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Preliminary report on the brine shrimp (*Artemia salina*) from El Jadida salterns, Morocco

Rapport préliminaire sur Artemia salina *des salines d'El Jadida, Maroc*

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Mots clés : *salines du complexe lagunaire Sidi Moussa-Oualidia, Maroc,* Artemia, Palaemonetes varians, *compétiteurs nutritionnels.*

ABSTRACT

Sadkaoui F., M. Moncef, J. Sif, R. Gaudy – Preliminary report on the brine shrimp (Artemia salina) *from El Jadida salterns, Morocco.* Mar. Life, ***10*** *(1-2) : 33-41.*

Although Artemia salina *(L., 1758) populations have been reported from almost every country in the Mediterranean region, data relative to their presence and distribution in Morocco are fragmentary. The present paper contributes to localising* Artemia *sites in the lagoon complex Sidi Moussa-Oualidia, province of El Jadida, Morocco, and provides data on the ecology of this species in the studied area. The eight salterns belonging to this complex were prospected on June 1997, October 1997, February 1998 and March 1998. Bisexual populations were found in Bear Al Assara, Shlouhs, Sidi Moussa, Laaoumra, Sidi Brahim, Souzama and Salines Marocaines salterns. In the Ouled Salem saltmarsh, abandoned since February 1996 and now dominated by* Artemia *predators, this anostracan was not present. In the studied area, the biological cycle of* Artemia *begins at the end of September-early October, and it is interrupted after the heavy winter precipitations, especially in Bear Al Assara, Shlouhs, Sidi Moussa and Laaoumra salterns exposed to high levels of fresh ground water. This early* Artemia *disappearance is due to predators, notably* Palaemonetes varians *and* Mugil *sp., and to the occurrence of food competitors such as* Brachionus plicatilis *and* Hexartra fennica, *in addition to changes in the phytoplanktonic community. In Sidi Brahim, Souzama and Salines Marocaines salterns, with clayish less permeable soil texture, this branchiopod survives reaching high densities at the end of the spring and the early summer. From June onwards,* Artemia *density decreases as a consequence of increasing water temperature and salinity and decreasing dissolved oxygen rates, and the reproductive mode switches to oviparity, Souzama being the most productive saltern in terms of brine shrimp cysts.*

RÉSUMÉ

Sadkaoui F., M. Moncef, J. Sif, R. Gaudy - [Rapport préliminaire sur Artemia salina *des salines d'El Jadida, Maroc].* Mar. Life, ***10*** *(1-2) : 33-41.*

Artemia salina *(L., 1758) a fait l'objet de nombreuses études dans les pays riverains de la Méditerranée. Cependant, les données relatives à sa présence et à sa distribution au Maroc sont fragmentaires. Le présent travail contribue à la localisation des sites d'Artemia dans les salines du complexe lagunaire Sidi Moussa-Oualidia, province d'El Jadida, Maroc. De même, il fournit des données sur son écologie dans la zone. Les huit salins du complexe ont été prospectés en juin et octobre 1997 puis en février et mars 1998. Des populations bisexuelles ont été trouvées dans les salins Bear Al Assara, Shlouhs, Sidi Moussa, Laaoumra, Sidi Brahim, Souzama et Salines Marocaines. Au niveau du salin Ouled Salem, abandonné depuis février 1996 et dominé par les prédateurs, cet anostracé n'a pas été trouvé. Au niveau de la zone d'étude, le cycle biologique d'*Artemia*, qui commence vers fin septembre - début octobre, est interrompu après les fortes précipitations hivernales dans les salins Bear Al Assara, Shlouhs, Sidi Moussa et Laaoumra où la nappe phréatique est sub-affleurante. Cette disparition précoce d'*Artemia *est tributaire de l'apparition de prédateurs notamment* Palaemonetes varians *et* Mugil *sp. et de compétiteurs nutritionnels comme* Brachionus plicatilis *et* Hexartra fennica *en plus des changements dans la communauté phytoplanctonique. Dans les salines Sidi Brahim, Souzama et Salines Marocaines, au sol marno-argileux moins perméable, ce branchiopode survit à la dessalure, atteignant des densités élevées durant le printemps et le début d'été. À partir de fin juin, la densité d'*Artemia *décroît suite aux augmentations excessives de la température et de la salinité et des diminutions des teneurs d'oxygène dissous. La production des cystes est alors déclenchée avec le maximum de production enregistré dans Souzama.*

INTRODUCTION

Populations of *Artemia* have been reported from many localities in Morocco, particularly in the littoral salt marshes of Larache (Amat 1980 a , b), Tanger El Balya, Est of Tanger (Stella, 1933), Melouya estuary (Vanhaecke *et al.*, 1987), Oued Amma Fatma and Oued Chebeica, South of Tantan (Dumont, 1979) as well as in the continental salterns of Moulay Brahim (Gauthier, 1929), in sebkhas, notably Bou Areg (Vanhaecke *et al.*, 1987) and Zima (Thiery, 1986; Saadi, Champeau, 1987). However, knowledge about its presence and distribution in the salterns of the lagoon complex Sidi Moussa-Oualidia is so far non-existent.

In recent years interest in *Artemia* has increased steadily and, as a result, the occurrence of this anostracan has been studied and recorded in a growing number of countries. The present paper contributes to broaden the list of *Artemia* sites in Morocco and in Africa, and gives data on the ecology of this genus in the studied area.

GENERAL PRESENTATION OF THE STUDIED AREA

Topography

The studied salterns (figure 1) belong to the lagoon complex Sidi Moussa-Oualidia (32°40'-33°06'N-8°50'W). They fill up the interdunal depression located to the South-West of El Jadida, between Sidi Abed to the North and Oualidia to the South. On their eastern side, they are bordered by agricultural fields or by 50 to 80 m high cliffs, and in the western side by dunes which separate them from the sea. These commercial solar salterns consist of a series of shallow ponds connected in a gradient of increasing salinity (figure 2). Sea water is pumped into the first pond and flows by gravity through the consecutive evaporation ponds. While passing through the pond system, salinity levels gradually increase as a result of evaporation. As the salinity increases, salts with low solubility precipitate as carbonates and sulfates. Once the sea water has evaporated to about one tenth of its original volume

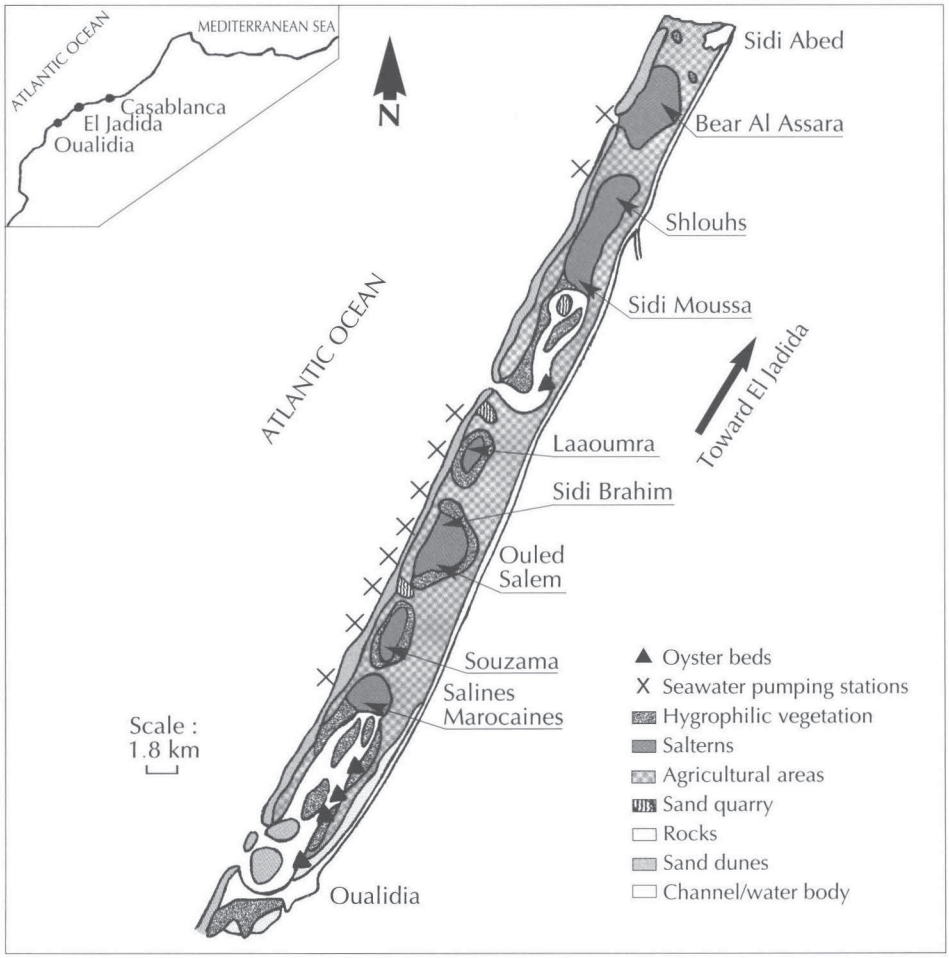

Figure 1 - Location of sampling stations in the Sidi Moussa-Oualidia lagoon complex. / *Localisation des stations échantillonnées dans le complexe lagunaire Sidi Moussa-Oualidia.*

Table I - Location and surface area of the salterns in the Sidi Moussa-Oualidia lagoon complex. / *Localisation et superficie des salines du complexe lagunaire Sidi Moussa-Oualidia.*

Salterns	Surface (ha)
Bear Al Assara (A)	60
Shlouhs (B)	40
Sidi Moussa (C)	50
Laaoumra (D)	50
Oueld Salem (E)	30
Sidi Brahim (F)	48
Souzama (G)	35
Salines Marocaines (H)	40

(about 260 $g.L^{-1}$), mother brine is pumped into the cristallizing ponds where sodium chloride precipitates. From the North to the South, there are several salterns (table I) of variable surface (Abdoul, 1996).

Pedology

The studied salterns are located on sand-muddy to clayish soils. However, the abundance of water resources, on account of the high level of phreatic water layers, ensures the good functioning of the saltmarshes and entails leakage in some of them.

Climatological conditions

According to the Emberger coefficient (1975), the prospected salterns are located in a semi arid region

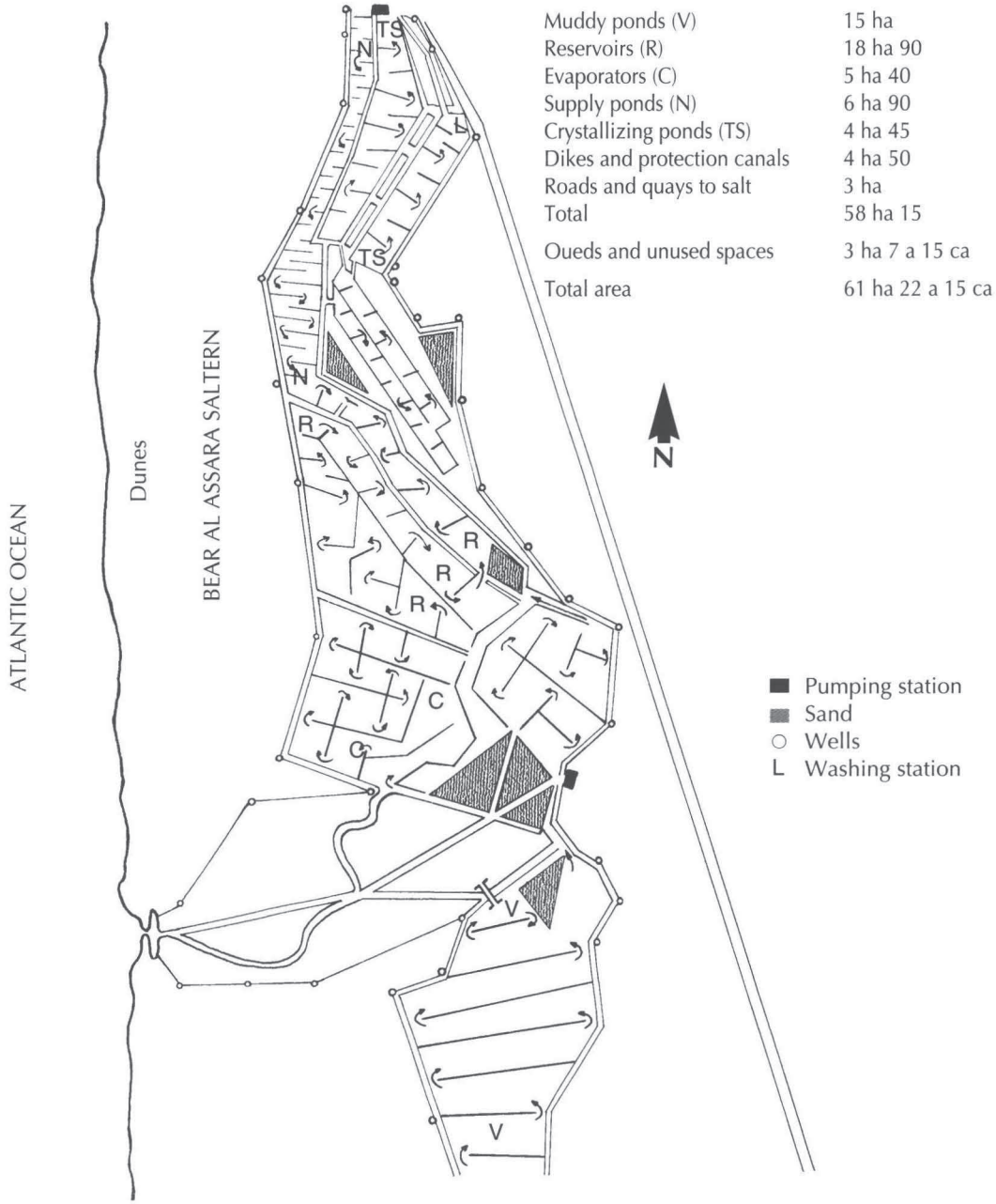

Figure 2 - Detail of Bear Al Assara saltern. / *Détail des salines de Bear Al Assara.*

with a dry period of approximately seven months.

Winds blow in permanence and are relatively strong, generally from a north and/or north-westerly direction.

Ecological interest

The importance of the Sidi Moussa-Oualidia lagoon complex for the migration of palearctic waterbirds has already been shown by Pienkowski (1971). Their passage occurs twice a year, in autumn and spring.

Socio-economic interest

Local populations in the studied area are involved in various activities such as agriculture, salt production, pastures, humid area vegetation utilization, in decreasing order of importance.

MATERIAL AND METHODS

During 1997/1998, four seasonal surveys of the entire area were made on June 1997, October 1997, February 1998 and March 1998, respectively. On the other hand, the Ouled Salem saltern was only surveyed in summer, since it had lost the structure of a saltworks since February 1996 and was dominated by predators.

Determination of abiotic parameters

In addition to the data on precipitation, kindly provided by the Oualidia meteorological station, the following abiotic parameters were measured on water samples, taken from the ponds (see further) :

- pH: measured by a pH meter (WTW; pH. 522), allowing determination to 1/10 pH unit;
- dissolved oxygen: measured by the volumetric method of Winkler;
- water temperature: determined (directly in the field) with a thermometer graduated to the nearest 0.1°C;
- salinity: determined with a Baumé areometer (graduated from 0°Be to 30°Be, 1°Be = 10 $g.L^{-1}$);
- depth: measured with a bar graduated to cm.

Determination of biotic parameters

The *Artemia* population density was determined according to the method of Heurteux and Marazanof (1965). A cylinder (height: 60 cm; diameter: 30 cm) without bottom is used to take the water sample. On each occasion, three samples were taken per pond to compensate for the patchy distribution of *Artemia*. The samples were pooled and filtered through a plankton net with 80 µm mesh size. The abiotic and biotic parameters were determined in this filtered water, while the animals were preserved in 4% formalin. At high brine shrimp

Table II - Patterns of change of abiotic parameters during the four surveys carried out in the Sidi Mousssa-Oualidia lagoon complex. A: Bear Al Assara; B: Shlouhs; C: Sidi Moussa; D: Laaoumra; E: Ouled Salem; F: Sidi Brahim; G: Souzama; H: Salines Marocaines. d: depth (cm); T: temperature (°C); S: salinity ($g.L^{-1}$); O_2: dissolved oxygen ($mg.L^{-1}$); *: not sampled pond. / *Évolution des paramètres abiotiques durant les quatre prospections effectuées au niveau du complexe lagunaire Sidi Mousssa-Oualidia. A : Bear Al Assara ; B : Shlouhs ; C : Sidi Moussa ; D : Laaoumra ; E : Ouled Salem ; F : Sidi Brahim ; G : Souzama ; H : Salines Marocaines. d : profondeur (cm) ; T : température (°C) ; S : salinité ($g.L^{-1}$) ; O_2 : oxygène dissous ($mg.L^{-1}$) ; * : pas d'échantillon.*

		Parameters																			
		Summer survey					Autumn survey					Winter survey					Spring survey				
		pH	d (cm)	S ($g.L^{-1}$)	T (°C)	O_2 ($mg.L^{-1}$)	pH	d (cm)	S ($g.L^{-1}$)	T (°C)	O_2 ($mg.L^{-1}$)	pH	d (cm)	S ($g.L^{-1}$)	T (°C)	O_2 ($mg.L^{-1}$)	pH	d (cm)	S ($g.L^{-1}$)	T (°C)	O_2 ($mg.L^{-1}$)
Ponds	A1	*	*	*	*	*	*	*	*	*	*	9.3	27	5	17.5	3.0	*	*	*	*	*
	A2	*	*	*	*	*	*	*	*	*	*	10.0	30	20	18.5	11.1	*	*	*	*	*
	A3	8.5	20	50	27.5	2.8	8.8	22	20	30.0	8.6	10.0	20	25	23.0	6.8	9.6	28	85	25.0	9.4
	A4	7.6	12	230	28.5	1.4	8.3	25	90	32.0	4	9.2	35	60	23.0	3.5	9.0	25	100	24.0	2.1
	A5	7.2	18	270	37.0	0.4	8.3	23	110	32.0	3.5	8.7	45	95	23.0	2.8	8.7	47	150	25.0	2.3
	B1	9.1	22	72	27.0	8.1	8.1	19	72	23.0	4.1	9.4	40	50	18.0	4.0	9.9	30	50	24.0	7.3
	B2	7.7	12	200	35.0	3.8	8.2	23	150	24.0	3.3	8.5	43	100	18.0	2.0	8.6	26	140	25.0	4.2
	C	8.0	10	190	40.0	1.9	8.3	12	70	34.0	6.4	8.8	23	70	24.0	2.3	8.6	9	120	25.5	1.4
	D1	8.5	15	130	34.0	5.2	8.7	21	53	24.0	6.5	8.5	27	105	21.5	1.7	8.4	26	150	25.0	2.8
	D2	7.2	11	230	36.0	0.4	7.3	3	260	28.0	5	8.5	43	115	23.0	1.5	8.5	13	170	29.0	1.9
	E	8.3	15	50	25.0	2.0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	F1	*	*	*	*	*	8.3	46	80	27.0	7.7	*	*	*	*	*	*	*	*	*	*
	F2	7.6	11	150	35.0	1.4	8.2	14	150	29.0	5	8.5	43	80	23.0	1.7	8.6	28	115	25.0	3.1
	G1	8.1	18	70	27.0	3.5	8.6	19	55	25.0	6.2	*	*	*	*	*	9.1	32	68	21.0	3.8
	G2	7.5	13	100	30.0	1.6	7.7	15	200	30.0	2	9.3	27	45	25.0	6.5	8.8	40	145	24.0	1.9
	G3	7.5	15	180	28.0	1.0	7.5	16	200	30.0	1.2	8.7	15	120	26.0	2.1	8.7	49	150	23.0	1.3
	G4	7.5	8	215	31.0	0.6	7.3	13	225	31.0	3.7	8.6	60	130	23.0	2.3	8.5	27	160	22.0	1.3
	H1	8.0	30	40	25.0	1.3	*	*	*	*	*	8.8	17	25	23.5	4.2	9.0	10	70	19.0	3.1
	H2	7.5	16	180	27.0	0.7	8.5	28	50	25.0	4.6	8.7	31	80	24.0	2.3	8.4	48	170	23.0	1.0
	H3	7.2	17	245	29.0	0.4	7.4	21	230	30.0	9.1	8.5	30	150	24.0	1.0	8.4	43	200	19.0	1.5

densities, subsamples were taken with the Motoda box. The animals were counted in Dollfus cuvette under the binocular. The developmental stages were determined according to Mura (1993).

RESULTS

Abiotic parameters (table II)

Precipitation (figure 3)

During the period surveyed, the area received extensive precipitation, with a maximum of 115 mm reached in December. The annual rate was 412 mm.

pH

pH fluctuated between 7 and 10. Most values ranged between 7.5 and 8.5, while extremely concentrated brines found during the summer survey showed lower pH.

Depth

Depth varied considerably and measured values shift from 60 cm in winter in G4 to 3 cm in autumn in the cristallizing pond D2.

Water temperature

Water temperature showed seasonal fluctuations similar to those of salinity. Minimum was recorded on mid-February in station A1 (17.5°C) and maximum was reached in C station (40°C) at the end of June. In the same saltern, highly saline ponds showed higher temperatures than ponds of lower salinity.

Dissolved oxygen

Dissolved oxygen showed considerable temporal and local variations. The less saline ponds were more oxygenated and, in all ponds, highest values

Table III - Total *Artemia* density (ind.L^{-1}) found in the studied ponds in the Sidi Moussa-Oualidia lagoon complex. A: Bear Al Assara; B: Shlouhs; C: Sidi Moussa; D: Laaoumra; E: Ouled Salem; F: Sidi Brahim; G: Souzama; H: Salines Marocaines. *: not sampled pond. / *Densité totale d'*Artemia *(ind.L^{-1}) enregistrée dans les bassins étudiés au niveau du complexe lagunaire Sidi Moussa-Oualidia. A : Bear Al Assara ; B : Shlouhs ; C : Sidi Moussa ; D : Laaoumra ; E : Ouled Salem ; F : Sidi Brahim ; G : Souzama ; H : Salines Marocaines. * : pas d'échantillon.*

		Surveys			
		June 97	October 97	February 98	March 98
Ponds	A1	*	*	0	*
	A2	*	*	0	*
	A3	0	0	0	0.125
	A4	0	0.125	112	370
	A5	0	0.5	4	32
	B1	0	77	0	0.25
	B2	0	14	30	1355
	C	0	0	58	20
	D1	0	0	26	21
	D2	0	0	28	57
	E	0	*	*	*
	F1	*	0	*	*
	F2	5	0	230	80
	G1	0	0	*	0.875
	G2	0	11	0	20
	G3	250	20	200	106
	G4	34	7	33	1392
	H1	0	*	0.5	0
	H2	1.125	0.375	0.375	117
	H3	9	0	80	250

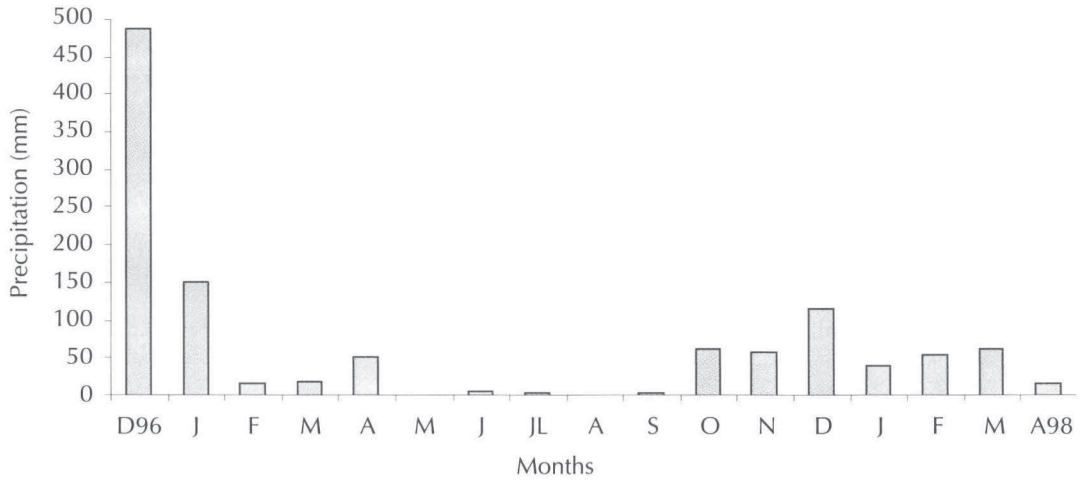

Figure 3 - Seasonal patterns of precipitation during the studied period in the Sidi Moussa-Oualidia lagoon complex. / *Évolution saisonnière des précipitations au cours de la période d'étude au niveau du complexe lagunaire Sidi Moussa-Oualidia.*

were recorded at the end of March (11 $mg.L^{-1}$) in A2, while the lowest (0.4 $mg.L^{-1}$) was found during the summer survey in A5, D2 and H3 cristallizing ponds.

Salinity

Salinity showed wide spatial and temporal variations. An increasing gradient was observed from the reservoir to the cristallizing ponds. As far as its temporal pattern of change is concerned, it was identical in the whole ponds, with minimal values recorded during winter (5 $g.L^{-1}$) in A1. From April onwards, a period of brine preconcentration, the salinity increased and reached its maximum value (270 $g.L^{-1}$) in A5 at the end of June.

Biotic parameters (table III and table IV)

Summer survey

In this period *Artemia* was not found in the salterns of Bear Al Assara, Shlouhs, Sidi Moussa, and Laaoumra (where it disappeared from April onwards). However, in Sidi Brahim, Souzama and Salines Marocaines, the occurrence of *Artemia* was limited to ponds with rather high salinity (≥ 150 $g.L^{-1}$) to avoid the occurrence of predators (e.g. mullet, *Palaemonetes varians*, copepods and Dytiscidae). In these high salinity ponds *Artemia* was abundant, of a vividly red colour, and the population was dominated by adults, especially females. Oviparity was the dominant reproductive mode and the cyst production greater or lesser according to the salterns, Souzama being the most productive.

In the Ouled Salem saltmarsh only *Mugil* sp and *Palaemonetes varians* were found. The saltwork was abandoned in February 1996 because of floods which occurred after the heavy winter precipitations and the high ground water level.

Autumn survey

Depending on the intake of seawater, which does not take place at the same time in the various salterns, and due to the limited September rainfall, *Artemia* was recorded in Bear Al Assara, Shlouhs, Souzama and Salines Marocaines. Densities of *Artemia* populations were low in general terms. The maximum reached was 77 $ind.L^{-1}$ in the B1 station with a population dominated by young stages, and ovoviviparity being the main mode of reproduction.

Winter survey

The excessive rainfall on December 1997 - January 1998 caused a considerable drop in salinity. A massive *Artemia* mortality was noted after the high densities attained at the end of autumn. Cysts

Table IV - Composition of *Artemia* population during the four surveys carried out in the Sidi Mousssa-Oualidia lagoon complex. A: Bear Al Assara; B: Shlouhs; C: Sidi Moussa; D: Laaoumra; E: Ouled Salem; F: Sidi Brahim; G: Souzama; H: Salines Marocaines. c: cysts; n: nauplii; mn: metanauplii; jd: just differentiated adults; a: adults; -: absent; +: present; ++: dominant ; *: not sampled pond. / *Composition de la population d'*Artemia *durant les quatre prospections effectuées au niveau du complexe lagunaire Sidi Mousssa-Oualidia. A : Bear Al Assara ; B : Shlouhs ; C : Sidi Moussa ; D : Laaoumra ; E : Ouled Salem ; F : Sidi Brahim ; G : Souzama ; H : Salines Marocaines. c : cystes ; n : nauplii ; mn : métanauplii ; jd : subadultes ; a : adultes ; - : absent ; + : présent ; ++ : dominant ; * : pas d'échantillon.*

		Parameters																			
		Summer survey					Autumn survey					Winter survey					Spring survey				
		n	mn	jd	a	c	n	mn	jd	a	c	n	mn	jd	a	c	n	mn	jd	a	c
Ponds	A1	*	*	*	*	*	*	*	*	*	*	-	-	-	-	-	*	*	*	*	*
	A2	*	*	*	*	*	*	*	*	*	*	-	-	-	-	-	*	*	*	*	*
	A3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
	A4	-	-	-	-	-	-	+	-	-	-	+	+++	+	+	+	+	+	+	+++	++
	A5	-	-	-	-	-	+	+	-	-	-	+	+	+++	+	+	+	++	+++	+	+
	B1	-	-	-	-	-	+	+++	++	+	-	-	-	-	-	-	-	-	+	+	+
	B2	-	-	-	-	-	+	++	++	+	-	-	+	-	+++	+	+	+++	++	+	++
	C	-	-	-	-	-	-	-	-	-	-	+	+	+++	+	+	+	+++	+	+	+
	D1	-	-	-	-	-	-	-	-	-	-	+	+++	+	+	++	+	++	++	+	+
	D2	-	-	-	-	-	-	-	-	-	-	+	+++	+	+	++	+	+	+++	-	++
	E	-	-	-	-	-	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	F1	*	*	*	*	*	-	-	-	-	-	*	*	*	*	*	*	*	*	*	*
	F2	-	-	+	+	+	-	-	-	-	-	+	+++	-	+	+	+	+++	-	-	++
	G1	-	-	-	-	-	-	-	-	-	-	*	*	*	*	*	+	+	-	+	+
	G2	-	-	-	-	-	+	+	++	++	+	-	-	-	-	-	+	+	++	+	++
	G3	-	+	+	+++	+++	+	++	+	+++	+	+	+	+	+++	+	+	+	-	+++	++
	G4	+	-	+	+++	+++	+	+	+	++	++	+	+++	+	++	+	+	+	+++	+	++
	H1	-	-	-	-	-	*	*	*	*	*	-	++	-	+++	+	-	-	-	-	-
	H2	+	+	+	++	+	-	-	+	+	-	-	-	-	+	+	+	+	+	+++	+
	H3	-	-	++	+++	+	-	-	-	-	-	+	++	+	++	++	+	++	+	++	++

appeared in the crystallizing ponds, in lower quantities however than in the summer season.

In most ponds, *Palaemonetes varians* and *Mugil* sp appeared. Similarly, a remarkable proliferation of filamentous macroalgae was observed, notably *Rhizoclonium riparium* and *Enteromorpha intestinalis*, associated with *Ulva lactuca* in lower salinity ponds.

In the Bear Al Assara saltern, the drop in salinity was so dramatic in the first ponds that it induced the presence of *Palaemonetes varians* at 20 $g.L^{-1}$ (A2) and an extraordinary *Daphnia* density at 5 $g.L^{-1}$ salinity (A1).

Spring survey

The substantial increase in salinity and temperature, compared to the winter values, allowed higher densities of *Artemia* (B2: 1,355 $ind.L^{-1}$; G4: 1,392 $ind.L^{-1}$). The population was dominated by young stages while among the few adults present, nauplii bearing females predominated.

However, the very low densities found in the other ponds were due to predation, especially by *Palaemonetes varians* (e.g. A3, B1 and G1) which attained densities of about 26 $ind.L^{-1}$, showing by transparency its digestive tract full of *Artemia*.

Pumping activities taking place only in Sidi Brahim (F2) (early pumping), resumably caused a decrease in *Artemia* density, from 230 $ind.L^{-1}$ at the end of winter to 80 $ind.L^{-1}$ at the spring onset, although abiotic conditions did improve.

In some ponds (H1 and G1) macroalgae putrefaction enhanced the development of insect populations.

DISCUSSION AND CONCLUSION

Abiotic parameters

pH

In comparison with the cristallizing ponds, low salinity ponds showed slightly more basic values. This can be attributed to CO_2 consumption by photosynthesis, and the formation of insoluble carbonate. In hypersaline ponds, where brine concentration occurs, pH tends towards neutrality.

Depth

Depth depends on precipitation, runoff, water intake and drainage, and underground water flow. Thus, the high values reached during the rainy season are reduced to some centimeters during the salt harvesting season.

Water temperature

A temperature gradient increase was usually observed from low to high salinity ponds, as a consequence of solar energy absorption and retention in higher salinity brines.

Dissolved oxygen

Dissolved oxygen fluctuated inversely to salinity changes (lower O_2 solubility at high salt concentrations), with wide variations in time and space, depending on the levels of algae photosynthesis and *Artemia* respiration. Higher values were recorded in winter and spring, when there was an intensive oxygen exchange at the air-water interface with high oxygen solubility and intensive photosynthesis by macroalgae.

Salinity

Theoretically, this parameter is governed by freshwater supplies and by evaporation which is, in turn, conditioned by air temperature and wind. In the case of salterns, other factors interfere to minimize the effect of these parameters, notably the opening and the closing of sluices. For the proper functioning of the salterns, salt farmers manipulate brines to obtain the desired salinities at the end of the circuits.

Biotic parameters

The biological cycle of *Artemia salina* in the salterns at the lagoon complex Sidi Moussa-Oualidia usually starts on September-early October (short time-lag from one pond to another) and is interrupted in the Northern salterns Bear Al Assara, Shlouhs, Sidi Moussa and Laaoumra by the winter precipitation and the subsequent salinity drop, due to the impermeable sand-muddy soil texture. Favouring the intake of fresh ground water, the winter salinity drop causes high mortality of the *Artemia* population as a consequence of osmoregulatory difficulties, as well as favouring the presence of food competitors, notably *Brachionus plicatilis* and *Hexartra fennica*, and predators, especially *Palaemonetes varians*. Similarly, the appearence of filamentous macroalgae, namely *Rhizoclonium riparium* and *Enteromorpha intestinalis*, with a strong capacity for pumping the medium nutrients, enter into competition with *Dunaliella*, hence depriving *Artemia* of its major food source. All these factors, associated with management practices, have entailed the disappearance of *Artemia* in the northern salterns.

In the studied area, the decapod *Palaemonetes varians* reached high densities in spring and early summer in ponds with salinity below 100 $g.L^{-1}$. At this salinity and 30°C (in G2) it has been found in a state of lethargy, suggesting that this value approaches its upper tolerance limit. Similarly, the mullet *Mugil* sp. was frequent in the same ponds and in the inter-pond canals.

According to Croghan (1958), *Artemia* has the capacity to keep its haemolymph hypertonic in diluted brines and hypotonic in concentrated ones. However, this osmoregulatory mechanism seems to be limited to a certain range. Papers dealing with mortality of *Artemia* following abrupt salinity drops have implicated the role of predation (Mura, 1985; Cuellar, 1990), osmoregulatory difficulties (Geddes, 1980; Jumalon *et al.*, 1987; Tackaert, Sorgeloos, 1991) and changes in the phytoplanktonic community (Stephens, Arnow, 1987), respectively.

Concerning the southern salterns (Sidi Brahim, Souzama and Salines Marocaines), although *Artemia* populations suffered high mortalities during winter, from March onwards favourable conditions increased brine shrimp density, due to the presence of the nauplii bearing females. Pumping works started in the same period as in the northern salterns, but the population subsisted and even proliferated, reaching high density in early summer.

At the end of this season, high temperature and salinity, combined with low dissolved oxygen rates, exert a selection on the plankton diversity, which consists exclusively of *Dunaliella*, as well as stimulating oviparity in *Artemia*, which entails a density decrease to complete disappearence of the whole populations in mid-August at a temperature of 40°C and 250 $g.L^{-1}$ salinity. This upper tolerance limit for salinity is greater than 170 $g.L^{-1}$, as stated previously by Aloui (1998) in Mégrine saltern (Tunisia). There is much confusion in the literature about the mechanisms responsible for the sudden shift from ovoviviparity to oviparity. Lenz (1980) and Mc Dermott (1974) attribute the oviparity to underfeeding, Okazaki (1987) reported that photoperiod and temperature are the two major factors controlling the mode of reproduction. Rahaman (1993) stated that sudden changes in environmental parameters may be a causative factor.

Finally, several items of evidence derived from this study of the Sidi Moussa-Oualidia lagoon complex confirm this place as an *Artemia* site of a certain interest. In this respect, it is worth mentioning:

- the role of climate: the semi-arid climate make the prospected zone well-suited to *Artemia* farming. According to Vanhaecke *et al.* (1987), the geographical distribution of the brine shrimp is limited by climatological conditions given that 97% of the *Artemia* biotopes are located in areas where yearly evaporation exceeds yearly precipitation. In this regard, Africa in particular, seems to be promising. Lavens and Sorgeloos (1996) note that the presence of saltworks is a clear indication of the possibility of *Artemia* farming during at least part of the year;
- the impact of waterbirds: at various periods of the year, in the studied zone it is possible to find about eleven bird genera (*Charadrius, Egretta, Calidris, Anas, Phoenicopterus, Ardea, Ciconia, Larus, Chlidonias, Sterna, Fulica*). Taking into account that *Artemia* cysts remain viable for one to three days upon ingestion by birds (Proctor *et al.*, 1967; Mac Donald, 1980), and that migrating birds can reach a speed of 50-100 $km.h^{-1}$ (Dorst, 1962), it is obvious that they can play an important role in dispersing *Artemia* all over the El Jadida area saltworks. Given that the *Artemia* biotopes are feeding grounds for many birds (Rooth, 1976), in particular flamingos, birds are also thought to be responsible for the north-south *Artemia* transfer in Europe and in Africa and for *Artemia* distribution in India (Royan *et al.*, 1970; Achari, 1971);
- anthropic action: several activities developed by the autochthonous population would appear to play an active role in the dispersal of *Artemia* cysts, for example the grazing of animals, which is a year round activity in the region. A socio-economic inquiry carried out by Abdoul (1996) in twelve douars (rural areas) in the studied zone has reported 119 bovines, 283 ovines and 39 equidae, and these animals may participate actively in the dispersal of this species.
- wind action: its permanent occurrence and varied direction in this area, in function of seasons, makes it the main *Artemia* spatial dispersal factor in its resistant state.

The area seems to be promising for the development of small scale *Artemia* farming. In South-East Asia (Vietnam, China, India and Taiwan), saltworks have transformed their activities into more profitable (in addition to salt production) *Artemia* production as cysts and/or biomass, which has become a reality by proper integration of extensive *Artemia* farming into aquaculture plants. This type of small-scale *Artemia* production in Morocco could also contribute to alleviating the local aquaculture dependence on costly and vital imports of this product.

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