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A review of the biology and ecology of *Artemia persimilis* Piccinelli & Prosdocimi, 1968 (Crustacea: Anostraca) as basis for its management

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Abstract

The genus *Artemia* (brine shrimp) is a small cosmopolitan crustacean, which primarily inhabits hypersaline water bodies, such as inland salt lakes, ponds and coastal lagoons. In Argentina two bisexual populations are encountered: *Artemia franciscana* and *A. persimilis*. The second is believed to be endemic to Argentina, but recently there have been some reports of their presence in a few locations in southern Chile. *Artemia* have been extensively studied because it is the most useful living food resource for the larval states of fish and crustaceans, and because of their unique reproductive strategies. Many authors in Argentina have agreed to indicate that *A. persimilis* needs special attention, and should be evaluated as a natural resource for aquaculture. The present paper provides a brief review of ecological aspects of *A. persimilis* and an overview of their use in aquaculture.

Key Words: *Artemia persimilis*, brine shrimp, ecology, aquaculture, Argentina

Introduction

In 982 an unknown Iranian geographer reported *Artemia* as brine worm from Urmia Lake, Iran (Asem, 2008) after that Schlösser pictured both sexes of *Artemia* clearly in 1756 (See Asem, 2008). Linnaeus in 1758 named this genus as *Cancer salinus* and this nomenclature was used until 1819, when Leach renamed it as *Artemia salina* (Asem *et al.,* 2010). During the first half of the nineteenth century several new populations of *Artemia* were recorded and controversy was generated around the name of the species. Early taxonomists gave species names to populations with different morphologies, or collected at different temperatures and salinities. Generally, different names were given to reproductively isolated populations (De los Ríos and Zuñiga, 2000). To solve the discrepancies in the nomenclature of the genus *Artemia*, Barigozzi (1946) and Goldschmidt (1952), renamed all the populations, independently of their location, as *Artemia salina*, but referred whether they were bisexual or parthenogenetic. In 1915, Abonyi published a list of 80 locations in 21 different countries where *Artemia* were found. However, in 1987, another study increased the number to 360 locations around the word (Vanhaecke *et al*. 1987). Furthermore, the existence of further undiscovered populations located in inaccessible areas remains a possibility. Currently, the family Artemiidae Grochowski is represented by seven bisexual species and a variety of parthenogenetic strains of diverse ploidy (in the Old-World and Australia) (Martin and Davis, 2001).

Brine shrimp of the genus *Artemia* (Crustacea, Anostraca) are very small invertebrates (8 to 12 mm long). In this genus, bisexual characteristics are defined by the criteria of reproductive isolation and parthenogenetic species (Crespo, 1999). Both types of reproduction can take place in the same strain. Thus, there are strains with sexual reproduction in which there are males and females, and stocks with parthenogenetic reproduction in which there are only females. *Artemia* present two types of reproduction: oviparous and ovoviviparous. The fact that both oviparous and ovoviviparous eggs are produced is related to environmental conditions, such as oxygen, salinity, temperature and food. Under successful conditions, development is ovoviviparous, whilst when these conditions are not favorable, development is oviparous and cysts become eggs. Eggs or resistant cryptobiotic cysts are part of a strategy for survival in temporary environments (Pastorino *et al.,* 2002).

The genus *Artemia* has a cosmopolitan distribution and it is found in all five continents, living in temporary inland pools or various hypersaline ecosystems in coastal lagoons rich in chloride, inland sulfate lakes and salt ponds. These water bodies suffer periods of drying or freezing and can range in size from small puddles on the sides of roads, to extensive saline lakes (Cohen, 1995). Despite the wide range of salinities tolerated, it has not conquered the sea, which could be due to the fact that it is very sensitive to predation and is rapidly eliminated in the presence of many predatory invertebrates and fish (Browne and MacDonald, 1982). In the American continent only two bisexual *Artemia* populations were found, *A. franciscana* and *A. persimilis* (Cohen *et al.,* 1999, 2012). The specie *A. franciscana* is the most dominant in the world, and in America, is found from Canada in the north to its most southern edge in Chile (Amat *et al.,* 2004).

The genus *Artemia* in Argentina

The literature about Argentinian *Artemia* strains describes mainly the presence of *A. franciscana*. However another Argentinian *Artemia* population was identified as *A. persimilis* (Piccinelli and Prosdocimi, 1968), which lives principally in hypersaline ecosystems and was believed endemic to Argentina until a few years ago when it was detected in Chile (Gajardo *et al*., 1998, 2004; De los Ríos-Escalante, 2010; Cohen 2012). *A. franciscana* is present in Argentina at 36°S and north of this latitude, although *A. persimilis* is confined to areas south of latitude 37°S (Ruiz *et al.,* 2008). The Table 1 shows the *A. persimilis* locations with their coordinates (Cohen 2012). In Italy, Halfer Cervini *et al*. (1968) and Piccinelli and Prosdocimi (1968) reported a rare presence of *A. persimilis* living in the salty marshes of San Bartolomeo in Sardinia.

Tab. 1: Geographical location of *A. persimilis* in Argentina (Cohen, 2012)

Locality	Province	Geographical coordinates
Lagoon in Area de Naicó	La Pampa province	36º52'S, 64º24'W
Salinas Grandes de Hidalgo	La Pampa Province	37º13'S, 63º26'W
salina Colorada Grande	La Pampa province	38°18'S, 63°42'W
Salina Colorada Chica	La Pampa province	38º23'S, 63º36'W
Salina Callaqueo	La Pampa province	38º34'S, 63º32'W
Salina El Chancho	La Pampa province	38°37'S, 65°45'W
Salinas Grandes Anzoátegui	La Pampa province	39°S, 63°47'W
Salinas Chicas	Buenos Aires prov.	38°44'S, 62°57'W
Salitral Negro	Buenos Aires prov.	38°44'S, 63°13'W
Salitral de la Vidriera	Buenos Aires prov.	38°42'S, 62°40'W
Epecuén Lake	Buenos Aires prov.	37°13'S, 62°81'W
Winchel Lagoon	Buenos Aires prov.	39º S, 62º 30'W
Villalonga Lagoon	Buenos Aires prov.	39°51'S, 62°32'W
Salina de Luzzetti	Buenos Aires prov.	40º35'S, 62º40'W
Pond at Route 3, km 1128	Río Negro province	40º43'S, 65ºW
Salitral Bajo del Gualicho	Río Negro province	40º24'S, 65º13'W
Lagoon near Rada Tilly	Chubut province	45°55'S, 67°34'W
Primera Lagoon (Caleta Olivia)	Santa Cruz province	46°27'S, 67°31'W
Segunda Lagoon (Caleta Olivia)	Santa Cruz province	46°27'S, 67°32'W
Salina in Estancia La Pava	Santa Cruz province	47°32'S, 66°38'W
Lagoon in Estancia El Caburé	Santa Cruz province	47°34'S, 66°31'W
Salitral Bajo Pichinini in Estancia Cerro Pancho	Santa Cruz province	47°45' S, 66°14'5W
Salitral Route 3, km 2035	Santa Cruz province	47°28'S, 67°16'W
Coastal salares Bahía Laura	Santa Cruz province	48°4' S, 66°48'W
Salitral from San Julián	Santa Cruz province	49°18'S, 67°44'W
Laguna Seca, near San Julián	Santa Cruz province	49°17'S, 67°46'W
Coastal salares in Gallegos N	Santa Cruz province	51°45'S, 69°13'W

However, under Laboratory conditions, attempts to breed Argentinean with Italian populations failed, probably because both populations belonged to different species (Barigozzi, 1989). Moreover, in recent years the existence of *A. persimilis* in Sardinia could not be confirmed.

In 2005 *A. persimilis* was found in the Salitral de La Vidriera (Buenos Aires province) (Mechaly and Cervellini, 2005). In salty places such as La Vidriera, *A. persimilis* shares the habitat with the clear-watered copepod *Boeckella poopoensis*, and the ciliophora *Rhopalophyra, salina Kahl* (Cervellini *et al*., 2005). All these species were detected in a very low density. These results differ with the observations in the literature that describe the non-coexistence between *B. poopoensis* and brine shrimps (Echaniz *et al*., 2006; Vignatti *et al*., 2007). *A. franciscana* does not share habitats with the halophilic copepod *B. poopoensis* found in saline lakes in the Peruvian and Bolivian Andes (Hulbert and Chang, 1984; Williams *et al*., 1995). The non-coexistence could be due to the predation of *B. poopoensis* on *Artemia* nauplius (Hulbert *et al.,* 1986). Regarding this point, it is unclear if this predation ability is associated exclusively with *A. franciscana,* as this may not be the case with *A. persimilis*. The ostracoda *Limnocythere solum* (Whatley and Cholich, 1974) a species that belongs in clear-watered environments (Moguilevsky and Whatley, 1995) was also found in El Salitral de la Vidriera during the same period. The presence of *B. poopoensis* and *L. solum* were related to the physicochemical characteristics of the water, which were altered by high rainfalls prior to the sampling period, and which resulted in low salinity in the pond (Cervellini *et al*., 2002). Also De los Ríos-Escalante and Gajardo (2010) have studied the zooplankton assemblages in southern Chilean saline lakes (51-53°S) and revealed that in De los Cisnes lagoon both *A. persimilis, B. poopoensis* and harpacticoids copepods were found.

The genus *Artemia* in aquaculture; Overview of *A. persimilis*

The crustacean *Artemia* has attained much importance due to its high demand in aquaculture, as it represents one of the most widely used live diets in the culture of marine fish and crustaceans (Sorgeloos *et al.,* 1986). The success of a massive cultivation of shellfish and finfish largely depends on the availability of proper nutrition for both juveniles and adults. The mass culture of zooplankton, which is the natural food for the larval stages, it was not economically useful (Girin and Person- Le Ruyet, 1977). The discoveries of Seale (1933) and Rollefsen (1939), that the larval stages of *Artemia* are an excellent food source for young fish, represented an important breakthrough in the development of aquaculture. This live food can be easily produced from the cysts, which are found in large numbers on the banks of certain salty lakes. In fact, these cysts are diapause stage embryos that can be stored for years and, after hydration for 24 hours in seawater, produce a swimming larva.

Artemia is a good food source for many animals: foraminifera, coelenterates, flatworms, polychaetes, insects, chaetognaths and especially for various crustaceans and salty and freshwater fish (Sorgeloos, 1986). Kinne in 1977 indicated that over 85% of farmed marine animals were fed only with *Artemia,* or in combination with other foods. Following the Kyoto conference (FAO Technical Conference on Aquaculture, 1976) it was reported that there was, temporarily, a technical problem with the shortage of cysts (Sorgeloos, 1979). But the situation did not improve until late 1979, due not only to the exploitation of new natural water resources in Europe, Asia, America and Australia (Sorgeloos, 1986), but also to the success of *Artemia* inoculation and transplantation in Brazil and in Thailand (Sorgeloos *et al.,* 1979). For several years, the "*Artemia* Reference Centre" (ARC) at the University of Ghent (Belgium) has been studying the main aspects of the use of *Artemia* in aquaculture. The ARC works closely with various centers of aquaculture in developing countries, and coordinates the activities of the "International Study on *Artemia*", an interdisciplinary group composed of European and American laboratories studying different strains of *Artemia* in order to use them as food in aquaculture. As we mentioned previously, *Artemia* nauplii has been long considered the most suitable protein supplement and live food for the intensive production of crustaceans and fish larvae. In fact these are nutritionally adequate, readily available mobile prey, and perhaps more importantly, they can be easily hatched from their dormant cysts and then made commercially available. Moreover *Artemia* nauplii are an attractive and versatile live food for farmed species in their natural diet, where plankton is easily collected, but its cultivation on a commercial scale is less likely (Tackaert *et al.,* 1989).

Artemia is a very nutritious food that meets the requirements of macro and micronutrients required by fish and crustacean larvae, due to the presence of essential fatty acids or HUFAs (highly unsaturated fatty acids) (Crespo, 1999). In marine fish egg, miomembranes contain mainly long-chain fatty acids; the HUFAs are involved in normal development of the nervous system and vision in the early stages of the life cycle (Robin, 1995). Strong demand for *Artemia* causes bottlenecks in the supply, and in addition can cause high prices and low quality (Sorgeloos *et al.,* 1986). The quality of the cysts depends on a number of factors, such as the intrinsic nutritional quality, the characteristics of diapause, size of cysts and nauplii, among others, which can also influence the market value (Bossier *et al.,* 2004; Sato *et al*., 2004). Lavens and Sorgeloos (1996) have used other criteria to also define the quality of *Artemia* cysts as: percentage of cysts hatched and their synchrony times, as well as the number of cysts per gram (Triantaphyllidis, *et al.,* 1998). *A. franciscana* harvested at about 1,000 and 3,000 tons of cysts and biomass, respectively. 90% of the cysts that are consumed worldwide come from the Great Salt Lake (Utah, USA) (Castro *et al.,* 2000). Unfortunately, the production of this site suffered due climate change, and the stocks depleted, so it has been necessary to locate and evaluate new *Artemia* populations in order to contribute to the supply of domestic and international markets. However, other species are also being exploited, mainly in China, Brazil and Vietnam (De los Ríos, 2001).

The study of *A. persimilis* in Argentina is based primarily on systematic aspects and distribution (Cohen, 1995, 1998). Little is known about the characteristics of their life cycle and development, so pilot scale studies would be of great importance for ensuring sustainable development of aquaculture resources. Laboratory experiments have evaluated the use of *A. persimilis* in relation to the practical applicability of the resource in aquaculture (Mechaly *et al*., 2004). Different strains of *A. franciscana* (Platinum grade Argentemia) and *A. persimilis* (Artemix) were used and hatched in accordance with Sorgeloos' method. Hatching efficiency (Number nauplii/g cysts), rate of mortality to different concentrations of microalgae (*Nannochloropsis oculata*) and daily rate of growth of the nauplii were determined. The values obtained revealed that hatching efficiency was 180 000 nauplii/g cysts (74.5%) in 24 h, for *A. franciscana* and 175 000 (66.6%) in 30 h, for *A. persimilis*. The rate of mortality for both species was 80% at lower concentrations of algae (2 million cells algae/ml). The rate of growth in total length went from 465 mm for *A. persimilis* and 502 mm for *A. franciscana*, to 967 mm and 969 mm respectively at 72 h. The high rates of Hatching Efficiency and the adequate size of nauplii of *A. persimilis* constitutes the first result given values for this species in Argentina, and confirm the potential of the species to be used in aquaculture. On the other hand, it is important to note that in Argentina, in particular the region of Buenos Aires and La Pampa Province, there are numerous water bodies, which are a natural source for obtaining *A. persimilis* cysts, *e.g.* Salitral de La Vidriera, Salinas Chicas, among others.

In summary, the success of hatching rate and the appropriate naupliar size, confirms the potential of the nauplii of *A. persimilis* for production when it is compared with commercial strains of other *Artemia* species. Moreover, investigations of Sato *et al.* (2004) confirm that the cysts of the Argentinean *A. persimilis* present high quality in relation to their nutritional parameters and are comparable to the cysts that are traded in the international market. Furthermore, as pointed out by Vilela and Menezes (1994), the smaller sized nauplii are the most desirable for using as live food in marine fish and shellfish, therefore such approach would confirm the potential of *A. persimilis* for these purposes.

Conclusions and Perspectives

Artemia have been widely studied due to their high monetary value, as food for larval fish in aquaculture, and due to their unique reproductive strategies. For these reasons, *A. persimilis* shows promise as a good alternative for use as live food in Argentinian aquaculture and future research is needed on the potential for their commercial production. Thus, this natural resource needs further biological and ecological studies, to evaluate its potential as a food source for aquaculture.

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