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Hidrological and population studies on *Artemia franciscana* in Yavaros, Sonora, México

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Abstract: The climate in the Yavaros area is very suitable for the evaporation of sea water. It is desertic and the driest season is the spring. The annual ranges are: air temperature 15-30°C, rainfall 300-400 mm and evaporation 1,500-2,000 mm.

Each year, from June to January, the Yavaros salinas form a natural breeding habitat for *Artemia*.

Daytime samples taken in September, January and April showed the following ranges: dissolved oxygen 0.1 to 4.0 mL/L, temperature 22 to 42°C. salinity 66 to 355‰, phyjtoplankton 15 x 10^3 to 56 x 10^6 c/L and zooplankton 10.·. to 6.8 x 10^3 organisms/50L L. *Dunaliella, Nitzchia* and *Oscilatoria* were the most abundant in the phytoplankto. *Artemia* occurred in all of the 15 salinas in January and in most of them in September and April. Copepods were common in some samples.

The commercial harvesting of *Artemia cysts* in the Yavaros salinas is suggested.

The genus *Artemia* is particularly important in aquaculture as food for fish and crustacean larvae. Early in the century, Seale (1933) and Rollefsen (1939) had a very significant progress in hatchery aquaculture using 0.4 mm nauplii larvae of *Artemia,* which is an excellent food source for newborn fish larvae. *Artemia* has also been found to be a suitable food for the most diversified groups of aquatic organisms. Kinne (1977) mentioned that more than 85% of the marine animals cultivated thus far have been offered *Artemia salina* as food. Gabaudan *et al.* (1980) also demostrated that dried brine shrimp has been used succesfully as a protein source.

The world distribution of species of *Artemia* is discussed by Persoone & Sorgeloos (1980). *Artemia* is found in America from Canada to Peru and Argentina. In Mexico it is found in 14 places, mainly on the Pacific coast (Castro *et al,* 1985a). The strain from Yavaros was determined as *Artemia franciscana* (Kellog) (Martínez 1970).

Few Mexican populations of *Artemia* have been exploited. Castro *et al.* (1985b) for example, report an experimental *Artemia* production project near Mexico City. Also, some local people in Mexico City own small sea water reservoirs built to grow *Artemia* for selling in aquarium shops.

Even though there are natural *Artemia* populations in Mexico, there have been few studies of their habitats.

The aims of the present work are to evaluate the following parametres: oxygen, temperature, salinity, and the densities of *Artemia* and associated plankton. A preliminary assesment of the importance of the area as a potential source of *Artemia* cysts is also included.

STUDY AREA

The Yavaros Lagoon is situated in the Gulf of California, on the coast of Sonora State, Mexico, 26 40' N, 109 35' W. The salinas are at the south end of the Laggon (Fig. 1).

The climate in this area is desertic and the driest season is in spring, designated "BW", according to the Koppen system. The highest mean air temperature is 30°C in July and August (summer), and the lowest is 15°C in December-February (winter).

The predominat winds come from the southeast in summer, the rest of the year

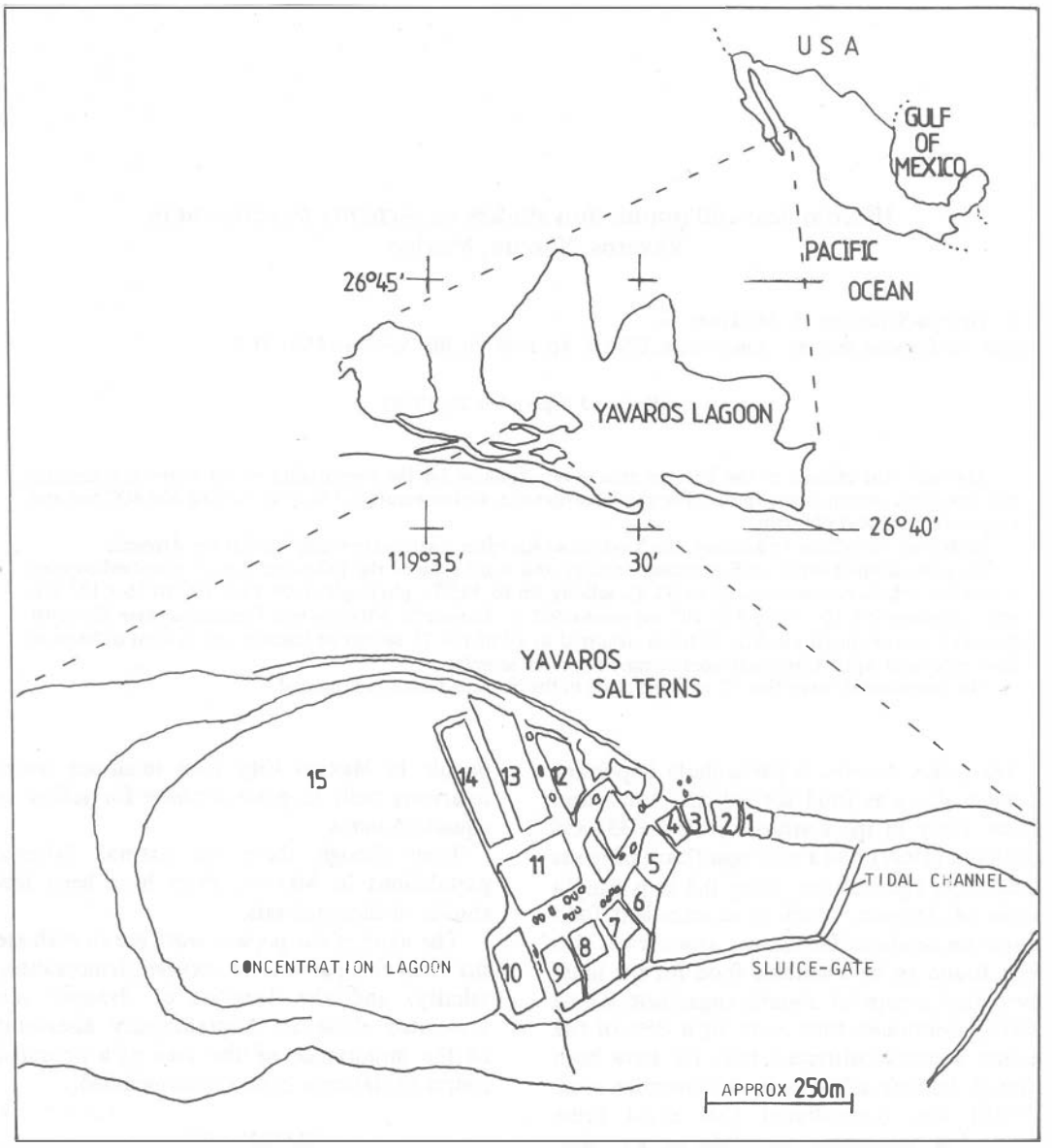

Figure 1. Area of study in Yavaros Lagoon.

come from the northwest. There are infrequent storms of gale force.

The rainfall occurs mainly in July-September, and for the rest of the year there is practically no rain in the littoral zone. The annual rainfall is 300-400 mm and the annual evaporation is 1,500-2,000 mm (Mexican meteorological system). Thus, conditions are extremely suitable for the production of salt by the evaporation of sea water.

Personal observations showed that once a year in June, in order to exploit salt, the Yavaros salinas are connected to the Yavaros Lagoon by a sluice-gate mechanism which permits the sea water to flow through a channel into the concentration lagoon and to the salinas where the water evaporates. The Yavaros salinas measure about 7 ha and have a depth of 40 cm (roughly 28,000 m^3). When the salterns are filled with sea water, the *Artemia* cysts left in

TABLE 1

Parameters of plankton and hydrology from September (1969) samples.
Abbreviations for stages of Artemia*: a = adults and juveniles, c = cysts, mn = metanauplii, n = nauplii*

		Phytoplankton						Zooplankton		
Saltern	Time hrs.	Cels/L	Composition	%	Density °Be	Salinity o/oo	Temp. °C	nos 50 L	Composition	%
1	1200	700,000	*Oscilatoria*	100	20	217	38.0	201	*Artemia* n	52
2	1215	400,000	*Dunaliella*	73	20	223	38.0	105	Copepods	45
			Oscilatoria	27					*Artemia* n	36
									Artemia a	10
3	1220	900,000	*Oscilatoria*	63	20	220	38.0	77	Copepods	50
			Dunaliella	37					*Artemia* n	37
									Artemia a	10
4	1230	655,000	*Oscilatoria*	52	21	253	38.5	10	copepods	100
			cysts	21						
5	1240	22,385,000	*Dunaliella*	93	21	258	38.0	29	copepods	100
			Oscilatoria	6						
			cysts	1						
6	1300	2,470,000	*Dunaliella*	91	21	262	38.5	10	*Artemia* a	100
			Oscilatoria	9						
7	1310	10,160,000	*Dunaliella*	90	23	258	39.0	0		
			Oscilatoria	5						
			cysts	5						
8	1317	195,000	cysts	64	19	209	39.0	29	copepods	65
			Oscilatoria	36					*Artemia*	34
9	1327	125.000	*Dunaliella*	100	16	173	37.2	77	copepods	57
									Artemia a	43
10	1337	1,760,000	*Dunaliella*	100	21	249	39.0	0		
11	1400	6,060,000	*Dunaliella*	62	25	356	42.0	58	copepods	100
			Oscilatoria	33						
			cysts	4						
			Nitzchia	1						
12	1410	500,000	*Oscilatoria*	76	16	175	37.5	10	*Artemia* n	100
			cysts	18						
			Dunaliella	14						
13	1415	2,370,000	*Oscilatoria*	50	17	188	39.0	10	*Artemia* a	100
			Dunaliella	47						
			cysts	2						
			Nitzchia	1						
14	1425	11,440,000	*Dunaliella*	96	19	203	39.0	19	copepods	50
			cysts	4					*Artemia* n	50
15	1350	56,860,000	*Nitzchia*	91	5	66	39.0	2.329		

the area the previous year absorb water. Then they begin their development, and after one or two days they hatch. In about three weeks they complete their biological cycle with egg production. Thus, many generations of *Artemia* appear each year from June to January while the processing of salt occurs.

MATERIAL AND METHODS

Visits to the Yavaros salinas were made in September 1969, January, April 1970, and May 1982. During the first three visits 15 salinas were sampled between 10:00 and 15:00 hrs. 77 samples were taken for oxygen and salinity, and 88 for phytoplankton and zooplankton analysis. During the fourth visit in May 1982 dry cysts were collected by 4 persons on the round edges of the salinas, where the sea water had evaporated. Roughly estimating in less than two hrs, after cleaning there were about 5 L in 100 m^2.

The temperature was measured with a -2 to 51°C thermometer; the salinity with a 0 to 220°/oo Golbert refractometer (water diluted when necessary); the density was measured with a 0 to 31° Be densimeter. In most places where the marine salt is exploited a densimeter is used instead of a salinometer. Both were used in the present work, and the results show that density and sality are related by the following functional regression equation: °Be = 1.3479 + 0.07945 (S °/00), r = 0.938, n = 43. where °Be: Baumè degrees; S°/oo: salinity

Oxygen was processed by the Winkler method (Carpenter 1965). Surface samples of phytoplankton using 30 cc bottles were fixed with potassium iodide and sodium acetate. After 24 hrs. in a 10 cc sedimentation chamber the phytoplankton samples were identified and counted under an Utermöl microscope. The numbers were calculated in cells per litre (c/L).

The zooplankton samples were filtered from a 50 L bucket of water taken from each saltern

TABLE 2

Parameters of plankton and hydrology from January (1970) samples.
Abbreviations for stages of Artemia: *a = adults and juveniles, c = cysts, mn = metanauplii, n = nauplii*

Saltern	Time	Phytoplankton Cells/L	Composition	%	Density °Be	Salinity °/oo	Oxigen ml/L	Temp. °C	Zooplankton nos 50/L	Composition	%
1	1245	170,000	*Dunaliella*	47	13	139	3.17	25.8	6.881	*Artemia* a	54
			Amphora	23						*Artemia* mn	33
			Spirulina subsalsa	12						*Artemia* c	13
			Nitzchia	12							
			cysts	6							
2	1300	15,000	*Dunaliella*	100	15	167	2.01	24.2	0.447	*Artemia* a	70
										Artemia n	15
										Artemia mn	9
										Artemia c	6
3	1335	2,270,000	*Dunaliella*	45	22	253	1.72	24.9	0.396	*Artemia* mn	93
			Anabaenopsis	44						*Artemia* c	7
			Oscilatoria	11							
4	1340	6,360,000	*Dunaliella*	90	23	258	1.51	26.2	0.128	*Artemia* mn	80
			Oscilatoria	7						*Artemia* c	20
			cysts	3							
5 y 6	1400	175,000	*Dunaliela*	37	14	161	1.15	24.0	0.374	*Artemia* a	69
			Nitzchia	20						*Artemia* mn	20
			Amphora	11						*Artemia* c	11
			Navicula	9							
			Schroederia setigera	3							
			cysts	20							
7	1410	2,190,000	*Oscilatoria*	70	10	111	3.74	23.6	0.473	*Artemia* a	75
			Nitzchia	17						*Artemia* mn	16
			Amphora	4						*Artemia* c	9
			Schroederia setigeria	4						*Fabrea salina*	
			cysts	3							
8	1418	650,000	*Dunaliella*	89	15	167	1.44	24.1	0.767	*Artemia* a	43
			Nitzchia	4						*Artemia* n	35
			S. setigera	1						*Artemia* mn	22
			Amphora	1						*Fabrea salina*	
			cysts	4							
9	1425	1,900,000	*Dunaliela*	78	21	249	1.65	25.2	0.364	*Artemia* n	65
			Oscilatoria	21						*Artemia* mn	24
			cysts	1						*Artemia* a	21
10	1445	270,000	*Dunaliella*	92	13	137	2.45	23.5	0.383	*Artemia* n	56
			Amphora	2						*Artemia* mn	15
			Nitzchia	2						*Artemia* c	22
			cysts	2						*Artemia* a	7
11	1505	495,000	*Dunaliella*	96	14	154	0.86	26.1	0.575	*Artemia* n	45
			Nitzchia	4						*Artemia* a	31
12	1530	1,720,000	*Dunaliella*	91	18	197	2.66	26.4	1.869	*Artemia* n	82
			cysts	9						*Artemia* c	15
										Artemia mn	1
										Artemia a	1
13	1108	50,000	*Dunaliella*	100	22	253	1.00	21.9	1.083	*Artemia* n	88
										Artemia c	10
										Artemia mn	1
										Artemia a	1
14	1124	39,200,000	*Dunaliella*	995	21	249	1.44	23.0	1.390	*Artemia* n	76
			cysts	0.5						*Artemia* a	5
										copepods	2
15	1455	1,640,000	*Nitzchia*	88	6	75	4.03	24.8	0.709	*Artemia* a	94
										Artemia n	4
										copepods	2
										Fabrea salina	

with a 180μ mesh net, and fixed with 4-5% formaldehyde solution. The animals were identified and counted as numbers in 50 L.

RESULTS

Results appear in tables 1-3.

The phytoplankton included *Dunaliella*, *Nitzchia* [including *N. longissima* (Brebisson)], *Oscillatoria*, *Anabaenopsis*, *Navicula*, *Schoederia setigera* (Schoder), *Amphora*, *Spirulina* (including *S. subsalsa* Oersted) and various kinds of phytoplankton cysts. The number of cells varied from 15×10^3 c/L to 56×10^6 c/L. *Nitzchia* reached a maximum of 51×10^6 c/L, *Dunaliella* 39×10^6 c/L, and *Oscillatoria* 2×10^6 c/L.

TABLE 3

Parameters of plankton and hydrology from April samples in 1970.
Abbreviations for stages of Artemia*: a = adults and juveniles, c = cysts, mn = metanauplii, n = nauplii*

		Phytoplankton							Zooplankton		
Saltern	Time	Cells/L	Composition	%	Density °Be	Salinity °/oo	Oxigen ml/L	Temp. °C	nos 50/L	Composition	%
1	1005	3'080,000	*Dunaliella*	58	25	294	1.18	28.0	19	*Artemia* n	50
			Nitzchia	3						*Artemia* a	50
			N. longissima	36							
			Oscilatoria cysts	2							
2	1030	3'950.000	*Dunaliella*	57	25	294	1.03	28.0	10	*Artemia* a	100
			N. longissima	38							
			Oscilatoria zoosporas	2 1							
3	1035	690.000	*Dunaliella*	92	27	314	0.59	28.0	10	*Artemia* a	100
			Oscilatoria	8							
4	1045	1'590,000	*Dunaliella* cysts	56 20	25	312	0.73	29.9	0		
			Schroederia	12							
			zoosporas	9							
			N. longissima	1							
			Amphora	1							
5	1100	410,000	*Dunaliella* cysts	68 32	29	338	0.11	28.8	0		
6	1115	235.000	*N. longissima*	91	20	232	1.47	26.7	0		
			Dunaliella cysts	29 3							
7	1130	1'175,000	*N. longissima*	91	14	152	2.21	28.0	77	*Artemia* a	20
			Dunaliella	3						*Artemia* c	80
			Amphora sp	2							
			Spirulina subsalsa	2							
			cysts	1							
			Nitxchia	5							
8	1135	25,000	*N. longissima*	100	19	147	1.77	30.5	2377	*Artemia* a	31
										Artemia c	26
										Artemia n	23
										Artemia mn	20
9	1200	530,000	*Dunaliella*	51	27	312	1.03	29.0	29	*Artemia* n	66
			Oscilatoria	49						*Artemia* c	34
10	1205	45.000	*N. longissima*	100	16	281	1.92	29.0	29	*Artemia* n	66
										Artemia c	34
11	1220	330.000	*N. longissima*	79	18	206	1.47	32.0	69	*Artemia* c	65
			Dunaliella cysts	20 1						*Artemia* a	45
12	1230	310.000	*Dunaliella*	50	25	299	0.73	34.4	123	*Artemia* c	56
			cysts	20						*Artemia* n	18
			Oscilatoria	13						*Artemia* a	18
										Artemia mn	8
13	1240	235,000	*Oscilatoria*	51	26	309	1.03	32.3	15	*Artemia* n	50
			Dunaliella	44						*Artemia* c	50
			Nitxchia								
14	1235	470,000	*Dunaliella*	70	25	299	0.88	34.5	0		
			Oscilatoria	22							
			cysts	8							
15	1310	850,000	*N. longissima*	97	9	147	2.81	30.0	15	*Artemia* c	50
			S. subsalsa	1						copepods	50
			Nitzchia	1							
			cysts	1							

The zooplancton included *Artemia,* copepods, rotifers, nematodes, and the protozoan *Fabrea salina* Henneguy. Adults of *Artemia* reached a maximum density in January (saltern 1) with about 74/L. *Artemia* cysts were recorded in most of the salterns in both January and April. When *Artemia were* registered in the samples they varied as follows: cysts 10 to 626/50 L, nauplii 10 to 1,543/50 L, metanauplii 8 to 2,185/50 L, and adults 10 to 3,757/50 L. The lowest values in saltern 10 (with about 240 m^3 of water) were about 48,000 *Artemia* nauplii in April and 1'056,000 in January. The highest values in saltern 1 with 2,400 m^3 were about 45'072,000 cysts, 104'880,000 metanauplii and 180'336,000 adults in January. Cysts collected since May 1982 in September 1986 hatched in an aquarium with a rough estimate of more than 60% survival.

The temperature recorded varied from 22 to 42°C and *Artemia* was sampled from 22 to 39 °C.

The salinity varied from 66 to 356°/oo, and *Artemia* was recorded between 66-314°/oo (6.6-26.3 °Be). Although it is possible that the salinity is lower (around 37 0/00)when the sluicegate is opened.

The oxygen concentration varied from 0.1 mL/L to 4.0 mL/L, with an average of 1.6 mL/L, although *Artemia* was found only between 0.6 mL/L and 4.0 mL/L.

It seems that the Yavaros salinas have not changed in 20 years in their general aspects. The production of salt has been the same (486 m. t. per ha) for several years.

DISCUSSION

The plankton associated with *Artemia* was similar to that found in Alviso Salt Ponds by Carpeland (1957), but the temperature was higher (22-42°C) than in Alviso (8-33°C) and than the temperature reported by Peirse (1914) in the Salton Sea (11-34°C). It is similar to that found in Thailand (around 40 C, Vos & Tansutapanit 1979). High temperatures may relate to the short generation time as found by Carpeland (1957) and confirmed by Primavera *et al.* (1980). The hatching rate is faster (Sorgeloos 1980) and the moulting period is reduced (Hentschel 1980).

The salinity of 340 0/00 was comparable to that reported for the Great Lake, Utah (Post & Youssef 1977). The range was 66-355°/oo in Yavaros (in Alviso: 5-304°/oo, in the Salton Sea: 14-170°/oo).

Similar concentrations (25-100/L) of adult *Artemia* were found in a Long Island Saline (Davies 1978), which are lower than in Mono Lake, California (400/L) (Lenz 1980). The figures may not be directly comparable owing to the very patchy distribution of the shrimp.

In countries like Mexico which have an extense littoral zone with many marine lagoons, tidal flats, and appropriate weather conditions, it is easy to build salinas and inoculate them with *Artemia* cysts. In these one could produce both salt and *Artemia* which could be harvested at any development stage.

Persoone & Sorgeloos (1980) estimated that a good *Artemia* biotope produces 10 to 20 kg of cysts per ha per season. In the Alviso Salt Ponds, Carpeland (1957) obtained a maximum of 13 g/m^3 (dry weight) of *Artemia* and estimated a 56 lbs/acre/year harvest (=62.8 kg/ha), besides the production of salt. A rough estimate in Yavaros salinas was 5 cm^3 of cysts/m^2 (dry weight) ($\approx$ 1.45 g/m^2).

In the Yavaros salinas the production of salt is about 486 mt. per ha. The production of *Artemia* which has not been exploited yet. With an adecuate use, the exploitation could be significant.

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RESUMEN

El clima en el área de Yavaros es adecuado para la evaporación de agua marina. Es desértico y la estación más seca es la primavera. El ámbito anual de la temperatura es de 15-30°C, la precipitación es de 300-400 mm y la evaporación es de 1,500-2,000 mm. Cada año de junio a enero las salinas de Yavaros forman un habitat natural de reproducción de *Artemia*.

Se muestreó durante el día en septiembre, enero y abril, resultando los siguientes ámbitos: oxígeno disuelto de 0.1 a 4.0 mL/L, temperatura de 22 a 42°C, salinidad de 66 a 355°/oo, fitoplancton de 15x10^3 to 56x10^6 c/L, zooplancton de 10° a 6.8x10^3 organismos/50 L. *Dunaliella, Nitzchia* y *Oscillatoria* fueron las más abundantes en el fitoplancton. *Artemia* apareció en las 15 salinas, en la mayoría de ellas en septiembre y abril, y podría cultivarse comercialmente. Los copépodos fueron abundantes en algunas muestras.

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