INTRODUCTION

Controlled production of marine and freshwater fishes in an economic way is the prime target of most aquaculture entrepreneurs. Aquaculture can be defined as a general term for the production of valuable biomass in confined bodies of water plus the sum of biological techniques required for the rearing and maintenance of target biota. Culture of microalgae, seaweeds, molluscs, shrimps and fishes can be carried out in stagnant, aerated or flowing freshwaters, brackish waters and marine waters (Bardach et al., 1972).

Culture of fishes in ponds has been practised since ages in several countries. The origin of fish culture in China is attributed to Wen Fang, the founder of the Chou dynasty. This has been reported in Fan Li's fish culture classic dated as back as 460 B.C. (Bardach, 1968). The initial practice of rearing carps for mere pleasure slowly gave way to culturing of fish for food. The Japanese practiced oyster culture as early as 2000 B.C. The Japanese and Philippines along with Chinese have been the pioneers in developing intensive aquaculture techniques. Now several other countries around the world have adopted culture practices as their major business.

Edible marine products have a world wide acceptance. The recognition of the high nutritional value of many of these marine animals has further increased their demand. The higher initial investment, rising
cost of fuel and limited resources coupled with fluctuations in capture fish production have often resulted in shortage of supply to the markets. The increasing gap between the supply and demand of preferred marine food products, especially shrimps, and the obvious potential for intensified fish production in inland and brackish waters have further induced entrepreneurs all over the world to take up aquaculture activities.

India also has taken up culture of fishes and shellfishes and is slowly replacing the traditional type of culture practices with semi-intensive and intensive methods where higher yields are achieved in shorter periods. Traditional aquaculture has been practiced since long in the coastal low-lying estuarine regions within India (Muthu, 1978). Though India has developed several techniques for culture of various species groups, there still exists biotechnical and economic obstacles. Substantial improvements at various levels are needed to have control over reproductive biology and achieve higher production.

The steady increase in the number of fish and shellfish farms has resulted in a demand for seeds of cultivable fishes and shellfishes throughout the year. The acute shortage of seeds in the wild during all the months of the year, prompted establishment of hatcheries, where, the marine fishes/shellfishes could be induced to spawn and the larvae reared up to a stage when they could be transferred to the growout ponds.

Larval production and rearing in hatcheries depend on several inputs and large scale mortality was a frequent factor associated with them (Mohamed and Laxminarayana, 1983). Studies on the causative factor
leading to mass mortality, revealed that the food item supplied have a vital function on the survival rate of the larvae (Mohamed and Laxminarayana, 1983). The nutritive value of the food supplied also had an important role. Larvae fed with highly nutritious food items had healthy growth and showed minimum mortality due to nutritional deficiencies (Muthu, 1983a,b; Kulasekarapandian, 1987).

Several studies (May, 1970; Lasker et al., 1970; Murphy, 1970; Mock, 1973; Liao et al., 1971; Ivleva, 1973; Masters, 1975; Kinne, 1977; Silas and Muthu, 1977; Ukeles, 1977; McVey, 1983; Nellen, 1986; Kulasekarapandian, 1987) have been carried out to identify suitable live food items to be fed to fish and shellfish larvae reared in the hatcheries. Naturally available zooplankton and phytoplankton were tried and their suitability was studied. Of these, rotifers, _Artemia, Moina_ etc. have been identified as excellent diet for fish and shellfish larvae (Seale, 1933; Rollefsen, 1939; May, 1970; D'Agostino and Provasoli, 1970; Mock, 1974; Howell, 1973; Sulkin, 1975; Sulkin and Epifanio, 1975; Kittaka, 1976; Conklin and Provasoli, 1978; Watanabe et al., 1978; Schluter, 1980; Trotta, 1980; Frieda B Taub, 1982; Muthu, 1983a,b; Kulasekarapandian, 1987).

These live food organisms play an important role in the dietary regime of cultivable fishes and shellfishes, particularly in the larval stages. They form nutritionally balanced diets. They are nonpolluting and readily accepted by the cultured organisms (Muthu, 1983a,b; Kulasekarapandian, 1987).
The scarcity of these live food forms in nature throughout the year led to the formulation of artificial diets. These artificial diets were nutritionally balanced and prepared on a large scale and stored appropriately, to be used whenever needed (Ahemed Ali, 1982a; Alikunhi et al., 1980). The advantage of artificial diet was that it could be used as an alternative when the live food was not available. But, unlike the live food organisms, they were not very stable under water and often resulted in turbidity and rapid deterioration of water quality. So, till this day natural live food organisms are preferred as the ideal food for larval diet.

Existing literature reveals that among the few species utilized as live food, the brine shrimp Artemia comes in for prime consideration (Seale, 1933; Rollefson, 1939; Wickins, 1972; Serfling et al., 1974; Shelsser and Gallagher, 1974; Anonymous, 1978; Schauer et al., 1979; Sorgeloos et al., 1975; Sorgeloos, 1978, 1980; Beck et al., 1980). Artemia has been found to be a suitable food for a diverse group of cultivated organisms. For example: Homarus americanus (Gallaher et al., 1976), Macrobrachium rosenbergii (Aquacop, 1977), Penaeus kerathurus (San Feliu et al., 1976), P. aztecus (Venkataramaiah et al., 1973), Callinectes sapidus (Millikin et al., 1980), Solea solea and Scophthalmus maximus (Aronovich and Spektorova, 1971), Sparus auratus (Alessio, 1974) and Dicentrarchus labrax (Barahona - Fernandes and Girin, 1976).

Kinne (1977) has indicated that more than 85% of the marine animals, cultivated so far, has been fed with Artemia. In most cases, it is the freshly hatched nauplii that is used to rear the larval stages.

Even five decades ago, Seale (1933) and Rollefesen (1939) described the high nutritive value of the nauplii of this potential species as a live food. Since then, much attention has been given to the maximum production of Artemia and its application as food to various cultured species. The principal reason why brine shrimp larvae are so widely used for aquaculture purpose is that, their culture can be started from an apparently inert source, the inactive dry embryos or cysts which need only be hatched.

When kept vacuum-dry, cysts remain viable for years; they can be easily transported all over the world and easily hatched to nauplii within approximately 24 hours on immersion in sea water. Intense research by scientists in many advanced countries under the guidance of the Artemia Reference Centre in Belgium, has proved that Artemia is the best live food (Sorgeloos, 1980), available in the salt pans, which can transform the entire aquaculture the world over, as also salt production by ensuring much higher quality of natural salt produced in the pans (Davis, 1980).

Extensive research on various aspects of brine shrimp has been carried out at various institutes and mass rearing techniques have been
reported (Bossuyt and Sorgeloos, 1980; DE Los Santos et al., 1980; Primavera et al., 1980; Robichaux, 1980; Versichele and Sorgeloos, 1980; Beck et al., 1980; Bruggeman et al., 1980; Fujita et al., 1980; Tobias et al., 1980; Vanhaecke and Sorgeloos, 1980; Sorgeloos, 1980; Sorgeloos and Kulasekarapandian, 1984; Camra and Rocha, 1987; Jumalon and Ogburn, 1987; Vu Do Quynch and Nguyen NgocLam, 1987; Bhargava et al., 1987). In spite of the progress achieved, Sorgeloos et al. (1979) indicated that much fundamental as well as practical research is still necessary to optimize the achievements obtained so far. The recognition of the existence of potential areas along our coastal zone for brackish water prawn and fish culture has enhanced Artemia culture in India. In this regard, intensive research to study the biology and ecology of Artemia in the natural habitat is imperative.

Artemia populations are found from tropical to temperate regions and from temporary ponds to large salt lakes (Loffler, 1961; Por, 1968; Persoone and Sorgeloos, 1980; Melack, 1983; Dana, 1984) and are adapted to a broad range of habitats. Compared to brine shrimp's biology, ecological studies on the Artemia are very meagre. (Persoone and Sorgeloos, 1980). In large temperate lakes such as Mono Lake and Great Salt Lake, annual salinity changes are small and seasonality is determined primarily by the temperature cycle (Lenz, 1987). The population dynamics of Artemia in these two lakes have been studied (Manson, 1967; Wirick, 1972; and Lenz, 1980, 1982, 1984, 1987) and two major generations have been reported per year. Gillespie and Stephens (1977) estimated up to five generations in the Great Salt Lake. Artemia in Fallon ponds, Nevada (USA) also
has similar instar distribution pattern like that of Mono Lake (Dana, 1984). A comparative life history study of *Artemia* found in Mono Lake and Layason Island was done by Lenz and Dana (1987).

Conte and Conte (1988) studied the abundance and spatial distribution of *Artemia* in Lake Abert, Oregon (USA). Mitchell and Geddes (1977) reported the distribution of *Artemia* within a salt work in South Australia and Geddes (1979) listed other localities where *Artemia* occurs in Australia. Marchant and Williams (1977a) studied the population dynamics of brine shrimp in two salt lakes in Western Victoria, Australia. Biomass estimation of *Artemia* in lake Grassmere, Marlborough, New Zealand, has been done by Haslett and Wear (1985). This study was of commercial interest as it ascertained whether adequate yields of *Artemia* could be filtered from ponds without deliteriously affecting reproductive potential or placing currently satisfactory levels of high salt production at risk. The role of *Artemia* in maintaining a healthy biological system in salt production has been well documented by Davis (1977, 1980).

Wear and Haslett (1987) studied the biology and ecology of *Artemia* from the Lake Grassmere, New Zealand. The population dynamics of the Australian brine shrimp, *Parartemia zietziana* was studied by Geddes (1975a, 1975b, 1980; Marchant and Williams, 1977a). Shallow tropical and subtropical hyper-saline ponds, which have smaller annual temperature range, become uninhabitable for *Artemia* during parts of the year due to salinity fluctuations (Lenz, 1987). Though tropical lakes may desiccate as ephemeral temperate ponds, studies on Caribbean and Indian lakes have shown that the disappearance of *Artemia* may also
be due to extreme dilution. Such reports are available from Curacao and Bonaire, Aniiles (Kristensen and Hulscher - Emeis, 1972); Vepallodai and Tuticorin, South India (Ramamoorthi and Thangaraj, 1980) and Didwana Lake, Rajasthan, India (Bhargava et al., 1987).

According to Floris (1933), the first investigation on brine shrimp in Yugoslavia was in Capod'Istria by Steurer (1903). Barigozzi (1946) observed that these *Artemia* were parthenogenetic. Rodriguez (1987) reported the presence of *Artemia* populations in solar salt works in the southern province of Cadiz, Spain. The presence of *Artemia* and *Brachylossia* populations in the coastal lagoons and salt pans of Sardinia, Italy were observed by Mura et al. (1987). The occurrence of *Artemia* in Shurabil Lake, Iran was reported by Ahmadi (1987).

In addition to the above studies on population distribution of *Artemia*, several works on population variation related to the ecological conditions have been carried out. Spitchak (1980) reported the ecological conditions of *Artemia* habitats in the USSR. Castro et al. (1987) presented primary data such as geographical location, climate, mean temperatures, precipitation and soil type for *Artemia* population from eight sites in Mexico. Studies on the effect of different temperatures on the biology of *Artemia* in different salinities were done by Radchenko (1985). Usually *Artemia* tolerates extreme ranges of salinity, pH and other environmental conditions but is intolerant to substance like potassium (Martin and Wibur, 1921; Boone and Becking, 1931).

Jennings and Whitaker (1941) studied the effect of salinity upon the rate of excystment of *Artemia*. Ecological factors affecting the
hatchability of Artemia cyst in inland saline lakes were studied by Sawchyn (1987). Sato (1966a,b) discussed the effect of pH and ions on hatching of Artemia cyst.

Cole and Brown (1967) studied the chemistry of different Artemia habitats. Chemical composition of Mono Lake was reported by Manson (1967). Stephens and Gillespie (1976) studied the nutrient concentrations of Great Salt Lake and found that the concentration of phosphates are comparatively higher than nitrogen compounds.

Phytoplankton forms the food of Artemia in natural habitats. Artemia can attain high densities in their natural habitats (Bradbury, 1971; Wirick, 1972; Gillespie and Stephens, 1977; Ramamoorthi and Thangaraj, 1980; Scelzo and Volgar, 1980; Lenz, 1984). Artemia is a voracious feeder on phytoplankton (Anderson, 1958; Manson, 1967; Wirick, 1972). As in the case of other zooplankters (Frost 1972), the grazing rate of Artemia is very high (Reeve, 1963; Lenz, 1982). Conte and Conte (1988) studied the major algal species found in the Artemia habitat, Lake Abert, Oregon (USA). Majic and Vukadin (1987) reported the major phytoplankton genera found in the Artemia biotope of Yugoslav Salt Works.

It has been observed that the size of brood also correspondingly reduces with decrease in algal density, during summer season. This has been observed in major Artemia habitats like Mono Lake (Lenz, 1982; Dana and Lenz, 1986), Great Salt Lake (Wirick, 1972), Bocachica Salt Lake (Scelzo and Voglar, 1980), Pomeronje and Burgas Lakes (Ludskanova 1974) and Layson lagoon (Lenz and Dana 1987). This has been attributed
possibly due to limited food availability (Browne, 1982).

Manson (1967) and Wetzel (1975) made primary productivity studies in Mono Lake and Great Salt Lake respectively and observed a high rate of annual primary production in these salinas. But during summer, the primary production and algal mass were low due to the grazing of the *Artemia* population (Wirick, 1972). Similar low primary production has been measured in *Artemia* habitats such as Solar Lake, Sinai (Cohen *et al.*, 1977b), Salterns in Mexico (Javor, 1983), and Little Manitou Lake, Canada (Haynes and Hammer, 1978).

Edmondson (1966) suggested that high predation and competition are the limiting factors restricting *Artemia* to the higher salinity habitats. Nimura (1987) suggested a probable reason why *Artemia* is confined to isolated confined waters. The absence of *Artemia* from other habitats is due to its inability to withstand predation (Persoone and Sorgeloos, 1980). Not only insects (Bhargava *et al.*, 1987) but also other invertebrates like copepod (Kristensen and Hulscher Emeis, 1972) predate on *Artemia* causing mass disappearance of *Artemia* especially during low saline periods. Among the vertebrates, water birds have been identified as one of the major predators on *Artemia* in natural habitats. (Carpelan, 1957; Bradbury, 1971; Winkler, 1977; Mac Donald, 1980; Wear and Haslett, 1987; Bhargava *et al.*, 1987).

Eventhough extensive studies have been carried out on the *Artemia* population in general, in different parts of the world, studies in relation to ecology is very much limited. Ecological studies on *Artemia* population in Bocachica Lake, Margarita Island, Venezuela were conducted by
Kristensen (1971) and Scelzo and Volgar (1980). Vieira and Galbano (1985) and Majic and Vukadin (1987) have carried out preliminary ecological studies in relation to different hydrological parameters such as temperature, pH, dissolved oxygen and salinity in the salt works of Portugal and Yugoslavia respectively. In addition to the above works, studies were also made on the nutrients like nitrite, nitrate and phosphate and their influence on *Artemia* population (Vieira and Galbano, 1985). The effect of environmental parameters on cyst formation in *Artemia* was studied by Berthalemy-Okazaki and Hedgecole (1987). Iwasaki (1976) reported the reproductive pattern of *Artemia* with regard to food and temperature.

In most of the southeast Asian countries like Philippines, Thailand, Vietnam etc., existence of natural populations of *Artemia* has not been recorded probably due to failure of dispersion and adverse climatological conditions, especially monsoon climates (Sorgeloos, 1978; Persoone and Sorgeloos, 1980). However, occurrence of *Artemia* in many habitats in these countries has come into picture by artificial inoculation in the system (Hutasing, 1977; Vos and Tunsutapanich, 1979; Sorgeloos, 1980; Tunsutapanich, 1983; Sahavacharin, 1981; Vanghaecke, 1983; Vos *et al.*, 1984; Mot, 1984).

With regards to the work on *Artemia* in India, the available information is very much limited. The occurrence of *Artemia* has been reported only from few pockets such as Bombay (Kulkarni, 1953), Sambar Lake (Baid, 1958), Tuticorin (Royan *et al.*, 1970), Karsewar Island (Achari, 1971), Gulf of Kutch (Royan, 1979), Vedaranyam (Basil *et al.*, 1987) and Didwana Lake (Bhargava and Alam, 1980).
Studies on *Artemia* in relation to its ecological aspects is very much limited in the world in general and in India in particular. In this context, the report of Persoone and Sorgeloos 1980, "Among the 2700 papers of the recently updated *Artemia* bibliography, it is hard to find more than 50 articles which are strictly ecologically oriented" is worth mentioning.

Ramamoorthi and Thangaraj (1980) and Ramanathan and Natarajan (1987) have covered some basic ecological factors such as temperature, pH, dissolved oxygen, salinity etc. from the Tuticorin area in relation to the occurrence of *Artemia*. Similar basic studies from two distinct geographically isolated lakes are also known from the works of Basil et al. (1987) (Vedaranyam) and Bhargava et al. (1987) (Didwana Lake, Rajasthan). The studies of Bhargava et al. (1987) also covers the estimation of nutrients like nitrite, nitrate, phosphate and silicate. However, there is still paucity of information in this field especially related to the ecological factors in a given area.

The necessity for this indepth study is felt very much appropriate especially in the present day context of India, popularising shrimp culture and establishing number of hatcheries in later part of 1980's. On the information collected through Marine Product Export Development Authority (MPEDA) and other state fisheries departments, it is hopefully aimed that the production from culture will be doubled to the extent of 50,000 tonnes from the existing production of 25,000 tonnes by the turn of this centuary. Correspondingly the present area under culture of 60,000 ha will be stepped upto 1 lakh, with the establishment of chain of hatcheries in all maritime states (G. Santhanakrishnan, pers. commun.).
Therefore, need for having more indepth studies on Artemia related to many relevant ecological parameters in an area, is felt very much. Keeping this view in mind, the present study has been initiated to know more about the Artemia population relating to the maximum environmental parameters such as hydrographical, nutrients present in the habitat, food availability, meteorological and predation. This is very much in tune with a recent report emphasising the scope for detailed studies on population biology and ecology of Artemia resulting from the deliberations arrived through a recent symposium organised on Artemia by Bay of Bengal Programme (BOBP, FAO) at Madras in 1989 (Vishnu Bhat and Easwaraprasad, 1989).