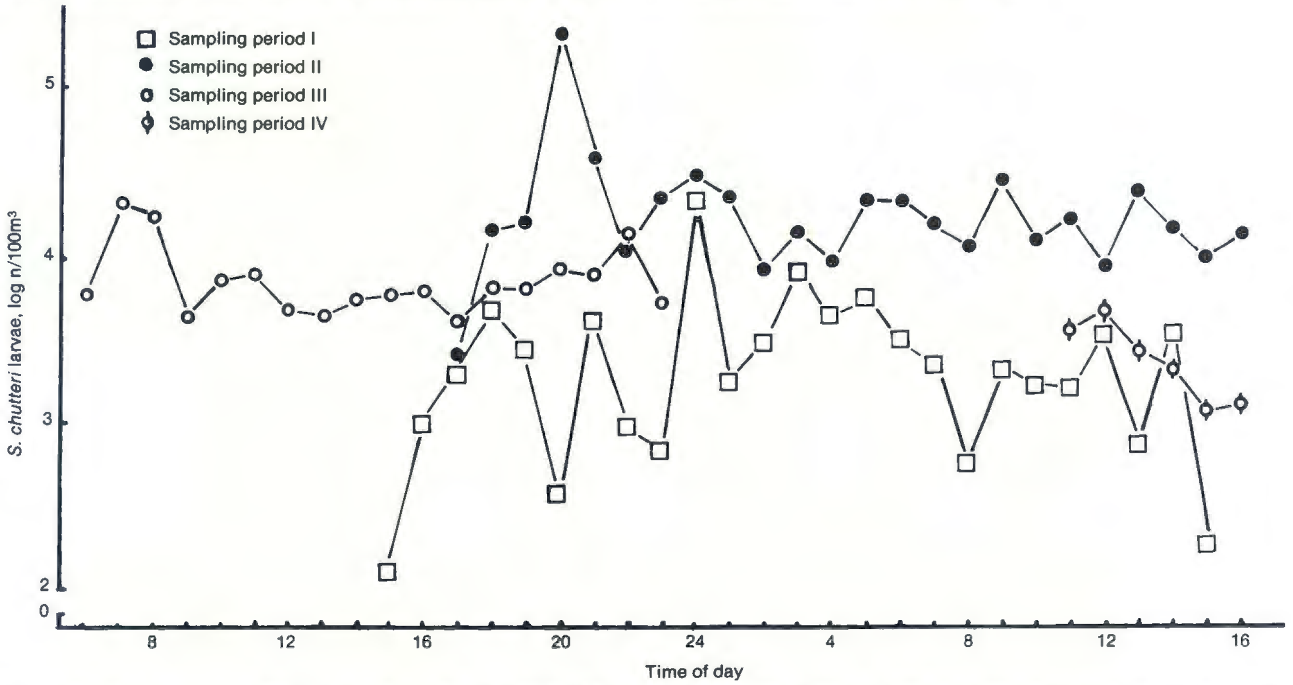

FIG. 3 Drift of *S. chutteri* larvae in the Orange River at Marksdrift during 4 sampling periods at different water-levels from 16–22 July 1982. Samples taken at hourly intervals

After the water had dropped, larvae, which had remained in pools where no water flow was discernible, were collected and a random sample of 500 was measured. Samples were preserved in plastic bags with formalin added to obtain an approximate 2% solution.

In the laboratory Simuliidae were identified specifically and all other invertebrates and their eggs to the family level. To determine the larval instars, *S. chutteri* larval head capsules were measured, using the method described by De Moor (1982 a). The moulting rate was assessed by counting drifting head capsules of *S. chutteri*. All counts were calculted to a standard of numbers of invertebrates per 100 m^3 water filtered, and a logarithmic transformation was undertaken on the data counts for the diagrams. Counts of larval and head capsule drift made during different sampling periods were compared by means of the paired t-test, or, where variances were heterogeneous at $P<0,05$, the non-parametric Wilcoxon paired observation test (Zar, 1974).

Because of the low numbers of larvae found in some samples no statistical analysis was used to compare drift of different larval instars of *S. chutteri*; instead either hourly means or total numbers are given in Tables 1 and 2.

RESULTS

The drift comprised 98,7% Simuliidae, of which all the specimens that were identified specifically belonged to *S. chutteri*; 0,75% Chironomidae; 0,3% Ephemeroptera; 0,15% Copepoda, and 0,1% Trichoptera. Strong drift variations were observed, since drift generally increased at night and during periods of changing water-levels.

S. chutteri *larval drift during different sampling periods*

A comparison of the 4 sampling periods using the t-test for paired observation showed that, apart from sampling periods I and IV, there was a significant difference ($P<0,05$) between larval drift in all the sampling periods (Fig. 3; Table 1).

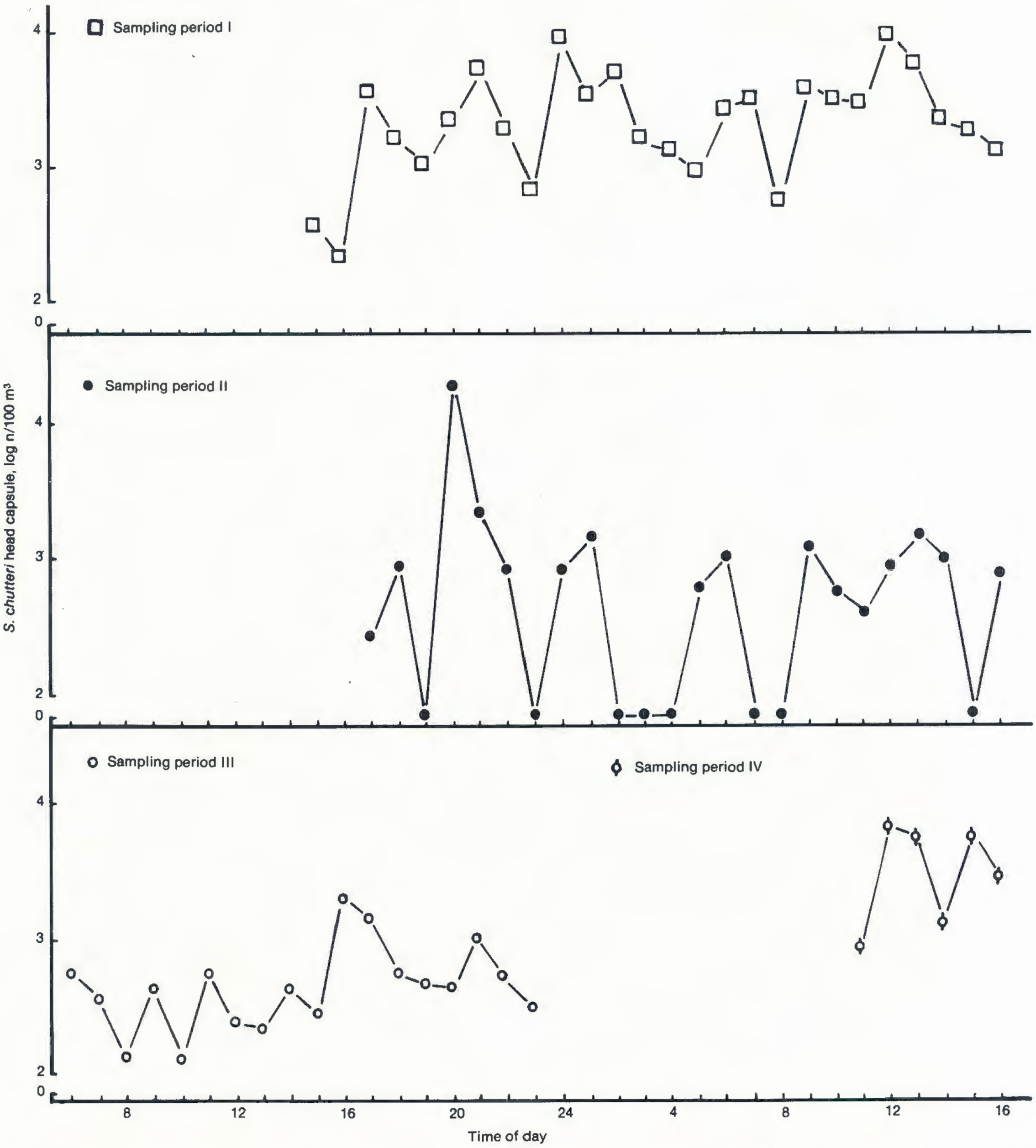

FIG. 4 Drift of *S. chutteri* head capsules in the Orange River at Marksdrift during 4 sampling periods at different water-levels from 16–22 July 1982. Samples taken at hourly intervals

As soon as the water-level dropped below the limits of normal fluctuation, the mean 24-hour drift, calculated from hourly drift samples, increased more than sixfold. In sampling period III, 68 hours after the start of water-level reduction, the rate of water-level decrease was lower (0,21 cm/h) than at the beginning (0,44 cm/h). Compared with sampling period I only twice the amount of drifting *S. chutteri* larvae was noticed (Table 1). When the water-level had risen again, the mean drift returned to its original rate. It was noticed, however, that many larvae were dead or dying and that many disintegrated larvae were present. These were not counted. The intestines of 70% of the 5th to 7th instar larvae were empty.

Drift rate of the 7 instars of S. chutteri.

In general, 2nd, 3rd and 4th instar larvae were those most commonly found in the drift, the 2nd instar being dominant in the 1st 2 sampling periods (Table 2).

Although drift of most instars at night was higher than during the day, 1st instar larvae drifted less at night in sampling periods I and III, and 2nd and 3rd instar larvae

TABLE 1 Mean hourly drift of *S. chutteri* larvae/100 m³ during 4 sampling periods at different water-levels of the Orange River at Marksdrift, 16–22 July 1982

Sampling period	Water-level	Day (07h00–18h00)	Night (19h00–06h00)	Total (24 hours)
I	Normal fluctuation	3 029	4 926	3 978
II	Dropping 0,44 cm/h	15 229	36 460	25 844
III	Dropping 0,21 cm/h	7 812	8 454*	8 133
IV	Normal fluctuation	2 692**	—	—

* 5 hours extrapolated to 12 hours

** 6 hours extrapolated to 12 hours

drifted less at night in sampling period III. As shown in Table 2 and expressed as a factor in Table 3, the total day and night drift of each larval instar increased throughout sampling period II but, apart from 7th instar, larvae started to decrease during sampling period III. By this time 1st instar larvae had dropped to below their original level. During sampling period IV the day-time drift of 2nd instar larvae had also dropped to below their original level.

Head capsules and eggs

The drift of head capsules was very variable and revealed no periodicity (Fig. 4).

TABLE 2 Total day- and night-drift of 7 larval instars of *S. chutteri* during 4 sampling periods at different water-levels of the Orange River at Marksdrift, 16–22 July 1982

Larval instar	Time: Day: 07h00–18h00 Night: 19h00–06h00	Larvae per 100 m³ drifting in sampling periods			
		I	II	III	IV
I	Day	6 692	12 305	4 217	3 864**
	Night	6 361	26 678	3 977	—
	Total 24 hours	13 053	38 983	8 194	—
II	Day	6 211	65 187	27 663	2 240**
	Night	18 065	143 095	21 034*	—
	Total 24 hours	24 276	208 282	48 697	—
III	Day	2 885	42 593	31 375	9 220**
	Night	11 471	94 249	22 494*	—
	Total 24 hours	14 356	136 842	53 869	—
IV	Day	5 743	26 996	15 024	6 992**
	Night	10 720	85 617	14 179*	—
	Total 24 hours	16 463	112 613	29 203	—
V	Day	4 622	20 529	10 151	5 598**
	Night	8 480	60 048	17 158*	—
	Total 24 hours	13 102	80 577	27 309	—
VI	Day	209	8 755	3 291	2 160**
	Night	1 173	16 961	6 394*	—
	Total 24 hours	1 382	25 716	9 685	—
VII	Day	144	2 895	1 630	826**
	Night	2 844	9 532	29 191*	—
	Total 24 hours	2 988	12 427	30 821	—

* 5 hours extrapolated to 12 hours

** 6 hours extrapolated to 12 hours

TABLE 3 Change of total day-time drift (07h00–18h00) of 7 larval instars of *S. chutteri* expressed as a factor (F) comparing sampling period I (F = 1,00) with sampling periods II, III and IV, Marksdrift, Orange River, 16–22 July 1982

Larval instar	Factor of change in drift from sampling period I to sampling periods:		
	II	III	IV
I	1,84	0,63	0,58
II	10,50	4,45	0,36
III	14,76	10,88	3,20
IV	4,70	2,62	1,22
V	4,44	2,20	1,21
VI	41,89	15,75	10,33
VII	20,10	11,32	5,74

F > 1 relates to drift increase, F < 1 relates to drift decrease

A comparison of the head capsules found in the drift during different sampling periods (excluding zero values in sampling period II) showed that in sampling period I drift was significantly higher than in sampling period II ($P<0{,}01$) and sampling period III ($P<0{,}001$). In sampling period IV drift was significantly higher than in sampling periods II and III ($P<0{,}05$). Differences between sampling periods I and IV, and between II and III, were not significant.

The drift of simuliid eggs was very low, as eggs were found in only 6 out of 75 samples. No conclusions about the influence of water-level manipulation on the drift of eggs could thus be made.

Benthic samples from artificial substrates, rocks and pools

The 2 polythene strips left in the rapid for 48 hours before water-level reduction remained free of *Simulium* larvae. The 2 further polythene strips placed in the rapid at 15h00 on 18 July 1982 and left there for 48 hours while the water-level was falling were colonized respectively by 192 and 245 *S. chutteri* larvae.

All larvae scraped from rocks in turbulent water and found in pools after the water-level had dropped, belonged to the species *S. chutteri*. The distribution of larval instars is indicated in Table 4.

TABLE 4 Comparison of larval instars of *S. chutteri* collected before water-level manipulation from rocks in a rapid with those found in quiet pools with no water flow after the water-level had dropped, Marksdrift, Orange River, 16–22 July 1982

Larval instar	Percentage of larval instars from	
	Rocks	Pools
I	0	0
II	16	0
III	48	2
IV	22	15
V	10	48
VI	4	30
VII	0	5

Chemical and physical data

Water temperatures in the river varied throughout the sampling periods from 9 °C–13 °C. After the water-level had dropped, temperatures measured in pools at 14h00 varied from 18 °C–21 °C, depending on their size. Conductivity measured in the river at a flow rate of 53,4 m^3/s was 102 $\mu S/cm$ and the pH 6,2. At a flow rate of 6,4 m^3/s conductivity was 140 $\mu S/cm$ and the pH 6,5. After the river had risen again to 53,4 m^3/s conductivity was 105 $\mu S/cm$ and the pH 6,1.

DISCUSSION

Drift variations due to sampling in turbulent water with changing water-levels were acceptable considering the high drift differences between consecutive sampling periods.

The high percentage of simuliid larvae in the drift (98,7%) results from the situation of the sampling point 100 m below the Marksdrift gauging weir. As previously observed (Howell & Holmes, 1969; Car, 1981), the *Simulium* population in lake outflows is especially high because of increased amounts of suspended organic matter. The following factors, which are essential for the occurrence of *S. chutteri*, help to explain why it was the only simuliid species found at Marksdrift.

As already observed by Chutter (1968), the biotope most successfully explioted by *S. chutteri* is a stony river bed exposed to a regularly fluctuating water-level. His suggestion that *S. chutteri* as an early colonizer is more abundant in the drift than other simuliid species has been proved by De Moor (1982 b). According to these 2 authors the advantage of colonizing newly-submerged stones is the lack of predators, which do not settle in these areas. Coetzee (1982) mentions that *S. chutteri* has been found in large numbers in the Great Fish River only after the Orange River had been diverted into it. It can therefore be assumed that the continuous water flow and high percentage of suspended matter in the Orange River favour the presence of *S. chutteri*.

De Moor (1982 b) found that aquatic stages of *S. chutteri* prefer current velocities of more than 56 cm/s, and at a water velocity of 87 cm/s 99% of the simuliid population were *S. chutteri*. Therefore a velocity of 100 cm/s–120 cm/s in the present study area seemed to be ideal for the survival of this species. The author observed *S. chutteri* larvae attached to irrigation pipes from the Orange River near Kakamas at a water velocity of 150 cm/s.

The usual drift pattern shows peaks at sunrise and sunset and higher drift at night than during day-time (De Moor, 1982 b). Even when this pattern was disrupted by daily water-level fluctuation and the water-level manipulation, a higher drift density could still be observed at night during all the sampling periods. When comparing the drift of the different larval instars, it must be remembered that this study was undertaken in mid-winter when very few larvae of 1st and 7th instars were present. After the 1st and 2nd instar larvae had drifted off, their numbers were low in the last sampling period because of low recruitment, as the low numbers of eggs found in the drift indicate. Third instar larvae were well represented in sampling period I and their drift increased in the following sampling periods more than that of most other larval instars. As only 2% of simuliid larvae found in pools after the water-level had dropped belonged to the 3rd instar, it can be concluded that this instar is still able to drift easily. The high percentage of 3rd instar larvae on rocks in the rapid indicates that turbulent flowing water seems to be ideal for their survival.

The drift increase of 6th instar larvae by the factor 10,34, and of 7th instar larvae by the factor 5,74 after the water-level had risen again, indicates that many of the larvae, most of them damaged and with empty intestines, had drifted out of pools after the water-level had risen. The decreasing amount of drift from 12h00–15h00 in the last sampling period could indicate that simuliid larvae from pools influenced the drift pattern less with the passage of time after the water-level had returned to its original height. As large simuliid larvae normally drift very little (De Moor, 1982 b), it can be suggested that many of them cannot resettle and would therefore die.

There are 2 possible reasons for the low drift of head capsules during water-level manipulation when larval drift was high: 1. Fewer head capsules drifting off simuliid larvae because part of the larval population had settled in pools. 2. As head capsules drift off only when simuliid larvae moult, the moulting rate was probably lower because the larvae had been subjected to the physical stress of drifting and therefore had less opportunity for moulting. An increase in head capsule drift after the water had returned to its original level in sampling period IV was probably caused by the head capsules drifting out of pools.

Polythene strips were colonized within 48 hours after the water-level had dropped, possibly because of the increased drift density of the simuliid larvae. These could settle only with difficulty on stones, since the area available to them in the river bed had been reduced.

Compared with data the author obtained at a breeding site of *S. chutteri* in the Vaal River (conductivity 650 μS/cm, pH 7,3, temperature rising above 27 °C), it appears that physical and chemical factors in this study fluctuated in a range well within the tolerance limits of *S. chutteri* and therefore had no influence on the drift pattern.

CONCLUSION

Water-level manipulation, hitherto believed to be effective mainly by desiccating the pupae of *S. chutteri* (Howel *et al.*, 1981), exerts its greatest influence on simuliid larvae when undertaken in winter. While small instar larvae are able to remain in the drift, 5th–7th instar larvae settle out in pools where they cannot feed adequately. Contrary to observations in April by Howell *et al.* (1981) most larvae can survive a 72-hour period in still water in July, when temperatures are lower. The main effect of water-level manipulation in winter is irritation of the large larvae, most of which cannot resettle after the water-level has risen again. De Moor (1982 b) suggested that, in the Vaal River, July and August are the ideal months for this kind of population control of *S. chutteri*. This would also be the case in the Orange River, where most of the simuliid population is in the larval stage in July.

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