

149

The Brine Shrimp, *Artemia salina* & Its Culture Potential in India

JOSEPH P. ROYAN, M. V. M. WAFAR & SUMITRA-VIJAYARAGHAVAN

National Institute of Oceanography, Dona Paula 403004, Goa

Received 12 December 1977; revised received 12 April 1978

Studies on a natural population of *A. salina* in the salt pans of Tuticorin indicate several characters differentiating the Indian strain from other strains. The Indian strain shows completely parthenogenetic reproduction and predominance of oviparity. These shrimps reach a maximum size of only 10 mm and attain early maturity and reproduce in 12 days. *Artemia* cysts hatch out at higher salinities of 130-160‰, thus suggesting that the hatchability of these cysts in nature is entirely different from laboratory conditions and might be on ecological adaptation. The potential annual yield of *Artemia* eggs from 1 ha is about 30 kg. In view of its increasing exploitation, necessary resource management and utilization measures for optimizing the yield are suggested. Advantages of culturing *A. salina* to enhance natural production of eggs are indicated.

ARTEMIA SALINA thrives and reproduces in salinities as high as 200‰. The eggs possess a unique character of remaining dormant for several years, which has made the brine shrimp a valuable material to be used for the culture of fish, shrimp, etc. In aquaculture, *Artemia* nauplii hatched from cysts are used for feeding the larvae of a wide variety of organisms¹. In addition to the demand of *Artemia* in aquaculture, newly hatched nauplii and adults in live and frozen conditions are used by fish hobbyists². The commercial importance of *Artemia* and the scientific interest this species generates because of its unusual adaptability to high salinity, have made it an extensively well studied animal³. However, it is surprising to note that in spite of its potential importance in aquaculture, hardly any study has been made on its natural populations, density, growth, reproduction and the yield of eggs. Such a study will help in exercising a better control over the natural population used very profitably for harvesting the eggs and thus alleviating the need to depend on the unpredictable supply of eggs from wild populations.

In India, *A. salina* has been recorded from Bombay⁴, Sambhar Lake⁵, in the salt pans of Tuticorin⁶ and in Karsewar Island off Tuticorin⁷ and these areas are shown in Fig. 1. In the present study, only the natural population occurring in the salt pans of Veppalodai near Tuticorin (South India) has been investigated.

Materials and Methods

Description of area — Veppalodai salt farm has an area of about 800 ha and has many smaller units used as condenser and crystallizer pans. One such unit (total area, 5.56 ha) was selected for the study. This unit consisted of 3 rows of condenser pans and 1 row of crystallizer pans. The first 2 rows of condenser pans were alike with 44 pans of 836 m² each. The third condenser row had 45 pans, each measuring 418 m² and a total of 44 such pans included the crystallizer row. The sea-

water was pumped from the sea into large reservoir tanks where it was allowed to evaporate and when a salinity of about 100-120‰ was reached the water was allowed to flow into the condenser pans. The salinity in the condenser pans ranged from 130 to 180‰. This water was then transferred into the next 15 pans. Likewise, for every 10‰ rise in salinity, the seawater is transferred into different pans till the salinity reaches 180‰. It is then passed into the crystallization pans. The interval between every change is about 4 days and the whole process of condensation is completed in about 25 days.

Collections were made during the 1st week of June 1976. Data on environmental parameters

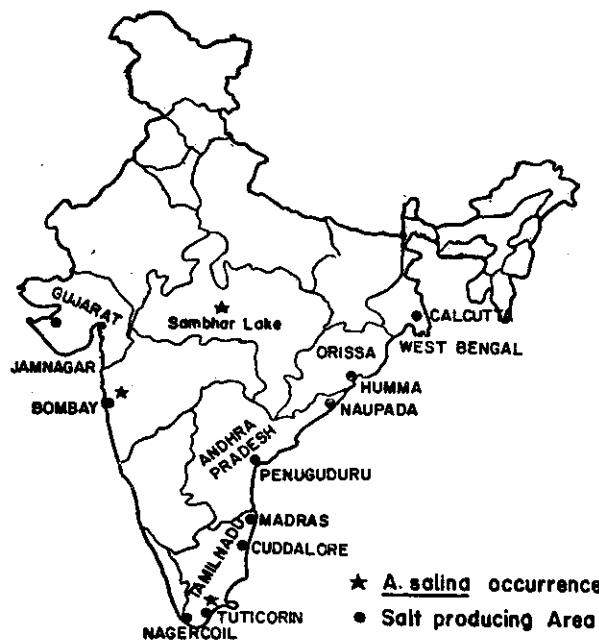


Fig. 1 — Salt producing areas along the coastline of India and locations of *Artemia* occurrence

were collected by routine procedures. *Artemia* were collected from different pans by filtering 10 l of saline water through a net of bolting nylon with 0.3 mm mesh width. For the density estimates, the shrimps were collected from different regions of the pans and the values were averaged. Length of the shrimp was measured under a dissecting microscope using an eye lens fitted with an ocular micrometer. Calculations of the production of eggs were made by taking the rate of production of 10 eggs/female/day (ref. 2). Number of eggs were converted to dry weight using a factor of 200 eggs/mg dry weight. Annual yield of eggs was calculated only for 6 months which is the period of occurrence and abundance of *Artemia* in these ponds.

Results

Table 1 gives the values of temperature, dissolved oxygen, pH, specific gravity, phosphate and total alkalinity in different condenser pans and one crystallizer pan. None of the parameters except specific gravity showed any definite relation with salinity. pH remained constant in all pans. Though the oxygen levels varied in the different pans, no marked decrease with increasing salinity was noted. Phosphate levels were very low and in some of the pans, they were recorded in traces only.

The relationship between the animal and the number of eggs in the brood showed that the number of eggs varied from 15 to 56 in animals measuring 6.5 to 10.2 mm and thus registering a linear relationship. Animals even at 6 mm size were mature and carried eggs. Maximum size of the adult in the present study was 10.2 mm. No male was ever seen. All the adults were found to carry eggs, thus suggesting parthenogenetic reproduction in the entire population. Viviparity does not appear to be significant; only about 5% of the adults carried nauplii and eggs in the brood pouch.

Fig. 2 gives the size-frequency distribution of the shrimps in pans with salinity ranging from 138 to 188‰. Total residence time was 25 days. Functional adults (5 mm) were abundant at salinity 138‰ and except for 1 or 2 individuals, all the adults carried mature eggs. At 140‰ adult population persisted but juveniles appeared in smaller numbers. This indicates that the release of eggs occurs at 138‰ salinity, just before the water was transferred. The juvenile population increased and

became dominant at 145‰ salinity. It formed a prominent mode at 4.5 mm size and became adults in 150 and 160‰ salinities. Further release of eggs occurred in 150‰ salinity as evidenced by the presence of metanauplii. This batch of eggs would have been released only by the adults derived from the release of eggs in 138 or 140‰ salinity pans, since the other adult population found in 138‰ diminished in density at salinities 140‰ and 145‰ and becomes insignificant at 150‰ salinity. The metanauplii found in 150‰ salinity grew to 2.5 mm size at 160 and 170‰ salinities, became juveniles (4.5 mm) at 174‰ salinity and reached the adult stage at 188‰ salinity. When this salinity is reached, crystallization commences and the population is lost in further higher salinities. Thus, the two generations of *Artemia* could be

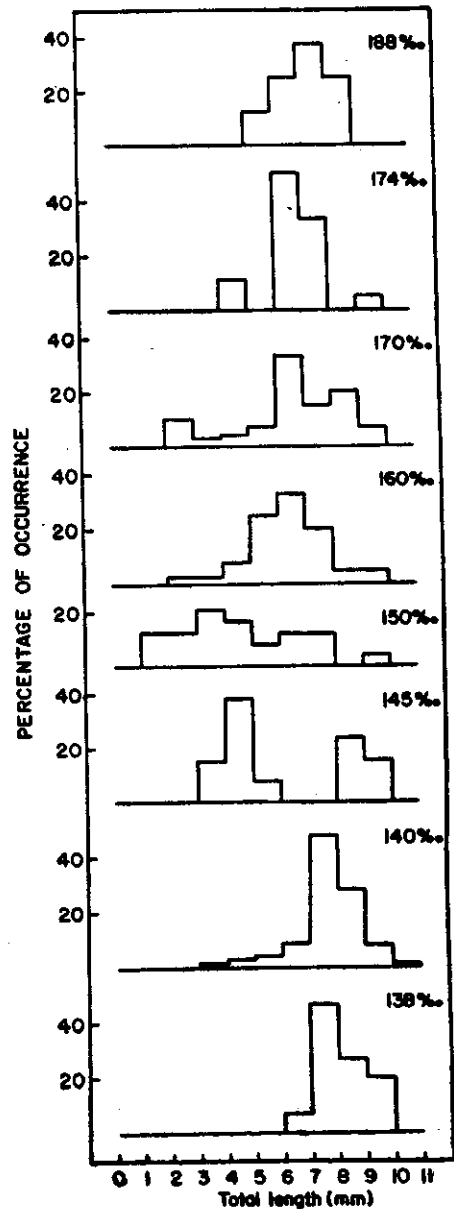


Fig. 2 — Length frequency distribution of *Artemia* in different condenser pans

TABLE 1 — ENVIRONMENTAL PARAMETERS IN DIFFERENT CONDENSER PANS

Salinity ‰	Temp. °C	Dissolved oxygen ml/litre	pH	Sp. gravity	Phosphate ppm	Total alkalinity ppm
138	34	2.58	8.4	1.12	0.01	125
140	34.3	1.57	8.4	1.13	0.01	130
145	35.5	2.02	8.4	1.13	Traces	126
150	35	2.13	8.4	1.13	Traces	128
160	36.5	2.46	8.4	1.14	0.01	125
174	36.2	2.91	8.4	1.15	0.008	122
188	36	2.02	8.4	1.2	Traces	120
213	35.8	1.68	8.4	1.21	Traces	124

identified — one recruited at 140‰ salinity which developed into adults at 150/160‰ salinities and the other recruited at 150‰ salinity and developing into adults at 170/180‰ salinities. Predominance of metanauplii in 150‰ salinity and the occurrence of full grown and mature adults at 180‰ indicate that the animal grows fast and takes a much shorter time of 12 days to mature. This is a relatively short duration as compared to the other strains of *Artemia*^{8,9,10}.

In Table 2, the density of animals in different pans, ratio of mature to immature individuals, egg production rates and annual potential yield of eggs are given. The density of the shrimps varied from 1300 to 9100/m³ with a mean value of 4100/m³. In earlier observations, Parker¹¹ observed 1200 *Artemia* per m³ in Lake Urmi and Mason¹² reported 4000 adults and 12000 nauplii/m³ in Mono Lake. Maximum density was found in 140 and 170‰ salinities and the percentage of mature animals was high in salinities 130, 140 and 180‰. However, neither the density of animals nor the percentage of egg producing adults showed any relationship with the increase in salinity. Egg production/day was high in 140‰ salinity (12.5 million) than in other salinities (0.4-3.8 millions). The calculated annual production of eggs in the study area was 57780 million eggs equivalent to a weight of about 289 kg. Allowing a loss of about 30% eggs by wind drift into crystallizers, predation and for those left over to tide over the adverse conditions, the net yield would amount to 200 kg. The study area extends over 5.56 ha and the potential production of *Artemia* eggs will be about 36 kg/ha.

Discussion

Two interesting facts emerge from this study. The first concerns the differences between the Indian strain and other strains and the other indicates the hatchability of *Artemia* cysts.

In nature, *Artemia* is represented by several biotypes, the basis of which is genetic heterogeneity, thus leading to differences in the life span, maturity stages and type of reproduction^{8,9}. Experiments¹³ have demonstrated differences in the hatching rate, minimum illumination period needed for maximum

hatching, length of freshly hatched larvae, growth rate and mode of reproduction in several strains collected from different regions. Royan^{14,15} has studied the optimum temperature, salinity and light conditions needed for maximal hatching of *Artemia* cysts (50%) collected from the area of the present study and showed that differences in hatching rate differentiate the Indian strain from other strains. To these may be added the present findings, i.e. parthenogenetic reproduction, predominance of oviparity, small maximum length of the adult (10 mm) and early maturity and reproduction (12 days), as characterizing the Indian strain of *A. salina*. It is possible, however, that early maturity and reproduction are influenced by food availability and this might become more significant in high saline waters where food supply may vary considerably, since only a few algae can thrive and reproduce in such conditions.

Insignificant viviparity and the presence of two generations of *A. salina* in the high saline condenser pans indicate that the eggs released in the high saline conditions obviously hatch out. This is contrary to the laboratory results obtained on the hatching of *Artemia* cysts^{10,13,14} which indicate that hatching of *Artemia* cysts is maximal at 35‰ and decreases with increasing salinity and that the cysts do not hatch at salinities beyond 70‰. This disparity could probably be ascribed to the differences in the laboratory and natural conditions and to the ecological adaptations of the shrimp. The mechanism of reproduction in *Artemia* still remains unresolved¹⁸ and that among the several environmental and biological factors determining the mode of reproduction, the most obvious one in nature which induces oviparity is the low dissolved oxygen concentration. Sorgeloos *et al.*¹⁹ reasoned that this is an ecological adaptation to survive adverse environmental conditions. Application of this argument to high saline waters with low dissolved oxygen as in the present study, will support the observed oviparity but will not explain the presence of the second generation. A logical explanation for this would be that at least a fraction of eggs released at higher salinities hatch out. A supporting evidence for this conclusion can be drawn from the observations of Ivleva⁹ that *A. salina* sometimes produces eggs which can develop immediately after being laid and without passing through the diapause and dehydration stages, and that the formation of this type of egg can often be observed in laboratory conditions and sometimes in nature^{16,17} and thus leading to the theory that 2 types of oviparity exist, one with resting eggs and another which hatch immediately^{18,19}. Although the existence of such eggs is considered rare²⁰ this might well be a mechanism evolved in nature, especially in the presence of negligible viviparity, to keep the population growing as long as favourable conditions persist. However, the possibility that *Artemia* might exhibit a different biology in nature than in the laboratory conditions cannot be ruled out. In an earlier experiment²¹ it has been observed that preadults of *Artemia* reared in filtered seawater attain maturity only when the mud from its natural habitat is introduced into the culture jar. Further,

TABLE 2 — DENSITY AND EGG PRODUCTION IN *A. salina* AT DIFFERENT PONDS

Salinity %	Density No./m ³	No. animals/tank	Percentage of mature animals	Egg production/day in millions	Annual egg production in 15 ponds in millions	Dry wt kg
130	1500	318554	80	2.5	6750	33.75
140	9100	1932558	65	12.5	33750	168.75
150	1850	196442	19	0.4	1080	5.4
160	4000	424740	30	1.3	3510	17.55
170	6900	732676	52	3.8	10260	51.3
180	1300	138040	65	0.9	2430	12.15
Total					57780	288.9

since the mode of reproduction is strongly strain dependent²², the influence of genetic control over the type and quality of eggs needs serious consideration.

A great market potential of *Artemia* cysts exists in many countries of the world for their use in aquaculture. The average annual yield (3.6 g/m²) of *Artemia* cysts in the present study compares favourably with the estimates (0.11-0.45 and 2.8-5.6 g/m²) made in the salt farms of California²⁰. At the current rate of \$ 60/kg of *Artemia* cysts, the annual yield from 1 hectare of saline waters will give a return of about \$ 2160/year which is even more profitable than the returns obtained from fish culture, with practically no risk. The vulnerability of *Artemia* to such an easy exploitation is sufficient to warrant proper resource management and utilization.

Till now, the supply of *Artemia* cysts comes from the USA but the fluctuating US import and the escalation of price have led to the beginning of commercial exploitation of these cysts from the Indian salt pans and at present the cysts are being sold at \$ 60/kg. With increasing demand of *Artemia* cysts, this exploitation is bound to increase rapidly and will reach an optimum level fairly soon. To maintain the exploitation at the optimum level and to ensure sustained yield of *Artemia* cysts, it becomes necessary to undertake a detailed survey and regulatory measures. It would be very necessary to undertake a survey of saline lagoons and salt pans along the east and west coasts of India for the occurrence of *Artemia*. A study of their density, potential egg production, and cyst evaluation would be essential along with the susceptibility of *Artemia* to natural and man made changes in the habitat. These steps are essential for a proper management and utilization of *Artemia* resources.

Production of *Artemia* eggs can be greatly enhanced by undertaking the culture of *Artemia* and already efforts are underway to develop the simplest and the easiest technology. The Indian strain of *A. salina* has far more advantages as compared to other strains for intensive culture by virtue of its parthenogenetic and oviparous life history. India has a coastline of about 5700 km with a large number of saline ponds and salt producing sites (Fig. 1). These locations offer excellent scope for the introduction and culture of *Artemia* and any venture in this field would definitely prove to be profitable.

Acknowledgement

The authors express their gratitude to Shri John Motha, Senior Managing Partner of Sahayamatha Salterns Private Ltd, Tuticorin, for permitting them to carry out this study. Thanks are due to Dr S. Z. Qasim for his keen interest and for critically going through the manuscript.

References

1. BARDACH, J. E., RYTHER, J. H. & McLARNEY, W. O., in *Aquaculture: The farming and husbandry of fresh-water and marine organisms* (Wiley Interscience, New York), 1972, 868.
2. HELFRICH, P., *The feasibility of brine shrimp production on Christmas Island*, Sea Grant Technical Report UNIHI-SEAGRANT-TR-73-02, 1973, 173.
3. SORGELOOS, P., in *A bibliography on the brine shrimp Artemia salina L.* (edited by E. Jaspers), European Mariculture Society, Special Publication No. 1, 1976, 107.
4. KULKARNI, C. V., *J. Bombay nat. Hist. Soc.*, **51** (1953), 951.
5. BAID, I. C., *Oikos.*, **19** (1968), 292.
6. ROYAN, J. P., KRISHNAN, P. N. & SELVARAJ, A. M., *Curr. Sci.*, **39** (1970), 14.
7. ACHARI, G. P. K., *Indian J. Fish.*, **18** (1971), 196.
8. GILCHRIST, B. M., *Proc. zool. Soc. Lond.*, **134** (1960), 221.
9. IVLEVA, I. V., in *Mass cultivation of invertebrates: Biology and methods* [Academy of Sciences of the USSR, All-Union Hydrobiological Society, Izdatel'stvo "Nauka", Moskva (in Russian)], translated in English by Israel Programme for Scientific Translations, Jerusalem, 1973, 148.
10. VON HENTIG, R., *Einfluss von Salzgehalt und Temperatur auf Entwicklung, Wachstum, Fortpflanzung und Energiebilanz von Artemia salina*, Ph.D. thesis, University of Hamburg, 1970, 136.
11. PARKER, G. H., *Am. Nat.*, **34** (1900), 315.
12. MASON, D. T., *Univ. Calif. Publs Zool.*, **83** (1967), 1.
13. SORGELOOS, P., BAEZA-MESA, M., BENIJTS, F. & PERSOONE, G., *Research on the culturing of the brine shrimp, Artemia salina L. at the State University of Ghent* in the Proceedings of the 10th European Symposium on Marine Biology, Ostend, Belgium, September 17, 1975, Vol. 1, 473.
14. ROYAN, J. P., *Mahasagar, Bull. natn. Inst. Oceanogr.*, **8** (1975), 183.
15. ROYAN, J. P., *Mahasagar, Bull. natn. Inst. Oceanogr.*, **9** (1976), 83.
16. STEFANI, R., *Riv. Biol.*, **52** (1960), 463.
17. STEFANI, R., *Riv. Biol.*, **54** (1961), 457.
18. LOCHHEAD, J. H. & LOCHHEAD, M. S., *Anat. Rec.*, **78** (1940), 75.
19. SCIACCHITANO, I., *Riv. Biol.*, **9** (1927), 70.
20. NIMURA, Y., *Bull. Jap. Soc. scient. Fish.*, **33** (1967), 690.
21. ROYAN, J. P., unpublished data.
22. METALLI, P. & BALLARDIN, E., *Curr. Topics Radiat. Res. Q.*, **7** (1972), 181.