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Zygogenetic and parthenogenetic *Artemia* in Cadiz sea-side salterns

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Abstract: Two different forms of *Artemia* coexist in salterns on the Atlantic shore of South West Spain near Cadiz: a bisexual or zygogenetic strain and a parthenogenetic strain. The relative frequency of the 2 types may vary with the season and is governed by unknown ecological factors. Laboratory experiments and observations made on salterns suggest that the bisexual and parthenogenetic forms vary in frequency during the year according to temperature and salinity changes. From late spring to late autumn, parthenogenetic forms are dominant. After the November rains, bisexual or zygogenetic individuals appear, competing with the parthenogenetic form and becoming more numerous during winter. A marked ecological advantage exists for the bisexual strain in low temperatures and salinities; parthenogenetic strain(s) are better adapted to higher temperatures and salinities. Nutrition, sexual interaction and differential reproductive ability of both forms require further investigation.

INTRODUCTION

The 140 salterns on the Cadiz coast together cover an area of 8000 ha, mainly a wide plain of quaternary silt built on Pliocene layers and extending between Cadiz and San Fernando (Gavala, 1927 and Clavijo, 1960, both cited in Arias, 1978). Salt extracting has been terminated in 80 % of the salterns. The total amount of salt currently extracted scarcely attains 90,000 metric tons yr^{-1}. The only persisting economic activity is concerned with aquaculture: with finfish and other marine species which enter the 'esteros' spontaneously (Arias, 1978).

Vigorous development of autochthonous brine shrimp populations throughout the year, together with mild weather and preexisting salterns, provides a rationale for brine shrimp exploitation and for aquaculture development.

MATERIAL AND METHODS

Fourteen samples of cysts, kindly provided by Dr. E. Pascual (Instituto de Investigaciones Pesqueras-Cádiz), were collected in 9 different salterns, located between San Fernando and Cadiz Bay, over several months during 1978 and 1979. Subsamples of these cysts were hatched in 500 cm^3 glass jars, filled with 36 ‰ S sea water, and vigorously aerated at 25 °C. Nauplii were carefully removed from hatching debris, by differential buoyancy in brine, and through positive phototaxis. They were placed in a batch culture system. Several 10-l cylindrical transparent containers with adequate aeration and with the same salinity and temperature conditions as used for hatching, were employed. A suspension of the alga *Tetraselmis* sp. was used as food. Batch cultures were kept until brine shrimps attained adulthood and reproductive maturity.

Adult brine shrimp were removed from the batch culture, lightly anaesthetized with a few drops of water-chloroform suspension and sorted by sex. Females were sorted once again as to zygogenetic or parthenogenetic origin, based on their brood pouch or ovisac shape (Amat, 1979, 1980a, b). Individuals in mating couples were detached to check whether the females were zygogenetic or parthenogenetic. It is assumed that males are exclusively from the bisexual or zygogenetic strain.

RESULTS

The 14 samples studied are specified in Table 1. Most samples give rise to both bisexual and parthenogenetic individuals in varying percentages, except those from the salterns 'Consulado' (February, 1979) and 'San Juan Bautista' (September, 1979), from which only parthenogenetic females were obtained (Fig. 1).

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Table 1. Sampled salterns, cyst collecting dates and experimental population composition for each sample, expressed as percentage of the total number of individuals observed

Saltern	Cyst collection date	Parthenogenetic females (%)	Zygogenetic females (%)	Zygogenetic males (%)	Total no. of individuals
Barbanera	April 1978	1	47	52	1196
San Juan Bta.	July 1978	98.50	0.75	0.75	818
San Pablo	September 1978	79.50	10.50	10	1332
La Chica	September 1978	74.80	12.90	12.30	1614
Consulado	February 1979	100	–	–	914
Santiago	March 1979	71.90	13.50	14.60	783
San Cayetano	March 1979	44.50	26.50	29	*1576
San Cayetano	March 1979	29.60	34.30	36	**1680
Santa Barbara	April 1979	0.20	51.70	48.10	1221
El Molino	April 1979	8	51	41	1485
San Juan Bta.	May 1979	2.60	60	37.40	915
San Juan Bta.	June 1979	3.50	50	46.50	1527
San Juan Bta.	July 1979	75	13.50	11.50	1602
San Juan Bta.	September 1979	100	–	–	1285

* 74 % legitimate matings 26 % illegitimate matings
** 85 % legitimate matings, 15 % illegitimate matings

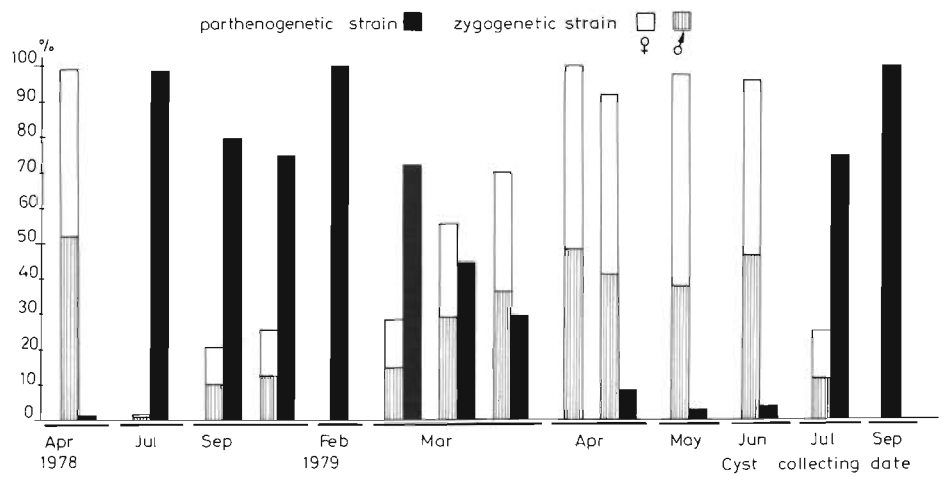

Fig. 1. Distribution of experimental population composition according to Table 1

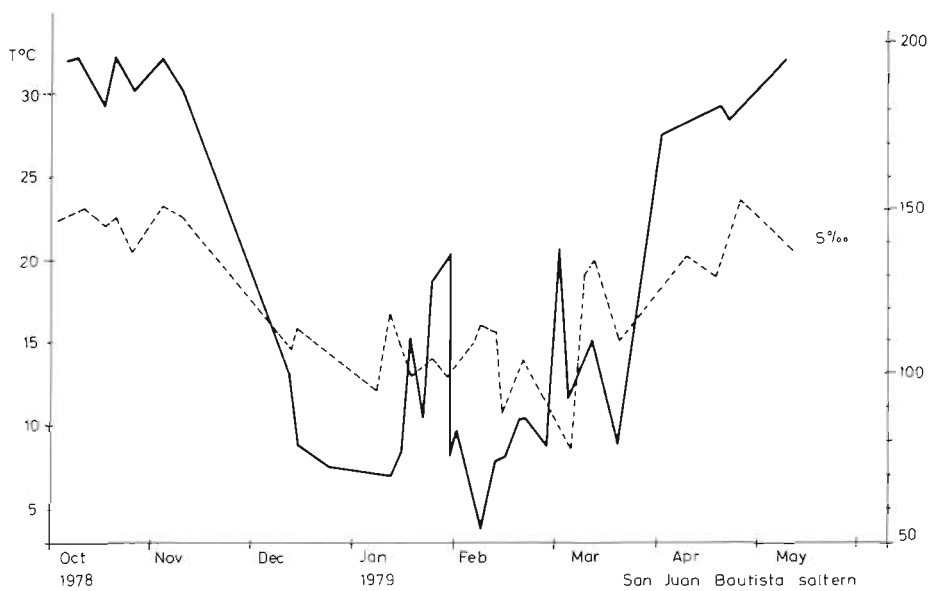

Fig. 2. Temperature and salinity recorded in 'San Juan Bautista' saltern ponds from October 1978 to May 1979. (After Sarasquete, 1979)

Mating couples were also observed, mostly of a legitimate type, i.e. with male and female both from the bisexual strain. However, in the 2 'San Cayetano' saltern (March, 1979) samples, substantial percentages of illegitimate matings, formed by parthenogenetic females and zygogenetical males were seen. Fig. 2 shows the temperature and salinity data, recorded in 'San Juan Bautista' saltern during 1978 and 1979.

DISCUSSION AND CONCLUSIONS

From earlier observations (Versichele, 1978; Amat, 1979; Sarasquete, 1979) it can be concluded that during summer and autumn *Artemia* populations are almost exclusively parthenogenetic, while during winter and spring, they are usually either bisexual or mixed bisexual and parthenogenetic.

The phenomenon of seasonal changes of bisexuality and parthenogenesis has not so far been studied in a systematic way, except by Sarasquete (1979). The present research aims to relate the annual cyclic population turnover to temperature and salinity.

The experiments described here, carried out on cyst samples, do not reflect the populations in the salterns at the time when cysts were collected, but rather those present during the month prior to cyst collection. In principle, there are difficulties in pooling data on the incidence of parthenogenetic and bisexual forms from different salterns, because there may be different stocks present in each saltern; however, this seems improbable.

From experimental results as well as temperature and salinity variations (Fig. 2) recorded in the natural environment, it is possible to infer a relationship between the 2 ecological factors and the composition of natural populations. Zygogenetic individuals dominate in samples collected during March, April, May and June; these would have been offspring from females in the natural populations which developed from January to April/May, i.e. at a time when temperatures and salinities are lowest. On the other hand, laboratory populations from cysts collected between July and February have a preponderance of parthenogenetic females, derived from females developing from June to November, i.e. in summer and autumn, when temperatures and salinities in the salterns attain maximum values.

This conclusion receives further support from results of inoculation experiments with the same strains recently performed by the author in the saltern 'La Trinidad', river Ebro delta, province of Tarragona, Spain. The individuals of the bisexual strain tolerate temperatures as low as 8 °C from February onwards. In contrast, the inoculation of 2 parthenogenetic strains, diploid and tetraploid, failed completely under the same temperature conditions in inoculated ponds. Inoculation of parthenogenetic strains was successful only when it started in late March, with temperatures ranging between 19 and 20 °C.

I conclude that the 2 forms are different: the bisexual or zygogenetic: strain represents a 'cold form', the parthenogenetic strain(s) a 'warm form'. Future research should take into account additional factors, such as nutrition (microalgae versus particulate organic matter; Stefani, 1961), or reproductive competition (erroneous matings between parthenogenetic females and zygogenetical males; Browne, 1980).

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