by spraying only after sundown when the target species is most active and most non-target species resting.

In conclusion we recommend Sumithion at 142 gm/ha A.1. delivered in aqueous solutions at 731 ml/ha for the control of *Ae. taeniorhynchus;* even if applied through dense mangrove canopy under tropical conditions.

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GENERATION AND INSTAR SUCCESSION OF THE BLACK FLY *SIMULIUM PENOBSCOTENSIS* (DIPTERA: SIMULIIDAE)[1]

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ABSTRACT. There were 3 generations of *Simulium penobscotensis* Snoddy and Bauer in 1978. The 2nd and 3rd generations were made up of 3 and 4 cohorts respectively. Development from instars 1–3 through the pupal stage took 9–13 days. Late August and September cohorts were numerically small.

INTRODUCTION

The problem of black fly pests of humans during the summer has been prevalent in central Maine for more than a decade (Waters 1969, Sleeper 1975). The specific pest was originally thought to be *Simulium nyssa* Stone and Snoddy (Stone and Snoddy 1969). However, it was recently identified as a closely related species, *S. penobscotensis* Snoddy and Bauer, which has been indistinguishable from *S. nyssa* as an adult (Snoddy and Bauer 1978, May et al. 1977). Electrophoretic work with iso-enzymes indicated that *S. nyssa* either was not a biting pest or only contributed slightly to the problem. *S. penobscotensis* is primarily a warm river insect and uses vegetation as its larval and pupal substrate (Bauer 1977, Boobar and Granett 1978).

Determinations of instar frequencies in periodically sampled black fly populations have been used to establish number of generations and larval developmental

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rates. Recent studies have considered the species *S. virgatum* (Reisen 1975, 1977), *S. ornatum, S. lineatum* (Ladle et al. 1977), *Prosimulium mixtum/fuscum, Stegopterna mutata* and *Cnephia dacotensis* (Ross and Merritt 1978).

Previous work has shown that *S. penobscotensis* has 7 larval instars (Granett 1979). Reported here are studies of instar frequencies with the objective of determining the number and timing of generations and developmental rates of the larvae.

STUDY AREA

Collections were made from the Penobscot River in Winn and Lincoln, Penobscot Co., Maine. The river current in the collection areas ranged between 0.25 and 0.75 m/sec with mean water temperatures during collections of 16.5°C in June 1978, 22°C in July, 22.6°C in August, and 18.5°C in September. Aquatic vegetation in the river consisted primarily of *Potamogeton* spp. and *Sparganium* spp.

METHODS

Periodic samples of immature black flies were taken on *Potamogeton* between 6 June and 19 September, 1978. Intensive sampling was done from a single weed bed in Winn between 17 July and 6 September, 1978. For this latter series, 3–5 samples of *Potamogeton* were sheared and placed in jars under water for each sampling date. Contents of the jars were transferred to 70% ethanol in the laboratory and black flies were hand-separated from the vegetation. Vegetation samples were air-dried and weighed. Black fly numbers were reported as insects/g dry vegetation.

Larval and pupal black flies were identified to species using the keys of Wood et al. (1963), Davies et al. (1961), Stone and Snoddy (1969), and Snoddy and Bauer (1978), and counted. *Simulium penobscotensis* larvae were separated by instar (Granett 1979).

RESULTS AND DISCUSSION

The predominant species of black flies were *S. penobscotensis, S. vittatum* Zetterstedt and *S. fibrinflatum* Twinn. The seasonal changes in the frequency distribution of *S. penobscotensis* instars are shown in Figure 1. At each collection date all instars of *S. penobscotensis* were not present in equal numbers but could be separated into groups of individuals which appeared to have hatched from eggs at approximately the same time. These groups, termed cohorts, showed progressive increases in maturity with each successive collection. Cohorts were considered to be grouped within generations because the immature stages of separate cohorts overlapped to the extent that adults of one cohort could not possibly have laid the eggs of the immediately succeeding cohort. Seven cohorts were subjectively identified and designated by a letter and by an underline of included developmental stages in Figure 1. Because cohorts overlapped, the limits of each cohort shown are not clearly defined and so are not presented inclusive of all instars.

Early instars of *S. penobscotensis* continuously appeared during July and August. The time for development from instars 1–3 to pupae was between 9 and 13 days. For instance cohort A developed from instars 2, 3, and 4 to pupae in 9 days, cohort B from instars 1 and 2 to pupae in 12 days, and cohort E from instars 1, 2, and 3 to pupae in 13 days.

The cohorts A and B observed in July were seen as distinct groupings throughout their development and tended not to merge with one another; however, cohorts C through G in August were less distinct.

In the September collections early instars were very scarce indicating a low rate of egg hatch. No *S. penobscotensis* were found on the last collection date, 19 September. These data indicate that *S. penobscotensis* probably overwinters in the egg stage rather than as a larva. The fact that eggs do not hatch in the late summer and fall suggests that photoperiod rather

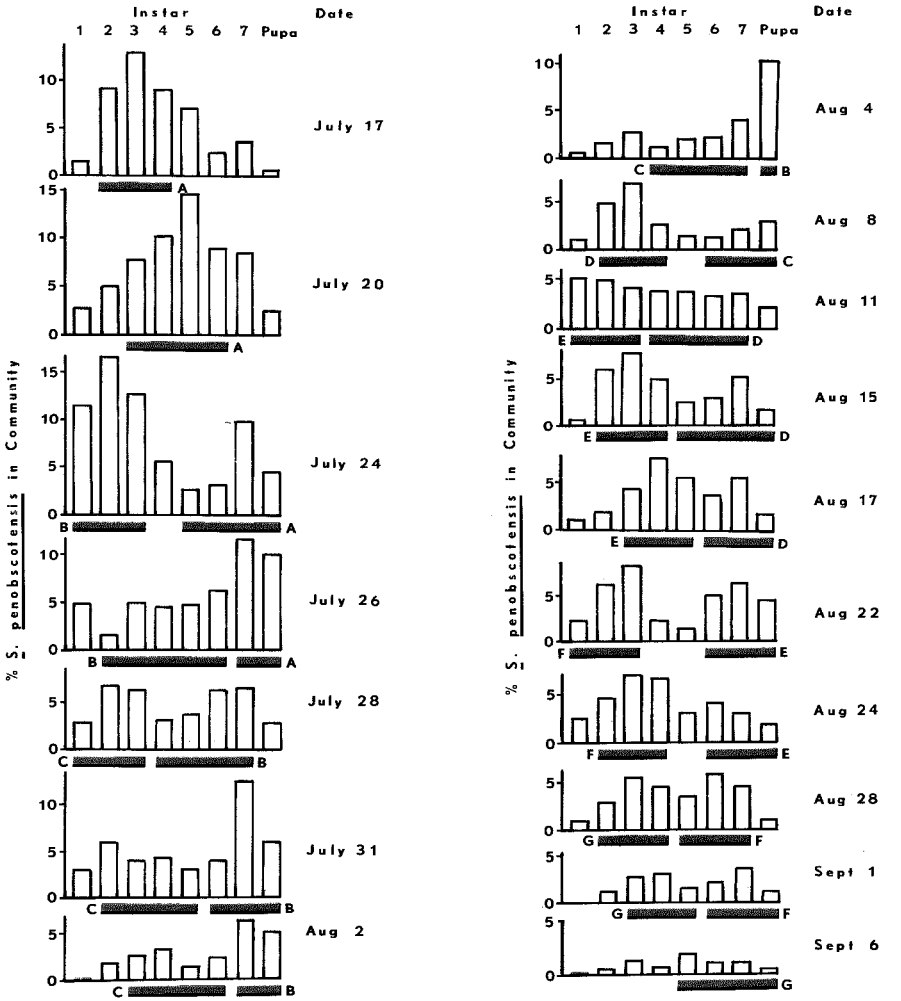

Fig. 1. *Simulium penobscotensis* instar and cohort succession from the Penobscot River, Maine, July through September, 1978.

than temperature is the controlling factor since the temperature remained high through the beginning of September (Table 1).

The seasonal proportions of *S. penobscotensis* to the total black fly community are shown in Table 1. These percentages along with the *S. penobscotensis* numbers/g dry vegetation for the July and August collections indicated that 3 generations of *S. penobscotensis* occurred in 1978. The high percentages on 6 and 23 June indicated the first generation peak. Data for this generation were too incomplete to determine if cohorts were present. The percentages next peaked between 17 and 26 July and during this time the numbers of *S. penobscotensis*/g dry vegetation also peaked thus indicating the second generation. Comparison of population values with the cohort succession shown in Figure 1 shows that the 2nd generation consisted of cohorts A, B, and C.

A third generation was initiated by cohort D on 8 August while the populations peaked 15 August. Generations 2 and 3 overlapped; cohorts C and D were present at the same time in the river.

The estimates of population size indicated that cohort size varied greatly (Table 1). Cohorts A, B, and D were larger than cohorts C, E, F, or G as indicated by *S. penobscotensis* numbers/g dry vegetation in the collections with these cohorts.

From the above data, suggestions can be made concerning possible control strategies for this species. The generations consisted of a number of cohorts which did not overlap completely. Most larval control agents, whether chemical, biological, or mechanical, are not effective against the egg or pupal stages, and

Table 1. Number of larvae and pupae of *Simulium penobscotensis*/ g dry vegetation and the % this species constituted of the total simuliid population in collections from the Penobscot River, Maine, 1978.

Generation	Collection Date	Water °C	*S. penobscotensis* %	*S. penobscotensis* per g dry veg.	Cohorts
I	6/06	12	45		
	6/15	16	12		
	6/23	19	39		
	7/12	23	2		
II	7/17	22	52		
	7/20	23	58	773	A
	7/24	21	64	614	AB
	7/26	24	42	1077	AB
	7/28	24	38	801	BC
	7/31	21	38	331	BC
	8/02	21	22	533	BC
	8/04	22	26	166	BC
III	8/08	22	21	302	D C
	8/11	25	30	463	D
	8/15	25	30	921	DE
	8/17	—	31	574	DE
	8/22	—	35	172	EF
	8/24	—	30	204	EF
	8/28	21	36	215	FG
	9/01	19	15	70	FG
	9/06	20	8	67	G
	9/19	15	0		

tend not to have residual activity. Repetitive applications of control agents may be necessary to have effect on non-overlapping cohorts within generations.

Efficient control procedures for *S. penobscotensis* should concentrate on the larger cohorts. In generation 2, cohorts A and B made up the bulk of the population. If cohort C was not controlled the population of this generation would still be much reduced. In generation 3 cohorts D and E constituted the largest part of the population, while the F and G cohorts were very small. Control programs will require careful monitoring to determine timing of treatments to achieve control of the desired cohorts.

Monitoring techniques will have to include species identifications. Peaks of *S. penobscotensis* occurred when this species made up only 42% and 30% of the black fly community (26 July and 15 August). Hence the other species present, *S. fibrinflatum* and *S. vittatum*, which are not biters of humans in Maine (Bauer and Granett, unpublished data), constituted the majority of the black flies present even at peak *S. penobscotensis* sampling dates.

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