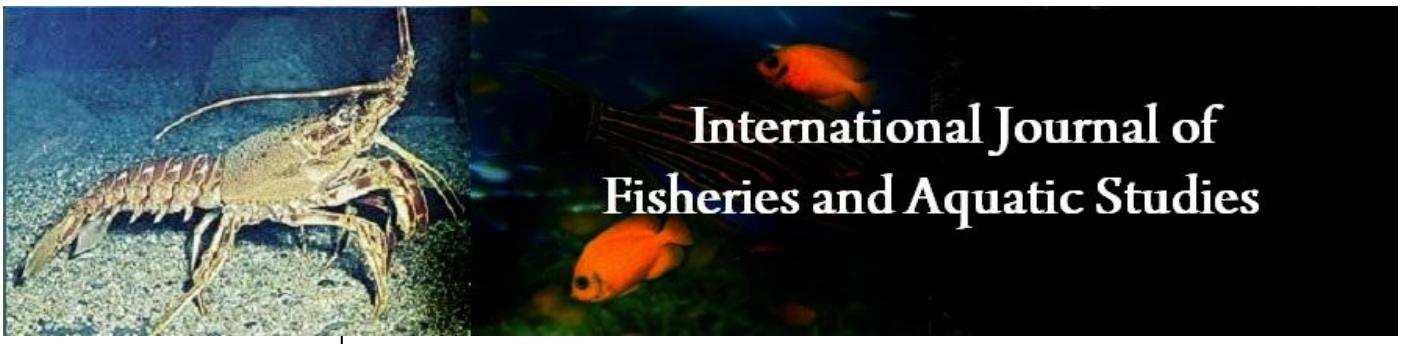


**E-ISSN: 2347-5129**
**P-ISSN: 2394-0506**
(ICV-Poland) Impact Value: 5.62
(GIF) Impact Factor: 0.549
IJFAS 2017; 5(6): 86-92
© 2017 IJFAS
www.fisheriesjournal.com
Received: 12-09-2017
Accepted: 13-10-2017

**Jorge CM**
Live Food Production Laboratory. El Hombre y su Ambiente Department. Universidad Autónoma Metropolitana Xochimilco. Calz. del Hueso No.1100. Col. Villa Quietud. México

**Germán CM**
Live Food Production Laboratory. El Hombre y su Ambiente Department. Universidad Autónoma Metropolitana Xochimilco. Calz. del Hueso No.1100. Col. Villa Quietud. México

**María del Carmen MD**
Live Food Production Laboratory. El Hombre y su Ambiente Department. Universidad Autónoma Metropolitana Xochimilco. Calz. del Hueso No.1100. Col. Villa Quietud. México

**Andrés Elías CC**
Live Food Production Laboratory. El Hombre y su Ambiente Department. Universidad Autónoma Metropolitana Xochimilco. Calz. del Hueso No.1100. Col. Villa Quietud. México

**Fernando DS**
Live Food Production Laboratory. El Hombre y su Ambiente Department. Universidad Autónoma Metropolitana Xochimilco. Calz. del Hueso No.1100. Col. Villa Quietud. México

**Correspondence**
**Jorge CM**
Live Food Production Laboratory. El Hombre y su Ambiente Department. Universidad Autónoma Metropolitana Xochimilco. Calz. del Hueso No.1100. Col. Villa Quietud. México

# Reproductive potential of *Artemia franciscana* (Kellogg, 1906) from Mexico inland waters cultured in laboratory at different salinity

**Jorge CM, Germán CM, María del Carmen MD, Andrés Elías CC, Fernando DS**

**Abstract**
Four populations of *Artemia franciscana* from Mexico inland waters (Cuatro Ciénegas, Coahuila; Santo Domingo, Zacatecas; Las Salinas, San Luis Potosí and Texcoco, Edo. de México) were compared with respect to their reproductive potential. Each population was cultivated in 200 L beakers at a salinity of 60, 80, 100 and 120 $gL^{-1}$. Temperature was maintained at 25 ± 2 ºC, with continuous light and aeration and pH between 8 to 10. The organisms were fed *ad libitum* with 50 mL of rice bran and 1 L of mixed solution of *Tetraselmis* sp. and *Pinnularia* sp. microalgae. When organisms reach sexual maturity stage, they were separated in 25 glass beakers of 250 mL, introducing one female and two males to determine reproductive potential in each salinity concentration experimental. Total life cycle was of 47- 68 days range. Reproductive period was of 30 to 45 days, number of broods were 7 to 11, nauplii produced per female were 39 to 58 and cyst production per female were 0 to 65. All values increase with salinity concentration. Calculated biomass was 161.28 to 501.12 g range and calculated cysts production was 100.46 to 180.40 g. This information could lay biological bases for laboratory culture exploitation or semi intensive culture system at their natural habitat, depending their culture management to obtain adult or cysts wet biomass.

**Keywords:** *Artemia franciscana,* Mexico, inland waters, reproductive potential, salinity

## Introduction
One of the most important physicochemical variable which modify the organism's habitat is salinity, because it affects the life cycle and development of aquatic organisms directly and above all, those who lives in wide range salinity changes like coastal lagoons and water bodies or manmade salterns which produce salt. An organism that lives in this habitat is the brine shrimp *Artemia* who lives in those hypersaline habitats with substantial changes in salinity concentration [1, 2]. This brine shrimp is represented by distinct species which are widely distributed around the world, occupying coastal lagoons, inland waters bodies and water bodies used to produce salt [3, 4].

*Artemia* is a unique organism which has the capacity to adapt to habitats that have salinity concentration under 10 $gL^{-1}$ [5] and up to 340 $gL^{-1}$ [6]; and to habitats that have low biodiversity and relative simple food web structure [7]. This capacity of *Artemia,* allow to escape from their predators and food competitors, allowing with their nauplii-adult stage development be successful under these salinity extreme conditions. In some cases, allowing high densities due the presence of halobacterium and microalgae which resist same salinity conditions [8] and were used as food source for this non-selective efficiently filter feeding organisms [9].

In Mexico, it dominates the specie *Artemia franciscana* Kellogg 1906 [10], which is distributed at 26 sites both in coastal and inland saline waters, with specific salinity concentration and temperature ranges, so that each population may varied considerably regarding their physiological responses to cope specific physical-chemical conditions from each natural habitat. The carried-out studies with Mexican *Artemia* populations were about biometric and reproductive characteristics [11-25]. It is important to mentioned that *Artemia* production salinity concentration was between 40-60 $gL^{-1}$. Also, studies with reproduction and potential reproductive goal were made [25, 26].

*Artemia* was considered as an important economy source to fish and crustacean larviculture, because it was used as essential food to their development [27-29]. That is why in recent years, worldwide, the studies were indicted to find or to obtain a population *Artemia* strain that cover the potential characteristics (small size nauplii and cysts, rapid hatching, better development and, high adult and cysts biomass) that aquaculture needs.

The goal of this study was the comparison effects of different salinities concentrations (60, 80, 100 and 120 $gL^{-1}$) in reproductive potential (total days of life cycle, days of reproductive period, number of broods, nauplii and cysts production per female) of four Mexican inland waters *A. franciscana* populations to maintained populations at laboratory conditions. Not only obtained adult wet biomass was used as directly food to aquatic organisms, but also wet cysts biomass to maintain a cysts stock of Mexican populations, allowing with this to maintain the biodiversity of this genus in Mexico.

## Materials and methods

### Cysts from Mexican *A. franciscana*

This study was made at Live Food Production Laboratory from El Hombre y su Ambiente Department from Universidad Autónoma Metropolitan de Xochimilco. The experimental cysts were taken from cysts bank storage at a fridge (-10 °C) to maintain dehydration and diapause process.

### Geographical localization of studied *A. franciscana* populations

Local sites, abbreviation, habitat type and, geographical localization of experimental populations was shown in Table 1 and fig 1.

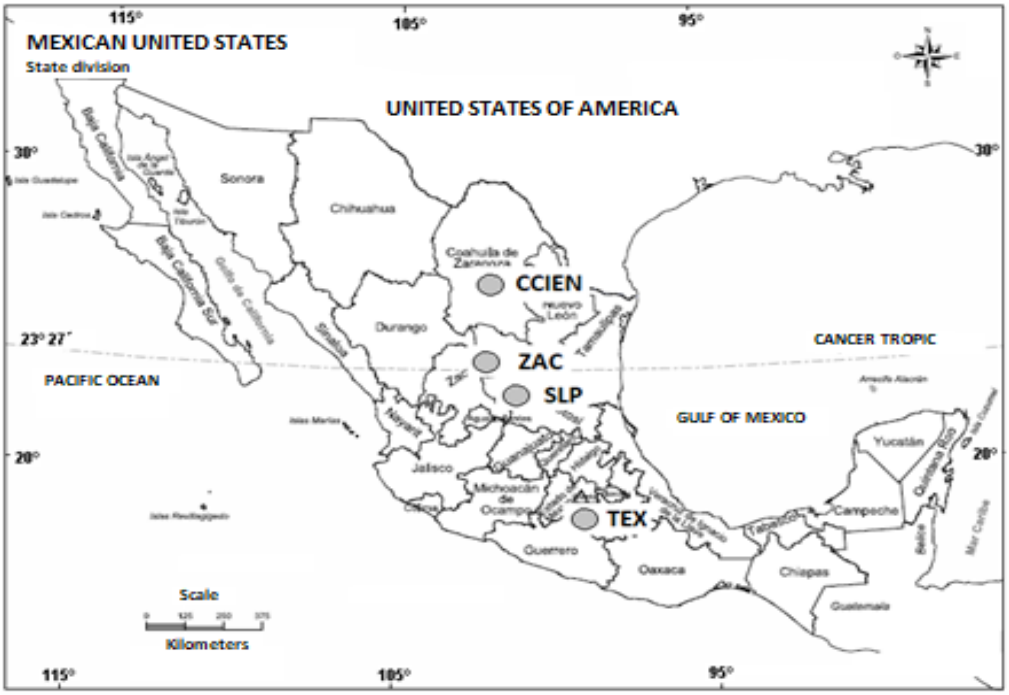


**Fig 1:** Geographical localization of Inland waters *A. franciscana* populations in México.

**Table 1:** Mexican *A. franciscana* populations used in this experiment.

| Locality | Abbreviation | Geographical coordinates |
|---|---|---|
| Cuatro Ciénegas, Coahuila | CCIEN | 26°55'51''N; 102°02'22'' W |
| Santo Domingo, Zacatecas | ZAC | 23°19'20''N; 101°46'51''W |
| Las Salinas, San Luis Potosí | SLP | 22°39'16''N; 101°43' W |
| Ecatepec, Estado de México | TEX | 19° 32' N; 99° 00' W |

### Organisms fed

During the experiments, the organisms were fed every third day with 50 mL of rice bran (300 g in 4 L of brine solution water) and one liter from each microalga: *Tetraselmis* sp. (Kylin: Butcher) and *Pinnularia* sp. (Cleve) at a concentration of 500 x $10^3$ cel $mL^{-1}$) [30].

### Experimental design

One gram from each *A. franciscana* population were set to hatch in a 4 L beaker with 40 $gL^{-1}$ salinity concentrations, pH of 8-10, temperature of 25 °C±2 °C, and permanent aeration and light [30]. Hatching nauplii were collected and placed in 200 L beakers and filled with 160 L of 60, 80, 100 and 120 $gL^{-1}$ salinity water concentration. Population density was adjusted to 1-2 org $mL^{-1}$ to avoid growth problems because available space habitat [30].

For each experimental treatment, when organisms reached sexual maturity were separated by sex (male/female), and cultured at same physicochemical conditions for two weeks. After that time, organisms were placed in 25 glass beakers of 250 mL (two males/one females per beaker) to determined daily couple match, total days of life cycle, reproductive period (days), number of broods and, nauplii and cysts production per female. The dead males were replaced [31]. Every day, until females died, observations were made to determine reproductive potential from each salinity concentration, which was monitored with an AO (0-150 $gL^{-1}$ range) refractometer to maintain salt concentration.

**Information processing**

All obtained data was placed in a data base in Excel 10 program to determined mean values (±S.D.). To determined reproductive potential from each experimental salinity concentration, values of nauplii and cysts produced per female were multiplied by brood's number to determined total production per female and values were extrapolated to 160 L volume water production, considering a 1 org $mL^{-1}$ density, with a percentage of 50% of females and survival of 30%.

To determined total wet biomass of nauplii and cysts, their total production values were multiplied per 0.001 g for adult stage biomass and per 0.000001 g for cysts stage (mean values obtained per 100 adult stage organisms and 1,000 cysts), using a Digital Granary Scale Balance Ohaus (0.0001 g accuracy).

The total number of broods, nauplii and cysts produced, were normalizer with following formula:

$$\text{Transformed data} = \sqrt{\text{Value} + 0.5}$$

**Statistical analysis**

To determine significant differences ($p$<0.05) between salinities concentration and reproductive variables in all populations, it was applied a two-ways ANOVA analysis and Tukey test to compare multiple mean values, considering salinity and population as principally variables [32, 33], using Systat 12.0 (Systat Software Inc., California, USA) program.

**Results**

**Total life cycle**

In Table 2 it is shown the mean values of total life cycle per female from each experimental salinity concentrations (60, 80, 100 and 120 $gL^{-1}$). It can be observed that mean values increase with salinity. ZAC population showed the lowest value (47±4 days) at 60 $gL^{-1}$ salinity and higher values was shown in CCIEN population (68±3 days) at 120 $gL^{-1}$ salinity.

ANOVA analysis show that 60, 80, 100 and 120 $gL^{-1}$ experimental salinities did not present significant differences (p=0.690, p=0.414, p=0.353, p=0.633 respectively) between populations, but with respect to same population cultured at different salinities, it did show significant differences ($p$<0.001) in all populations.

Two-ways ANOVA analysis show significant differences ($p$<0.001). Salinity has 81.59% of that significance weight, population variable only has 0.67% of that difference and interaction between salinity/population the 0.44%.

**Table 2:** Mean values (±S.D.) of life cycle (days) of Inland waters *A. franciscana* populations cultured at experimental salinities.

| Population | Experimental salinity ($gL^{-1}$) | | | |
|---|---|---|---|---|
| | 60 | 80 | 100 | 120 |
| CCIEN | 50 ±5 | 57 ±3 | 62 ±2 | 68 ±3 |
| ZAC | 47 ±4 | 55 ±4 | 61 ±4 | 67 ±3 |
| SLP | 48 ±4 | 56 ±3 | 63 ±3 | 67 ±2 |
| TEX | 49 ±3 | 54 ±4 | 61 ±3 | 67 ±3 |

**Reproductive period**

Table 3 show the mean values of reproductive period (in days) at different experimental salinities. The lowest value was shown in TEX population with 28±6 days at 60 $gL^{-1}$. Highest value was shown in CCIEN population with 45±7 days at 120 $gL^{-1}$.

**Table 3:** Mean values (±S.D.) of reproductive period duration (days) of Inland waters *A. franciscana* populations cultured at experimental salinities.

| Population | Experimental salinities ($gL^{-1}$) | | | |
|---|---|---|---|---|
| | 60 | 80 | 100 | 120 |
| CCIEN | 33±10 | 39 ±5 | 35 ±7 | 45 ±7 |
| ZAC | 30 ±9 | 37 ±8 | 38 ±6 | 43 ±6 |
| SLP | 31 ±6 | 37 ±9 | 40 ±7 | 40 ±5 |
| TEX | 28 ±6 | 36 ±8 | 44 ±7 | 41 ±4 |

ANOVA analysis shown no significant differences between 60, 80 and 120 $gL^{-1}$ (p=0.663, p=0.786, p=0.171 respectively) salinities, but at 100 $gL^{-1}$ experimental salinity, CCIEN/TEX populations showed significant differences (p=0.21). With respect to obtained values from each population cultured at different salinities, ANOVA analysis showed significant differences between all populations (CCIEN p=0.002; ZAC p=0.004; SLP p=0.027; TEX $p$<0.001). Applied Tukey test was found that in CCIEN population, the significant differences were shown at 120/60 and 120/100 (p=0.002; p=0.011 respectively); to ZAC and SLP populations at 120/60 (p=0.002, p=0.034 respectively) salinities and for TEX population at 60/80 (P=0.049) and 100/120 $gL^{-1}$ ($p$<0.001) salinities.

Two-ways ANOVA analysis shown significant differences ($p$<0.001). Salinity variable has 27.53% of that significance, population variable has 0.19% and for their interaction (salinity/population) was 6.89%.

**Number of Broods**

Table 4 show mean values of number of broods at experimental salinities. The lowest value founded in all population was at 60 $gL^{-1}$ salinity. Meanwhile, highest values were found in CCIEN population with 12±3 days at 120 $gL^{-1}$.

ANOVA analysis showed no significant differences between all salinities (60 $gL^{-1}$ p=0.114; 80 $gL^{-1}$ p=0.179, SLP p=0.513; TEX p=0.597). With respect to each population cultured at different salinities, ANOVA analysis showed significant differences in all cultured populations ($p$<0.001). However, Tukey test showed that to CCIEN population there were significant differences ($p$<0.001) between 60/100, 120 and 80/60,120 salinities. For ZAC population, were 60/80,100,120 ($p$<0.001), for SLP population were 60/120 salinities ($p$<0.001) and, for TEX population 100/60, 80 and 120/60, 80 salinities ($p$<0.001).

The two-ways ANOVA analysis showed significant differences ($p$<0.001). Salinity variable had the highest weight value of that significance with 49.21%, population variable with 0.94% and for their interaction (salinity/population) was 3.00%.

**Table 4:** Mean values (±S.D.) of number of broods of Inland waters *A. franciscana* populations cultured at experimental salinities.

| Populations | Experimental salinities ($gL^{-1}$) | | | |
|---|---|---|---|---|
| | 60 | 80 | 100 | 120 |
| CCIEN | 7 ±1 | 9 ±1 | 11 ±2 | 12 ±3 |
| ZAC | 7 ±1 | 9 ±2 | 11 ±3 | 11 ±2 |
| SLP | 7 ±1 | 9 ±1 | 9 ±2 | 11 ±2 |
| TEX | 7 ±1 | 8 ±1 | 10 ±2 | 11 ±1 |

**Nauplii produced per female**

Table 5 show mean values of nauplii produced per female at experimental salinities. The lowest value was obtained by TEX population with 32±10 at 60 $gL^{-1}$, meanwhile highest

mean value was from CCIEN and ZAC populations with 58±6 and 58±9 respectively at 120 $gL^{-1}$.

**Table 5:** Mean values (±S.D.) of nauplii produced per female of Inland waters *A. franciscana* populations cultured at experimental salinities.

| Populations | Experimental salinities ($gL^{-1}$) | | | |
|---|---|---|---|---|
| | 60 | 80 | 100 | 120 |
| CCIEN | 39±10 | 46 ±5 | 48 ±7 | 58 ±6 |
| ZAC | 39 ±11 | 50 ±11 | 53 ±10 | 58 ±9 |
| SLP | 46 ±10 | 47 ±6 | 53 ±8 | 57 ±8 |
| TEX | 32 ±10 | 45 ±5 | 51 ±8 | 57 ±9 |

ANOVA analysis showed no significant differences in all experimental salinities (60 $gL^{-1}$ p=0.052; 80 $gL^{-1}$ p=0.588, 100 $gL^{-1}$= 0.424; 120 $gL^{-1}$= 0.969). Regarding to obtained mean values at each population cultured at different salinity concentration, ANOVA analysis showed significant differences between all populations ($p$<0.001). However, Tukey test showed to CCIEN population significant differences at 120/60, 80, 100 salinities ($p$<0.001). For ZAC population between salinities 60/100,120 ($p$<0.001), for SLP population at 60/120 (p=0.022) salinity and TEX population at 60/80,100,120 and 120/80 salinities ($p$<0.001).
Two-ways ANOVA analysis showed significant differences ($p$<0.001). Salinity variable had the highest weight value of significance with 37.78%, population variable with only 2.64% and the interaction between salinity/population with 3.73% of significant weight.

**Cysts produced by female**
Table 6 show mean values of cysts produced per female in all experimental salinities. Salinities of 60 and 80 $gL^{-1}$ did not shown cysts production in all populations. The lowest value was 54±5 with CCIEN population at 100 $gL^{-1}$. The highest mean value was for TEX population with 65±3 at 120 $gL^{-1}$ and 65±4 for SLP population at 100 $gL^{-1}$ salinity concentrations.

**Table 6:** Mean values (±S.D.) of cysts production per female of Inland waters *A. franciscana* populations cultured at experimental salinities.

| Populations | Experimental salinities ($gL^{-1}$) | | | |
|---|---|---|---|---|
| | 60 | 80 | 100 | 120 |
| CCIEN | 0 | 0 | 54±5 | 60 ±6 |
| ZAC | 0 | 0 | 57 ±5 | 60 ±5 |
| SLP | 0 | 0 | 65 ±4 | 63 ±7 |
| TEX | 0 | 0 | 57 ±7 | 65 ±3 |

ANOVA analysis did not show significant differences for 100 $gL^{-1}$ salinity (p=0.001), but Tukey test showed that SLP population have significant differences with CCIEN, ZAC and TEX ($p$<0.001). At 120 $gL^{-1}$ salinity, did not show significant differences between populations (p=0.130). With respect values obtained at same population but cultured at different salinities, ANOVA analysis shown significant differences ($p$<0.001). However, Tukey test show to CCIEN no significant differences (p=1.000), for ZAC population to 100/120 (p=0.319) and 60/80 (p=1.000), for SLP population did not show significant differences at 100/120 (p=0.746) and 60/80 (p=1.000). TEX population did not show significant differences at 60/80 salinities (p=1.000).
The two-ways ANOVA shown significant differences between variables ($P$<0.001). The highest weight significance was for population variable (97%). For salinity variable was only 0.18% and for the interaction between salinity/population was 0.36%.

**Reproductive potential**
Table 7 show theoretical reproductive potential values in all experimental salinities. The mean values increase with salinity concentration in all populations. The reproductive potential increase from 161.28 g (60 $L^{-1}$, TEX), to 501.12 g (120 $gL^{-1}$, CCIEN). Cysts biomass increase from 104.65 g (100 $gL^{-1}$, TEX), to 180.40 g (120 $gL^{-1}$, CCIEN) in 21 days of cultured system. The Mexican *A, franciscana* inland waters populations began to produce cysts at 100 $gL^{-1}$ salinity concentrations.

**Table 7:** Theoretical values of reproductive potential of Inland waters *A. franciscana* cultured at different experimental salinities.

| Populations | Culture salinity | Culture beaker: 160 L. Density 1 org $mL^{-1}$. Survival: 30%. | | | |
|---|---|---|---|---|---|
| | | Total nauplii | Calculated biomass (g) | Total cysts | Calculated cysts biomass (g) |
| CCIEN | 60 | 6,552,000 | 196.56 | 0 | 0 |
| | 80 | 9,936,000 | 298.08 | 0 | 0 |
| | 100 | 12,672,000 | 380.16 | 1,129,075,200 | 112.90 |
| | 120 | 16,704,000 | 501.12 | 1,804,032,000 | 180.40 |
| | | | | | |
| ZAC | 60 | 6,552,000 | 196.56 | 0 | 0 |
| | 80 | 10,800,000 | 324 | 0 | 0 |
| | 100 | 13,992,000 | 419.76 | 1,315,947,600 | 131.59 |
| | 120 | 15,312,000 | 459.36 | 1,515,888,000 | 151.58 |
| | | | | | |
| SLP | 60 | 7,728,000 | 231.84 | 0 | 0 |
| | 80 | 10,152,000 | 304.56 | 0 | 0 |
| | 100 | 11,448,000 | 343.44 | 1,004,562,000 | 100.45 |
| | 120 | 15,048,000 | 451.44 | 1,564,239,600 | 156.42 |
| | | | | | |
| TEX | 60 | 5,376,000 | 161.28 | 0 | 0 |
| | 80 | 8,640,000 | 259.20 | 0 | 0 |
| | 100 | 12,240,000 | 367.20 | 1,046,520,000 | 104.65 |
| | 120 | 15,048,000 | 451.44 | 1,613,898,000 | 161.38 |

## Discussion

To make a correct management of inland waters *A. franciscana* populations from Mexico, it is important to know that not only food type variable can modify adult stage or cysts biomass, it should also be considered food quality that was applied in *A. franciscana* culture and it is important to apply mixed diets that contain microalgae and bacteria that allow better growth and maturity female rates and get better nauplii or cysts production [33]. Also, it is important to considered food concentration in culture medium, since this depends nauplii survival and growth until they reach maturity stage and their future reproductive period as adult stage or cysts biomass. One variable which was not considered to make proper *Artemia* sp. culture in laboratory conditions was to know sex proportion in culture medium, because even though it is desirable to have higher female concentration, it is better when male proportion is higher to assure females fertilization to obtain higher nauplii or cysts production [34].

Carbohydrates intake in *Artemia* sp. diet is important to obtain maximum total length and highest values of biomass production. At this aspect, not only external carbohydrates source was important but also need to considered bacteria source from culture medium. These two conditions contribute to nutrient rupture from microalgae source and can be better used because of their transformation by produced bacteria enzymes [35].

Many times, when salinity increase in culture medium, it is not considered density or viscosity increase in culture medium, this condition increase organisms energetic budget to maintain actively swimming, not only to obtain their food, but also oxygen intake to make their physiological functions and in this case, carbohydrates plays an important role. This energetic budget, not considered, can delay growth in cultured organisms to reach adult stage and cause a decrease in oviparous or ovoviviparous reproduction. That is why is important to consider a carbohydrates input with rice or wheat bran or bacteria source. Bacteria source can be obtained by Biofloc system, which is rich of heterotrophic bacteria [35].

It is important to increase a carbon/nitrogen supplement when *Artemia* sp. culture is made in high densities, because it promotes growth, organism's maturation and increase the fecundity values [36]. These authors used pork and tapioca composed to increase C/N relation and they observed that cysts production increased 2.8 kg (control test) to 9.96 kg (wet weight $ha^{-1}$). Incorporation of adequate fertilizer source, improve not only microalgae production, but also the growth of heterotrophic bacteria; this extra contribution of energy source, allow that biological activities under adverse physical-chemical conditions, can be carried out properly. This C/N relation (20:1), can increase cysts production per female in 24 to 90 (120 $m^2$ pond), and cysts production was 28 to 38 kg (wet weight) [37]. If obtained information in this study is extrapolated to that area, it would be obtained a cysts production of 5.00 to 8.62 kg $month^{-1}$.

Also, it is important to considered nauplii density inoculation in culture medium [38]. When 3 to 5 million of nauplii $m^2$ were inoculated, biomass (adult stage) production was 5 kg 1,000 $m^2$ $day^{-1}$ and cyst production of 2 kg 1,000 $m^2$ $month^{-1}$. Unlike this study results, when were extrapolated to that area, was obtained 2.14 to 6.65 kg $day^{-1}$ (biomass) and 41.69 to 71.87 kg $month^{-1}$ of cysts.

It is important to mention that obtained results in reproductive potential studies (biomass and cysts production), cannot agree with reproductive potential estimated in specific habitat or physicochemical condition, because can be influenced for multi variable conditions, and *Artemia* sp. populations replay different from each variable like salinity, oxygen concentration, organism densities, type of food and density applied [9]. Their results obtained 34 cysts $female^{-1}$ at 80 $gL^{-1}$ salinity and 15 to 127 cysts $female^{-1}$ at 120 $gL^{-1}$, unlike findings in this study where at 80 $gL^{-1}$ salinity, populations did not produce cysts, meanwhile at 100 and 120 $gL^{-1}$ salinities, quantity were 54-65 cysts $female^{-1}$.

Another important variable to produce cysts was photoperiod, mostly when culture medium has most hours in darkness at >25 °C [39]. Lowest temperature culture conditions, with continuous light decrease cysts production and stimulate ovoviviparous condition, that is why in this study nauplii production was maintained during all experiment, almost at 100 and 120 $gL^{-1}$ salinities. Food and oxygen levels were not critical variables to determined oviparous condition, but they are important for growth and reproduction of *Artemia* sp. populations [39].

Nauplii and cysts production are related with light intensity [40]. Reproduction pattern can be modified by light type and their intensity. These authors mentioned that at low light intensity, oviparous condition increase in culture medium (57.92% for 0 luxe; 22.65% 5000 luxe). But with respect to their study with female organisms of *A. urmiana*, they observed that number of offspring oscillate between 935 nauplii and 685 cysts up 100 luxe, meanwhile below that intensity it decrease to 234 nauplii and 217 cysts. These authors also mentioned that when *Artemia* sp. culture medium was exposed to 2000 to 5000 luxe increase nauplii and cysts production because population organisms showed higher swimming activity and higher gregarious behavior, which induced to reproduction activity.

In other studies [41, 42], were mentioned that cysts production began at salinity up to 95 $gL^{-1}$, according with this experiment, because below that salt concentration, all population did not produce cysts. At same time, it is important to know that pond or beaker depth induce oviparous condition in *Artemia* sp. populations, because cysts production decrease below 40 cm depth.

*Artemia* biomass production of 15.72 $gL^{-1}$ can obtained after 15 culture days, when 10 nauplii $mL^{-1}$ in 1.5 L beakers were inoculated [43], unlike with was obtained in this study with 161.28-501.12 g (160$L^{-1}$). Regarding to the obtained in culture beakers of 700 L [44] with 26.45 to 33.86 g of cysts and 813.6 a 1226.7 g of biomass in 38 culture days. In this study were obtained 705.6 to 2,192 g of biomass in 21 culture days (values extrapolated to 700 L). When *A. franciscana* specie was cultured at 100 $gL^{-1}$ [45], it was obtained 162 cysts per 40 females, at 120 $gL^{-1}$ 196 cysts per 40 females and in 140 $gL^{-1}$ salinity culture medium there are no data, because population died. Unlike this study, that female organisms produce 2,160 (100 $gL^{-1}$) to 2,600 (120 $gL^{-1}$) per 40 females.

Finally, biological implications for these results allow to make better management of natural habitat *Artemia* sp. populations, not only for specie conservation, but also for their commercial exploitation management, maybe not complete, biomass and cysts demand to aquaculture or aquarist industries in Mexico, but must be able to supply at local state country level.

## Conclusion

These results show that is possible to make laboratory management of *A. franciscana* Mexican populations to obtain

cyst and adult stage biomass production, which can be used as food source to fish and crustacean growth, reproduction, or survival experiments.

**References**


1. Williams WD, Geddes MC. Anostracans from Australians salt lakes, with particular references to a comparison of *Parartemia* and *Artemia*. In: Browne RA, Sorgeloos P, Trotman CNA (eds.). *Artemia* Biology, CRC Press, Boca Raton, Florida, USA. 1991, 384, 351-368.
2. Browne RA, Wanigasekera G. Combined effects of salinity and temperature on survival and reproduction of five species of *Artemia*. Journal of Experimental Marine Biology and Ecology. 2000; 244(1):29-44.
3. Vanhaecke P, Siddal SE Sorgeloos P. XXII. Combined effects of temperature and salinity on the survival of *Artemia* of various geographical origin. International study on *Artemia*. Journal of Experimental Marine Biology and Ecology. 1987; 98:167-183.
4. Van Stappen G, Zoogeography. In: Abatzopoulos TJ, Beardmore JA, Clegg JS, Sorgeloos P. (eds.). *Artemia*: Basic and Applied Biology: 171-224. (Kluwer Academic Publishers, Dordrecht. The Netherlands), 2002, 286.
5. Abatzopoulos TJ, Agh N, Van Stappen G, Razavi-Rouhani SM, Sorgeloos P. *Artemia* sites in Iran. Journal of the Marine Biological Association of the United Kingdom. 2006; 86:229-307.
6. Post FJ, Youssef NN. A prokaryotic intracellular symbiont of the Great Salt Lake brine shrimp *Artemia salina* (L.). Canadian Journal of Microbiology. 1977; 23:1232-1236.
7. Mayer RJ. Morphology and biometry of three populations of *Artemia* (Branchiopoda: Anostraca) from the Dominican Republic and Puerto Rico. Hydrobiologia. 2002; 486:29-38.
8. Persoone G, Sorgeloos P. General aspects of the ecology and biogeography of *Artemia*. In: Persoone G, Sorgeloos P, Roels O, Jaspers E. (eds). The Brine Shrimp *Artemia*, Vol. 3. Ecology, Culturing, Use in Aquaculture. Universa Press, Wetteren, Belgium, 1980, 3-24.
9. Camargo WN, Ely JS, Duran-Cobo GM, Sorgeloos P. Influence of Some Physicochemical Parameters on *Artemia* Biomass and Cyst Production in Some Thalassohaline Aquatic Environments in the Colombian Caribbean. Journal of the World Aquaculture Society. 2004; 35(2):274-283.
10. Castro BT, Malpica SA, Castro JM, Castro GM, De Lara AR. Environmental and biological characteristics of *Artemia* ecosystems in México: and updated review. In: Munawar, Lawrence, Munawar and Malley (eds) Aquatic Ecosystems of México. Status and scope. Backhuys Publishers, Leiden, The Netherlands, 2000, 191-202.
11. Gallardo C, Castro J. Reproduction and genetics of mexican *Artemia*. In: Sorgeloos P, Bengtson D, Decleir W, Jaspers E. (Eds.) *Artemia* research and its applications. Morphology, genetics, strain characterization, toxicology, Universa Press, Wetteren, Belgium. 1987; 1, 541, 249-253.
12. Castro MG, Castro MJ, De Lara AR, Gallardo RC, Salazar Y, Sánchez B. Características biométricas generales, modo de reproducción y aislamiento reproductivo de la población silvestre de *Artemia* sp. de Salinas de Hidalgo, San Luis Potosí. Revista Latinoamericana de Acuicultura. 1989; 39:18-25.
13. Castro BT, Gallardo RC, Castro MJ, Malpica SA. Importancia del tamaño de los quistes descapsulados y de nauplios de *Artemia franciscana* (Texcoco), para la alimentación de organismos acuáticos. Revista Investigaciones Marinas. 1994; 18(2):150-154.
14. Castro T, Castro G, Castro J, Malpica SA, De Lara R. Morphometric characteristics and quality of *Artemia* sp. cysts (Crustacea: Anostraca), living in sulphated waters in Coahuila, Mexico. Ciencias Marinas. 1997; 23(4):491-503.
15. Castro BT, Castro MJ, López CJ, Miramontes B, Malpica SA, Castro MG *et al.* Primeros estudios del branquiópodo *Artemia* en las salinas Real de las Salinas, Campeche. Revista Oceanología. 1998; 17(3):10-20.
16. Castro MJ, Malpica SA, Castro MG, Castro BT, De Lara AR. Variación del patrón reproductivo de dos poblaciones mexicanas de *Artemia franciscana* (Branchiopoda: Anostraca) y su comparación con la población de Bahía de San Francisco, California. Revista Biología Tropical. 1999; 47:99-104.
17. Castro TB, Castro MJ, Gajardo G, Vera V, Gallegos LMA. Manuscript A bio-ecological and distributional database on the brine shrimp Artemia from Latin American and Caribbean sites. Hidrobiología. 2002; 42:199-209.
18. Castro MJ, Castro BT, Arredondo FJI, Castro MG, De Lara AR, Malpica SA. Crossbreeding studies in seven *Artemia franciscana* strains from Mexico. Journal of Biological Research. 2004; 2:35-41.
19. Castro T, Gajardo G, Castro J, Castro G. A biometric and ecologic comparison between *Artemia* from Mexico and Chile. Saline Systems. 2006a; 2(13):1-10.
20. Castro JM, Castro TB, Sánchez J, Castro GM, Castro A, Zaragoza J *et al.* Cysts and nauplii biometry characteristics of seven *Artemia franciscana* (Kellog, 1906) populations from Mexico. Revista de Biología Marina y Oceanografía. 2006b; 41(2):187-193.
21. Castro MJ, Monroy DMC, Castro MG, Castro BT, De Lara AR. Los estudios morfométricos y de aislamiento reproductivo, como herramientas para determinar características fenotípicas en poblaciones del género *Artemia* en México. Revista Contactos. 2006c; 59(1):49-53.
22. Castro MJ, Castro MG, De Lara AR, Monroy DMC, Orozco RDI, Torrez RJA. 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). Revista Digital Ebios. 2013a; 2(4):32-41.
23. Castro MJ, Castro MG, Danae de O, Roberta B. Biometric comparison of four populations of *Artemia franciscana* (Kellog, 1906) (crustacea: Anostraca) from México and Perú. International Journal of *Artemia* Biology. 2013b; 3(1):3-11.
24. Castro MJ, Castro MG, Castañeda TH, Monroy DMC, Ocampo CJ, Cruz CI *et al.* Salinity effects on growth of four *Artemia franciscana* (Kellog, 1906) populations, cultured in laboratory conditions from Yucatán Peninsula. Journal of Ecology and the Natural Environment. 2015; 7(7):210-217.
25. Castro MJ, Castro MG, Roberta B, Danae de OC. Salinity effects of the reproductive patterns of five coastal Pacific *Artemia franciscana* strains from México. International

Journal of Science and Knlowdege. 2013c; 2(1):26-33.
26. Velasco SJ, Retana ODA, Castro MJ, Castro MG, Monroy DMC, Ocampo CJA *et al.* Salinity effect on reproductive potential of four *Artemia franciscana* (Kellog, 1906) Mexican populations grown in laboratory. International Journal of Fisheries and Aquatic studies. Journal of Fisheries and Aquatic studies. 2016; 4(3):247-253.
27. Bengston DA, Léger P, Sorgeloos P. Use of *Artemia* as a food source for aquaculture. In: Browne RA, P Sorgeloos and CNA Trotman. (eds.), *Artemia* Biology. (CRC Press, Boca Raton, Florida. USA). 1991, 255-285.
28. Dhont J, Sorgeloos P. Applications of *Artemia*. In: Abatzopoulos TJ, Beardmore JA, Clegg JS, Sorgeloos P. (eds), *Artemia*: Basic and Applied Biology. Kluwer Academic Publishers, Dordrecht, The Netherlands. 2002, 286, 251-277.
29. El-Bermawi N, Baxevanis AD, Abatzopoulos TJ, Van Stappen G, Sorgeloos P. Salinity effects on survival, growth and morphometry of four Egyptian *Artemia* populations (International Study on *Artemia*. LCVII). Hydrobiologia. 2004; 523:175-188.
30. Castro MG, Malpica SA, De Lara RA, Castro MJ, Castro BT. Técnicas de cultivo de especies planctónicas e invertebrados útiles para la acuicultura. Serie Académicos. CBS. No.37. UAM-Xochimilco, 2010, 65.
31. Agh N, Van Stappen G, Bossier P, Sepehri H, Lofti V, Rouhani SMR *et al.* Effects of salinity on survival, growth, reproductive and life span characteristics of *Artemia* populations from Urmia Lake and neighboring lagoons. Pakistan Journal of Biological Sciences. 2008; 11:164-172.
32. Tatsuoka MM. Selected topics in advanced statistics. An Elementary Approach. No.6. Discriminant Analysis. Ed. IPAT. Illinois, EUA, 1970, 57.
33. Kachigan SK. Multivariate statistical analysis. A conceptual introduction. Radius Press, New York, USA, 1991, 283.
34. Wayne WA, Maciej-Gliwicz Z. Limnological control of brine shrimp population dynamics and cyst production in the Great Salt Lake, Utah. Hydrobiologia. 2001; 466:119-132.
35. Baert P, Nguyen TNA, Burch A, Sorgeloos P. The use of *Artemia* biomass sampling to predict cyst yields in culture ponds. Hydrobiologia. 2002; 477:149-153.
36. Toi HT, Boeckx P, Sorgeloos P, Bossier P, Van Stappen G. Bacteria contribute to *Artemia* nutrition in algae-limited conditions: A laboratory study, Aquaculture. 2013; 388(391):1-7.
37. Sui LY, Wang J, Nguyen VH, Sorgeloos P, Bossier P, Van Stappen G. Increased carbon and nitrogen supplementation in *Artemia* culture ponds results in higher cyst yields. Aquaculture International. 2013; 21:1343-1354.
38. Ronald L, Van Stappen G, Van Hoa N, Sorgeloos P. Effect of carbon/nitrogen ratio manipulation in feed supplements on *Artemia* production and water quality in solar salt ponds in the Mekong Delta, Vietnam. Aquaculture Research. 2014; 45:1906-1912.
39. Zmora O, Avital E, Gordin H. Results of an attempt for mass production of *Artemia* in extensive ponds. Aquaculture. 2002; 213:395-400.
40. Nambu Z, Tanaka S, Nambu F. Influence of Photoperiod and Temperature on Reproductive Mode in the Brine Shrimp, *Artemia franciscana*. Journal of Experimental Zoology. 2004; 301A:542-546.
41. Asil SM, Fereidouni AE, Ouraji H, Khalili KJ. Effects of different light intensities on growth, survival, reproductive and life span characteristics of *Artemia urmiana* (Günther 1890). Aquaculture Research. 2013; 44:554-566.
42. Singh K, Khandagale PA. Optimal water characteristics for commercial production of cysts of the brine shrimp, *Artemia* in salt ponds. Crustaceana. 2006; 79(8):913-923.
43. Briski E, Van Stappen G, Bossier P, Sorgeloos P. Laboratory production of early hatching *Artemia* sp. cysts by selection. Aquaculture. 2008; 282:19-25.
44. Maldonado-Montiel TDJ, Rodriguez-Canche LG. Biomass production and nutritional value of *Artemia* sp (Anostraca: Artemiidae) in Campeche, Mexico. Revista de Biología Tropical. 2005; 53(3-4):447-454.
45. Rajamani M, Kumar S, Maharajan A, Vimaia S. Production of cysts and biomass of the exotic species of brine shrimp *Artemia franciscana* (Kellog) in out-door culture system. Indian Journal of Fisheries. 2005; 52(1):61-71.
46. Moraga P, Ávila PR, Vilaxa OA. Salinidad y temperatura óptimas para reproducción ovípara y desarrollo de *Artemia franciscana*. IDESIA. 2015; 33(1):85-92.