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STUDY OF THE ENVIRONMENTAL FACTORS ASSOCIATED WITH OVIPOSITION BY *AEDES CASPIUS* AND *AEDES DETRITUS* ALONG A TRANSECT IN ALGERIA

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ABSTRACT. *Aedes detritus* in western Algeria oviposits in irregularly flooded salty environments. The highest density of *Aedes caspius* eggs was found in soils with a high organic content and a salinity : organic matter ratio of <1. We studied the relationship between oviposition abundance by both species and a number of major ecological factors along a transect. Ecological factors examined were plant species associations, vegetative cover, and soil organic content and salinity. High vegetative growth was essential for oviposition by both species. Alternatively, eggs of *Ae. detritus* were found in soils that had high salinity and a salinity : organic matter ratio of >1. Conditions in northern Africa differ from those found north of the Mediterranean Sea, where oviposition is associated with climate and seasonal conditions.

KEY WORDS *Aedes caspius, Aedes detritus,* egg distribution, vegetational zones, plant cover, organic content, salinity, Algeria

INTRODUCTION

In Algeria, the synclinal topography and the seasonally variable climate have created coastline and inland basins. These temporarily flooded depressions are of various sizes and are characterized by moist and saline hydromorphic topsoil covered by halophytic vegetation. *Aedes caspius* (Pallas) and *Aedes detritus* (Haliday) oviposit abundantly under these conditions. Oviposition takes place in well-defined, moist sites (Sergent and Sergent 1903; Rioux 1958; Senevet and Andarelli 1954, 1963, 1964). An accurate knowledge of the oviposition sites requires definition of ecological zones. Vegetation density often acts as an indicator of the number of larvae. The purpose of this study was to test for a correlation between egg distribution and various vegetative and soil factors. The study was conducted from 1989 to 1990 in the northwestern part of Oran (Sebkha), Algeria.

MATERIALS AND METHODS

Soil characteristics: The organic matter content of soil was measured following Anne (1945), and soil salinity was measured according to the Mohr colorimetric method. The origin and the duration of natural and artificial flooding were recorded.

Biotic factors: Eggs were sampled on a monthly basis from 1989 to 1990. Eggs were identified to species on the basis of general morphology and visible reticulations on the exochorion (Gabinaud et al. 1975). Soil samples were taken from a transect crossing different vegetation belts (Braun Blanquet et al. 1952) (Fig. 1). The technique consisted of counting the number of eggs found in a sample of 10 cm^2 of soil surface at a depth of 3 cm. The vertical distribution of eggs was determined with a metallic cylinder (5 cm long × 25 cm^2 diameter) open at both ends and with a cutting blade on the lower end. The full length of the cylinder was thrust into the soil and the sample was divided into 1-cm-high sections with a square metal plate (Service 1968b).

Factor analysis was used to indicate graphically how egg density was influenced by organic matter and salinity (Thioulouse 1990). Samples without eggs were not included in this analysis.

RESULTS

Surface hydrology: Both natural and artificial flooding were observed. Natural flooding was a function of local relief and soil texture (Fig. 1). Three kinds of habitats were distinguished on the basis of the duration of water stagnation on the surface: semipermanent, temporary, and short-lived. Semipermanent areas occurred in low lying areas in which submersion lasted for ~8 months and moisture remained in the soil for up to 10 months. Temporarily flooded areas could be submerged for >3–4 months and were commonly affected by the vertical motion of a shallow underground water table. Short-lived flooded habitats were impregnated with water after strong rains on the highest point of the site and submersion lasted for 8–10 days.

Artificial flooding arose from wastewater effluent from a nearby leather-processing factory. This water was saturated with organic matter. This source was constant even during the hot dry seasons and resulted in a semipermanent submersion of the site.

Vegetation zones: Nine vegetation zones were identified on the basis of the most common plant species present (Fig. 1). The *Arthrocnemum* zone occurred in areas most affected by the underground water table. The highest salinity was recorded in these areas. The greatest accumulation of organic matter was found in the lowest areas, where the

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Table 1. Distribution of *Aedes caspius* and *Aedes detritus* eggs at various depths in the soil.

Plant grouping	Samples (depth, cm)	Viable eggs Number	%
I, *Salicornia radicans,* 100% cover, clayey texture	0–1	851	90.0
	1–2	74	7.8
	3–4	0	0
	4–5	0	0
Total	0–5	945	99.9
II, *Arthrocnemum glaucum* prostrate, 70% cover, silty texture	0–1	136	44.3
	1–2	107	34.8
	2–3	46	15.0
	3–4	17	5.5
	4–5	1	0.3
Total	0–5	307	99.9
III, *Suaeda fruticosa,* 50% cover, sandy-silty texture	0–1	5	11.1
	1–2	21	48.8
	2–3	17	40.0
	3–4	0	0.0
Total	0–5	43	99.9
Total I + II + III	0–1	992	76.6
	1–2	202	15.6
	2–3	83	6.4
	3–4	17	1.3
	4–5	1	0.0
Grand total	0–5	1,295	99.9

moisture level was greatest and the vegetation was dense.

Vertical egg distribution was measured in three vegetational zones: *Salicornia radicans, Arthrocnemum glaucum* (prostrate), and *Suaeda fruticosa* (Table 1). The highest percentage of viable eggs was found in the first 3 cm; the depth to which the eggs were buried was related to soil texture and structure.

Plants were found in clusters of various sizes. Thirty samples were taken from the center and the northern and southern edges of these clusters (Table 2). Egg density inside the shrubs, where the vegetative topsoil humus was thickest, was much greater than at the periphery. Presumably, this habitat provides a microclimate that protects the soil from direct sun exposure, and moist conditions offer the best oviposition site. Plant covering and the trapped organic matter may also produce an environment favorable to egg survival.

Table 2. Distribution of *Aedes caspius* and *Aedes detritus* eggs by location (10 samples from halophyte shrubs).

Position	*Aedes caspius*	*Aedes detritus*	Total	%
North	72	146	218	9.2
Center	1,067	886	1,953	82.2
South	81	124	205	8.6

Table 3. Egg collections of *Aedes caspius* from September 1989 to June 1990.

Vegetation group	Sep	Oct	Nov	Jan	Feb	Mar	Apr	May	Jun	Total	Frequency
G1 *Glyceria festucaeformis*	0	0	0	0	0	0	0	0	0	0	0.00
G2 *Juncus maritimus*	100	25	8	0	0	0	0	0	0	133	0.33
G3 *Salicornia radicans*	77	142	441	1,791	1,032	4,554	1,604	3,321	1,397	14,359	1.00
G4 *Salicornia fruticosa*	237	521	601	1,675	755	1,072	956	1,225	383	6,425	1.00
G5 *Arthrocnemum glaucum* erect	46	45	164	0	0	18	43	93	47	456	0.77
G6 *Arthrocnemum glaucum* prostrate	0	148	13	21	0	21	0	33	0	236	0.55
G7 *Spergularia marginata*	0	0	0	0	50	0	0	21	0	71	0.22
G8 *Suaeda fruticosa*	0	0	0	10	0	0	0	0	0	10	0.11
G9 *Scirpus maritimus*	0	0	74	126	0	123	0	133	0	456	0.44

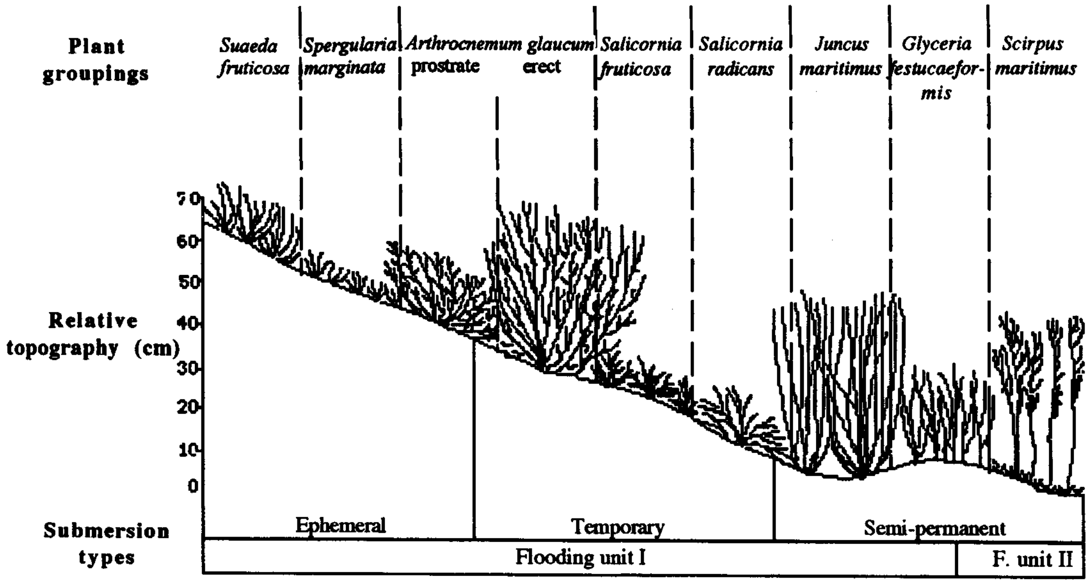

Fig. 1. Vegetative zones relative to submersion patterns along the *Aedes caspius* and *Aedes detritus* transects.

Nine monthly samples were taken from various vegetation zones. In each zone, we measured the amount of plant cover and the soil salinity and organic matter content. No eggs were found in the *Glyceria festucaeformis* zone. Most eggs were found in the *S. radicans* and *S. fruticosa* zones (Tables 3 and 4). *Aedes caspius* was most often found in zones with plants requiring greater humidity and in which soils had salinity levels of 6.5–7.7 g NaCl/kg dry soil. In contrast, *Ae. detritus* was found associated with plants in more xeric zones where soils had salinities of 18–4,128 g NaCl/kg dry soil.

Seasonal variation in the surface water layer played a key role in the choice of oviposition sites. When the water level was low, humid sites were bounded by *S. radicans* and *S. fruticosa,* and eggs of both species were most abundant in these sites. *Aedes caspius* eggs were usually predominant. Eggs of both species were found in low-lying vegetational zones (*Scirpus maritimus, Juncus maritimus,* and *S. radicans*) that remained moist during the dry season. Again, *Ae. caspius* eggs were most abundant. *Arthrocnemum, Spergularia marginata,* and *S. fruticosa* vegetation zones were the most favorable to *Ae. detritus* oviposition during high water.

Aedes caspius oviposited among plants in lower and moister sites, whereas *Ae. detritus* oviposited in higher, more saline soils. However, because of the fine-scale spatial heterogeneity, eggs of both species were found together. Plant covering influenced oviposition rates to a great extent (Fig. 2 and Table 5). Most *Ae. caspius* eggs occurred in areas where plant covering was 75–100%. In contrast, *Ae. detritus* eggs were found in sites where the covering varied from 50 to 100% (Fig. 2).

The results of factor analysis are shown in Fig. 3. The 1st and 2nd axes account for 75% and 19.5% of the total variation, respectively. Analysis of the distribution of sites with respect to the factors presented in Table 5 indicates that the salinity values increase along the X-axis and abundance of both

Table 4. Egg collections of *Aedes detritus* from September 1989 to June 1990.

Plant group	Sep	Oct	Nov	Jan	Feb	Mar	Apr	May	Jun	Total	Frequency
G1 *Glyceria festucaeformis*	0	0	0	0	0	0	0	0	0	0	0.00
G2 *Juncus maritimus*	360	10	21	0	0	0	0	0	0	391	0.33
G3 *Salicornia radicans*	62	128	347	1,023	605	485	730	1,052	304	4,736	1.00
G4 *Salicornia fruticosa*	85	686	574	944	1,350	347	4,880	617	272	9,755	1.00
G5 *Arthrocnemum glaucum* erect	49	22	246	18	0	130	227	623	165	1,480	1.00
G6 *Arthrocnemum glaucum* prostrate	0	42	13	18	0	144	0	232	0	449	0.44
G7 *Spergularia marginata*	0	0	46	90	269	0	0	52	0	457	0.44
G8 *Suaeda fruticosa*	0	0	0	271	0	0	0	0	0	271	0.11
G9 *Scirpus maritimus*	0	0	0	40	0	23	0	94	0	167	0.33

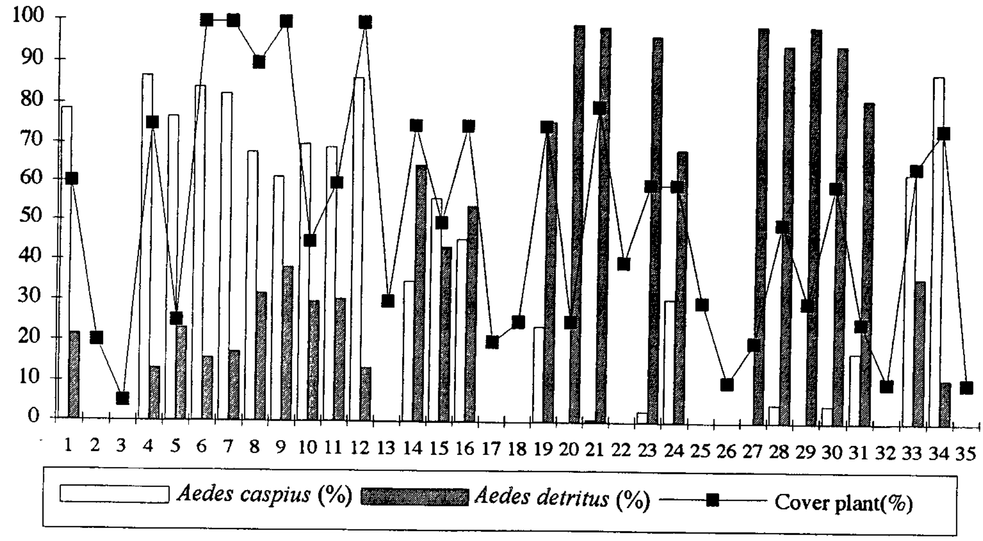

Fig. 2. Relationship between percentages of *Aedes caspius* and *Aedes detritus* and percentage of plant cover at 35 sites along the transect.

Table 5. Variation of viable *Aedes caspius* and *Aedes detritus* egg numbers depending on key factors.

Plant group	Plant species	Species code coor. An.	Cover in %	Organic matter (g/kg dry soil)	Salinity (gNaCl/kg dry soil)	No. viable eggs *Aedes caspius*	No. viable eggs *Aedes detritus*
II	*Juncus maritimus*	Sp1	60	12.39	6.4	11	3
	Glyceria festucaeformis		20	10.2	3.4	0	0
	Glyceria festucaeformis		5	9.6	3.1	0	0
III	*Salicornia radicans*	Sp2	75	10.63	5.64	433	66
	Salicornia herbacea	Sp3	25	6.68	4.47	90	27
	Salicornia radicans	Sp4	100	9.28	5.6	979	184
	Salicornia radicans	Sp5	100	11.71	4.74	522	109
	Salicornia radicans	Sp6	90	9.81	7.2	589	277
	Salicornia radicans	Sp7	100	10.75	7.4	445	278
	Salicornia herbacea	Sp8	45	13.25	4.25	238	101
	Salicornia fruticosa	Sp9	60	2.93	5.31	25	11
IV	*Salicornia frusticosa*	Sp10	100	26.09	7.68	843	131
	Glyceria festuacaeformis		30	5.94	11.2	0	0
	Salicornia fruticosa	Sp11	75	11.6	6.71	107	198
	Salicornia fruticosa	Sp12	50	20.18	6.1	180	140
	Salicornia fruticosa	Sp13	75	12.2	5.23	125	148
	Obione portulacoides		20	3.23	9.61	0	0
	Obione portulacoides		25	5.12	8.74	0	0
V	*Arthrocnemum glaucum* erect	Sp14	75	6.17	13.61	85	272
	Arthrocnemum glaucum erect	Sp15	25	6.27	41.28	0	50
	Arthrocnemum glaucum erect	Sp16	80	5.31	34.3	1	195
	Arthrocnemum glaucum erect		40	3.61	42.13	0	0
	Arthrocnemum glaucum prostrate	Sp17	60	7.2	21.3	3	106
VI	*Arthrocnemum glaucum* prostrate	Sp18	60	20.13	17.47	33	74
	Arthrocnemum glaucum prostrate		30	4.31	40.06	0	0
	Arthrocnemum glaucum erect		10	6.65	43.05	0	0
VII	*Spergularia marginata*	Sp19	20	4.67	18.02	0	38
	Spergularia marginata	Sp20	50	7.49	17.6	1	21
	Spergularia marginata	Sp21	30	8.79	21.17	0	25
VIII	*Suaeda fruticosa*	Sp22	60	10.99	18.32	3	64
	Suaeda fruticosa	Sp23	25	11.49	15.8	11	51
	Bromus sp.		10	2.16	7.2	0	0
IX	*Scirpus maritimus*	Sp24	65	17.41	6.56	163	94
	Scirpus maritimus	Sp25	75	16.38	4.9	181	23
	Scirpus maritimus–Cyanophyceae		10	12.91	3.17	0	0

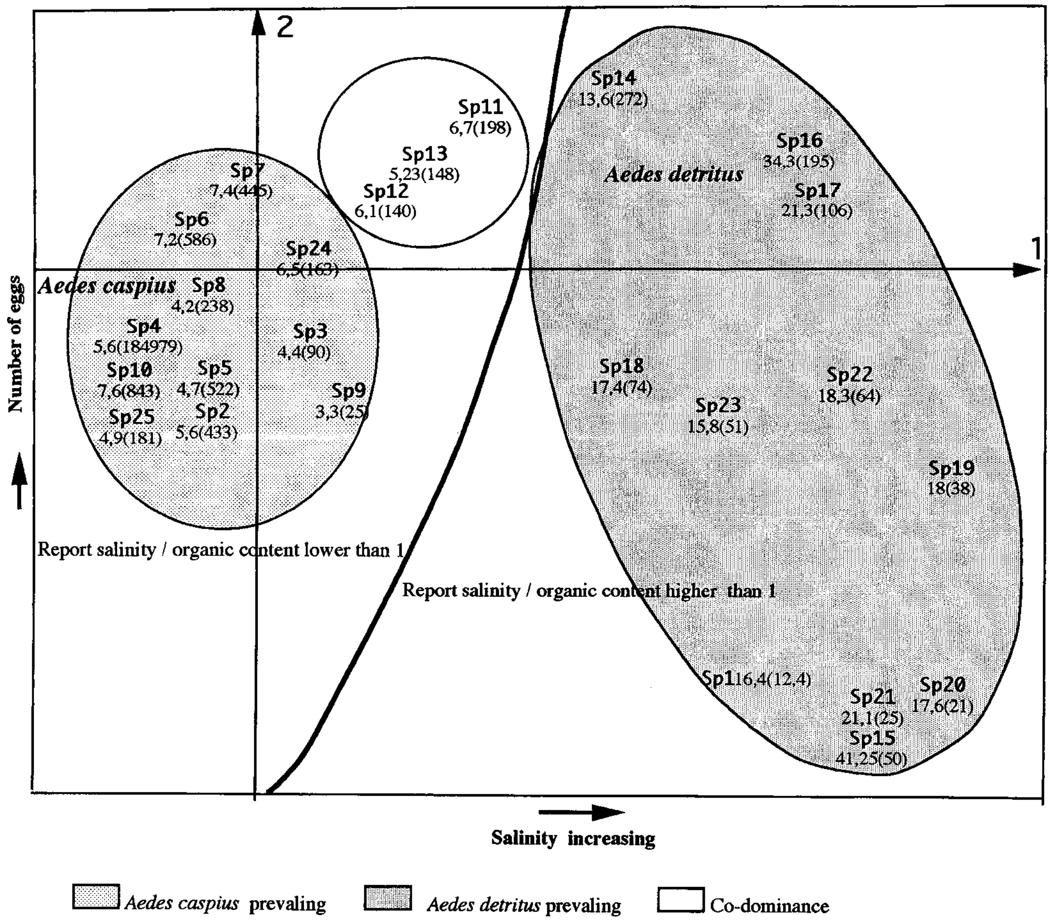

Fig. 3. Factor analysis of the relationship between the abundance of *Aedes caspius* and *Aedes detritus* eggs and organic content and salinity of soils at sites along the transect. The distribution of sites along the X-axis corresponds to salinity, whereas sites are distributed along the Y-axis according to the abundance of eggs from either species.

species increases along the Y-axis. *Aedes detritus* eggs were located in areas of high soil salinity. *Aedes caspius* eggs were located in areas of low soil salinity. The intermediate sites (Spl 1, Sp12, and Sp13) represent samples taken where the number of eggs were greatest for both species. Sites fell into 3 groups: the 1st group consisted of sites where the salinity was high and *Ae. detritus* was predominant. The 2nd group contained sites where *Ae. caspius* predominated and salinity was lower. The 3rd group contained both species and had an intermediate level of salinity. Most (96% = 4,896/5,068) of the *Ae. caspius* eggs were laid in soil with organic matter >9 g/kg dry soil. The eggs of *Ae. detritus* were found on soils where the rate of organic matter was ~4 g/kg dry soil and salinity was 18.3–4,128 g NaCl/kg dry soil.

DISCUSSION

Eggs of *Ae. detritus and Ae. caspius* were found at a depth of ≤3 cm. Egg density was highest in the center of halophytic shrubs, where moisture and organic matter content were highest. Egg distributions correlated both spatially and temporally with vegetation zones. Low lying sites with high vegetative covering were moist for longer periods of time and contained more eggs of both species. Egg abundance was lower in semipermanent sites. *Aedes caspius* eggs were most abundant in low-lying sites with higher organic matter and lower salinity. *Aedes detritus* eggs were most abundant in higher sites with lower organic matter and high salinity.

Oviposition in temporarily flooded areas, where the oviposition of both species was greatest for most of the year, was dependent on the water table. The succession of flooding and drought is conducive to high density hatching in both species. Competition at the larval stage may have created pressure on both species to avoid temporarily flooded areas. *Aedes detritus* may have adapted to conditions of extreme salinity. This scheme is interesting because it shows that oviposition by both species in North Africa is not tied to seasonal or climatic conditions, as observed by some researchers (Gabinaud 1975), but instead results from oviposition habitat preference.

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