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

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Abstract

Three species of *Artemia* were found in American Continent, *A. franciscana* (Kellogg, 1906), *A. monica* (Verrill, 1869) and *A. persimilis* (Piccinelli & Prosdocimi, 1968), but only one of them was found in hypersaline coastal and inland waters habitats from Mexico: *Artemia franciscana*. The first report of *Artemia* in México is 1980 in coastal saline ponds from Bahia de Ceuta, Sinaloa. Until now, in Mexico were reported five sites in coastal ponds from Baja California peninsula; 13 sites in coastal waters and manmade salter ponds from the Pacific zone; eight sites from Pacific zone; two sites in Gulf of Mexico; six sites in Yucatan peninsula and five sites from inland waters habitat. Only Texcoco, Mexico, Las Salinas, San Luis Potosí, Ohuira, Sinaloa and Juchitan, Oaxaca sites, were used for a while to make some biomass and cysts commercial production. This paper presents and updated list of sites where *A. franciscana* were mentioned in Mexico in the literature and field survey. It is necessary to make more fields studies in Mexico and make production proposals to saline workers to management this natural resource in their own habitat, to obtained additional financial incomes.

Key Words: *Artemia*, biogeography distribution, Mexico

Introduction

The genus *Artemia* (Branchiopoda: Anostraca) is a complex of sibling species and superespecies defined by the criterion of reproductive isolation (Camara, 2012). Three species are found in American Continent: *Artemia monica* Verrill, 1869; *Artemia franciscana* Kellog, 1906 and *Artemia persimilis* Piccinelli & Prosdocimi, 1968. *A. monica* is restricted into alkaline hypersaline habitat called Mono Lake. *A. persimilis* can found in different habitat from Argentina. *A. franciscana* distributed in all other habitat from American Continent and Caribbean zone that had the conditions to feed, growth and the possibility to reproducing with biomass or cysts type.

Mexico is a country of great biological diversity possessing a wide range of both aquatic and terrestrial organisms. This is the result of its geography, which includes several kind of environment from tropical steppe, desert and temperate climates to polar climates on high ground. Temperatures vary from more than 30°C in the summer to below zero in winter. Mexico has 10,000 km of coastline. These include 12,500 square kilometers of coastal lagoons, which are areas of high productivity. In addition, there are 320 hydrographic basins which cover and area of 370,891 ha and of which 70 are lakes.

Mexico coastline and inland waters have many natural and manmade salt ponds dedicated to salt production, both Gulf of Mexico and Pacific coastline and inland salt waters both north, middle and south over the country. Unfortunately, many of them do not produce salt anymore and *A. franciscana* populations disappeared of those habitat. Other problem is the low budget to field investigations researches to know the presence or absence of *Artemia* populations in all the salt bodies (148) from Mexico (AMISAC, 2012).

Mexico has 148 salt water body sites distributed in all coastline water bodies. Also, salt production was made at inland water bodies like lagoons, for example, El Rey Lagoon, Coahuila, Jaco Lagoon, Chihuahua and Santa María Lagoon, San Luis Potosí or underground brines like in Veracruz, San Luis Potosí, Nuevo León States and State of Mexico. The highest salt production in Mexico become from Baja California State, Guerrero Negro locality with 82%of all salt production in Mexico and the other 18% become from 14 different Republic States, principally Sonora, Yucatán, Veracruz and Nuevo León. Many of these habitats have *Artemia* populations, but this is not commercially exploited at high level. The *Artemia* biomass is recollected manually in only few habitats by local people salt producers to sell it in aquarist industry or local aquaculture farmers.

Mexico had a great *Artemia* biomass or cyst production potential, but we need contacting University researches with field salt production peoples to convince them that they can obtained more benefits if they combine salt production with *Artemia* production.

Biogeography of *Artemia franciscana* in Mexico

One of the first reports of *A. franciscana* in Mexico is the inoculation of this strain in manmade salter ponds at inland waters habitat in Texcoco, State of Mexico (Castro *et al*., 2000). In 1979, The Fisheries Department and Universidad Autonoma Metropolitana Xochimilco started a project to assess the potential for *Artemia* production in Mexico. In 1980, was the first Mexico National report about *Artemia* founded in Bahia de Ceuta, Sinaloa (Castro, 1980), who mentioned the great production potential (biomass and cysts) of this *Artemia* population. Since 1984, eight populations were described with some environmental conditions and some biological characteristics about presence or absence of cysts (Castro *et al*., 1987b). Since 2000, three *Artemia* inland water populations were described (Coahuila, San Luis Potosí and Texcoco) and nine populations localized in Pacific, Gulf of Mexico and Yucatan Peninsula coastal waters.

Contreras (1987) performed the ecological prospective study of “Salinas el Barranco” habitat from Ejido Aquiles Serdan, Mpo. of Altamira, Tamaulipas located northeast Mexican Republic. Castro *et al*. (1987a), made the first experimental production of an introduced *A. franciscana* strain in alkaline waters in the State of Mexico (Texcoco), reported the physical and chemical analysis of the water and salt used for the *Artemia* culture tests.

Castro *et al*. (1989) performed the first report about *A. franciscana* localized in hypersaline inland waters in San Luis Potosí State at "Las Salinas de Hidalgo" site. The salt source become from a underground cavern and is dissolved injecting water and extracted with pump. The salt concentration is 25-35 gL^{-1} and increase by evaporation.

Correa *et al*. (1993b) described the biochemical composition of cyst from Yavaros, Sonora; and two localities from San Jose, Baja California. Yavaros population was identified as *A. franciscana* since 1983 by Abreu-Grobois. San José, Baja California populations were described by Correa-Sandoval in 1991. Correa & Bückle (1993), describe the morphology and biometry characteristics; Correa *et al.* (1993a) reproductive characteristics; and Correa & De la Rosa (1996) the allozymatic variation of these three *A. franciscana* populations.

Castro *et al.* (1995) obtained the values of biometry of *A. franciscana* from "Las Coloradas", Oaxaca State. These manmade saline ponds have and area of 50 has. The cysts were collected in 1993. Another locality in Oaxaca State is "El Marquez" saline ponds near Juchitan city (Lopez *et al*., 2000).

Torrentera y Dodson (1995) shown the biometry values of four populations of *Artemia* localized in Yucatan peninsula salterns. The cysts were collected during 1990-1992 period. Torrentera & Abreu-Grobois (2002) studied these same populations from cytogenetic variability and differentiation point of view. Torrentera & Dodson (2004) mentioned weather habitat conditions, phytoplankton, bacteria and birds (flamingos) population dominance, also cyst and biomass productions from these *Artemia* Yucatan sites. Tizol-Correa *et al*. (2006) mentioned the fatty acid composition of these same *Artemia* Yucatan habitats compared with Real de las Salinas, Campeche, Las Coloradas, Oaxaca and two Cuba populations.

Castro *et al*. (1997) performed the biometry characteristics of adult male and female *A. franciscana* population from Cuatro Cienegas, Coahuila State. The cysts were collected since 1994. This inland water habitat have a particularity, the highest salt component is sodium phosphate. This chemical condition did not changes the possibility to culture in sodium chloride medium and make cross breeding experiments with *A. franciscana* strains (personal comm. Castro, 2012).

Correa & Tapia (1998), describe the reproductive characteristics of San Quintin, Baja California *Artemia* population. The cysts were collected that year.

Castro *et al*. (1999) studied the crossbreeding experiments with Bahia de Ceuta, Sinaloa and Yavaros, Sonora and compared with *A. franciscana* from San Francisco Bay. The cysts and nauplii production increase when these two Mexican populations matched with *A. franciscana* from San Francisco Bay.

Castro *et al*. (2000) presents the environmental and biological characteristics of different *Artemia* ecosystems in Mexico. This review shows three inland water populations: Cuatro Cienegas, Coahuila, Salinas de Hidalgo, San Luis Potosi and Texcoco, Ecatepec, Mexico; and coastal water populations: Altamira, Tamaulipas, San José, Baja California, Pichilingue, Baja California Sur, Carmen Island, Baja California Sur, Yavaros, Sonora, Bahia de Ceuta, Sinaloa, Las Coloradas, Oaxaca and Sistema lagunar, Chiapas.

Castro *et al.* (2003) mentioned another locality in "La Esperanza, Ohuira, Sinaloa. These authors work's with the microelements concentration founded in six nauplii Mexican populations. The cysts of this locality were collected in 2001.

Maldonado-Montiel & Rodriguez-Canche (2004) studied the biomass production of *A. franciscana* population located in "Real de las Salinas", Campeche State, but they not mentioned the geographical location of this habitat. Rodriguez-Canche *et al*. (2006) mentioned the geographical localization of "Real de las Salinas", Calkini, Campeche. The cysts were collected during 1997-2000 period. The authors describe some biological characteristics of cysts and nauplii and biochemical composition.

Castro *et al.* (2006a) mentioned that *A. franciscana* in Mexico ranges from 32° and 14° north latitude, and between 117° (Northeast of Baja California) and 86° West (Isla Mujeres). Seventeen *A. franciscana* populations have been recorded so far in this country, 14 of them in coastal areas (four in the

Gulf of Mexico, 10 in the Pacific Coast) whereas the rest corresponds to inland water habitats. The authors described the geographic location, size, and altitude of the *Artemia* sites studied so far in Mexico. The largest site is Guerrero Negro, in the Baja California Peninsula, with 33,000 ha, whereas San Jose, in the same Peninsula, is the smallest (0.5 ha) and comparable in size to San Crisanto in the Yucatan Peninsula. Texcoco, in the State of Mexico, is located at the highest altitude (2,250 m above sea level). The main salt in water of studied habitat so far is sodium chloride, with the exception of Cuatro Cienegas, State of Coahuila, in which sulphate predominates. Of all populations recorded in this area, 13 have been studied with respect to reproduction (crosses with *A. franciscana*) and morphology, whilst fragmentary genetic information (allozyme and chromosome) is available. These populations combine the two usual modes of reproduction (viviparity and ovoviviparity), depending on the local conditions. The authors provide cysts, chorion thickness, and nauplii measurements. The El Marquez population in Oaxaca depicts the biggest cyst diameter and the thickest chorion, whilst samples from Bahia de Lobos and Celestun showed the smallest cysts and nauplii. Castro *et al*. (2006b) showed the geographical localization of seven *A. franciscana* populations in Mexico. The authors make the comparison of cysts and nauplii biometry among them.

Castro *et al*. (2010a) studied five Pacific coast Mexican populations and mentioned the geographical localization of these *Artemia* strains. Castro *et al.* (2010b) shown the last geographical localization of *Artemia* population found in Mexico in little saline habitat near Cancun, Quintana Roo. The authors works the reproductive potential of two population from Pacific coast, two populations from Yucatan peninsula and two populations from Inland waters in a culture medium of 100 and 120 gL^{-1} salinity.

Two more inland water sites have reported during 2010-2012. Castro (2011) reported in their PhD thesis the geographic location of Santo Domingo, Zacatecas State locality and biometry data of this population. Castro (2012 *per. communication*) confirms the presence of *A. franciscana* in inland water habitat at Zapotitlan, Puebla State. The *Artemia* population was inoculated with cysts from San Francisco Bay, maybe five or ten years ago.

The Figure 1 showed the geographical localization of natural habitats where *A. franciscana* populations were found in Mexico.

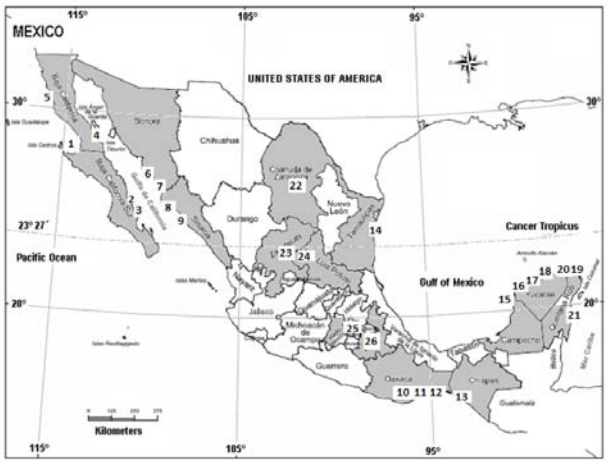

Fig. 1: natural habitats of *A. franciscana* in Mexico.

- Baja California coast (1: Guerrero Negro, Baja California Sur; 2: Pichilingüe; Baja California Sur; 3: Isla del Carmen; Baja California Sur; 4: San José, Baja California; 5: San Quintín, Baja California)

- Pacific coast (6: Yavaros, Sonora; 7: Bahía de Lobos, Sonora; 8: Ohuira, Sonora; 9: Bahía de Ceuta, Sinaloa; 10: Juchitan, Oaxaca; 11: El Marquéz, Oaxaca; 12: Las Coloradas, Oaxaca; 13: Sistema Lagunar, Chiapas)

- Gulf of México coast (14: Aquiles Serdán, Mpo. De Altamira, Tamaulipas; 15: Real de las Salinas, Campeche)

- Yucatán peninsula coast (16: Celestún, Yucatán; 17: San Crisanto, Yucatán; 18: Chuburna, Yucatán; 19: Las Coloradas, Yucatán; 20 Xtampú, Yucatán; 21: Cancún, Quintana Roo)

- Inland waters (22: Cuatro Ciénegas, Coahuila; 23: Santo Domingo, Zacatecas; 24: Las Salinas, San Luis Potosí; 25: Texcoco, State of México; 26: Zapotitlán de las Salinas, Puebla)

Table 1 provides an updated list of *A. franciscana* sites in Mexico based on literature data and field observations. The list was divided in Baja California, Pacific, Gulf of Mexico, Yucatan peninsula and inland water populations.

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Tab. 1: List of *Artemia franciscana* sites in Mexico.

Locality	Locality and State	Geographical coordinates	Ref.
Baja California peninsula	Guerrero Negro, Baja California Sur	27° 54' N; 114° 02' W	1
	Pichilingue, Baja California Sur	24° 16' N; 110° 20' W	1,2
	Isla del Carmen, Baja California Sur	23° 40' N; 111° 40' W	1,2
	San Jose, Baja California	29°15' N; 114°53' W	2,3,4,5,6
	San Quintin, Baja California	30° 25' N; 115° 56' W	7
Pacific coast	Yavaros, Sonora	26° 40' N; 109° 35' W	1,2,5,8,9,10,11,12,14
	Bahia de Lobos, Sonora	27° 18' N; 110| 30' W	10,14
	Ohuira, Sinaloa	24° 06' N; 107° 11' W	10,11,12,13,14
	Bahía de Ceuta, Sinaloa	23° 50' N; 106° 30' W	1,2,8
	Juchitan, Oaxaca	16° 26' N; 95° 01' W	10,11,12,13,14
	El Marquez, Oaxaca	16° 09' N; 95° 14' W	1,9,10,13,14
	Las Coloradas, Oaxaca	15° 33' N; 95° 33' W	2,11,16,17
	Sistema lagunar, Chiapas	15° 58' to 16° 30' N; 93° to 94° W	1,2
Gulf of Mexico coast	Aquiles Serdan, Mpo. of Altamira, Tamaulipas	22°34'27'' N; 97°52'36''W	18
	Real de las Salinas, Campeche	20° 02' N; 90° 14' W	10,12,14,17,19
Yucatan peninsula	Celestún, Yucatan	20° 52' N; 90° 23' W	10, 17, 20,21
	San Crisanto, Yucatan	21° 21' N; 89° 07' W	1,2,10,22
	Chuburna, Yucatan	21° 15' N; 89° 48' W	17, 20, 21, 23
	Las Coloradas, Yucatan	21° 36' N; 87° 59'W	17, 20, 21, 23
	Xtampu, Yucatan	21° 23' N; 88° 53' W	17, 20, 21, 23
	Cancun, Quintana Roo	21° 10´ N; 86° 47' W	10, 14
Inland waters	Cuatro Cienegas, Coahuila	26° 59' N; 102° 04' W	2, 10, 12, 14, 24, 25
	Santo Domingo Zacatecas	23° 18' N; 102° 21' W	10
	Las Salinas, San Luis Potosí	22°43' N; 102°21' W	1, 2, 9, 10, 11, 12, 25, 26
	Texcoco, State of Mexico	19° 32' N; 99° 00' W	1,2,9,10,11,12,14,25
	Zapotitlan Salinas, Puebla	18° 15' N; 19° 37' W	27 *Per. communication*

Ref.: 1. Castro *et al*. (1987); 2. Castro *et al.* (2000); 3. Correa *et al.* (1993a); 4. Correa *et al.* (1993b); 5. Correa *et al.* (1995); 6. Correa & Dela Rosa (1996); 7. Correa & Tapia (1998); 8. Castro *et al.* (1999); 9. Lopez *et al.* (2000); 10. Castro (2011); 11. Castro *et al.* (2003); 12. Castro *et al.* (2006); 13. Castro *et al.* (2010a); 14. Castro *et al.* (2010b); 15. Castro (2011); 16. Castro *et al.* (1995); 17. Tizol *et al.* (2006); 18. Contreras (1987); 19. Rodriguez *et al.* (2006); 20. Torrentera & Abreu-Grobois (2002); 21. Torrentera & Dodson (2004); 22. Maldonado *et al.* (2003); 23. Torrentera & Dodson (1995); 24. Castro *et al.* (1997); 25. Malpica *et al.* (2004); 26. Castro *et al*. (1989); 27. Castro (2012).

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