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Review of the biogeography of the genus *Artemia* (Crustacea, Anostraca)

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Abstract. In this study, we report on the known *Artemia* habitats worldwide. Recent literature information is incorporated about the taxonomic status of the various populations studied. The genus is composed of di-, tri-, tetra- and pentaploid parthenogenetic populations and of the following bisexual species: *A. franciscana franciscana*, *A. franciscana monica*, *A. franciscana* sp., *A. persimilis*, *A. salina*, *A. urmiana*, *A. sinica* and *A.* sp. from Kazakhstan. The problems of characterizing new brine shrimp populations are discussed. In view of the great importance of *Artemia* as part of the live food chain for the culture of fish and shellfish larvae and the present cyst shortage from the market, the need for commercial exploitation and development of new *Artemia* sources is now, more than ever, necessary.

Key words. *Artemia*, biogeography, brine shrimp.

Resumen. En este estudio presentamos los diferentes habitats de *Artemia* en todo el mundo. Se incluye informacion literaria reciente sobre la posicion taxonomica de las distintas poblaciones estudiadas. El género esta compuesto por poblaciones partenogeneticas di-, tri-, tetra- y pentaploides, y por las sigientes especies bisexuales: *A. franciscana franciscana*, *A. franciscana monica*, *A. franciscana* sp., *A. persimilis*, *A. salina*, *A. urmiana*, *A. sinica* y *A.* sp. de Kazakhstan. Se discuten tambien, los problemas relacionados con la caracterizacion de nuevas poblaciones. En vista de la gran importancia que tiene *Artemia*, como parte de la cadena alimenticia en el cultivo larvario de peces y mariscos, ademas de la escasez actual de quistes en el mercado, la necesidad de desarollo y explotacion comercial de nuevas fuentes de *Artemia*, es hoy mas que nunca, una exigencia.

Palabras clave. *Artemia*, biogeografia

INTRODUCTION

It is well known that the brine shrimp *Artemia* (Crustacea, Anostraca) inhabits hypersaline environments and has a wide geographical distribution (Persoone & Sorgeloos, 1980; Browne & MacDonald, 1982; Vanhaecke *et al.*, 1987). The diversification of the *Artemia* environments varies considerably in terms of anionic composition, climatic conditions and altitude. Depending on the prevailing anions, *Artemia* may inhabit chloride, sulphate or carbonate waters and/or combinations of two or even three major anions (Bowen *et al.*, 1985; Bowen *et al.*, 1988). It can be found in altitudes from as low as sea level to almost 4500 m in Tibet (Xin *et al.*, 1994) and in climatological conditions ranging from humid–subhumid to arid (Vanhaecke *et al.*, 1987). For further discussion of the geographical distribution of *Artemia* in relation to climate we refer to Vanhaecke *et al.* (1987).

Recently, considerable new information has become available about the existence of *Artemia* in Asia and especially in the People's Republic of China (Triantaphyllidis *et al.*, 1994a; Xin *et al.*, 1994). Moreover, considerable progress has been made in the genetic and morphometric study of Asian *Artemia* populations and comparisons with other well-studied populations have been performed (Pilla & Beardmore, 1994; Triantaphyllidis *et al.*, 1997a, 1997b). This paper provides an updated list of *Artemia* sites and is based on previous reviews (Vanhaecke *et al.*, 1987), recent literature reports as well as personal communications received at the *Artemia* Reference Center (University of Ghent, Belgium). These biogeographical data are discussed in connection to the most recent knowledge of genetic and morphometric data on the genus *Artemia*.

BIOGEOGRAPHY OF *ARTEMIA*

Tables 1–7 provide a list of all known *Artemia* sites grouped per continent. The geographical coordinates (if known) are

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TABLE 1. *Artemia* sites in Africa. For abbreviations and references see Tables 8 and 9.

Country	Locality	Geographical coordinates	Mode of reproduction	Species	References
Algeria	Chegga Oase	34°29′N–05°53′E	—	—	1
	Chott Djeloud	34°03′N–06°20′E	—	—	1
	Chott Ouargla	31°57′N–05°20′E	—	—	1
	Dayet Morselli	35°30′N–00°46′W	—	—	1
	Gharabas Lake	35°35′N–00°25′W	—	—	1
	Sebket Djendli	35°43′N–06°32′E	—	—	1
	Sebket Ez Zemouk	35°53′N–06°33′E	—	—	1
	Sebket Oran	35°32′N–00°48′W	—	—	1
	Tougourt	33°06′N–06°07′E	—	—	1
Egypt	Port Fouad	—	P	*A. par*	33
	Qarun Lake	—	P	*A. par*	33
	Solar Lake (Sinai)	29°10′N–34°50′E	P	*A. par*	1, 3
	Wadi Natron	30°10′N–30°27′E	B	*A. sal*	1, 3, 33
Kenya	Elmenteita	00°27′S–36°15′E	—	—	1
Libya	Mandara	26°40′N–13°20′E	B	*A. sp*	1
	Ramba-Az-Zallaf (Fezzan)	27°N–13°E	—	—	1
	Quem el Ma	26°41′N–13°22′E	—	—	1
	Trouna	26°50′N–13°30′E	—	—	1
	Gabr Acun (Fezzan)	27°N–13°E	—	—	1
Madagascar	Salins de Diego Suarez	12°19′S–49°17′E	—	—	1
	Ankiembe saltworks		P(3n)	*A. par*	2, 3
	Ifaty saltworks		B	*A. fra*	2
Morocco	Larache	35°12′N–02°20′W	P	*A. par*	1
	Moulaya estuary	35°07′N–02°20′W	—	—	1
	Qued Ammafatma	28°18′N–12°00′W	—	—	1
	Qued Chebeica	28°25′N–11°50′W	—	—	1
	Sebket Bon Areg	35°10′N–02°50′W	—	—	1
	Sebket Zima	32°05′N–08°40′W	—	—	1
Mozambique	Lagua Quissico	24°41′S–34°46′E	P	*A. par*	1, 13
Namibia	Vineta Swakopmund	22°40′S–14°34′E	P(2n,4n)	*A. par*	1, 3
Niger	Teguidda In Tessoun	17°26′N–06°39′E	—	—	1
Senegal	Dakar	14°34′N–17°29′W	—	—	1
	Lake Kayar	14°55′N–17°11′W	—	—	1
	Lake Retba	14°50′N–17°20′W	—	—	1
South Africa	Coega Salt Flats	33°46′S–25°40′E	P	*A. par*	1, 3
	Swartkops	33°52′S–25°36′E	—	—	1
	Veldrif salterns	33°S–18°E	B	*A. sal*	34
	Santa Maria, Sal Is., Cape Verde Islands		—	—	36
Tunisia	Bekalta	36°48′N–10°20′E	B	*A. sal*	1
	Chott Ariana	36°54′N–10°18′E	B	*A. sal*	1
	Chott El Djerid	33°42′N–08°26′E	—	—	1
	Megrine	36°47′N–10°14′E	B	*A. sal*	1
	Sebket Kowezia	36°26′N–09°46′E	—	—	1
	Sebket mta Moknine	35°39′N–10°53′E	B	*A. sal*	1
	Sebket Sidi el Hani	35°31′N–10°27′E	—	—	1
	Sfax	35°45′N–10°43′E	B	*A. sal*	1

given and, when available, information about the mode of reproduction (parthenogenetic or bisexual), the ploidy level of the parthenogenetic populations and the species designation.

Despite the effort made in recent years to report on new *Artemia* populations, our knowledge of the biogeography of this anostracan is still very limited for many Asian, African and Eastern European regions. Interest is focused on Asian regions where new species have recently been described (Pilla & Beardmore, 1994). A literature survey reveals that the genus *Artemia* is composed of several bisexual species and numerous parthenogenetic populations. The parthenogenetic populations are composed of di-, tri-, tetra- and pentaploid individuals or mixtures of different ploidies and are grouped under the binomen *A. parthenogenetica* for taxonomic convenience. For further information on the distribution of sexual and parthenogenetic populations see Browne & MacDonald (1982).

In the New World, reproduction is exclusively sexual and the following species have been described.

A. franciscana

According to Bowen *et al.* (1985), '*A. franciscana* is a superspecies (a set of ecologically isolated and

TABLE 2. *Artemia* sites in Australia and New Zealand. For abbreviations and references see Tables 8 and 9.

Country	Locality	Geographical coordinates	Mode of reproduction	Species	References
New Zealand	Lake Grassmere	41°38′S–174°05′E	B	*A. fra*	1
Queensland	Bowen	20°00′S–184°16′E	—	—	1
	Port Alma	23°22′S–150°32′E	B	*A. fra*	1
	Rockhampton		B	*A. fra*	1
South Australia	Dry Creek, Adelaide	34°55′S–138°20′E	P	*A. par*	1
Western Australia	Dampier	20°35′S–116°51′E	—	—	1
	Lake McLeod	23°59′S–113°40′E	—	—	1
	Port Hedland	20°25′S–118°35′E	B	*A. par*	1
	Rottnest Island	32°00′S–115°27′E	P	*A. par*	1
	Shark Bay	25°15′S–113°20′E	P,B	*A. par*, *A. fra*	1

physiologically distinct semispecies and species)'. This superspecies groups populations that are isolated reproductively in nature: *A. franciscana franciscana* Kellogg (1906) (e.g. in Great Salt Lake, Utah, U.S.A.; in coastal saltworks in North, Central and South America), *A. franciscana monica* Verrill (1869) (in Mono Lake, California, U.S.A.) and *A. franciscana* sp. which includes the populations in the low-chloride, high-carbonate lakes in Nebraska (U.S.A.) (Browne & Bowen, 1991). Due to ecological barriers that separate many *A. franciscana* populations, incipient speciation occurs (Bowen *et al*., 1985; Abreu-Grobois, 1987). According to Browne & Bowen (1991), the diversification among these populations is due mainly to differences in lakewater chemistry, and thus intolerance for each other's natural habitat.

Endemic *A. franciscana* populations can be found throughout the American continent. As a result of the introduction of *A. franciscana* in solar saltworks for improved salt production and/or for harvesting cysts and biomass for use in the aquaculture industry, permanent populations of this species are also found in Brazil (Persoone & Sorgeloos, 1980), Australia (Geddes, 1980), the People's Republic of China (Triantaphyllidis *et al*., 1994b, 1995), Egypt (P. Baert, personal communication) as well as in Europe (in Portugal; L. Narciso, personal communication). Seasonal *A. franciscana* farming is practised in many tropical and subtropical countries such as the Philippines (De Los Santos *et al*., 1980), Thailand (Tarnchalanukit & Wongrat, 1987), Vietnam (Vu Do & Nguyen Ngoc, 1987), Sri Lanka (Kuruppu, personal communication) and Madagascar (E. Miasa, personal communication). However, due to the particular climatic conditions of these countries, the *Artemia* populations are not permanent and annual inoculations are required. *Artemia* dispersal can take place through migrating birds; this phenomenon has been well documented in the case of *A. franciscana* (Vanhaecke *et al*., 1987).

A. persimilis (Piccinelli & Prosdocimi, 1968)

This species is found in Argentina but is also reported to exist in the Mediterranean basin (in Sardinia; Piccinelli & Prosdocimi, 1968). However, in recent years its existence in Sardinia could not be confirmed (Barigozzi, 1989). This species has forty-four chromosomes, contrary to the forty-two of all other bisexual species.

In the Old World both modes of reproduction have been recorded. *A. parthenogenetica* is distributed in the Mediterranean region, in Africa, in Asia and Australia. Four bisexual species have been described. *A. salina* (Leach, 1819) is distributed in the broader Mediterranean basin, *A. urmiana* (Günther, 1900) exists in Iran in Lake Urmia, *A. sinica* (Cai, 1989) is distributed in Central and Northern provinces of the People's Republic of China (P.R. China) and *Artemia* sp. (Pilla & Beardmore, 1994) exists in Kazakhstan (unknown region). *A. tunisiana* (Bowen & Sterling, 1978) is a synonym of *A. salina* and according to the Code of Zoological Nomenclature, it should no longer be used (Principle of Priority, Article 23; for a detailed discussion see Triantaphyllidis, 1995; Triantaphyllidis *et al*., 1997c).

In *Artemia* taxonomy, the following criteria have been used for species designation: (i) the overall morphology of the adults as well as some characteristics such as shape of furca or frontal knob morphology in males, (ii) the specific chromosome number, (iii) the genetic distance (Nei's D) as determined by allozyme electrophoresis, and (v) cross-breeding experiments for demonstration of the reproductive isolation under laboratory conditions (Clark & Bowen, 1976; Beardmore & Abreu-Grobois, 1983; Abreu-Grobois, 1987). The above-mentioned criteria are fulfilled by the species *A. franciscana*, *A. persimilis*, *A. tunisiana* and *A. urmiana* (Browne & Bowen, 1991). Recently Pilla & Beardmore (1994), studying Eastern Old World populations, demonstrated that *A. urmiana*, *A. sinica* and a population from Kazakhstan (unfortunately of unknown origin) exhibit great morphological and genetic differentiation. However, under laboratory conditions these populations are cross-fertile without evidence of hybrid breakdown (Pilla & Beardmore, 1994). Complete infertility exists between all Old World populations and New World *A. franciscana* (Pilla & Beardmore, 1994) and this is probably the case for *A. persimilis*, because of its different number of forty-four chromosomes (see above). Absence of a genetic barrier between *A. urmiana*, *A. sinica* and *A*. sp. from Kazakhstan has also been demonstrated by Truong (1995), who managed to reach F_6 generation in some cases. Since post-mating barriers to gene flow seem to be very weak in the case of

TABLE 3. *Artemia* sites in North America. For abbreviations and references see Tables 8 and 9.

Country	Locality	Geographical coordinates	Mode of reproduction	Species	References
Canada	Akerlund Lake	52°18′N–109°15′W	B	*A. sp*	1
	Alsask Lake	51°20′N–109°52′W	B	*A. sp*	1
	Aroma Lake	51°18′N–108°33′W	B	*A. sp*	1
	Berry Lake	52°07′N–105°30′W	B	*A. sp*	1
	Boat Lake	50°17′N–109°59′W	B	*A. sp*	1
	Burn Lake	49°49′N–105°27′W	B	*A. sp*	1
	Ceylon Lake	49°27′N–104°36′W	B	*A. sp*	1
	Chain Lake	50°30′N–108°43′W	B	*A. sp*	1
	Chaplin Lake	50°25′N–106°38′W	B	*A. fra*	1, 28
	Churchill	58°45′N– 94°00′W	B	*A. sp*	1
	Coral Lake	49°51′N–102°21′W	B	*A. sp*	1
	Drybore Lake	49°43′N–105°30′W	B	*A. sp*	1
	Enis Lake	52°10′N–108°19′W	B	*A. sp*	1
	Frederick Lake	49°59′N–105°38′W	B	*A. sp*	1
	Fusilier Lake	51°50′N–109°44′W	B	*A. sp*	1
	Grandora Lake	52°06′N–107°00′W	B	*A. sp*	1
	Gull Lake	50°06′N–108°27′W	B	*A. sp*	1
	Hatton Lake	50°02′N–109°50′W	B	*A. sp*	1
	Horizon Lake	49°32′N–105°17′W	B	*A. sp*	1
	Ingerbright Nath	50°22′N–109°19′W	B	*A. sp*	1
	Landis Lake	52°13′N–108°27′W	B	*A. sp*	1
	La Perouse	55°14′N– 98°00′W	B	*A. sp*	1
	Little Manitou Lake	51°48′N–105°30′W	B	*A. fra*	1, 28
	Lydden Lake	52°09′N–108°13′W	B	*A. sp*	1
	Mawer Lake	50°46′N–106°22′W	B	*A. sp*	1
	Meacham Lake	52°07′N–105°47′W	B	*A. sp*	1
	Muskiki Lake	52°20′N–105°45′W	B	*A. sp*	1
	Neola Lake	52°03′N–107°49′W	B	*A. sp*	1
	Oban Lake	52°09′N–108°09′W	B	*A. sp*	1
	Richmond Lake	52°01′N–108°01′W	B	*A. sp*	1
	Shoe Lake	49°55′N–105°27′W	B	*A. sp*	1
	Snakehole Lake	50°30′N–108°30′W	B	*A. sp*	1
	Sybouts Lake-East	49°02′N–104°24′W	B	*A. sp*	1
	Sybouts Lake-West	49°02′N–104°27′W	B	*A. sp*	1
	Verlo West	50°19′N–108°37′W	B	*A. sp*	1
	Vincent Lake	50°13′N–108°57′W	B	*A. sp*	1
	Wheatsone Lake	49°49′N–105°24′W	B	*A. sp*	1
	Whiteshore Lake	52°08′N–108°17′W	B	*A. sp*	1
USA					
Arizona	Kiatuthlana Red Pond	34°50′N–109°26′W	B	*A. fra*	1, 28
	Kiatuthlana Green Pond	34°50′N–109°26′W	B	*A. fra*	1, 28
California	Carpinteria Slough	34°24′N–119°30′W	B	*A. sp*	1
	Chula Vista	32°36′N–117°05′W	B	*A. sp*	1
	Mono Lake	38°00′N–119°00′W	B	*A. f. mon*	1
	Moss Landing, Monterey Bay	36°48′N–121°46′W	B	*A. fra*	28
	Owens Lake	36°25′N–117°56′W	B	*A. sp*	1
	San Diego	32°50′N–117°10′W	B	*A. sp*	1
	San Francisco Bay	37°28′N–122°30′W	B	*A. fra*	1
	San Pablo Bay	38°00′N–122°16′W	B	*A. fra*	1
	Vallejo West Pond	38°12′N–122°15′W	B	*A. sp*	1
Hawaii	Christmas Islands	01°50′N–157°20′W	B	*A. sp*	1
	Hanapepe	21°54′N–159°30′W	B	*A. sp*	1
	Laysan Atoll	25°30′N–167°00′W	B	*A. fra*	1, 28
Nebraska	Alkali Lake	43°32′N–100°38′W	B	*A. sp*	1
	Ashenburger Lake	42°N–102°W	B	*A. sp*	1
	Antioch (Potash) Lake	42°04′N–102°34′W	B	*A. fra*	28
	Cook Lake	42°N–102°W	B	*A. sp*	1
	East Valley Lake	42°N–102°W	B	*A. sp*	1
	Grubny Lake	42°N–102°W	B	*A. sp*	1
	Homestead Lake	42°N–102°W	B	*A. sp*	1
	Jesse Lake	42°06′N–102°39′W	B	*A. fra*	1
	Johnson Lake	42°N–102°W	B	*A. sp*	1

contd

TABLE 3. *contd*

Country	Locality	Geographical coordinates	Mode of reproduction	Species	References
Nebraska *contd*	Lilly Lake	42°N–102°W	B	*A. sp*	1
	Reno Lake	42°N–102°W	B	*A. sp*	1
	Richardson Lake	42°N–102°W	B	*A. fra*	1, 28
	Ryan Lake	42°N–102°W	B	*A. sp*	1
	Sheridan County Lake	42°N–102°W	B	*A. sp*	1
	Sturgeon Lake	41°59′N–102°40′W	B	*A. fra*	28
Nevada	Fallon Pond	39°31′N–118°52′W	B	*A. fra*	1, 28
North Dakota	Miller Lake		B	*A. sp*	1
	Stink (Williams) Lake		B	*A. sp*	1
New Mexico	Laguna del Perro	34°32′N–106°01′W	B	*A. sp*	1
	Loving Salt Lake	32°17′N–104°04′W	B	*A. sp*	1
	Quemado	34°17′N–108°28′W	B	*A. fra*	1
	Zuni Salt Lake	34°27′N–108°46′W	B	*A. fra*	1, 28
Oregon	Lake Abert	42°35′N–120°15′W	B	*A. sp*	1
Texas	Cedar Lake	34°48′N–102°16′W	B	*A. fra*	28
	McKenzies Playa	32°41′N–102°10′W	B	*A. sp*	1
	Mound Playa	33°10′N–101°56′W	B	*A. sp*	1
	Playa Thahoka	33°12′N–101°34′W	B	*A. sp*	1
	Raymondville	26°10′N– 97°48′W	B	*A. sp*	1
	Rich Playa	33°13′N–102°03′W	B	*A. sp*	1
	Snow drop Playa	32°59′N–101°40′W	B	*A. sp*	1
Utah	Great Salt Lake	41°00′N–112°30′W	B	*A. fra*	1
Washington	Cameron Lake	48°18′N–119°32′W	B	*A. fra*	28
	Deposit Thirteen	48°13′N–119°30′W	B	*A. fra*	28
	Penley Lake	48°17′N–119°32′W	B	*A. fra*	28
	Hot (Bitter) Lake	48°58′N–119°29′W	B	*A. fra*	1, 28
	Omak Plateau	48°25′N–119°24′W	B	*A. sp*	1
	Soap Lake	47°33′N–119°25′W	B	*A. sp*	1

Eastern Old World *Artemia* populations, it is evident that a combination of criteria should be considered for characterizing new *Artemia* populations (i.e. morphology, genetic distance, cytogenetics, ecological isolation and cross-breeding experiments). Geographic distance is also a very important factor since it can act as a barrier to gene-flow. Although under laboratory conditions some populations (i.e. from Eastern Old World) can exchange genetic material, in nature they are isolated. Further regional explorations are recommended to verify the possible existence of ‘geographically intermediate’ populations between these three species. This would help us to understand better the evolution of the genus. It would be interesting to know whether these species are allopatric, and therefore distributed without geographical overlap, or if there is allopatric hybridization in some zones.

Genetic analysis of the species *A. sinica* and *A*. sp. from Kazakhstan did not change substantially the phylogenetic tree of *Artemia* proposed by Abreu-Grobois (1983, 1987). The phylogenetic events in the genus *Artemia* have been described as follows (Pilla, 1992; Thomas, 1995):

1 Separation of New World and Old World bisexual lines.
2 Separation of *A. franciscana* and *A. persimilis* lines.
3 Separation of *A. salina* line from *A. sinica*, *A. urmiana* and *A*. sp. from Kazakhstan.
4 Separation of *A. sinica* line from *A. urmiana* and *A*. sp. from Kazakhstan.
5 Origin of parthenogenesis after mutational events (Barigozzi, 1980) from a common line with *A. urmiana*.
6 Origin of tetraploidy from the diploid ancestral line.
7 Origin of pentaploidy from the tetraploid line.

According to Abreu-Grobois & Beardmore (1982) the triploids have arisen in several independent events from diploids. The origin of parthenogenesis is monophyletic and relates closely to the line which led to *A. urmiana* (Beardmore & Abreu-Grobois, 1983). The evolution of parthenogenesis and later on polyploidy, must have taken place at roughly 5.4–1.7 million years ago, respectively (Beardmore & Abreu-Grobois, 1983) and it seems likely that the centre of origin of parthenogenetic *Artemia* is the Mediterranean, where ≈6 million years ago the whole basin underwent a dramatic increase in salinity and subdivision of habitats (Hsü, 1972; Beardmore & Abreu-Grobois, 1983). This event could have produced many opportunities for colonization by parthenogenetic forms (Beardmore & Abreu-Grobois, 1983; Abreu-Grobois, 1987). The coincidence of these genetic and geological data is remarkable. For more discussions about phylogeny, evolution and speciation of the genus *Artemia* the reader should refer to Barigozzi (1980), Abreu-Grobois & Beardmore (1982), Beardmore & Abreu-Grobois (1983) and Abreu-Grobois (1987).

Apart from the interest to scientists regarding the biology and evolution of *Artemia*, its value as a suitable food organism has made it an indispensable link in the larval

TABLE 4. *Artemia* sites in Central America and the Carribean. For abbreviations and references see Tables 8 and 9.

Country	Locality	Geographical coordinates	Mode of reproduction	Species	References
Bahamas	Great Inagua	21°00′N– 75°20′W	B	*A. sp*	1
	Long Island	23°20′N– 75°07′W	B	*A. sp*	1
	San Salvador	24°00′N– 74°35′W	B	*A. sp*	1
Brit. Virgin Islands	Anegada	18°45′N– 64°24′W	B	*A. sp*	1
Caribbean Islands	Antigua	17°00′N– 61°45′W	B	*A. sp*	1
	St Kitts	17°20′N– 62°45′W	B	*A. sp*	1
	St Martin	18°04′N– 63°06′W	B	*A. sp*	1
	South Caicos	21°31′N– 71°32′W	B	*A. sp*	14
Costa Rica	Gulfo Nicova	10°00′N– 84°49′W	B	*A. sp*	1
	Bahia salinas, Guanacaste		B	*A. fra*	4
Dominican Republic	Isla Cabra	19°53′N– 71°40′W	B	*A. sp*	1
	Las Calderas		B	*A. sp*	1
	Monte Cristi	19°52′N– 71°39′W	B	*A. sp*	1
	Puerto Alejandro		B	*A. sp*	1
	Punta Salinas	18°20′N– 71°04′W	B	*A. sp*	1
Haiti	Grandes salines	18°N–72°W	B	*A. fra*	1
Mexico	San Quintin	30°28′N–115°58′W	B	*A. fra*	6
Baja California Norte	Pichilingue, La Paz	24°17′N–110°20′W	B	*A. fra*	6
Baja California Sur	Guerrero Negro	28°06′N–114°03′W	B	*A. fra*	6
	Isla del Carmen	26°00′N–111°40′W	B	*A. fra*	6
Sonora	Laguna de Yavaros	26°43′N–109°33′W	B	*A. fra*	6
Coahuila	Salinas 5 km SE Cuatrocienegas		B	*A. sp*	6
Chiapas	Laguna del Mar Muerto	16°N–94°W	B	*A. sp*	6
	La Joya	27°27′N–106°15′W	B	*A. sp*	6
	Buenavista	27°27′N–106°15′W	B	*A. sp*	6
	Los Palos		B	*A. sp*	6
	Solo Dios		B	*A. sp*	6
	Carretas	15°30′N– 93°13′W	B	*A. sp*	6
	Pereyra	15°30′N– 93°13′W	B	*A. sp*	6
	Chanchuto	15°30′N– 93°13′W	B	*A. sp*	6
	Panzacola		B	*A. sp*	6
Estado de Mexico	Brine El Caracol, Sosa Texcoco		B	*A. sp*	6
Oaxaca	Ponds W. Salina Cruz	16°10′N– 95°10′W	B	*A. sp*	6
San Luis Potosi	Las Salinas	22°40′N–101°42′W	B	*A. sp*	6
Sinaloa	Bahia de Ceuta	24°05′N–107°00′W	B	*A. sp*	6
Yucatan	San Crisanto	24°05′N–107°00′W	B	*A. sp*	6
	Celestun		B	*A. sp*	7
	Chuburna		B	*A. sp*	7
	Xtampu		B	*A. sp*	7
	Las Coloradas		B	*A. sp*	7
Netherlands Antilles	Aruba	12°30′N– 70°00′W	B	*A. sp*	1
	Bonaire Duinmeer	12°04′N– 68°13′W	B	*A. fra*	1
	Gotomeer	12°14′N– 68°20′W	B	*A. sp*	1
	Pekelmeer	12°04′N– 68°16′W	B	*A. sp*	1
	Martinus	12°09′N– 68°17′W	B	*A. sp*	1
	Slagbaai	12°16′N– 68°25′W	B	*A. sp*	1
	Curaçoa Fuik	12°03′N– 68°51′W	B	*A. sp*	1
	Rifwater	12°08′N– 68°20′W	B	*A. sp*	1
Nicaragua	Salinas Grandes, Leon		B	*A. fra*	5
Puerto Rico	Bahia Salinas	17°57′N– 67°12′W	B	*A. fra*	1
	Bogueron	18°01′N– 67°10′W	B	*A. sp*	1
	Cabo Rojo	17°56′N– 67°08′W	B	*A. sp*	1
	La Parguera	17°59′N– 67°03′W	B	*A. sp*	1
	Ponce	18°66′N– 66°38′W	B	*A. sp*	1
	Tallaboa salterns	17°58′N– 66°42′W	B	*A. fra*	1, 28

rearing of most marine fish and shellfish species (Léger *et al.*, 1986; Bengtson *et al.*, 1991). The total annual world consumption of *Artemia* cysts for the aquaculture industry is estimated to be about 2000 metric tonnes (Triantaphyllidis *et al.*, 1994b). This amount is expected to increase further in the years to come, as the demand for fish-fry and shrimp-postlarvae is increasing continuously (Sorgeloos & Sweetman, 1993). Currently, the majority of all marketed

TABLE 5. *Artemia* sites in South America.

Country	Locality	Geographical coordinates	Mode of reproduction	Species	References
Argentina	Bahia Blanca	38°43′S–62°15′W	B	*A. sp*	1
	Buenos Aires	34°30′S–58°20′W	B	*A. per*	1
	Hidalgo	37°10′S–63°32′W	B	*A. per*	1
	Mar Chiquita	30°39′S–62°30′W	B	*A. sp*	1
Bolivia	Lake Canapa		B	*A. sp*	1
	Lake Chulluncani	16°22′S–67°30′W	B	*A. sp*	1
	Lake Hedonia		B	*A. sp*	1
	Lake Poopo	18°23′S–66°58′W	B	*A. sp*	1
Brazil	Aracati	4°32′S–37°45′W	B	*A. sp*	1
	Cabo Frio	22°51′S–42°03′W	B	*A. fra*	1
	Fortaleza	3°45′S–38°35′W	B	*A. sp*	1
	Icapui	4°42′S–37°21′W	B	*A. sp*	1
	Macau	5°00′S–36°40′W	B	*A. fra*	1
	Mundau	33°15′S–39°24′W	B	*A. sp*	1
Chile	Salar de Surire	18°50′S–69°30′W	B	*A. sp*	8
	Playa Yape (Iquique)	20°40′S–70°15′W	B	*A. sp*	8
	Salar de Pintados (I Region)	21°30′S–69°40′W	B	*A. sp*	8
	Salar de Llamara (II Region)	21°18′S–69°37′W	B	*A. sp*	8
	Salar de Atacama (laguna Cejas y Tebenquiche)	23°10′S–68°10′W	B	*A. fra*	8, 9
	Puerto Viejo (Copiapo)	27°20′S–70°57′W	B	*A. sp*	8
	La Pampilla (Coquimbo)	29°58′S–71°25′W	B	*A. sp*	8
	Palo Colorado (Los Vilos)	31°58′S–71°25′W	B	*A. sp*	8
	Salinas de Cahuil (Pichilemu)	34°25′S–72°10′W	B	*A. sp*	8
	Salinas de Constitución (VII Región)	35°09′S–72°21′W	B	*A. sp*	8
Colombia	Galerazamba	10°25′S–74°40′W	B	*A. sp*	1
	Manaure	12°09′S–71°55′W	B	*A. sp*	1
Ecuador	Galapagos (S. Salvador)	0°S–89°W	B	*A. fra*	1, 28
	Pacoa	2°00′S–80°50′W	B	*A. sp*	1
	Salinas	2°20′S–80°58′W	B	*A. sp*	1
Peru	Caucato	13°40′S–76°05′W	B	*A. sp*	1
	Chicama	7°42′S–79°27′W	B	*A. sp*	1
	Chilca	12°35′S–76°41′W	B	*A. sp*	1
	Estuario de Virrila	5°50′S–80°50′W	B	*A. sp*	1
	Guadalupe	7°17′S–79°28′W	B	*A. sp*	1
	Pampa de Salinas	11°14′S–77°35′W	B	*A. sp*	1
	Pampa Playa Chica	11°14′S–77°35′W	B	*A. sp*	1
	Puerto Huarmey	10°03′S–78°08′W	B	*A. sp*	1
	Tumbes	3°37′S–80°27′W	B	*A. sp*	1
Venezuela	Boca Chica	10°57′N–64°26′W	B	*A. sp*	1
	Coya Sal	10°56′N–68°15′W	B	*A. sp*	1
	Coche	10°41′N–63°58′W	B	*A. sp*	1
	Coro Coastline	11°30′N–69°45′W	B	*A. sp*	1
	La Orchila	11°49′N–66°00′W	B	*A. sp*	1
	Las Aves	12°00′N–67°17′W	B	*A. sp*	1
	Los Roques	11°50′N–66°38′W	B	*A. sp*	1
	Port Araya	10°39′N–64°17′W	B	*A. sp*	1
	Tucacas	10°48′N–68°19′W	B	*A. sp*	1

cysts originate from one location, the Great Salt Lake (Utah, U.S.A.). This situation renders the market extremely vulnerable and dependent upon weather conditions (Van Stappen & Sorgeloos, 1993). The exceptionally wet winter of 1994 affected the cysts harvests seriously (Sorgeloos, 1995), and resulted in a dramatic increase of cysts prices, if not to a serious shortage in the market. Unpredictability of harvests and lack of alternative cyst sources can become a bottleneck for the development of aquaculture. Earlier reports have warned the aquaculture community that attention should be focused on the development of alternative/complementary cyst sources (Bengtson *et al.*, 1991). These reports, apparently, have not been considered and dependence from a single source still remains a serious draw-back.

The current situation now justifies, more than ever, the exploitation and development of new *Artemia* sources. The one-source *Artemia* problem can be solved either by natural harvesting from new *Artemia* sites (such as Lake Urmia in Iran, many lakes in the People's Republic of China as well

TABLE 6. *Artemia* sites in Asia. For the Chinese populations the code numbers of Xin *et al.* (1994) are also given. For abbreviations and references see Tables 8 and 9

Country/ Province	Locality	Geographical coordinates	Mode of reproduction	Species	References
P.R. China					
01 Liaoning	01 Jinzhou	121°E–40°48′N	P	*A. par*	10
	02 Yingkou	122°E–40°40′N	P(2,4,5n)	*A. par*	10, 15
	03 Dongjiagou	122°E–39°20′N	P(2n)	*A. par*	10, 11
	04 Pulandian	122°E–39°N	P(2n)	*A. par*	10, 11
	05 Lushun	121°20′E–30°50′N	P(2,4,5n)	*A. par*	10, 15
	06 Fuzhouwan	121°30′E–39°30′N	P	*A. par*	10
02 Hebei	01 Nanpu	118°20′E–39°05′N	P(2n)	*A. par*	10, 11
	02 Luannan	118°30′E–39°10′N	P	*A. par*	10
	03 Daqinghe	118°50′E–39°15′N	P	*A. par*	10
	04 Huanghua	117°40′E–38°20′N	P(2n)	*A. par*	10, 27
03 Tianjin	01 Hangu	117°50′E–39°25′N	P(2n)	*A. par*	10, 11
	02 Tanggu	117°40′E–39°N	P(2,4,5n)	*A. par*	10, 25
04 Shandong	01 Chengkou	117°40′E–38°10′N	P(2n)	*A. par*	10, 26
	02 Yangkou	119°E–37°20′N	P(2n)	*A. par*	10, 11
	03 Dongfeng	120°10′E–36°05′N	P(2,5n)	*A. par*	10, 15
	04 Gaodao		P	*A. par*	10
	05 Xiaotan		P	*A. par*	10
	06 Nanwan		P	*A. par*	10
	07 Jimo		P	*A. par*	10
05 Jiangsu	01 Xuyu	113°36′E–34°36′N	P	*A. par*	10
	02 Lianyungang	119°30′E–34°40′N	P	*A. par*	10
06 Zhejiang	01 Zhanmao	122°18′E–30°31′N	P	*A. par*	10
	02 Shunmu	122°15′E–29°50′N	P	*A. par*	10
	03 Zhujiajian	122°23′E–29°50′N	P	*A. par*	10
07 Fujian	01 Shanyao	118°53′E–25° 8′N	P	*A. par*	10
	02 Xigang	117°55′E–23°25′N	P	*A. par*	10
	03 Huian		P	*A. par*	10
08 Guangdong			P	*A. par*	10
09 Hainan	01 Dongfang		P	*A. par*	10
	02 Yinggehai	108°36′E–18°30′N	P(2,4,5n)	*A. par*	10, 15
10 Taiwan	01 Beimen	121°07′E–23°20′N	B	*A. sp*	10
11 Xinjiang	01 Aibi	83°53′E–44°55′N	P(2,4n)	*A. par*	10, 11, 15, 26
	02 Dabancheng	88°E–43°N	P(2,3,4,5n)	*A. par*	10, 26
	03 Balikun	93°E–43°30′N	P(2,4n)	*A. par*	10, 11
	04 Aletai	88°E–48°N	B	*A. sp*	10
12 Tibet	01 Yanjing	98°30′E–29°N	B	*A. sp*	10
	02 Shenzha	88°40′E–31°N	B	*A. sp*	10
	03 Bange	89°40′E–31°40′N	—	—	10
	04 Gaize	84°10′E–32°20′N	—	—	10
	05 Geji	81°10′E–32°24′N	—	—	10
	07 Zhangchaka	82°23′E–32°47′N	—	—	10
	08 Wumacuo	83°10′E–32°30′N	—	—	10
	09 Jibuchaka	84°10′E–32°N	—	—	10
	10 Dongcuo	84°40′E–32°10′N	—	—	10
13 Qinghai	01 Gahai	97°47′E–37°02′N	P(2n)	*A. par*	10, 11
	02 Xiaocaidan	95°06′E–37°N	P	*A. par*	10
	03 Dacaidan	95°20′E–37°48′N	P	*A. par*	10
	04 Suban	94°E–39°N	P	*A. par*	10
	05 Keke	98°E–37°N	P(4n)	*A. par*	10, 15
	06 Chaka	99°E–37°40′N	P	*A. par*	10
	07 Tuosu	96°54′E–37°10′N	P	*A. par*	10
14 Gansu	01 Gaotai	99°10′E–39°44′N	B	*A. sp*	10
15 Inner Mongolia	01 Haolebaoji	108°30′E–38°54′N	B	*A. sin*	10, 11
	02 Haotongyin	108°55′E–39°10′N	B	*A. sin*	10, 11
	03 Taigemiao	109°55′E–39° 5′N	B	*A. sin*	10, 11
	04 Ejinor	112°30′E–45°20′N	B	*A. sin*	10, 11
	05 Beidachi	107°30′E–38°N	B	*A. sin*	10, 11
	06 Jilantai	103°36′E–39°48′N	B	*A. sin*	10, 11
	07 Wuqiangi	109°E–41°N	B	*A. sin*	10, 11
	08 Shanggendalai	116°E–42°20′N	B	*A. sin*	10, 11
	09 Dagenor	116°E–42°30′N	B	*A. sin*	10, 11

contd

TABLE 6. *contd*

Country/ Province	Locality	Geographical coordinates	Mode of reproduction	Species	References
15 Inner Mongolia *contd*	10 Bayannor	116°E–44°N	B	*A. sin*	10, 11
	11 Zhunsaihannor	115°E–43°N	B	*A. sin*	10, 11
	12 Erendabusen	111°E–44°N	B	*A. sin*	10, 11
	13 Chagannor	110°E–40°N	B	*A. sin*	10, 11
	14 Huhetaolergai	110°E–37°N	B	*A. sin*	10, 11
	15 Hangjinqi	101°E–40°N	B	*A. sin*	10, 11
16 Ningxia			—	—	10
17 Shaanxi	01 Dingbian	107°30′E–37°40′N	—	—	10
18 Shanxi	01 Yuncheng	111°E–35°N	B	*A. sin*	10, 15
02 Hebei	11 Shangyi	114°41′E–41°06′N	B	*A. sin*	10, 15
	12 Zhangbei	114°42′E–41°10′N	B	*A. sin*	10, 15
	13 Kangbao	114°36′E–41°48′N	B	*A. sin*	10, 15
India					
Rajasthan	Didwana	27°03′N–74°05′E	—	—	12
	Sambhar Lake		—	—	12
Gujarat	Gulf of Kutch	23°20′N–71°00′E	P	*A. par*	12
	Balamba salterns	23°42′N–70°17′E	P	*A. par*	12
	Mithapur	23°00′N–70°10′E	P	*A. par*	12
	Jamnagar	22°30′N–70°08′E	—	—	12
Bombay	Vadala	18°55′N–72°50′E	—	—	12
	Bhayander		P	*A. par*	12
	Bahinder	18°55′N–72°50′E	—	—	12
Madras	Kelambakkam	13°05′N–79°07′E	—	—	12
	Vedaranyam	10°01′N–79°50′E	—	—	12
Tuticorin	Veppalodai	85° 9′N–78°08′E	—	—	12
	Pattanamaruther	85° 5′N–78°08′E	—	—	12
	Spic Nagar	85° 0′N–78°08′E	—	—	12
	Thirespuram	85° 0′N–78°08′E	—	—	12
	Karsewar Island	85° 0′N–78°10′E	—	—	12
	Saltwater springs		P	*A. par*	12
	Harbour		—	—	12
Kanyakumari	Thamaraikulam	80° 4′N–77°68′E	P	*A. par*	12
Iraq	Abu-Graib, Baghdad	33°20′N–44°30′E	P	*A. par*	1
	Basra	30°25′N–47°51′E	—	—	1
	Dayala	33°30′N–44°30′E	—	—	1
	Mahmoodia	33°N–44°E	—	—	1
Iran	Urmia Lake	37°20′N–45°40′E	B	*A. urm*	1
	Schor-Gol	37°03′N–45°32′E	—	—	1
	Shurabil	48°17′N–38°15′E	—	—	1
	Athlit	32°42′N–34°56′E	—	—	1
Israel	Eilat North	29°32′N–34°56′E	P	*A. par*	1
	Eilat South	29°28′N–34°56′E	—	—	1
Japan	Chang Dao	34°N–132°E	—	—	1
	Tamano	34°35′N–133°59′E	—	—	1
	Yamaguchi	34°10′N–131°32′E	P	*A. par*	1
Kuwait		29°N–47°E	—	—	1
Korea	Pusan	35°05′N–129°02′E	—	—	1
Pakistan	Karachi saltworks	24°48′N–66°58′E	P	*A. par*	16
Sri Lanka	Bundala	6°12′N–81°15′E	—	—	1
	Hambantota	6°07′N–81°07′E	—	—	1
	Palavi	7°58′N–79°51′E	—	—	1
	Putallam	8°02′N–79°50′E	P	*A. par*	1
Taiwan	Peinan Salina		—	—	1
Turkey	Balikesir, Aivalik		—	—	1, 17
	Camalti, Izmir	38°25′N–27°08′E	P	*A. par*	1, 17
	Tuz Golii	38°45′N–45°30′E	—	—	1
	Ankara Salt Lake		—	—	17
	Konya Karapinar-Meke Salt Lake		—	—	17
	Gokceada (Imbros)		—	—	18

TABLE 7. *Artemia* sites in Europe. For abbreviations and references see Tables 8 and 9.

Country	Locality	Geographical coordinates	Mode of reproduction	Species	References
Bulgaria	Burgas	42°33′N–27°29′E	P	*A. par*	1
	Pomorve	42°26′N–27°41′E	—	—	1
Croatia	Sečovlje, Portoroz	45°29′N–13°36′E	P(4n)	*A. par*	24
	Strunjan	45°32′N–13°36′E	P	*A. par*	24
	Ulcinj	41°55′N–19°12′E	P	*A. par*	24
Cyprus	Akrotiri Lake	34°34′N–32°58′E	—	—	1
	Larnaca Lake	34°56′N–33°35′E	B	*A. sal*	1
France	Aigues Mortes	43°34′N– 4°11′E	P	—	1
	Carnac-Trinité sur Mer	47°36′N– 3°05′W	—	—	1
	Guérande-le Croisic	47°20′N– 2°26′W	P	*A. par*	1
	La Palme	42°50′N– 3°00′E	—	—	1
	Lavalduc	43°24′N– 4°56′E	P	*A. par*	1
	Mesquer-Assérac	47°26′N– 2°29′W	—	—	1
	Porte La Nouvelle	42°57′N– 3°02′E	—	—	1
	Salin de Berre	43°24′N– 5°05′E	P	*A. par*	1
	Salin de Fos	43°26′N– 4°56′E	—	—	1
	Salin de Giraud	43°24′N– 4°44′E	P	*A. par*	1
	Salins d'Hyères	43°07′N– 6°12′E	—	—	1
	Salin des Pesquiers	43°07′N– 6°12′O	—	—	1
	Sète	43°25′N– 3°42′E	P	*A. par*	1
	Sète-Villeroy (Languedoc)	43°23′N– 3°37′E	B	*A. sp*	35
	Villeneuve (Languedoc)	43°32′N– 3°50′E	B	*A. sp*	35
Greece	Citros, Pieria	40°22′N–22°36′E	P(4n)	*A. par*	19, 20, 21
	Megalon Embolon, Thessaloniki	40°28′N–22°49′E	P(4n)	*A. par*	19, 20, 21
	Kalloni, Lesbos	39°10′N–26°18′E	P(4n)	*A. par*	22
	Polychnitos, Lesbos	39°01′N–26°09′E	P(4n)	*A. par*	22
	Mesolongi	38°18′N–21°36′E	P	*A. par*	1
	Milos Island	36°35′N–24°30′E	P	*A. par*	1
Italy	Quartu or salina di Poetto, Cagliary	39°13′N– 9°08′E	B	*A. sal*	1, 3
	Carloforte, Sardinia	39°08′N– 8°17′E	B	*A. sal*	1, 3
	Cervia, Ravenna	44°16′N–12°21′E	P(4n)	*A. par*	1, 31
	Commachio, Ferrara	44°41′N–12°10′E	P(4n)	*A. par*	1, 31
	Margherita di Savoia, Foggia	41°25′N–16°05′E	P(2,4n)	*A. par*	1, 31
	Sant' Antioco, Sardinia	39°02′N– 8°30′E	B	*A. sal*	1, 3
	Santa Gilla, Sardinia	39°14′N– 9°06′E	P(2n)	*A. par*	1, 31
	Siracuse, Sicily	37°04′N–15°18′E			1
	Tarquinia, Viterbo	42°29′N–11°45′E	B	*A. sal*	1, 31
	Trapani, Sicily	38°01′N–12°30′E	B	*A. sal*	1, 31
Kazakhstan	Borli	51°45′N–78°00′E	P	*A. par*	32
	Mangyshlak peninsula	43°40′N–52°30′E	—	—	32
	Maraldi	51°15′N–78°40′E	P	*A. par*	32
	Sejten	51°50′N–78°15′E	P	*A. par*	32
Portugal	Alcochete	38°45′N– 8°57′W	P	*A. par*	1
	Tejo estuary	38°50′N– 9°00′W	—	—	1
	Sado estuary	38°25′N– 8°43′W	—	—	1
	Ria de Aveiro	40°37′N– 8°38′W	—	—	1
	Ria de Farc	37°02′N– 7°55′W	—	—	1
Romania	Lake Techirghiol	43°04′N–28°34′E	P	*A. par*	23
	Lacul Sârat Brâila		P	*A. par*	23
	Movila Miresii		—	—	23
Slâric Prahova	Baia Baciului		P	*A. par*	23
Slâric Prahova	Baia Neagrâ, SP		P	*A. par*	23
	Baia Verde I, SP		P	*A. par*	23
	Baia Verde II, SP		P	*A. par*	23
	Baia Verde III, SP		P	*A. par*	23
	Baia Rosie, SP		P	*A. par*	23
Telega	Telega Bâi		P	*A. par*	23
	Telega II		P	*A. par*	23
	Telega III		P	*A. par*	23
	Ocra Sibiului		P?		23
	Sovata		P?		23

contd

TABLE 7. *contd*

Country	Locality	Geographical coordinates	Mode of reproduction	Species	References
Russia	Bolshoe Shklo	52°35′N–79°15′E	P	*A. par*	32
	Bolshoe Jarovoe	52°50′N–79°45′E	P	*A. par*	32
	Buazonsor	52°40′N–79°30′E	P	*A. par*	32
	Karachi Lake	55°20′N–76°55′E	B	*A. sp*	32
	Kulundinskoe	52°55′N–79°40′E	P	*A. par*	32
	Kurichje	52°05′N–79°30′E	P	*A. par*	32
	Kutchukskoje	52°38′N–79°30′E	P	*A. par*	32
	Maloe Jarovoe	53°00′N–79°15′E	P	*A. par*	32
	Mirabilit	52°30′N–79°05′E	P	*A. par*	32
	Mormishanskoje 1	52°30′N–81°20′E	P	*A. par*	32
	Mormishanskoje 2	52°25′N–81°15′E	P	*A. par*	32
	Petuchovo	52°10′N–79°30′E	P	*A. par*	32
	Schekulduk	52°27′N–79°00′E	P	*A. par*	32
	Soljonoe	52°45′N–81°50′E	B	*A. sp*	32
	Tanatar	51°35′N–79°35′E	B	*A. sp*	32
Spain					
Alava	Añana		P(4n)	*A. par*	30
Albacete	Petrola		P(4n)	*A. par*	30
	Pinilla		P(4n)	*A. par*	30
Alicante	Bonmati, S. Pola	38°13′N– 0°35′W	B,P(2,4n)	mixed	29, 30
	Bras de Port, S. Pola	38°13′N– 0°35′W	B	*A. sal*	29
	Calpe	38°39′N– 0°03′E	P(2n)	*A. par*	29, 30
	La Mata		P(2n)	*A. par*	30
	Molina del Segura	38°03′N– 1°11′W	B	*A. sal*	29
	Salinera Espanola, S. Pola	38°13′N– 0°35′W	B	*A. sal*	29
	Villena	38°39′N– 0°52′W	B	*A. sal*	29
Burgos	Poza de la Sal	42°40′N– 3°30′W	B	*A. sp*	29
Cadiz	Sanlucar de Barrameda		P	*A. par*	29
	Dos hermanos		B,P(2n)	mixed	29, 30
	San Eugenio		B,P(2n)	mixed	29, 30
	San Felix	36°30′N– 6°20′W	B	*A. sal*	29, 30
	San Fernando	36°22′N– 6°17′W	B	*A. sal*	29
	San Juan		B,P	mixed	29
	San Pablo		B,P	mixed	29
	Santa Leocadia		B,P	mixed	29
	Barbanera		B	*A. sal*	29, 30
Canary islands	Janubio, Lanzarote	28°56′N–13°50′W	P(2n)	*A. par*	29
Cordoba	Encarnacion		P(4n)	*A. par*	29
	Ouente Montilla		P(4n)	*A. par*	29
Formentera	Salinera Espanola	38°40′N– 1°26′E	B	*A. sal*	29
Guadalajara	Armalla	40°54′N– 1°59′W	P(4n)	*A. par*	29
	Imon	41°10′N– 2°45′W	P(4n)	*A. par*	29, 30
	Olmeda	41°06′N– 2°34′W	P(4n)	*A. par*	29, 30
	Rienda	41°06′N– 2°34′W	P(4n)	*A. par*	29
Huelva	Ayamonte	37°13′N– 7°24′W	P(2n)	*A. par*	29
	Lepe	37°15′N– 7°12′W	P(2n)	*A. par*	29
	Isla Cristina	37°13′N– 7°19′W	P(2n)	*A. par*	29
	San Juan del Puerto	37°20′N– 6°50′W	B	*A. sal*	29
Huesca	Rolda		P	*A. par*	29, 30
	Peralta de la Sal	42°00′N– 0°24′E	P	*A. par*	29
Ibiza island	Salinera Espanola	38°55′N– 1°35′E	B	*A. sal*	29, 30
Jaen	San Carlos		B	*A. sal*	29
	Don Benito		B	*A. sal*	29
Malaga	Fuente de Piedra		B,P(2n,4n)	mixed	29, 30
Mallorca	Campos del Puerto	39°26′N– 3°01′E	B	*A. sal*	29, 30
Murcia	San Pedro del Pinatar	37°50′N– 0°50′W	B	*A. sal*	29, 30
	Jumilla		B	*A. sal*	29, 30
	sal. Punta Galera		B	*A. sal*	29
	sal. Catalana		B	*A. sal*	29
Soria	Medinaceli	41°12′N– 2°30′W	P(4n)	*A. par*	29, 30
Tarragona	Delta del Ebro	36°25′N– 6°18′W	P(4n)	*A. par*	29, 30
Teruel	Arcos de las Salinas		P(4n)	*A. par*	29

contd

TABLE 7. *contd*

Country	Locality	Geographical coordinates	Mode of reproduction	Species	References
Spain *contd*					
Zaragoza	Chiprana		P(4n)	*A. par*	29, 30
	Bujaraloz	41°29′N– 0°10′W	P(4n)	*A. par*	29, 30
Ukrainia	Bolshoe Otar Mojnakskoe	45°N–33°E	—	—	32
	Dscharylgach	46°35′N–32°45′E	—	—	32
	Ghenicheskoe Lake	46°15′N–34°40′E	—	—	32
	Kujalnic liman	46°43′N–30°55′E	P	*A. par*	32
	Popovskoe (=Ojburgskoe)	45°20′N–53°00′E	P	*A. par*	32
	Sakshoe Lake (Crimea)	45°10′N–33°30′E	—	—	32
	Sasyk Lake	45°15′N–33°25′E	—	—	32
	Shtormovoe	45°20′N–53°05′E	B	*A. sp*	32
	Tchokrakskoe	45°25′N–36°15′E	B	*A. sp*	32
	Tobetchikskoe	45°10′N–36°20′E	P	*A. par*	32

TABLE 8. List of references given in Tables 1–7.

1: Vanhaecke *et al.* (1987); 2: Eustache Miasa, personal communication; 3: Own observations; 4: Odio (1991a); 5: Odio (1991b); 6: Maeda-Martinez (1991); 7: Torrentera & Dodson (1995); 8: Gajardo (1995); 9: Gajardo & Beardmore (1993); 10: Xin *et al.* (1994); 11: Thomas (1995); 12: Peter Marian, personal communication; 13: Sousa (1994); 14: McLean (1994); 15: Triantaphyllidis *et al.* (1994a); 16: Shah & Qadri (1992); 17: Koray (1988); 18: Cihan Coru, personal communication; 19: Abatzopoulos *et al.* (1986); 20: Abatzopoulos *et al.* (1989); 21: Abatzopoulos *et al.* (1993); 22: Triantaphyllidis *et al.* (1993); 23: Liliana Pana, personal communication; 24: Petrović (1991); 25: Triantaphyllidis *et al.* (1995); 26: Pilla (1992); 27: Triantaphyllidis *et al.* (1994b); 28: Bowen *et al.* (1988); 29: Amat (1980); 30: Amat *et al.* (1995b); 31: Baratelli *et al.* (1990); 32: Vladimir M. Baichorov & Lubov L. Nagorskaja, personal communication; 33: Peter Baert, personal communication; 34: Amat *et al.* (1995a); 35: Thiéry & Robert (1992); 36: Lanna Cheng, personal communication.

TABLE 9. List of abbreviations for Tables 1–7.

B: bisexual population; P: parthenogenetic population.

2, 3, 4, 5n: indicates the ploidy level of a parthenogenetic population (2: diploid; 3: triploid, etc).

A. fra: *A. franciscana*; A. f. mon: *A. franciscana monica*; A. per: *A. persimilis*; A. sal: *A. salina*; A. urm: *A. urmiana*; A. sin: *A. sinica*; A. par: *A. parthenogenetica*

as in countries of the former Soviet Union), or by an alternative approach that has been used during the last couple of decades in many developing countries: inoculation of saline waters with non-endemic *Artemia* nauplii. In some south west Asian countries this deliberate inoculation has proved to be successful, with great impact on socio-economic benefits (i.e. in Vietnam, Vu Do & Nguyen Ngoc, 1987). However, this practice carries certain dangers whenever inoculated waters (or adjacent water bodies) house natural *Artemia* populations that, due to competition, might become extinct (Beardmore, 1987). Since most of the inoculation material is of *A. franciscana* origin this danger is possible since numerous laboratory studies have demonstrated the superior performance of *A. franciscana* compared to other bisexual and parthenogenetic species (Browne *et al.*, 1988; Browne & Halanych, 1989; Triantaphyllidis *et al.*, 1995; Browne *et al.*, 1984, 1991). During the Second International Symposium on the brine shrimp *Artemia*, the following resolution was adopted (Beardmore, 1987): 'The Second International Symposium on *Artemia* meeting in Antwerp, Belgium, in September 1985 resolves that all possible measures be taken to ensure that the genetic resources of natural *Artemia* populations are conserved. Such measures include the establishment of gene-banks (cysts), close monitoring of inoculation policies and where possible the use of indigenous *Artemia* for inoculating *Artemia*-free waters'. Natural co-existence of *Artemia* species in the same habitat has been described by Piccinelli & Prosdocimi (1968) and Amat (1983). Recently, Triantaphyllidis *et al.* (1994b) demonstrated that incubation of cysts at high temperatures (36–37°C) allows *A. franciscana* to hatch but suppresses hatching of cysts from all the other *Artemia* species. Incubation at high temperatures can be applied routinely to check for possible contamination of a population with *A. franciscana* cysts.

As Bengtson *et al.* (1991) pointed out, small-scale production in human-controlled saltworks is not expected to contribute significantly to world cyst supplies, but it could provide opportunities for local commercial developments, especially in countries with restricted import opportunities, and where local availability of *Artemia* cysts is the first requirement in consideration of a viable hatchery industry.

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