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Biometry characteristics comparison of *Artemia franciscana* inland waters strains from México with "originally" specie from San Francisco, Bay (SFB) population.

Comparación de las características biométricas de *Artemia franciscana* de aguas interiores de México, con respecto a la especie originaria de la población de Bahía de San Francisco (BSF).

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ABSTRACT

Artemia populations were restricted at hypersaline coastal and inland water bodies and show great plasticity differences in their life cycle, biometry and biochemical characteristics causing geographical isolation and formed different *Artemia* phenotypes. That´s why four Mexican *Artemia* inland waters populations were studied (CCIEN, SLP, ZAC and TEX), and compared with *A. franciscana* "originally specie" biometric data (hydrated cysts, decapsulated embryos, nauplii and adult (male and female) stage. ANOVA and Tukey test was applied to show significant differences ($P<0.05$), also a discriminate analysis was made based on population type classification. CCIEN population has the biggest biometric data and TEX has the lowest values. The differences in biometric variables which are not modified by genetic pool conditions are: total length, abdomen length, antennae length, abdomen width. The variables that were modified by genetic pool were: furca length, head width, eye diameter and distance between eyes. Discriminant analysis shown that Mexican cysts diameter, nauplii length, male and female length were different with respect SFB strain with respect total length, furca length and head width. Therefore based on the results, we can infer that the Mexican populations of inland waters have begun to separate from the species *A. franciscan* SFB, but also forming two groups of stocks, where the population of ZAC begins to separate from the other three (SLP, CCIEN, TEX), due to ecological isolation, caused by the ionic composition of the habitat where each is.

Key words: *Artemia franciscana*, biometry, inland waters, Mexico.

RESUMEN

Las poblaciones de *Artemia* se encuentran restringidas en cuerpos de agua hipersalinos, ya sean costeros o de aguas interiores, las cuales muestran una plasticidad diferente ya sea en su ciclo de vida, biometría y características bioquímicas, las cuales causan un aislamiento geográfico formando diferente fenotipos de *Artemia*. Es por eso que se estudiaron cuatro poblaciones de Artemia de aguas interiores (CCIEN, SLP, ZAC y TEX), las cuales fueron comparadas con los valores biométricos de la "especie original" de *Artemia franciscana* (quistes hidratados, embriones descapsulados, nauplios y adultos: machos y hembras). Pruebas de ANDEVA y Tukey fueron aplicadas a los datos para encontrar diferencias significativas ($P<0.05$), así como un análisis discriminante basado en el tipo de clasificación por población. La población de CCIEN tuvo los valores biométricos más altos y la población de TEX, los más bajos. Las diferencias encontradas en las variables biométricas que no son modificadas por el pool genético de la población fueron: longitud total, longitud de abdomen, longitud de antenas y ancho del abdomen. Las variables biométricas modificadas genéticamente fueron: longitud de la furca, ancho de la cabeza, diámetro del ojo

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y distancia entre los ojos. El análisis discriminante muestra que el diámetro del quiste, la longitud del nauplio y la longitud tanto del macho como de la hembra fueron diferentes con respecto a la población de BSF, considerando tres medidas principales longitud total, longitud de la furca y ancho de la cabeza. Basado en estos resultados, podemos inferir que las poblaciones Mexicanas de aguas interiores comienzan a separarse de la especie de *A. franciscana* de BSF, pero que además forman dos grupos, en donde la población de ZAC se comienza a separar de las otras tres (SLP, CCIEN, TEX) debido al aislamiento ecológico, causado principalmente por la composición iónica del hábitat de donde procede cada una de las poblaciones.

Palabras clave: *Artemia franciscana*, biometría, aguas interiores, México.

INTRODUCTION

The genus *Artemia* comprises a complex of sibling species and super species defined by a criterion of reproductive isolation (Browne and Bowen 1991). A group named "New World" species is composed of *Artemia franciscana* Kellogg, 1906 (North, Central and South America), *Artemia persimilis* Piccinelli & Prosdocimi, 1968 (Argentina) and *Artemia monica* Verrill, 1869 (USA). Another group named "Old World" species is represented by *Artemia salina* (Linnaeus, 1758) (Mediterranean basis), *Artemia urmiana* Günther, 1899 (Lake Urmia, Iran), *Artemia sinica* Cai, 1989 (China) and subspecie *Artemia sinica sinica* Cai, 1989, *Artemia tibetiana* Abatzopoulos *et al.*, 1998 (Tibet`s high Plateau) and subspecie *Artemia sinica tibetiana* Abatzopoulos *et al.*, 1998; and some parthenogenetic population(s) of *Artemia*.

Some information is available on the survival and growth rate characteristics of bisexual and parthenogenetic *Artemia* populations (Vanhaecke et al. 1984, Browne et al. 1984, Wear and Haslett 1986, Browne et al. 1991, Triantaphyllidis et al. 1995, Triantaphyllidis et al. 1997[a], Triantaphyllidis et al. 1997[b], Browne and Wanigasekera 2000, Abatzopoulos et al. 2003, Baxevanis et al. 2004, Castro 2004, El-Bermawi et al. 2004, Abatzopoulos et al. 2006[b], Agh et al. 2008) cultivated in different salinities. The decline of *Artemia* cyst harvests not only from the Great Salt Lake in Utah, USA since 1977 (Lavens and Sorgeloos 2000), even other habitats, has intensified the search for alternative resources, especially in inland lakes that have a natural source of *Artemia* and can be used and cultivated for commercial exploitation.

Artemia populations were restricted at hypersaline coastal and inland water bodies (Persoone and Sorgeloos 1980), and show great plasticity differences in their life cycle (Lenz and Browne 1991), morphology (Amat 1980, Schrehardt 1987), and biochemical characteristics (Léger et al. 1986). Differences are attributed to different degree of intra population characters and the gene "pool" for each species (Abreu-Grobois 1987, Gajardo and Beardmore 1993). Other researchers like Gilchrist (1960), Baid (1963), Vanhaecke and Sorgeloos (1980), Lenz and Dana (1987), (Correa et al. 1993), indicated that geographical isolation and habitat characteristics are formed different *Artemia* phenotypes, with different biological, chemical and physiological characteristics (Erhardt et al. 1971, Amat 1980, Castritsi and Christodoulopoulou 1987, Lysenko 1987, Yaneng 1987, Castro et al., 1989 and Correa and Bückle 1993).

Inland waters *Artemia* have specific biological characteristics, due to isolation pattern in their habitat areas. These populations mainly have different ionic compositions in the living environment which is actually described their biological characteristics. They are differentiated because of evolutionary, morphology and reproductive performance which is consequently caused speciation process for each species (Asem et al. 2009, 2010), Castro et al. 2011).

Therefore, the main goal of current study is to determine morphological variation of inland water Mexican *Artemia* and their originally specie from San Francisco Bay, which are isolated by geographical barriers.

MATERIAL AND METHODS

Populations used in the experiment: This study was conducted at the Laboratorio de Alimento Vivo of the Universidad Autónoma Metropolitana-Xochimilco, Mexico. The cysts' habitat and their geographical localization are listed in Tab.1 and Fig.1.

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Table 1. Geographical coordinates of *A. franciscana* inland waters populations.

Locality and State	Geographical coordinates
Cuatro Cienegas, Coahuila	26° 59' N; 102° 04' W
Santo Domingo Zacatecas	23° 18' N; 102° 21' W
Las Salinas, San Luis Potosí	22° 43' N; 102° 21' W
Texcoco, State of Mexico	19° 32' N; 99° 00' W

Fig.1. Habitat distribution of inlands water Mexican *A. franciscana* populations.

Cysts diameter and nauplii length: For each Mexican inland water strain, 0.1 g of cysts were taken and hydrated with tap water during 1 h. One hundred hydrated cysts was diameter measured with a dissection microscope equipped with a camera and Image-Pro Plus 7.0 (MediaCybernetics®) software program. Then the same 100 cysts were decapsulated with hypochlorite sodium solution to eliminate the cyst shell. The chorion thickness was obtained by diameter difference between hydrated and decapsulated cyst mean values diameter. To obtain nauplii mean value length, 0.2 g of cysts of each Mexican strain was hatching in a beaker with 35 g L^{-1} salinity, pH 8-10 and temperature of 22 ± 0.2°C with continuous illumination and aeration. One hundred newborn nauplii (24 h) were measured with the same microscope.

Male and female adult biometry: Collected nauplii from 0.5 g hatching cysts for each strain were inoculated in 200 L plastic beaker with 160 L of water at 80 g L^{-1} salinity, with pH 8-10 and a temperature of 23 ± 2°C. Each third day, the organisms were fed with 50 mL of rice bran (100 g L^{-1} solution) and every day with a 1 L *Tetraselmis* sp. microalgae (500,000 cel mL^{-1}). The organisms were maintained at these conditions during 14 days until sexual dimorphism was observed. One hundred males and one hundred females were separating from each other and cultured at same conditions another 7 days. Then, the organisms were fixed with acetic acid solution and biometry variables were taken: total length (tl); abdomen length (al); furca length (fl); antenna length (anl); abdomen width (aw); head width (hw); eye diameter (ed); distance between eyes (dbe), and in females: ovisac width (ow), with same dissection microscope.

Statistical analysis: Stem and leaf displays and Box Plot were performed to ensure that the assumption of normality was being met for each data set. A descriptive statistical analysis was made to obtain mean values and standard deviation for length biometry. Analyses of one-way variance (ANOVA) were also used to determine significant differences between Mexican inland waters strains (Tatsuoka 1970, Kachigan 1991). The least significant differences (LSD) pair-wise comparison (Tukey method; $P<0.05$) was used to compare pairs of sample means after ANOVAs for each biometry character studied were generated. Type classifications were based on population at discriminate analysis (Sokal and Rohlf 1981, Kachigan 1991). The SYSTAT 13 (Systat Software Inc., Calif. USA) software package was used for the statistical analysis.

RESULTS

Cysts diameter and nauplii length: The mean values and ± D.S. are shown in Table 2. The population CCIEN has the biggest value of hydrated cyst diameter, but this measure is not significantly different ($P<0.05$) with other Mexican strains. The SFB strain has the smallest value. The biggest value of decapsulated embryo was found in ZAC strain, but at the same way, the ANOVA analysis did not show significant differences between Mexican strains. In this biometric value it sound interesting that SFB and TEX strains did not shown significant

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differences in ANOVA test analysis. With respect the nauplius length, SFB, TEX, SLP and ZAC strains did not show significant differences between them. CCIEN population has the biggest value and TEX is smallest than BSF strain.

Table 2. Mean values and ± S.D. of hydrated and decapsulated cysts, chorion thickness and nauplii length of inland waters Mexican *A. franciscana* strains.

Biometric variable	*Artemia franciscana* strains				
	CCIEN	ZAC	SLP	TEX	BSF*
Hydrated cyst	231.21[a]	230.25[a]	228.86[a]	230.23[a]	224.37
S.D.	± 4.40	±4.16	± 6.20	± 4.50	± 7.44
Decapsulated embryos	213.99[a]	216.04[a]	215.27[a]	212.37[a,b]	209.00[b]
S.D.	± 6.95	±6.61	±7.44	±4.28	± 7.47
Nauplius length	472.93	432.75[a]	425.52[a]	422.62[a]	426.19[a]
S.D.	± 26.60	± 15.74	± 22.74	± 29.01	± 13.91
Chorion thickness	8.61	7.10	6.79	8.93	7.69

*Values obtained from Castro (2004).
Same letter in a row show no significant differences between strains (P<0.05)

With respect discriminant analysis, in Table 3 are shown the classification results of discriminant analysis on cysts and nauplius biometry data.

Table 2. Classification results of discriminant analysis on cysts and nauplius biometric values showing the percentages of populations classified in each group.

Populations	% correct	*Artemia franciscana* strains				
		CCIEN	ZAC	SLP	TEX	BSF
CCIEN	87	87	0	10	0	3
ZAC	30	0	7	33	30	30
SLP	27	0	27	27	20	27
TEX	40	0	13	10	40	37
BSF	77	0	77	13	10	0

Only CCIEN and BSF strains are classified up 75% correct. The other populations (ZAC, SLP, and TEX) only reach 30% of classification.

In Table 4, are shown the canonical discriminant function (standardized by within variance) and canonical scores of group means values of the first two canonical functions who explained the 98% of data.

Table 4. First two canonical discriminant functions (standardized within variance) and canonical scores of group mean values.

Canonical discriminant functions standardized by within variance	Factor 1	Factor 2
Hydrated cyst	0.060	0.798
Decapsulated embryos	0.084	0.554
Nauplius length	0.986	-0.183

Canonical scores of group means	Factor 1	Factor 2
CCIEN	2.831	-0.104
SFB	-0.905	-1.228
SLP	-0.556	0.469
TEX	-0.808	0.288
ZAC	-0.562	0.575

Eigen values	2.093	0.446
Canonical correlation	0.823	0.555
Cumulative proportion	0.811	0.984

The discriminant analysis shows that nauplius length and hydrated cysts diameter were the variables that discriminate these *A. franciscana* strains (Fig.2). BSF and CCIEN strains are separately to other three strains (TEX, SLP and ZAC).

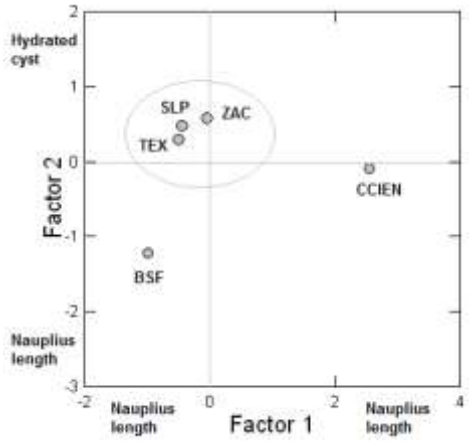

Fig. 2. Discriminant analysis comparison of cyst diameter, embryo diameter and nauplius length of Mexican inland waters strains with BSF.

Biometry of adult males: The mean values and ± D.S. are shown in Table 5. The SFB strain show the biggest values in all biometric variables considered. The highest value in total length in Mexican strains was obtained in ZAC and the

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Table 5. Mean male biometry values (± D.S.) of *A. franciscana* studied strains.

Strains	Biometry variables							
	tl	al	fl	anl	aw	hw	ed	dbe
C.CIEN	6.40[a]	2.68[a]	0.34	1.20[a]	0.48[a]	0.53[a]	0.36	1.50[a]
S.D.	± 0.82	± 0.51	± 0.07	± 0.24	± 0.06	± 0.12	± 0.07	± 0.24
ZAC	7.92	2.85[a]	0.14	0.74	0.50[a]	0.80	0.24	1.47
S.D.	±1.10	± 0.55	± 0.13	± 0.11	± 0.07	± 0.09	± 0.04	± 0.19
SLP	6.25[a]	2.74[a]	0.23	1.09	0.45[b]	0.51[a]	0.32	1.42[a]
S.D.	± 0.73	± 0.47	± 0.05	± 0.19	± 0.05	± 0.15	± 0.06	± 0.31
TEX	6.45[a]	2.65[a]	0.21	0.88	0.46[a,b]	0.57	0.28	1.19
S.D.	± 0.54	± 0.52	± 0.04	± 0.17	± 0.06	± 0.11	± 0.04	± 0.22
BSF*	8.69	3.87	0.26	1.24[a]	0.63	0.91	0.39	1.93
S.D.	± 0.20	± 0.17	± 0.02	± 0.04	± 0.03	± 0.02	± 0.02	± 0.07

total length (tl); abdomen length (al); furca length (fl); antenna length (anl); abdomen width (aw); head width (hw); eye diameter (ed); distance between eyes (dbe),
Same letter in column didn't shown significant differences (P<0.05).
*Values obtained from Castro (2004).

lowest value in SLP strain. The ANOVA analysis shows that a CCIEN strain has not significant differences with SLP and TEX populations. It should be noted that furca length and eye diameter variables, all studied strains show significant differences (P<0.05) between them.

The Discriminant analysis show that *Artemia* populations studied has the 96% correct values in the Jackniffed classification matrix (Table 6). In addition, 95% of information is explained with the first two factors of discrimination. The biometric variables with highest weight significance in the discrimination of the strains were positively the distances between eyes and head width and negatively form with antenna and furca (Fig. 3).

Table 6. Classification results of discriminant analysis on adult male biometry showing the percentages of populations classified in each group.

Populations	% correct	*Artemia franciscana* strains				
		CCIEN	ZAC	SLP	TEX	BSF
CCIEN	90	27	0	3	0	0
ZAC	100	0	30	0	0	0
SLP	93	1	0	28	1	0
TEX	97	0	0	1	29	0
BSF	100	0	0	0	0	30
Total	96	28	30	32	30	30

In Table 7, are shown the canonical discriminant function (standardized by within variance) and canonical scores of group means values of the first two canonical functions who explained the 95% of data.

Biometry of adult females: The mean values and ± D.S. are shown in Table 8. The females of SFB strain shown the biggest biometric values, only with furca length, CCIEN population from México has the highest value. The highest female total

Table 7. First two canonical discriminant functions (standardized within variance) and canonical scores of group mean values from adult *A. franciscana* males.

Canonical discriminant functions standardized by within variance	Factor 1	Factor 2
Total length	0.061	0.275
Abdomen length	-0.010	0.376
Furca length	-0.090	0.245
Antenna length	-0.086	0.182
Abdomen width	-0.046	0.509
Head width	0.093	0.491
Eyes diameter	0.037	0.393
Distance between eyes	0.973	-0.015

Canonical scores of group means	Factor 1	Factor 2
CCIEN	-5.286	-0.493
SFB	-1.165	7.255
SLP	-5.515	-2.489
TEX	-6.942	-2.821
ZAC	18.907	-1.452

Eigen values	96.285	14.304
Canonical correlation	0.995	0.967
Cumulative proportion	0.829	0.952

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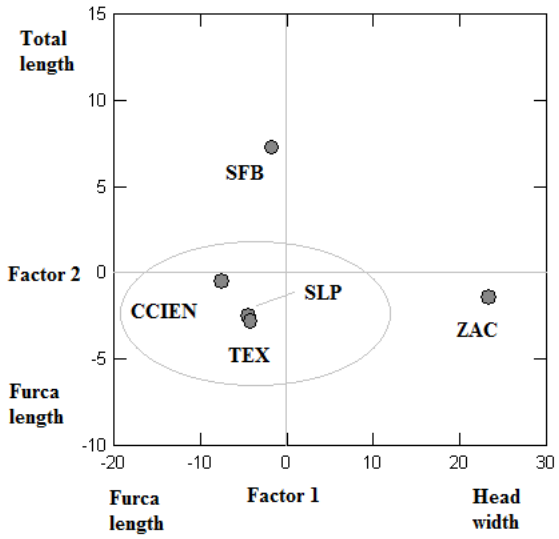

Fig. 3. Discriminant analysis comparison of adult male biometry of Mexican inland waters strains with BSF.

length value from Mexican strains was ZAC and the lowest value to TEX. The ANOVA analysis show that the studied female strains have significant differences ($P<0.05$) between them in total length, ovisac width and distance between eyes biometric variables. TEX strain show significant differences between other inland water female populations in all biometric variables considered. TEX strain only shows no significant differences with CCIEN in head width and with ZAC and SLP strains in eye diameter variable.

With respect Discriminant analysis, the female *Artemia* studied populations shown 98% correct classification in Jackniffed matrix (Table 9). The 97.3% of the information was explained with the two first discriminant factors. For females, biometric variables with the highest significant weight were head and total length in a positive way, while the furca length in negative way (Fig.4).

In Table 10, are shown the canonical discriminant function (standardized by within variance) and canonical scores of group means values of the first two canonical functions who explained the 97.3% of data.

DISCUSSION

This study provides an important opportunity to gain a better understanding at biometric studies with cysts, nauplii and adults (male and female) of *A. franciscana* specie of Mexico inland waters populations. Since as shown in this study with inland waters populations, three of them (ZAC, SLP and TEX) have been separated from the population of CCIEN, located north of Mexico, the country, the length and diameter of the nauplii hydrated cyst. CCIEN population has been separated from the other as the nauplius has the bigger sizes. In addition, the SFB population is separated from Mexico because it has the smaller size. These populations are separated possibly by the same characteristics as Vanhaecke and Sorgeloos (1980) mention in their study of cysts in different locations, which populations differed by three characteristics:

Table 8. Mean female biometry values (± D.S.) of *A. franciscana* studied strains.

Population	Biometric variables								
	tl	al	Fl	anl	ow	aw	hw	ed	dbe
C.CIEN	7.89	3.65[a]	0.49	0.62	0.60	1.59[a]	0.57[a]	0.27	1.24
DS	± 1.50	± 0.94	± 0.12	± 0.16	± 0.11	± 0.55	± 0.09	± 0.03	± 0.19
ZAC	10.04	3.73[a]	0.16	0.58[a]	0.64	1.64[a]	0.93	0.25[a]	1.38
DS	± 0.34	± 0.27	± 0.02	± 0.05	± 0.02	± 0.10	± 0.04	± 0.04	± 0.05
SLP	7.50	3.68[a]	0.34[a]	0.61[a]	0.50	1.19	0.46	0.23[a]	1.11
DS	± 0.77	± 0.64	± 0.08	± 0.08	± 0.05	± 0.26	± 0.10	± 0.03	± 0.15
TEX	6.57	3.16	0.46	0.51	0.42	0.87	0.59[a]	0.22[a]	0.85
DS	± 0.88	± 0.64	± 0.12	± 0.08	± 0.08	± 0.24	± 0.12	± 0.03	± 0.22
SFB*	11.15	5.26	0.32[a]	0.84	0.95	2.20	1.18	0.33	1.84
DS	± 0.34	± 0.22	± 0.02	± 0.04	± 0.04	± 0.12	± 0.04	± 0.01	± 0.05

total length (tl); abdomen length (al); furca length (fl); antenna length (anl); ovisac width (ow); abdomen width (aw); head width (hw); eye diameter (ed); distance between eyes (dbe).
Same letter in column didn't shown significant differences ($P<0.05$).
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Table 9. Classification results of discriminant analysis on adult male biometry showing the percentages of populations classified in each group.

Populations	% correct	*Artemia franciscana* strains				
		CCIEN	SFB	SLP	TEX	ZAC
CCIEN	93	28	0	2	0	0
SFB	100	0	30	0	0	0
SLP	100	0	0	30	0	0
TEX	97	0	0	1	29	0
ZAC	100	0	0	0	0	30
Total	98	28	30	33	29	30

Table 10. First two canonical discriminant functions (standardized within variance) and canonical scores of group mean values from adult *A. franciscana* females.

Canonical discriminant functions standardized by within variance	Factor 1	Factor 2
Total length	0.462	0.384
Abdomen length	0.198	-0.287
Furca length	-0.331	-0.653
Antenna length	0.141	-0.537
Ovisac width	0.521	-0.308
Abdomen width	0.497	0.016
Head width	0.533	0.299
Eyes diameter	0.062	-0.314
Distance between eyes	0.397	-0.094

Canonical scores of group means	Factor 1	Factor 2
CCIEN	-4.170	-3.396
SFB	17.571	-2.118
SLP	-7.411	-0.339
TEX	-11.226	0.614
ZAC	5.237	5.238
Eigen values	110.582	9.092
Canonical correlation	0.996	0.949
Cumulative proportion	0.899	0.973

the populations of smaller and larger shaped by other people *Artemia* species, and populations with intermediate size between the larger and smaller sizes.

Hontoria (1990), studied in 14 populations of *A. franciscana* finding cyst diameters ranging from 217-230 microns, dimensions similar to the Mexicans that are in a range of 228-231 microns, very similar to those obtained in *Artemia* (230 mm) and *Artemia sinica* (232 microns) (Asem et al.

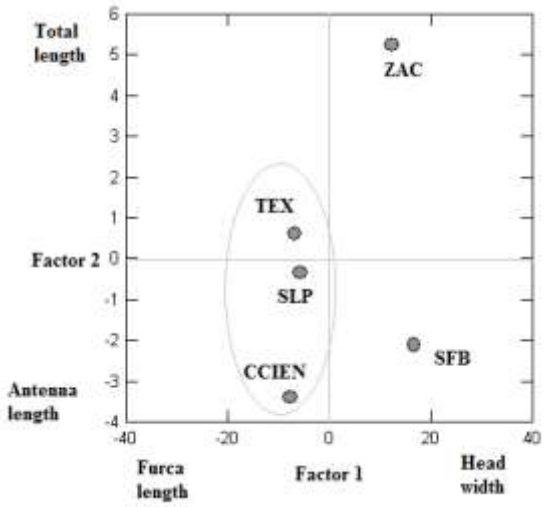

Fig. 4. Discriminant analysis comparison of adult female biometry of Mexican inland waters strains with BSF.

2007). These dimensions are smaller than cysts Galera Zamba (Colombia) having a diameter of 242 microns and Great Salt Lake, Utah (USA) with 245 microns, which is still the same species *A. franciscana* (Hontoria 1990). Cysts of Mexican populations of inland waters are smaller than *A. urmiana* (265.82 microns) (Asem et al. 2007), *Artemia* sp. (230.05 mm) and *A. sinica* (232.75 microns). Triantaphyllidis et al. (1996), notes that for two *Artemia* populations from Namibia and Madagascar, the cyst diameter values are 247.7 and 285.9 microns respectively, and decapsulated embryos with 233.1 and 246.2 microns.

One of the *Artemia* populations presented a larger diameter is *A. tibetiana* with a value of 323 microns. Cohen et al. (1999) reported values for *A. persimilis* in ranges of 230.3-246.1 microns.

Remarkably, the Mexican populations of inland waters, have ranges similar to SFB being of the species *A. franciscana* begin to separate from it because as authors mentioned (Bowen et al. (1985, 1988, Hontoria and Amat 1992, Asem et al. 2007), the ionic composition characteristic of a habitat as well as fluctuations seasonal physico-chemical and food availability in the different biotopes, where are located the various populations of *Artemia*, as mentioned Abatzopoulos et al. (2006) and Asem et al. (2007), produces an ecological isolation ,

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consequently resulting in differences not only morphological, but also biometric in nature.

In regard to biometrics of adults (male and female), as mentioned Asem and Rastegar-Pouyani (2007), sexual dimorphism gender *Artemia* populations present different patterns of size and therefore it is important study them separately. For although in most vertebrates, the male has a larger size due to sexual competition by getting female (Anderson 1994), in the case of other taxa, females are the ones with the largest size, as for *Artemia* (Figuerola 1999; Asem and Rastegar-Pouyani 2007).

In the case of the populations studied in this investigation, we observed that the population of SFB is separated from the Mexican to be larger, both for males and in females. But in the case of males, the inland populations, we observed that the population of ZAC is separated from the group consisting of the other three (CCIEN, SLP and TEX), because the length of the furca and the width of the head has a larger size. For females, the population of ZAC is separated by the width of the head and the total length. The other Mexican towns do so for the length of the furca. It is for this that Mayr and Ashlock (1991), and Asem and Rastegar-Pouyani (2007), note that it is important to study populations of *Artemia*, separating males and females, as agencies have marked sexual dimorphism significant differences.

As studies by Zhou et al. (2003), Asem (2005) and Asem and Rastegar-Pouyani (2007, 2008), with the species A. Sinica and A. tibetiana the inland Mexican populations showed that females had a better rating on their information than males, in contrast to what was found by Camargo et al. (2003), with a population of A. Franciscan from the Colombian Caribbean, where the males had a better classification matrix. For this reason it is best to perform studies of this genus Artemia populations, whereas in adulthood, both females and males.

The larger size of females is explained by Triantaphyllidis (1997), because of the advantage that occurs during mating, where the female of *Artemia* has to carry the male during copulation.

Therefore based on the results, we can infer that the Mexican populations of inland waters have begun to separate from the species *A. franciscana* SFB, but also forming two groups of stocks, where the population of ZAC begins to separate from the other three (SLP CCIEN TEX), due to ecological isolation, caused by the ionic composition of the habitat where each is (Bowen et al. 1985, Asem and Rastegar-Pouyani 2008).

BIBLIOGRAPHY

Abatzopoulos TJ, B Zhang and P Sorgeloos. 1998. *Artemia tibetiana*: preliminary characterization of a new *Artemia* species found in Tibet (People's Republic of China). Int. J. Salt Lake Res. 7: 41-44.

Abatzopoulos TJ, JA Beardmore, JS Clegg and P Sorgeloos. 2002. *Artemia*: Basic and Applied Biology. Kluwer Academic, Dordrecht, The Netherlands.

Abatzopoulos TJ, N El-Bermawi, C Vasdekis AD, Baxevanis and P Sorgeloos. 2003. Effects of salinity and temperature on reproductive and life span characteristics of clonal *Artemia* (International study on *Artemia*, LXVI). Hydrobiologia 492: 191–199.

Abatzopoulos TJ, N Agh, G Van Stappen, SM Razavi-Rouhani and P Sorgeloos. 2006[a]. *Artemia* sites in Iran**.** J. Mar. Biol. Assoc. U.K. 86: 229-307.

Abatzopoulos TJ, AD Baxevanis, GV Triantaphyllidis, G Criel, EL Pador, G Van Stappen and P Sorgeloos. 2006[b]. Quality evaluation of *Artemia urmiana* Günther (Urmia Lake, Iran) with special emphasis on its particular cyst characteristics (International Study on *Artemia*, LXIX). Aquaculture 254: 442-454.

Agh N, G Van Stappen, G Bossier, P Sepehri, H Lofti, V Rouhani and P Sorgeloos. 2008. Effects of salinity on survival, growth, reproductive and life span characteristics of *Artemia* populations from Urmia Lake and neighboring lagoons. Pak. J. Biol. Sci. 11: 164-172

Baxevanis AD, N El-Bermawi, TJ Abatzopoulos and P Sorgeloos. 2004. Salinity effects on maturation, reproductive and life span characteristics of four Egyptian *Artemia* populations. Hydrobiologia 513: 87–100.

Bowen ST, EA Fogarino, KN Hitchner, GL Dana, VHS Chow, MR Buoncristiani and JR Carl. 1985. Ecological isolation in *Artemia*: population differences in tolerance of anion concentrations. J. Crust. Biol. 5: 106–129.

Browne RA, SE Salee, DS Grosch, WO Segreti and SM Purser. 1984. Partitioning genetics and environmental components of reproduction and life span in *Artemia*. Ecology 65: 949-969.

Receive: August 10th, 2013. Accepted: October 30th, 2013. Published: December 1st, 2013.

Browne RA and ST Bowen. 1991. Taxonomy and population genetics of *Artemia*, p. 221-235. In Browne RA, P Sorgeloos and CNA Trotman (eds.) *Artemia* Biology. CRC Boca Raton, Florida, USA.

Browne RA and G Wanigasekera. 2000. Combined effects of salinity and temperature on survival and reproduction of five species of *Artemia*. J. Exp. Mar. Biol. Ecol. 244: 29-44.

Castro MJ. 2004. Caracterización Morfométrica y reproductiva (hibridación) de siete poblaciones de *Artemia franciscana* en México, en relación a su hábitat y latitud. Master Degree Thesis, Universidad Autónoma Metropolitana, México. 116 p.

Castro BT, JM Castro and GM Castro. 2003. *Artemia*, p. 67-81. In: Castro TB. (Comp.) Alimento vivo para organismos acuáticos. AGT. México.

Castro BT, AS Malpica, JM Castro, GM Castro and AR De Lara. 2000. Environmental and biological characteristics of *Artemia* ecosystems in México: and updated review, p. 191-202. In Munawar M, SG Lawrence, IF Munawar and DF Malley (eds.), Aquatic Ecosystems of México. Status and scope. Backhuys Publishers, Leiden, The Netherlands.

El-Bermawi N, AD Baxevanis, TJ Abatzopoulos, G Van Stappen and P Sorgeloos. 2004. Salinity effects on survival, growth and morphometry of four Egyptian *Artemia* populations (International study on *Artemia*, LXVII). Hydrobiologia 523:175-188.

Kachigan SK. 1991. Multivariate statistical analysis. A conceptual introduction. Radius. New York, EEUU.

Lenz PH. 1987. Ecological studies on *Artemia*: a review, p. 5-18. In Sorgeloos P, DA Bengtson, W Decleir y E.Jaspers (eds.), *Artemia* Research and its Applications, Vol. 3. Ecology, Culturing, Use in Aquaculture. Universa. Wetteren, Belgium.

Litvinenko LI, AV Koslov, AI Kovalenko and DS Bauer. 2007. Salinity of water as a factor to determine the development of the brine shrimp *Artemia* populations in Siberian lakes. Hydriobiologia 576: 95-101.

Mayer RJ. 2002. Morphology and biometry of three populations of *Artemia* (Branchiopoda: Anostraca) from the Dominican Republic and Puerto Rico. Hydrobiologia 486: 29-38.

Naceur HB, AB Rejeb-Jenhani and MS Romdhane. 2009. Ecobiological survey of the brine shrimp *Artemia salina* from Sabkhet El Adhibet (south-east Tunisia). J. Mar. Biol. Assoc. U.K. 89: 1109-1116.

Pilla EJS and JA Beardmore. 1994. Genetic and morphologic differentiation in old world bisexual species of *Artemia* (the brine shrimp). Heredity 72: 47-56.

Post FJ and NN Youssef. 1977. A prokaryotick intracellular symbiont of the Great Salt Lake brine shrimp *Artemia salina* (L.). Can. J. Microbiol. 23: 1232-1236.

Rodríguez-Almaraz AG, C Zavala, R Mendoza and AM Maeda-Martínez. 2006. Ecological and biological notes on the brine shrimp *Artemia* (crustacean: Branchiopoda: Anostraca) from Carmen Island, Baja California Sur, México. Hydrobiologia 560: 417-423.

Sokal RR and JF Rohlf. 1981. Biometry. W.H. Freeman. San Francisco, CA, EEUU.

Tackaert W and P Sorgeloos. 1991. Semiintensive culturing in fertilized ponds. p. 287-312. En Browne RA, P Sorgeloos y CNA Trotman (eds.). *Artemia* Biology. CRC. Boston, EEUU.

Tatsuoka MM. 1970. Selected topics in advanced statistics. An Elementary Approach. No.6. Discriminant Analysis. IPAT. Illinois, EEUU.

Triantaphyllidis GV, K Poulopoulou, TJ Abatzopoulos, CA Pinto-Perez and P Sorgeloos. 1995. International study on *Artemia* XLIX. Salinity effects on survival, maturity, growth, biometrics, reproductive and lifespan characteristics of a bisexual and a parthenogenetic population of *Artemia*. Hydrobiologia 302: 215-227.

Triantaphyllidis GV, GRJ Criel, TJ Abatzopoulos and P Sorgeloos. 1997[a]. International study on *Artemia*. LIII. Morphological study of *Artemia* with emphasis to Old World populations. I. Bisexual populations. Hydrobiologia 357: 139–153.

Triantaphyllidis GV, GRJ Criel, TJ Abatzopoulos, KM Thomas, J Peleman, JA Beardmore and P Sorgeloos. 1997[b]. International study on *Artemia*. LVII. Morphological and molecular characters suggest conspecificity of all bisexual European and North African *Artemia* populations. Mar. Biol. 129:477–487.

Triantaphyllidis GV, TJ Abatzopoulos and P Sorgeloos. 1998. Review of the biogeography of the genus *Artemia* (Crustacea, Anostraca). J. Biogeogr. 25: 213–226.

Vanhaecke P, SE Siddal and P Sorgeloos. 1984. International study on *Artemia*. XXII. Combined effects of temperature and salinity on the survival of *Artemia* of various geographical origins. J. Exp. Mar. Biol. Ecol. 80: 259-275.

Van Stappen G. 2002. Zoogeography, p. 171-224. In: Abatzopoulos TJ, Beardmore JA, Clegg JS and Sorgeloos P. (eds.), *Artemia:* Basic and Applied Biology. Kluwer Academic Publishers, Dordrecht. The Netherlands.

Receive: August 10th, 2013. Accepted: October 30th, 2013. Published: December 1st, 2013.

Wear RG and SJ Haslett. 1986. Effects of temperature and salinity on the biology of *Artemia fransiscana* Kellogg from Lake Grassmere, New Zealand. 1. Growth and mortality. J. Exp. Mar. Biol. Ecol. 98: 153-166.

Receive: August 10th, 2013. Accepted: October 30th, 2013. Published: December 1st, 2013.