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Review of the biogeography of *Artemia* Leach, 1819 (Crustacea: Anostraca) in Tunisia

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Abstract

Species of the brine shrimp *Artemia* are found in a variety of harsh environments worldwide. This branchiopod is widely used as a live food organism for marine fish and crustacean larvae in commercial hatcheries. In Tunisia it has been reported from 23 sites located at different hydrogeographical zones and shows various phenotypes and different biochemical and physiological characteristics which are related to many ecological changes. However, some information is available about its biological characteristics. In this work, we report on the distribution, taxonomy and biological characteristics of various *Artemia* populations from Tunisia. Moreover, a new *Artemia* population was signalled for the first time in Sabkhet Wadran.

Key Words: *Artemia*, biogeography distribution, biological characteristics, Tunisia

Introduction

The brine shrimp *Artemia* (Branchiopoda: Anostraca) is the main zooplanktonic organism inhabiting hypersaline environments all over the world (Triantaphyllidis *et al*., 1998) except Antarctica (Browne & MacDonald, 1982). This branchiopod has been reported in more than 600 coastal locations and inland waters (Van Stappen, 2002) and shows similar morphological characters. The diversification of the *Artemia* environments varies considerably in terms of anionic composition with chloride, sulphate or carbonate waters and/or combinations of two or even three major anions (Bowen *et al*., 1985), climatic conditions from humid-subhumid to arid and Saharan (Vanhaecke *et al*., 1987; Ben Naceur *et al*., 2009a) and altitude from as low as sea level to about 5040 m in Tibet (Yuan *et al*., 2007). This variability results in numerous different strains with various phenotypes and different biological, biochemical and physiological characteristics, which are related to many ecological changes (Triantaphyllidis *et al*., 1998). Bisexual *Artemia* comprise six recognized species: *Artemia salina* (L. 1758) from Mediterranean area and Africa, *Artemia urmiana* Günther, 1899 from Iran, *Artemia sinica* Cai, 1989 from P.R. China, *Artemia tibetiana* Abatzopoulos *et al*., 1998 from Tibet, *Artemia persimilis* Piccinelli & Prosdocimi, 1968 from Argentina and Chile and *Artemia franciscana* Kellogg, 1906 from the North, Central and South America. The parthenogenetic populations, with different degrees of ploidy, are present in the Old World (Eurasia and Africa), and were introduced in Australia (Amat *et al*., 2005).

Brine shrimp *Artemia* was first reported by an unknown Iranian author in 982 from Urmia Lake, Iran (see Asem, 2008). However, the first drawing of *Artemia salina* was illustrated in the French edition (1756) by Schlosser's concerning *Artemia* samples harvested from Lymington Lake (destroyed to day), England (Kuenen & Bass-Becking, 1938). Since then, many *Artemia* sites have been recorded and different taxa and morphological characteristics were attributed to the genus. The first trial to list all known *Artemia* sites dates back to 1922 when Artom reported 18 of them (Artom, 1922). Later, Stella (1933) and Barigozzi (1946) reported the occurrence of *Artemia* populations in 28 and 29 sites respectively, spread over the five continents. However, the first systematic effort to make an inventory of the various known *Artemia* populations was carried out by Persoone & Sorgeloos (1980), who listed 244 sites/populations. Vanhaecke *et al*. (1987), in their updated review, reported the presence of *Artemia* in 360 geographically distinct areas. The most recent investigations on *Artemia* biogeography have been published by Triantaphyllidis *et al*. (1998) with 505 *Artemia* sites and Van Stappen (2002) with 598 *Artemia* sites, distributed all over the world.

The biodiversity of *Artemia* populations has suffered a great change after the introduction of the invasive *Artemia franciscana* specimens all over the world such as in a Pacific Island and in Brazil (Persoone & Sorgeloos, 1980), Australia (Geddes, 1980), P.R. China (Triantaphyllidis *et al*., 1995), Egypt (Triantaphyllidis *et al*., 1998), Portugal (Triantaphyllidis *et al*., 1998; Amat *et al*., 2005), Morocco (Amat *et al*., 2005), France (Thiéry & Robert, 1992), Philippines (De Los Santos *et al*., 1980), Thailand (Tarnchalanukit & Wongrat, 1987), Vietnam (Vu Do & Nguyen Ngoc, 1987), Sri-Lanka and Madagascar (Triantaphyllidis *et al*., 1998) and Iraq (Dawood *et al*., 2010), and by the presence of *Artemia urmiana* in Lake Koyashskoe, Ukraine (Abatzopoulos *et al*., 2009).

Artemia sites in Tunisia

Tunisia is a North African country bordered on the north and the east by the Mediterranean Sea. Its western border opens on Algeria (965 km) and its South-eastern border on Libya (459 km). Tunisia covers 163610 km², it has a relief relatively contrasting according to the areas and a significant maritime front (1 298 kilometres) mainly directed towards the east. The climate of Tunisia is influenced by the Mediterranean and Saharan climate, and divided into 7 bioclimatic zones: subhumid, upper semi-arid, lower semi-arid, upper

arid, lower arid, upper Saharian and lower Saharian.

The Tunisian climate is characterized by long dry summers and short rainy winters, which generally implies a lack of a well-developed permanent surface hydrographic network. For this reason, ephemeral and temporary habitats are the most common and representative natural superficial waters (Ben Naceur *et al*., 2009b). Tunisian temporary saline lakes represent 29% of the totals superficies of wetland, they are formed by 54 Sabkhas (representing 22% of the totals superficies of wetland) and 17 chotts (representing 7% of the totals superficies of wetland). Sabkha is the local Gulf Arabic word for a salt flat and its geological usage implies intra-sediment evaporate growth beneath a flat geomorphic surface with an elevation that is dictated by the top of the capillary fringe (Warren & Kendall, 1985). The term chott is also used as geological equivalent to continental sabhka in the south of Tunisia. However, chott encompasses other related settings, including saline pans, distal alluvial fans, sand flats and dune fields (Warren, 2006). The Tunisian Chotts include a large region of ephemeral salt lakes that extend from the lowland of southern Tunisia to the Atlas Mountains. The climate in this part of North Africa is generally pre-Saharan, arid to semi arid with an annual rainfall between 80 and 140 mm and an average temperature of appreciatively 21.1 °C (Stivaletta *et al*., 2009).

The Mediterranean saline lake fauna was one of the earliest studied areas (e.g. Gauthier, 1928; Dumont *et al*., 1979; Margaritora, 1985; Mouelhi *et al*., 2000; Samaroui *et al*., 2006). The presence of *Artemia* in Tunisia was first reported by Seurat (1921) and Gauthier (1928) in Sabkhet Ariana and Sabkhet Sidi El Hani, respectively. Later, Ben Abdelkader (1985), Sorgeloos *et al*. (1986), Romdhane (1994), Triantaphyllidis *et al*. (1998) and Romdhane *et al*. (2001) announced the occurrence of *Artemia* populations in 10 other sites. Most recently, after the investigation of 49 saline lakes in Tunisia, Ben Naceur *et al*. (2009a, 2010a) reported the occurrence of brine shrimp *Artemia* in 22 sites located at different hydrogeographical zones. However, in the present work, new *Artemia* population harvested from Sabkhet Wadran is reported. Figure 1 and Table 1 represent the biogeography distribution of the branchiopod *Artemia* in Tunisia.

Sabkhet Ariana: located at 14 km North of Tunis. The depth, salinity and temperature vary with season, affected by precipitation and evaporation rates. Its maximum length and width are 8 and 4 km, respectively. During the rainy season, many smaller lagoons with fluctuating salinity appear around the central pond where *Artemia* occurs (Fig. 2). The faunistic study showed the presence of Anostraca (*Artemia* and *Branchinella spinosa*) (Ben Naceur *et al*. 2009c), Cladocera and Copepoda. The presence of *Artemia* was reported for the first time by Seurat (1921).

Sabkhet Sijoumi: Located 5 km South-West of Tunis. Its maximum length and width are 9 and 4 km, respectively. First signalization of *Artemia* population was reported by Romdhane *et al*. (2001).

Megrine saltwork: Recently, this site was repurchased and buried by the Lake Company for its transformation in an urban zone, but cysts collected, still exists in several laboratories (Institut National Agronomique de Tunisie, Tunisia; Institut National des Sciences et Technologies de la Mer, Tunisia; *Artemia* Reference Center, Belgium and Instituto de Acuicultura de Torre del Sal, Spain) and some other laboratories.

Sabkhet Korzia: situated at 13 km North-West of El Fahs. Its length is about 5 km and its width is approximately 3 km. Many zooplanktonic organisms are living in this lake (Anostraca, Cladocera, Nostracoda). Sorgeloos *et al*. (1986) first reported the presence of *Artemia* in this lake.

Sabkhet Assa Jriba: this sabkha is situated 6 km east of Nfidha city. The maximum length and width of the sabkha are 30 km and 2 km, respectively. The most important source of water feeding the sabkha is the Khaira Wadi (wadi: Arabic term traditionally referring ephemeral riverbed that contains water only during rainy season). During the rainy season, many

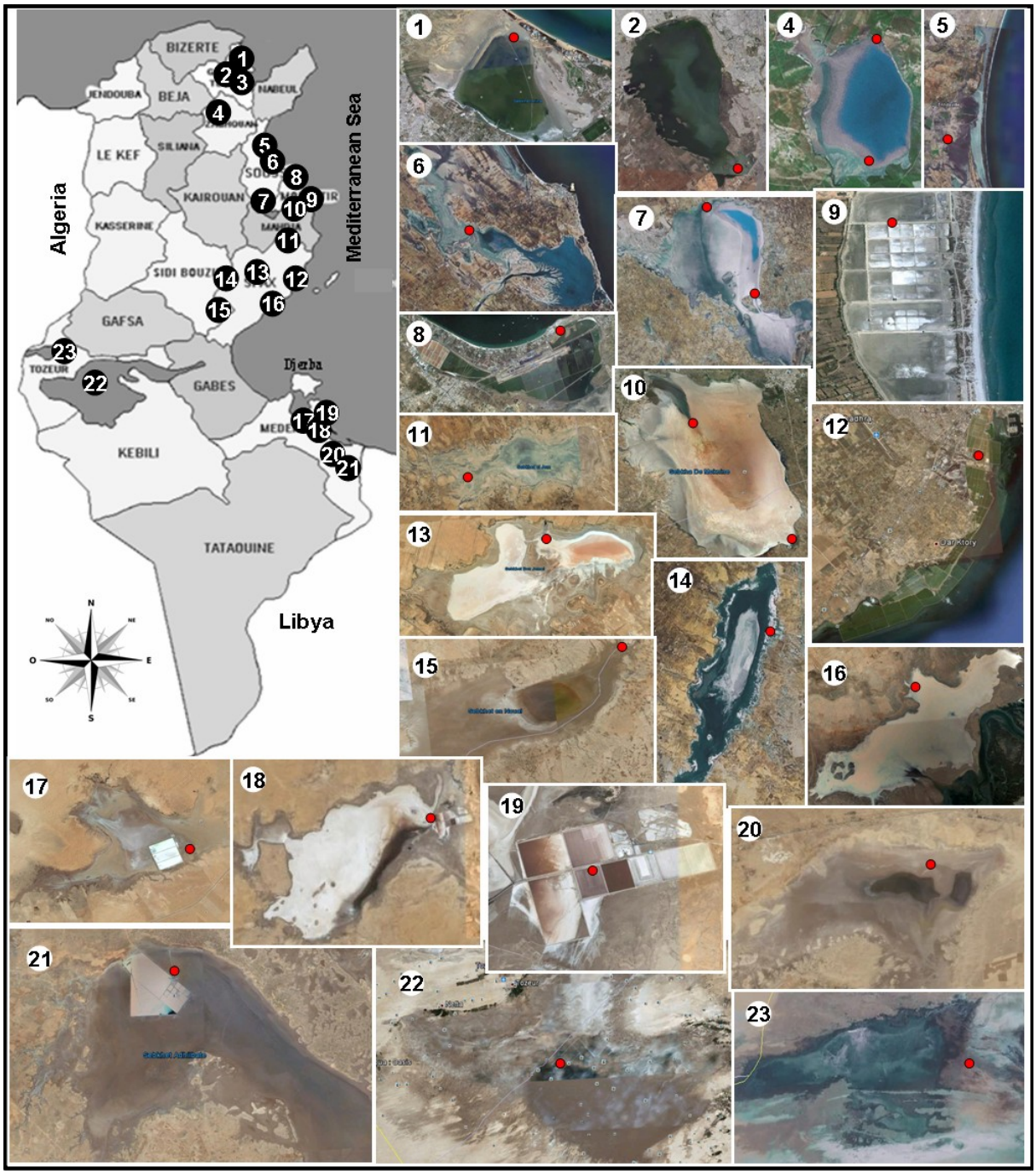

Fig. 1: Sabkha, chott and saltwork where the genus *Artemia* was observed in Tunisia. [1] Chott Ariana; [2] Sabkhet Sijoumi; [3] Megrine saltwork; [4] Sabkhet Korzia; [5] Sabkhet Assa Jriba; [6] Sabkhet Halk El Menzel; [7] Sabkhet Sidi El Hani; [8] Sahline Saltwork; [9] Bkalta Saltwork; [10] Sabkhet Moknine; [11] Sabkhet El Jam; [12] Sfax Saltwork; [13] Sabkhet Boujmal; [14] Sabkhet Mcheguig; [15] Sabkhet Noueiel; [16] Sabkhet Wadrane; [17] Mhabeul Saltwork; [18] Sabkhet El Melah; [19] Zarzis Saltwork; [20] Sabkhet Mnikhra; [21] Sabkhet El Adhibet; [22] Chott El Jerid; [23] Chott El Gharsa. Samplings zones were marked by the red point.

Table 1: Biogeography distribution of the genus *Artemia* in Tunisia (symbol (*) signify parthenogenetic population of *Artemia*).

Sites	Taxon status	Hydro-geographical zone	Type of habitat	Abbreviation	Geographical Coordinates	Approximate surface (km^2)	Altitude above sea level (m)	maximum depth (m)
Chott Ariana	*A. salina* [1,2,3]	upper semi-arid	Coastal Salt Lake	AR	36°55'38"N, 10°15'22"E	39	0-50	1.2
Sabkhet Sijoumi	*A. salina* [3,4] *Parthenogenetic [5]	"	Inland salt lake	SIJ	36°55'38"N-10°15'22"E	28-30	0-50	1.5
Megrine Saltwork	*A. salina* [4,6]	"	Coastal Saltwork	MEG	36°47'N-10°14'E	10	-	-
Sabkhet Korzia	*A. salina* [3,9]	"	Inland salt lake	KOR	36°24'47"N-09°47'10"E	12	200	-
Sabkhet Assa Jriba	*A. salina*[3]	lower semi-arid	Coastal Salt Lake	AJ	36°14'09"N, 10°26'20"E	60	0-50	-
Sabkhet Halk El Menzel	*A. franciscana* [9]	"	Coastal salt lake	HM	36°00'40"N-10°27'30"E	13-19.5	0-50	1
Sabkhet Sidi El Hani	*A. salina* [8,9]	"	Inland salt lake	SH	35°37'43"N-10°22'46"E	350	-	-
Sahline Saltwork	*A. salina* [4,7,8,9]	"	Coastal saltwork	SAH	35°45'58"N-10°46'58"E	12	0-50	-
Bkalta Saltwork	*A. salina* [2,8,9]	"	Coastal saltwork	BK	35°34'19"N-11°01'39"E	1.2	0-1	0.6
Sabkhet Moknine	*A. salina* [2,8,9]	"	Inland salt lake	MOK	35°36'20"N-10°55'37"E	40	-	-
Sabkhet El Jam	*A. salina* [3,1]	upper arid	Inland salt lake	JAM	35°09'29"N, 10°43'48"E	30	50	-
Sfax Saltwork	*A. salina* [6,8,9]	"	Coastal saltwork	SFX	35°45'N-10°43'E	15	-	-
Sabkhet Boujmal	*A. salina* [3]	"	Inland salt lake	BJ	34°57'53"N-10°24'04"E	50	0-50	1
Sabkhet Mcheguig	*A. salina* [3]	"	Inland salt lake	MCH	34°57'16"N-10°02'28"E	24	75	-
Sabkhet Noueiel	*A. salina* [3]	lower arid	Inland salt lake	NOL	34°27'28"N, 09°54'51"E	110	50	-
Sabkhet Wadrane	?	"	Coastal salt lake	WD	34°25'32"N, 10°20'12"E	40	-	2
Mhabeul Saltwork	*A. salina* [9]	"	Inland saltwork	MHB	33°24'35"N-10°51'20"E	3	0-25	0.7
Sabkhet El Melah	*A. salina* [3,8]	"	Inland salt lake	MEL	32°21'34"N-10°55'22"E	150	12	-
Zarzis Saltwork	*A. salina* [9]	"	Inland saltwork	ZAR	33°24'48"N-11°03'43"E	1.7	-	-
Sabkhet Mnikhra	*A. salina* [8,9]	"	Inland salt lake	MNK	33°08'59"N-11°20'09"E	17	25	1
Sabkhet El Adhibet	*A. salina* [3,4,7,8]	"	Inland saltwork	ADH	33°05'42"N-11°24'29"E	125	25	2
Chott El Jerid	*A. salina* [3]	upper Saharian	Inland salt lake	CJ	33°56'21"N, 08°26'50"E	5000	10	-
Chott El Gharsa	*A. salina* [3]	"	Inland salt lake	CG	34°09'07"N, 08°04'07"E	320	-1	-

[1] Triantaphyllidis et al. (1998); [2] Van Stappen (2002); [3] Ben Naceur et al. (2011d); [4] Romdhan et al. (2004); [5] Ghlala & Charfi-cheikhrouha (2008); [6] Triantaphyllidis et al. (1997); [7] Muñoz et al. (2008); [8] Mahdhi (2011); [9] Ben Naceur (2010); (?) unknown status

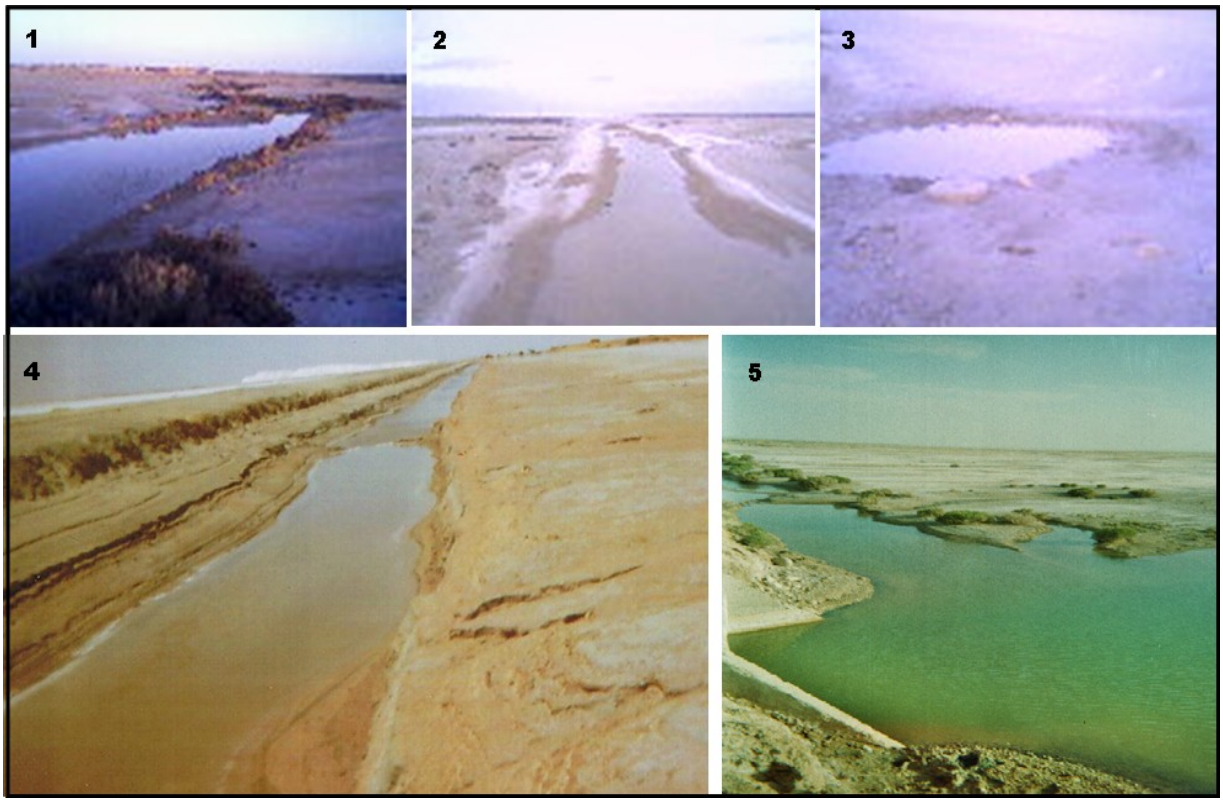

Fig. 2: Smaller lagoons around the central pond where *Artemia* occur: (1) Sabkhet Ariana, (2) Sabkhet El Jam, (3) Sabkhet Assa Jriba, (4) artificial canals in the borders of El Adhibet saltworks and (5) Chott El Gharsa.

smaller lagoons of some tens m^2 surface area appear around the central pond where *Artemia* occur (Fig. 2). First signalization of *Artemia* population was reported by Ben Naceur *et al*. (2009a).

Sabkhet Halk El Menzel: situated 25 km north-west of Sousse city. The maximum length and width of the lake are about 12 and 2 km, respectively. Sabkhet Halk El-Menzel is divided into a north (periodic area) and south (permanent area) arms. The most important source of water feeding the sabkha is the Essod Wadi. First signalization of *Artemia* population was reported by Ben Naceur *et al*. (2010a).

Sabkhet Sidi El Hani: located South-West of Sousse city. It is fed by a river system of Wadis as Cherita Wadi, Mansoura Wadi and Oum El Melah Wadi. Its maximum length and width are 30 km and 18 km with a throttling of 4 km of width in the center. Two saltworks use the site's underground water for salt production. The presence of *Artemia* in the site was first reported by Gauthier (1928). Figure 3 shows *Artemia* cysts on the shore of sabkhet Sidi El Hani.

Sahline Saltwork: It is situated 5 km South-West of Monastir city. The maximum length and width are 12 km and 6 km, respectively. First signalization of *Artemia* population was reported by Ben Abdelkader (1985).

Bkalta saltwork: It is an abandoned saltwork, situated at 100 m of the sea and located at 7 km North-West of Mahdia city. Its length and width are 0.4 and 8 km, respectively. *Artemia* seems to be the only meso-zooplanktonic organisms living in this site. The presence of *Artemia* was reported for the first time by Ben Abdelkader (1985).

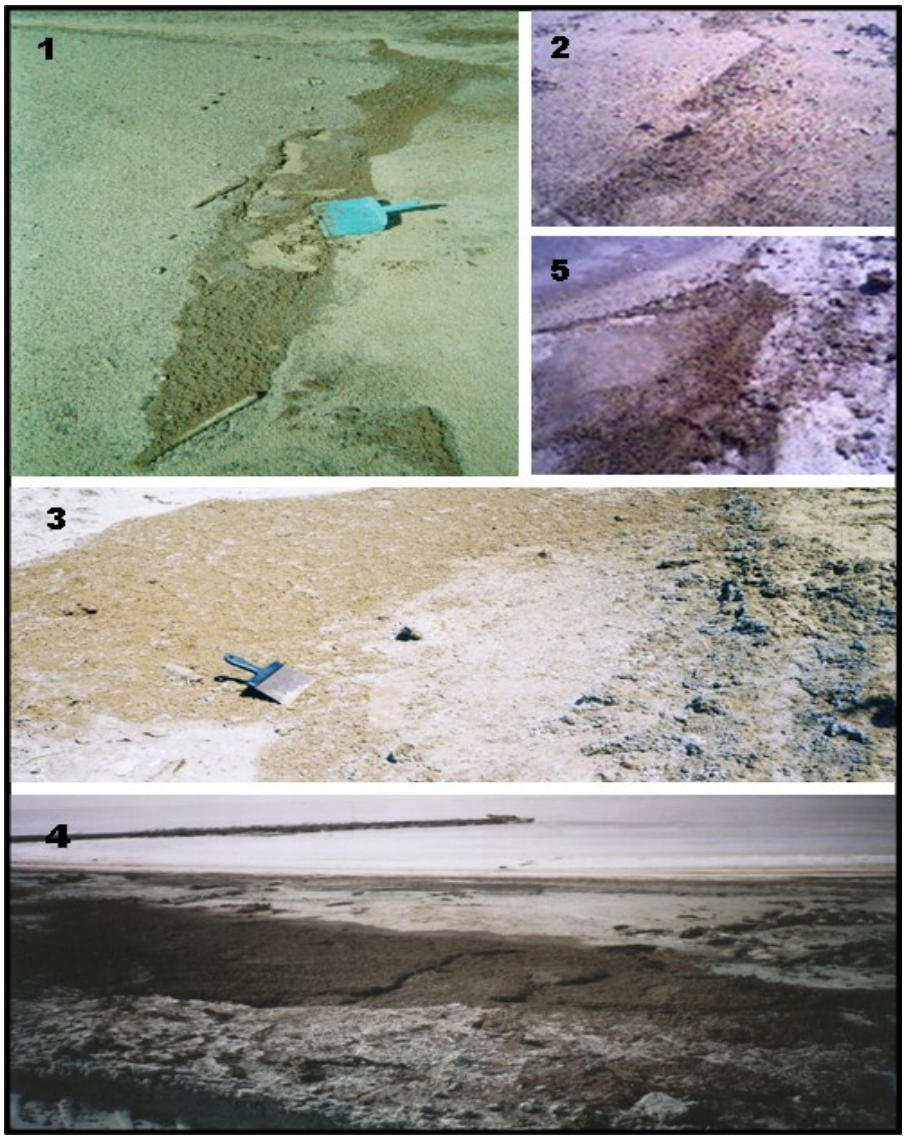

Fig. 3: *Artemia* cysts on the shore of different sabkha and saltworks from Tunisia. (1) Sidi El Hani, (2) Moknine, (3) Sfax, (4) El Adhibet and (5) El Melah.

Sabkhet Moknine: situated at 4 km of the sea and located at 8 km North-West of Mahdia city. It is fed by a many Wadis from which the most important is the Redjel Chiba Wadi. Its maximum length and width are 8 km and 4 km, respectively. Ben Abdelkader (1985) first reported the presence of *Artemia* in this Sabkha. Figure 3 shows *Artemia* cysts on the shore of Sabkhet Moknine.

Sabkhet El Jam: It is located 15 km south of El Jam city. The maximum length and width of the sabkha are about 12 and 2 km, respectively. The presence of *Artemia* in the sabkha was first reported by Ben Naceur *et al*. (2009a). During the rainy season, many smaller lagoons of some hundred m^2 surface area appear around the central pond where *Artemia* occur (Fig. 2).

Sfax saltwork: It is located in Sfax city. Its length is about 12 km. The water is permanent in this site; the most important source of water feeding of this site is the sea water by the intermediary of controlled water circuit. A number of different zooplanktonic organisms such as *Globorotalia truncatuloïdes, Perinereïs cultrifera, Oithona nana* and many other species exist in the site (Toumi 1998). Sfax saltwork it is one of the most important sites for waterbird in Tunisia, in fact, various and numerous bird species are observed in Sfax saltwork during the winter season. Ben Abdelkader (1985) first reported the presence of *Artemia* in this site in literature. Figure 3 shows *Artemia* cysts on the shore of Sfax saltworks.

Sabkhet Boujmal: situated 40 km northwest of Sfax city. Its length is about 6 km and its width is approximately 3 km. The most important source of water feeding the Sabkha is the El-Hallouf wadi. The presence of *Artemia* in Boujmal was reported for the first time by Ben Naceur *et al*. (2009a).

Sabkhet Mcheguig: this Sabkha is situated 70 km West-North-West of Sfax city. Its length is about 10 km and its width is approximately 2 km. Many waterbirds are observed during cold season. The presence of *Artemia* in the sabkha was first reported by Ben Naceur *et al*. (2009a).

Sabkhet Noueiel: located 60 km North-North-West of Gabes city. It is fed by Wadis systems from which the most important are the Assarj Wadi and Nouh Wadi. The maximum length and width are 22 km and 8 km, respectively. The presence of *Artemia* in the sabkha was first reported by Ben Naceur *et al*. (2009a).

Sabkhet Wadrane: It is located 5 km north of Kneiss Island and 21 km South-Wets of Mahres city. Its length is about 24 km and its width is approximately 4 km. The most important source of water feeding the lake is the Wadrane Wadi. The presence of *Artemia* in the sabkha was first reported in this work.

Sabkhet El Adhibet: located in SE Tunisia, 16 km from the Tunisian-Libyan frontier and occupied by industrial salt works (500 hectares). Maximum length and width are 8 and 7 km, respectively. Trenches delimiting saltworks were dug artificially to consolidate the dividing dykes of the basins, with an average depth of 0.75 m (Fig. 2). These artificial canals in the borders of saltworks are filled by rainwater accumulated during the rainy season until May or June, and *Artemia* occurs there. In Sabkhet El Adhibet, *Artemia* was reported for the first time by Romdhane *et al*. (2001). Figure 3 shows *Artemia* cysts on the shore of Sabkhet El Adhibet.

Sabkhet Mnikhra: It is located 10 km from Ben Guerdane city and 20 km before Tunisian-Libyan frontier. Maximum length and width are 8 and 3 km, respectively. The presence of *Artemia* in the sabkha was first reported by Ben Naceur *et al*. (2009a).

Mhabeul saltwork: Mhabeul saltwork is an abandoned saltwork, located 36 km North-East of Medenine city. The maximum length and width are 2 and 2 km, respectively. The saltwork is disjointed from the eastern larger Sabkhet El Melah by an accumulation of upper Pleistocene sediments, which avoids any connection of the former to the sea. Its sedimentation mode is mainly controlled by precipitation and runoff from a small wadi system (Schulz *et al*., 2002). *Artemia* seems to be the only meso-zooplanktonic organisms living in this site. The presence of *Artemia* in the saltwork was first reported by Ben Naceur *et al*. (2009a).

Sabkhet El Melah: situated at 38 km West-North-West of Medenine city. Maximum length and width are 20 and 12 km, respectively. Many waterbird were observed during the cold season. The presence of *Artemia* in Sabkhet El-Mellah was first reported by Romdhane (1994). Figure 3)\ shows *Artemia* cysts on the shore of Sabkhet El Melah.

Zarzis saltwork: located at the North-East of Sabkhet El Melah. Sea water is used for dissolving the layer of salt which can reach up to 20 meters per place. A large colony of flamingos was observed in the evaporation pond. *Artemia* are sampled in the evaporation pond and observed in the crystallizer pond. In Zarzis saltwork, *Artemia* was reported for

the first time by Ben Naceur *et al*. (2009a).

Chott El Jeride: located in the South of Tozeur city and in the West of Kebeli city, it is the largest saltern site in Tunisia. Its maximum length and width are 110 and 70 km, respectively. The present mean annual precipitation in the chott is about 80 to 140 mm. But the evaporation rate is about 1.500 mm, far exceeding the precipitation (Komatsu & Rossi, 2001). No other meso-zooplanktonic organism is living in this site with *Artemia*. Dumont *et al*. (1979) first reported the presence of *Artemia* in this site in literature.

Chott El Gharsa: situated 24 km North-West of Tozeur city. Chott El Gharsa is limited in its western part by the Algerian frontier, in the North-West by Chott El Djerid and is surrounded by Wadis and dunes. Its maximum length and width are 50 km and 16 km, respectively. Rarely covered with rain water, during the rainy season, many smaller lagoons of some tens m^2 surface area, and with fluctuating salinity appear around the central pond where several other species co-habit with the genus *Artemia* (Ben Naceur *et al*. 2009c) (Fig. 2). The presence of *Artemia* in Chott El Garsa was first reported by Romdhane (1994).

Tunisian *Artemia* characteristics

Taxonomical status

In the Mediterranean region, the autochthonous *Artemia salina* coexists with parthenogenetic diploid and tetraploid populations as well as with the invasive *Artemia franciscana* species (see Amat *et al*., 2005, 2007). Van Stappen (2002) published the last check list of the zoogeography of *Artemia* in the world; in this paper the author reported eight *Artemia* populations from Tunisia, including three of them as unknown populations. In fact, in Tunisia the taxonomical status of *Artemia* was often generically ascribed to *Artemia salina*, without any further investigation. Nevertheless, since the report of the presence of the invasive *Artemia franciscana* in the Mediterranean region (Thiéry & Robert 1992; Triantaphyllidis *et al*., 1998; Amat *et al*., 2005; 2007), it was necessary to make a taxonomical revision for all *Artemia* populations existing in Tunisia. Based on morphologic, morphometric and allozymic data, Ben Naceur (2010) and Ben Naceur *et al*. (2011d) reported that all Tunisian *Artemia* populations belong to *Artemia salina* except for *Artemia* population from Sabkhet Halk El Menzel (*Artemia franciscana*) and Sabkhet Wadran (unknown status, reported for the first time in this work). Moreover, it is very important to mention that Ghlala & Charfi-Cheikhrouha (2008) reported, following allozymic analysis, that *Artemia* population from Sabkhet Sijoumi are parthenogenetic. This ambiguity about taxonomical status of this population can be explained by the fact that the two samples (*Artemia salina* and parthenogenetic population of *Artemia*) were not collected in the same date (months and/or years) and that the parthenogenetic population appears only during a short period in this site and disappears after a few months. In the same way, Ghlala (2002) reported that, during the investigation of Sabkhet Sijoumi from January to June 2000, the first sampling (from January to April) harvested in this site was composed by male and female specimens, however during May, harvested samples appeared to be composed only by females' specimens, followed by reappearance of the bisexual population. Allozymic study revealed that specimens harvested in May belong to parthenogenetic population of *Artemia.*

Biological characteristics

Biotopes of the brine shrimp *Artemia* vary considerably with regard to physical and chemical parameters (Bowen *et al*., 1985; Abatzopoulos *et al*., 1998). This variability results in numerous different strains with various phenotypes and different biochemical and physiological characteristics which are related to many ecological changes (Triantaphyllidis *et al*., 1998). In the literature, cysts diameter (untreated and decapsulated), chorion thickness and nauplii length data from *Artemia* from Tunisia presents much variability. The difference in biometrical characteristics was not only observed from strain to strain but also from one harvest to another within same strain (Tab. 2).

Table 2: Different biological characteristics of the branchiopod *Artemia* from Tunisia reported in the literature (Abbreviations of populations see Tab. 1).

Populations	Diameter of hydrated untreated cysts (µm)	Diameter of hydrated decapsulated cysts (µm)	Chorion thickness (µm)	Nauplii instar-I length (µm)	Hatching percentage (%)	Synchronis-ation time (hours)	Linolenic acid content (decapsulated cysts) *(%) & **(mg.g^{-1})	Eicosapentaenoic acid content (decapsulated cysts) *(%) & **(mg.g^{-1})
AR	246.0 [1]	232.0 [1]	7.0 [1]	458.0 [1]	14.0 [1]	-	-	-
SIJ	263.6 [9] 260.9 [10]	238.6 [9] 233.8 [10]	12.5 [9] 13.5 [10]	437.9 [9] 436.7 [10] 453.5 [16]	75.0 [7] 11.0 [9] 14.3 [16]	31.5 [9] 20.8 [16]	4.4 [9]** 4.3 [10]** 4.5 [16]*	22.4 [9]** 22.5 [10]** 7.6 [16]*
MEG	238.0 [1] 258.8 [2] 245.6 [9]	226.0 [1] 234.1 [2] 228.9 [9]	6.0 [1] 12.4 [2] 8.3 [9]	447.0 [1] 467.7 [2] 475.8 [9] 440.6 [15]	70.2 [1] 60.5 [2] 80.0 [7]	22.0 [2]	15.6 [2]** 1.0 [15]**	7.3 [2]** 2.7 [15]**
KOR	253.0 [18]	-	-	475.8 [17] 472.7 [18]	80.0 [8]	-	-	-
HM	235.8 [14]	226.3 [14]	4.7 [14]	426.8 [14]	-	-	2.3 [14]**	12.2 [14]**
SH	240.0 [1]	230.0 [1]	5.0 [1]	450.0 [1] 455.2 [16]	8.0 [1] 43.1 [2] 59.3 [16]	18.0 [16]	13.8 [16]*	0.2 [16]*
SAH	236.0 [1] 222.6 [4] 221.7 [5] 244.4 [9]	226.0 [1] 205.3 [4] 204.6 [5] 211.8 [9]	5.0 [1] 8.6 [4] 8.5 [5] 16.3 [9]	444.0 [1] 445.2 [4] 445.5 [5] 434.1 [9] 432.8 [11]	66.0 [1] 25.7 [4] 43.7 [5] 18.0 [9] 38.2 [11]	48.0 [4] 48.0 [5] 48.0 [9] 17.0 [11]	4.3 [9]** 3.9 [11]** 3.7 [19]**	7.6 [9]** 20.8 [11]** trace [19]**
BK	252.0 [1] 251.6 [2]	230.0 [1] 228.0 [2]	11.0 [1] 11.8 [2]	480.0 [1] 482.0 [2] 465.2 [16]	68.0 [1] 83.2 [2] 62.3 [16]	15.8 [2] 19.8 [16]	3.9 [16]*	9.0 [16]*
MOK	244.0 [1] 252.6 [2] 219.6 [4] 220.2 [5]	232.0 [1] 199.9 [4] 199.1 [5]	6.0 [1] 9.8 [4] 10.6 [5]	454.0 [1] 451.1 [4] 449.3 [5] 435.8 [16]	14.2 [2] 33.3 [4] 53.7 [5] 31.2 [16]	49.0 [4] 39.0 [5] 21.0 [16]	14.8 [16]* 20.6 [19]**	0.6 [16]* trace [19]**

Table 2. Continued

Populations	Diameter of hydrated untreated cysts (µm)	Diameter of hydrated decapsulated cysts (µm)	Chorion thickness (µm)	Nauplii instar-I length (µm)	Hatching percentage (%)	Synchronis-ation time (hours)	Linolenic acid content (decapsulated cysts) *(%) & **(mg.g^{-1})	Eicosapentaenoic acid content (decapsulated cysts) *(%) & **(mg.g^{-1})
SFX	228.0 [1] 235.4 [2] 228.1 [5] 229.0 [6]	228.0 [1] 215.1 [2] 211.3 [5]	2.5 [1] 10.2 [2] 8.4 [5]	420.0 [1] 422.2 [2] 438.8 [5] 551.0 [6] 441.4 [16]	69.0 [1] 84.8 [2] 70.1 [5] 75.0 [7] 51.0 [16]	16.2 [2] 13.0 [5] 18.0 [16]	17.4 [2]** 1.0 [6]** 13.0 [16]*	3.1 [2]** 3.4 [6]** 2.8 [16]*
BJ	246.8 [13]	235.4 [13]	5.7 [13]	457.5 [13]	-	-	3.9 [13]**	4.6 [13]**
MCH	-	-	-	480.1 [16]	63.7 [16]	23.8 [16]	5.5 [16]*	12.3 [16]*
ADH	250.0 [9] 258.1 [12] 259.8 [12]	219.1 [9] 229.9 [12] 236.4 [12]	15.4 [9] 14.1 [12] 11.6 [12]	423.0 [9] 458.1 [12] 458.9 [12]	12.3 [3] 60.0 [8] 16.0 [9] 10.1 [12] 22.0 [12] 12.3 [3]	46.0 [9] 23.3 [12] 23.9 [12]	0.42 [3]** 4.1 [9]** 7.9 [12]** 9.4 [12]** 4.7 19]**	1.79 [3]** 20.2 [9]** 7.3 [12]** 15.9 [12]** trace [19]**
MNK	-	-	-	467.6 [17]	-	-	-	-
MHB	-	-	-	485.4 [16]	52.1 [16]	18.7 [16]	15.2 [16]*	2.8 [16]*
MEL	237.7 [5]	224.5 [5]	6.6 [5]	429.0 [5] 422.6 [16]	52.3 [5] 49.0 [16]	17.0 [5] 21.8 [16]	17.7 [16]*	1.3 [16]*
ZAR	-	-	-	470.4 [16]	41.6 [16]	20.0 [16]	6.1 [16]*	2.2 [16]*
CJ	-	-	-	-	80.0 [7]	-	-	-

[1] Aloui (2003); [2] Van Ballaer et al. (1987); [3] Ben Taarit (2004); [4] Mahdhi et al. (2010); [5] Mahdhi (2011); [6] Guermazi (2008); [7] Romdhan & Ghlala (2002); [8] Romdhan et al. (2004); [9] Ben Naceur (2004); [10] Ben Naceur et al. (2008a); [11] Ben Naceur et al. (2008b); [12] Ben Naceur et al. (2010b); [13] Ben Naceur et al. (2011b); [14] Ben Naceur et al. (2010a); [15] Ben Naceur et al. (2011c); [16] Ben Naceur et al. (2012); [17] Ben Naceur (2010); [18] Ben Naceur et al. (2006); [19] Hamrouni (2004).

Such inner population variations were thought to be due to differences in environmental factors or factors related to the harvesting, processing, and drying of cysts (Castro *et al*., 2006). Such as for cysts diameter, fatty acid profiles of Tunisian *Artemia* population vary from one strain to another and from batches from the same strain (Tab. 2).

The hatching performance such as hatching rate and hatching synchrony was among the most interesting parameters to *Artemia* researchers. As having been documented for the cysts from other areas (e.g. Smith *et al*., 1978; Vanhaecke & Sorgeloos, 1982), the hatching rate and synchronies of the Tunisian *Artemia* cysts are also considerably variable among populations and among cyst batches from the same strain (Tab. 2). Vanhaecke & Sorgeloos (1982), Bowen *et al*. (1978) and Ben Naceur *et al*. (2010b) suggested that hatching rate is not under complete genetic control but depend to some extent on the environmental condition under which cysts have been produced. On the other hand variation among cyst batches can also be due to different harvesting techniques (Vanhaecke & Sorgeloos, 1982) and /or impacted by repeated hydration-dehydration cycle in case when cysts were harvested from the shore of the salt ponds (Sorgeloos *et al*., 1976). Other factor susceptible to influence cysts hatching rate is the storage condition. For instance, the presence of oxygen appears to have the most retarding effect of hatching performance (Vanhaecke & Sorgeloos, 1982; Ben Naceur *et al*. 2011a).

To conclude, the brine shrimp *Artemia* has been reported from 23 inland and costal salt lakes (sebkha and chott) and saltworks in Tunisia. Most of them belong to *A. salina*, one locality contains both *A. salina* and parthenogenetic strains, and another locality is occupied by the exotic species *A. franciscana*. However, few information are available about *Artemia* density, biomass, biometry, nutritional quality, hatching characteristics and biomass of these populations, except for *Artemia* from some sites such as Sijoumi, Megrine, Sahline, Bkalta, Moknine, Sfax and Adhibet that have been used as a biological material and as a reference for several scientists. Moreover, a new *Artemia* population was signalled for the first time in Sabkhet Wadran.

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