ARTICLES

EFFECT OF SODIUM CHLORIDE ON LARVAL SNOW-MELT *AEDES* (DIPTERA: CULICIDAE)[1]

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ABSTRACT. The presence of sodium chloride, a salt commonly used to melt snow and ice, in larval media was detrimental to larval development and survival of the adults. Lethal concentrations were usually less than 5000 ppm NaCl. Sublethal concentrations caused extension of the juvenile developmental period and asynchrony of ecdysis.

Larvae of snow-melt *Aedes* appear early in the spring in collections of run-off water, much of which may contain NaCl applied to road surfaces to melt snow. Kardatzke and Liem (1972) reported that larvae of *Ae. stimulans* (Walker) from an Illinois population had a very low tolerance for NaCl when compared with *Ae. vexans* (Meigen). Liem (1975) reported that larval *Ae. vexans* over successive generations developed increased tolerance for NaCl. Parker (1979) reported a similar development of tolerance for NaCl in larval *Ae. caspius dorsalis* (Meigen). The purpose of this investigation was to appraise larval development and survival of snow-melt *Aedes* when reared in the presence of various concentrations of NaCl.

METHODS AND MATERIALS

Larvae used in this study were obtained from eggs laid by field-captured females collected, transported, and maintained following procedures of Kardatzke (1976). All females were collected in 1976 from Michigan north of 42°N latitude. The rearing technique used was that described by Kardatzke (1979). A minimum of 90 larvae reared in 3 pans was used with each salt concentration. Sodium chloride concentrations varied in increments of 1000 ppm NaCl. Observations were made daily with all exuviae and dead specimens removed and counted during these observations. LD_{50} was determined by statistically interpolating the theoretical LD_{50}.

RESULTS

Presence of sodium chloride in the larval rearing medium affected larval survival, duration of development and synchronization of ecdysis. Many of the 10 species, *Ae. abserratus* (Felt and Young), *Ae. canadensis* (Theobald), *Ae. cinereus* (Meigen), *Ae. communis* (De Geer), *Ae. diantaeus* Howard, Dyar, and Knab, *Ae. provocans* (Walker), *Ae. fitchii* (Felt and Young), *Ae. punctor* (Kirby), *Ae. sticticus* (Meigen), and *Ae. stimulans* differed in their response to the presence of NaCl. *Ae. provocans, Ae. fitchii, Ae. stimulans,* and *Ae. sticticus* are presented in detail because they exemplify these differences in tolerance. The other 6 species were grouped with 1 of the 4 above.

Ae. provocans was the least tolerant of all species exposed to NaCl. In non-saline medium this species required a mean of 11.6 days at 21°C to complete juvenile

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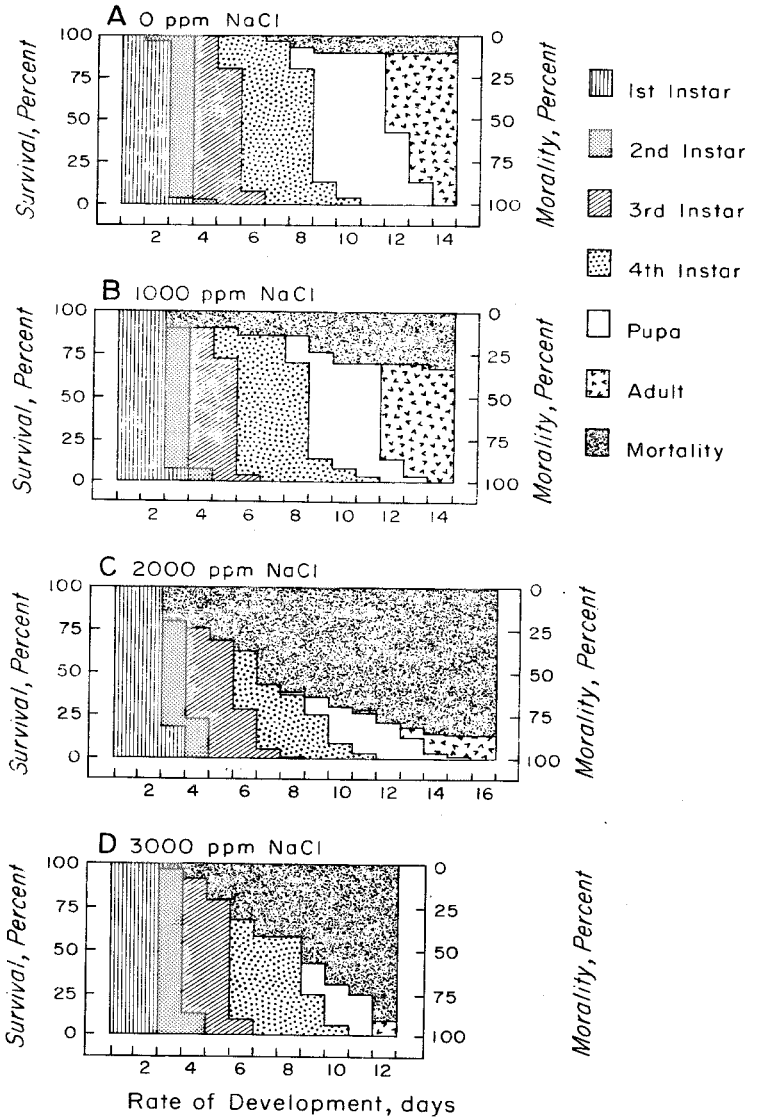


Figures 1A to D: Effect of different concentrations of sodium chloride in the rearing media on the rate of development and mortality of *Aedes provocans* at 21°C.

development (Fig. 1A). Although total duration of juvenile development did not increase as a result of adding NaCl, prolongation of development of some individuals during each juvenile stage preceded the death of the larvae prior to ecdysis. In the rearing medium containing 3000 ppm NaCl only 9% of the juveniles developed to adults (Fig. 1D). LD_{50} of NaCl for juvenile *Ae. provocans* was determined to be 1315 ppm (Table 1).

Juvenile *Ae. communis* tolerated the presence of NaCl in a manner similar to *Ae. provocans*. If 3000 ppm NaCl were added to the medium, few juveniles survived to the pupal stage, and these died prior to darkening of the cuticula. The developmental period of *Ae. communis* was prolonged slightly as the concentration of NaCl was increased (Table 1). LD_{50} of NaCl for juvenile *Ae. communis* was calculated to be 1458 ppm.

Ae. fitchii was moderately tolerant to NaCl. Larvae reared in non-saline medium required a mean of 13.4 days at 21°C to complete development with ecdysis being synchronous (Fig. 2A). The developmental period of each juvenile stage gradually lengthened as the concentration of NaCl in the medium increased (Table 1). Ecdysis lacked synchrony beyond instar 3 (Fig. 2B). At 3000 ppm. only 50% of the juveniles survived to the adult stage. These required a mean of 17.6 days to complete development (Table 1). At 5000 ppm, only 11% of the juveniles survived through the pupal stage (Fig. 2F). These required over 20 days to complete development. LD_{50} of NaCl for juvenile *Ae. fitchii* was calculated to be 3000 ppm (Table 1).

Ae. abserratus, Ae. cinereus, Ae. diantaeus, and *Ae. punctor* tolerated the presence of NaCl in the rearing medium in a manner similar to *Ae. fitchii*. LD_{50} of NaCl (Table 1) was determined to be 3130 ppm NaCl for *Ae. abserratus*, 3422 ppm NaCl for *Ae. cinereus*, 3130 ppm NaCl for *Ae. diantaeus*, and 3600 ppm NaCl for *Ae. punctor*. Developmental periods of the juvenile stages of these species were gradually lengthened as the concentration of NaCl in the medium increased.

Ae. stimulans was more tolerant to NaCl concentrations. In non-saline medium, juveniles required a mean of 12.1 days to complete development (Fig. 3A). Duration of development was not prolonged until the concentration of NaCl was 5000 ppm (Fig. 3). Survival to the adult stage did decrease at and above 3000 ppm NaCl (Table 1). LD_{50} of NaCl for juvenile *Ae. stimulans* was calculated to be 4083 ppm.

Ae. sticticus was relatively tolerant to NaCl. In non-saline medium juvenile development required a mean of 8 days (Table 1). Duration of development was not prolonged until the concentration of NaCl was 5000 ppm or greater (Fig. 4). LD_{50} of NaCl for juvenile *Ae. sticticus* was determined to be 4536 ppm.

Aedes canadensis (Table 1) tolerated the presence of NaCl in a manner similar to *Ae. sticticus*. LD_{50} of NaCl for juvenile *Ae. canadensis* was calculated to be 4538 ppm. The developmental period increased gradually once the concentration of NaCl exceeded 3000 ppm.

DISCUSSION

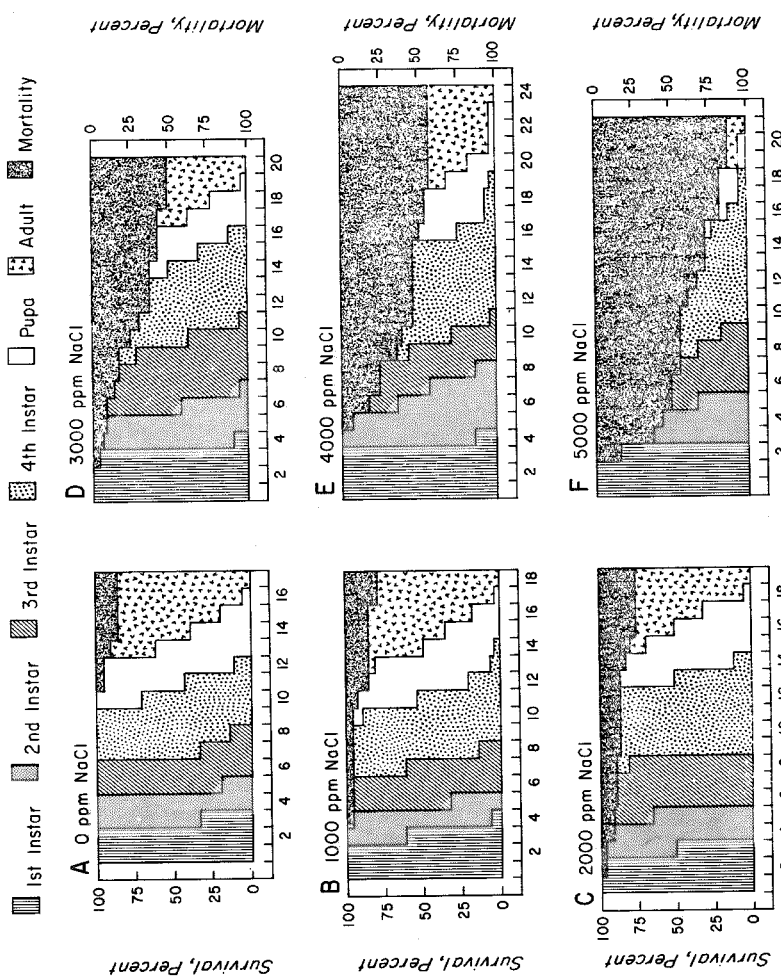
These results suggest that the presence of high concentrations of NaCl in run-off entering vernal pools can decimate a population of snow-melt *Aedes*. Contamination of these larval environments with NaCl may cause an extension of the juvenile developmental period and increased mortality in the juvenile stages so that fewer adults emerge.

Salts occur naturally in pools inhabited by snow-melt *Aedes*. Brummer-Korvenkontio *et al.* (1971) reported that larvae of several snow-melt species inhabited pools containing up to 1300 ppm of total salts. Kenk (1949) reported that total salinity of vernal pools was normally no greater than 1000 ppm of total salt. Berlin (1977) found levels of sodium of 670–1700 ppm in pools contaminated with road salts. With some species, such as *Ae. provocans* and *Ae. communis*, 1000 ppm

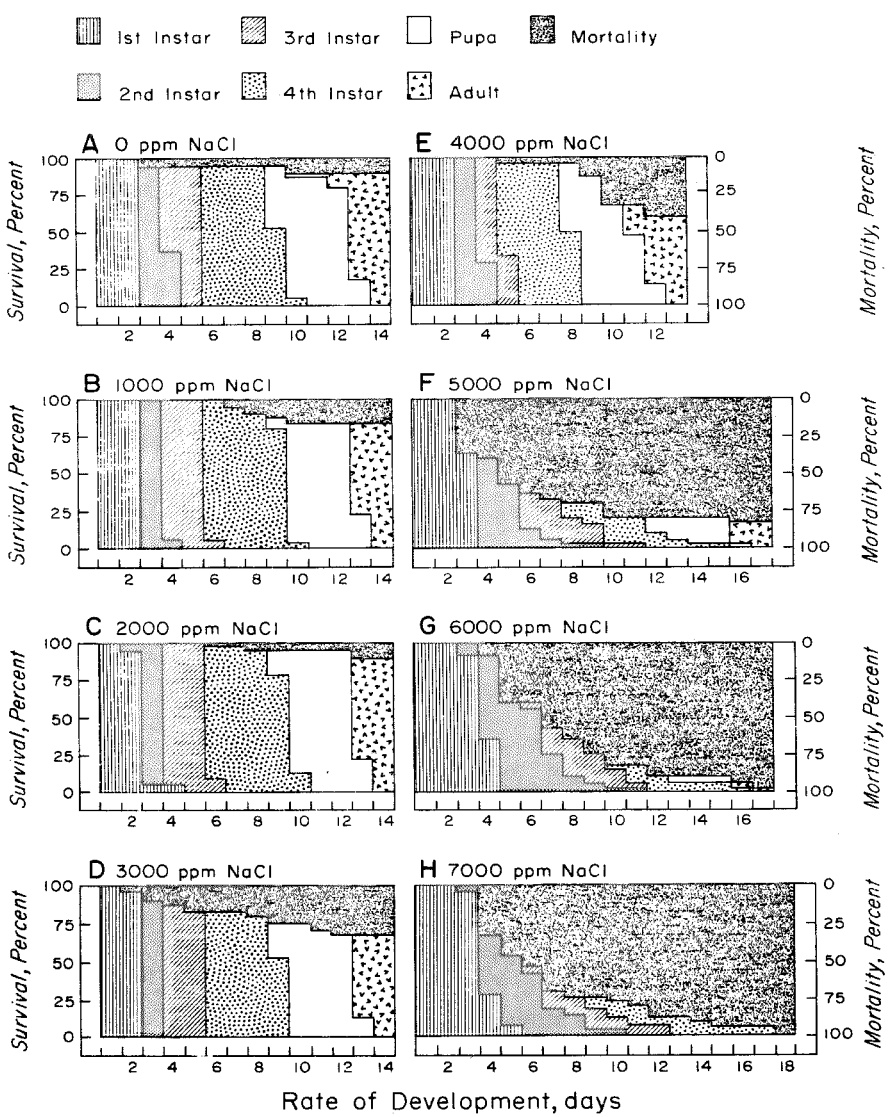
Table 1. Percentage of survival and mean duration of juvenile snow-melt *Aedes* when reared at 21°C[1] using a standardized rearing procedure and sodium chloride

Species of *Aedes*	0 ppm NaCl		1000 ppm NaCl		2000 ppm NaCl		3000 ppm NaCl		4000 ppm NaCl		5000 ppm NaCl		6000 ppm NaCl		7000 ppm NaCl		LD_{50} ppm NaCl
	% Survival	Mean Duration	% Survival	Mean Duration	% Survival	Mean Duration	% Survival	Mean Duration	% Survival	Mean Duration	% Survival	Mean Duration	% Survival	Mean Duration	% Survival	Mean Duration	
provocans	90	11.6	67	11.4	13	12.2	3	11.0	0	—	—	—	—	—	—	—	1315
communis	90	11.6	61	12.8	37	14.4	0	—	—	—	—	—	—	—	—	—	1458
fitchii	86	13.4	82	14.1	75	16.3	50	17.6	39	19.5	11	20.2	0	—	—	—	3000
aberratus	90	12.4	85	12.2	65	12.8	53	13.2	30	13.5	9	14.0	0	—	—	—	3130
cinereus	97	9.6	100	10.6	93	10.4	69	11.0	24	13.8	14	13.0	0	—	—	—	3422
diantaeus	85	19.0	67	20.9	51	22.0	30	23.0	5	23.5	0	—	—	—	3130		
punctor	92	11.7	78	11.6	77	11.8	32	12.9	25	12.9	0	—	—	—	3600		
stimulans	89	12.1	88	12.2	68	12.2	53	12.3	17	15.6	4	16.0	—	—	4083		
sticticus	100	8.1	97	8.0	87	8.3	69	8.5	65	8.1	37	10.1	7	10.0	0	—	4536
canadensis	97	12.2	90	11.8	100	11.5	87	12.4	64	12.4	38	13.8	0	—	—	—	4538

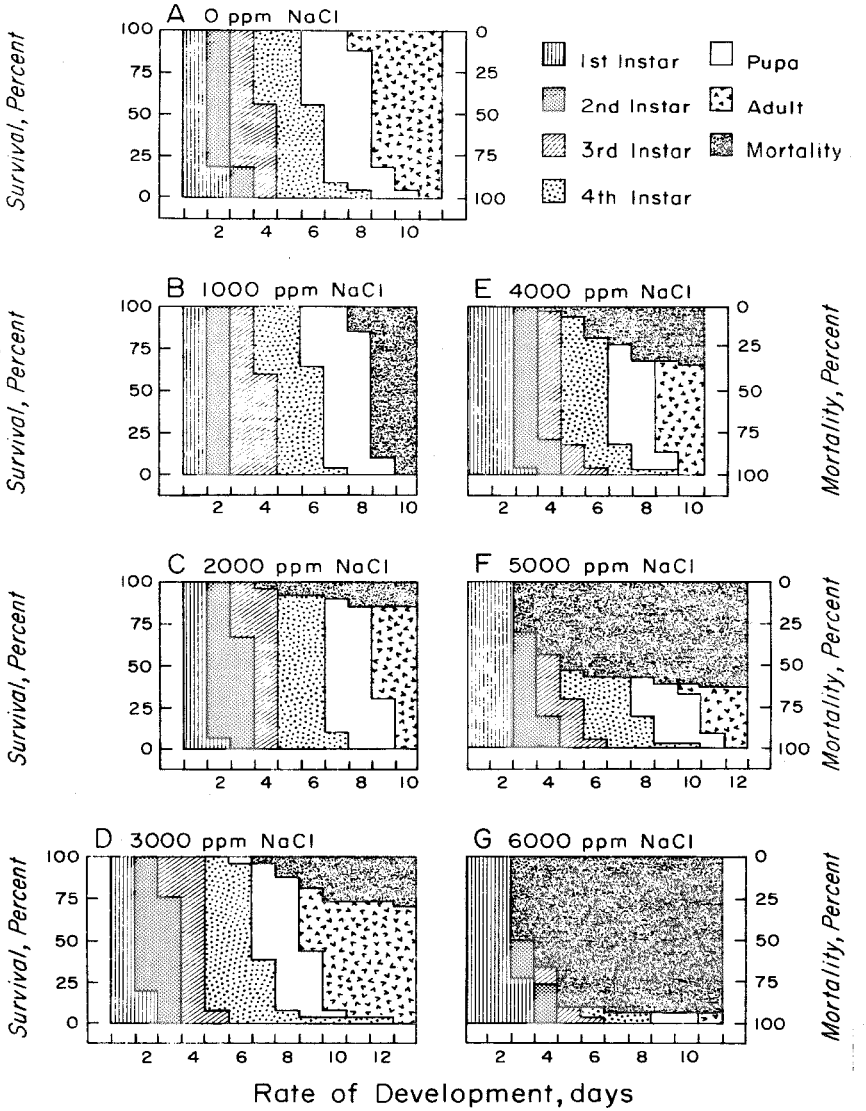
[1] *Ae. diantaeus* reared at 17°C.



Figures 2A to F: Effect of different concentrations of sodium chloride in the rearing media on the rate of development and mortality of *Aedes fitchii* at 21°C.



Figures 3A to H: Effect of different concentrations of sodium chloride in the rearing media on the rate of development and mortality of *Aedes stimulans* at 21°C.



Figures 4A to G: Effect of different concentrations of sodium chloride in rearing media on the rate of development and mortality of *Aedes sticticus* at 21°C.

of total salinity may be approaching their tolerance levels.

Certain snow-melt *Aedes* may experience extensions of their juvenile developmental span when exposed to sublethal concentrations of NaCl. The extension in juvenile span will increase the exposure of the larvae and pupae to parasites and predators, which potentially may cause a reduction in the population surviving to the adult stage. The increase in juvenile span also may expose the juveniles to the possibility that the pools will dry prior to emergence of the adults. Observations by Gjullin et al. (1961) support this possibility. They observed that *Ae. communis* frequently inhabits pools which exist just long enough to permit emergence of the adult. Any factor causing an extension of the juvenile span of *Ae. communis*, such as contamination of larval environment by NaCl may result in these pools drying prior to emergence of the adults.

Snow-melt species in the larval stages may develop some tolerance to NaCl. Larvae of *Ae. stimulans* from Michigan had an LD_{50} of NaCl of approximately 4000 ppm (Table 1). Kardatzke and Liem (1972) reported that an Illinois population of the same species has an LD_{50} for NaCl of less than 3000 ppm. Parker (1979) reported a 3-fold increase with larval tolerance of *Ae. c. dorsalis* within 4 generations when continuously exposed to 25,000 ppm NaCl.

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