

Integrated salt and brine shrimp *Artemia* production in artisanal salt works in the Mekong delta in Vietnam: a socio-economic success story as model for other regions in the world

Nguyen Van Hoa (1) and Patrick Sorgeloos (2)

(1) College of Aquaculture & Fisheries, Can Tho University, Vietnam

(2) Artemia Reference Center, Ghent University, Belgium

ABSTRACT Different South-East Asian countries with a typical monsoon climate produce significant quantities of solar salt during the dry season, even if lasting only a few months per year. Back in the late 1970s, the technical feasibility of integrating salt production with brine shrimp *Artemia* farming as a second crop has been demonstrated in the Philippines and in Thailand.

This combined salt-cum-*Artemia* production has become a very lucrative business with major socio-economic ramifications in the coastal area of Vinh Chau – Bac Lieu in the Mekong delta of Vietnam: over 500 families of salt farmers have improved their income with more than 5,000 US \$ per household and per dry season with the production and sales of brine shrimp. This paper introduces the site of Vinh Chau, where thousands of hectares of salt works could be switched into *Artemia* farming. Geographical, climatic condition, soil structure and general farming procedure for *Artemia* culture in these biotopes are presented.

1. GENERAL INTRODUCTION OF THE MEKONG DELTA COASTLINE AND ITS CLIMATIC CONDITIONS

1.1. Geomorphology

The Mekong Delta is situated at the lower course of the Mekong River in southern Vietnam (Fig. 1). In the southeast it borders the East sea (South China Sea). It mostly consists of Holocene fluviatile brackish water and marine sediments that were deposited during the last 5,000 years.

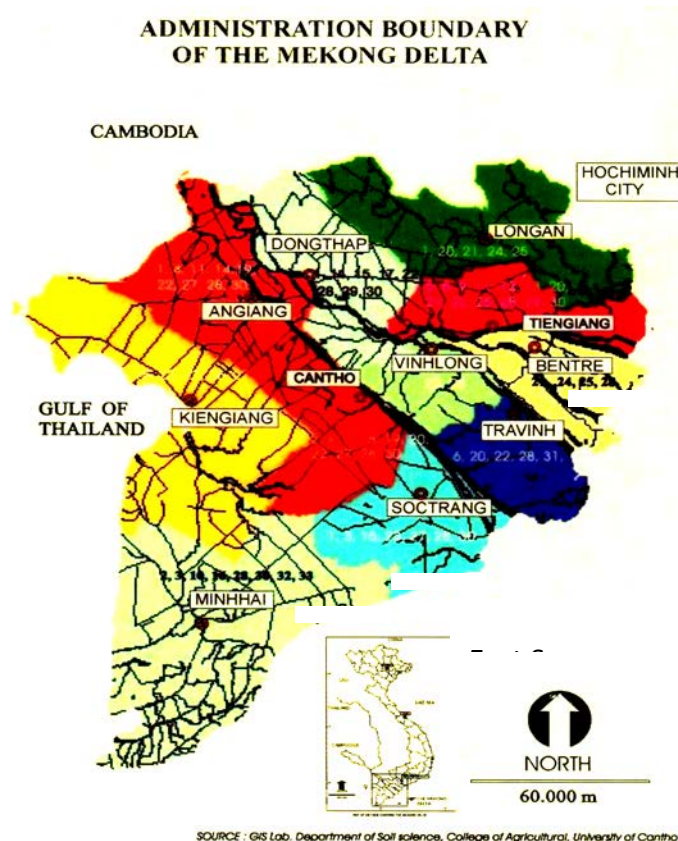


Fig. 1: Mekong Delta (South of Vietnam) with the location of Vinh Chau and Bac Lieu, where *Artemia franciscana* (SFB, USA) was introduced.

The coastal zone is flat with an average elevation in the order of 0.8 m above mean seawater level and this leads to frequent flooding. However, with the typical climate of two alternating monsoons, the combined actions of intense river sediment deposition, prevailing winds and the sea have created a slightly higher coastal belt in which flooding is less severe than further inland. Thus, average land elevations of some 1.6 – 1.8 m above mean seawater level, extending over fringes of 200 – 1,500 m wide, are frequent along the eastern coast between the Co Chien River mouth and the Ca Mau peninsula. Low dunes exist on some locations, e.g. in Tra Vinh. The coastal zone is intersected by an extensive system of natural and man-made channels that are connected with the main Mekong and Bassac River branches and the sea, thereby creating a vast number of “islands” so characteristic for an estuary. The coastal zone is affected by two tidal movements that surround the Delta: the semi-intensive-diurnal (twice daily) tides in the South China Sea with an amplitude of 2.00 – 3.75 m, and, the diurnal (daily) tides in the Gulf of Thailand with an amplitude of only 0.4 to 1.2 m. This coastline is characterized by tidal flats and relatively small areas of sandy ridges. At high tides, most of the coastal plain inundates with saline water from creeks or river branches, if not protected by coastal embankments, artificial levees or high bunds around the fields.

From Fig. 2 it is obvious that the Mekong Delta coastline displays significant dynamic features, and is characterized by active processes of erosion (abrasion) and accretion. In

affecting coastal stretches of extensive lengths (20–80 km), these phenomena are naturally caused by prevailing coastal currents, tidal range, wind set-up effects and wave action.

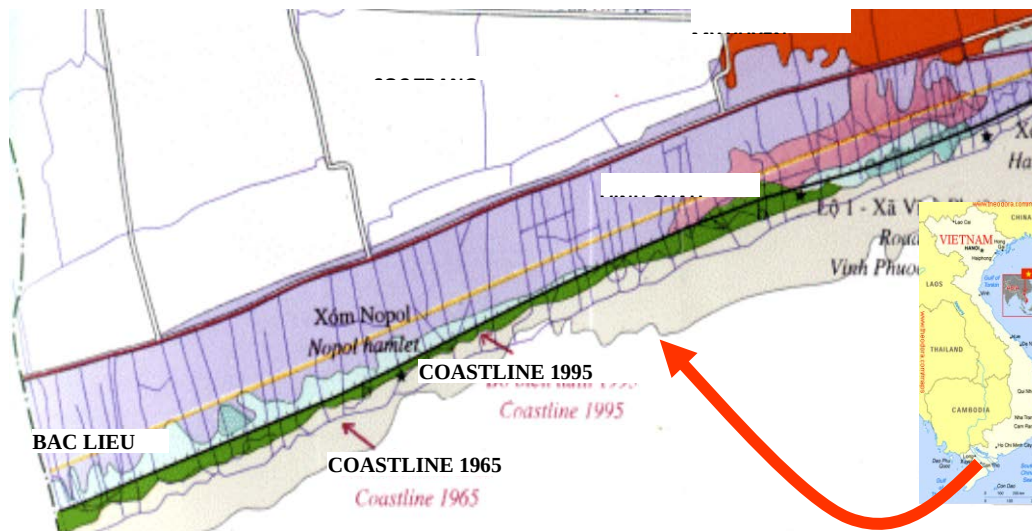


Fig. 2 : Lay out of Vinh Chau - Bac Lieu salt works (Mekong Delta, Vietnam) and erosion (small arrows indicating previous coastlines) along the coastal line.

1.2. Soil

Of the 12 main soil groups recorded from the Delta, only 4 are found in the fringe of the coastal plain. These are (1) sandy soils: found on narrow inland ridges between Bac Lieu and the South-eastern point of Soc Trang Province, and on a number of parallel ridges further inland in Tra Vinh Province; these soils have a high cation exchange capacity but fertility is very low due to salinity; (2) Permanent Saline Soils: situated on the sea side of the sandy soils, and along the southern and western coast of the Ca Mau peninsula; these soils are relatively fertile and acid accumulation is limited; (3) Permanent Saline Acid Soils: the majority of the inland southern Ca Mau peninsula, these soils can roughly be divided in Saline and Potential Acid Sulphate Soils (SPASS) and Saline and Actual Acid Sulphate Soils (SAASS); actual distribution of these two types within the study area remains unclear, but generally speaking, all lands that have been uprooted for shrimp pond construction classify as SAASS and experience acidification problems; (4) Dry Season Saline Soils: located further inland of the three soil groups mentioned above.

Exposure of acid soils to the air, for instance after excavation (for canal or pond construction), leads to oxidation of pyrite and formation of sulphuric acid, which acidifies soil and water. This leads to low pH values, that beyond certain threshold levels, inhibit most aquatic life as well as plant and crop growth. Values of pH 3 or less are frequently encountered in the coastal zone in particular at the start of the rainy season.

1.3. Climate

The coastal plain is dominated by a rainy south-west monsoon from end of April till October (85 % of the annual rainfall), and a dry north-east monsoon from November till April (15 % of the annual rainfall). The average annual rainfall varies from about 2,250 mm on the west coast to 1,250 mm in southern Tra Vinh. Within the Delta, the annual average temperature varies little and is 26 – 27°C, also the monthly mean temperature shows little variation, i.e. from 28.5°C in the warmest month (April) to 25.0°C in the coldest month (January). Annual evaporation rates range from 1,600 to 2,000 mm with highest values in March (2.0 – 5.5 mm/day) and lowest in October (1.8 – 2.0 mm/day). When combining rainfall and evaporation the data show that in most of the coastal zone rainfall exceeds evaporation during six months of the year.

The relative humidity is highest from August to October (84 – 90%) and lowest from February to March (65 – 80%). Sunshine and radiation vary with the seasons: highest monthly averages occur towards the end of the dry season, February to March (9 – 10 h/day and 450 – 550 cal/m², respectively) and are lowest in August to September/October (5 – 7 h/day and 360 – 400 cal/m², respectively).

NE winds prevail during the dry season, with velocities between 3 – 5 m/s, reaching 10 m/s in March and November/December, sometimes damaging the coastline. SW winds dominate during the rainy season and are also generally of low velocity. Typhoons, frequent in the central area of Viet Nam, are rare in the Delta.

1.4. Vinh Chau saltworks: specific characteristics of the study area

1.4.1. Geographic situation

Latitude 106° 05' – 106° 42' N; Longitude 9° 22' – 9° 24'. In the East and the South bordering the South China Sea, in the West adjoining to Bac Lieu province, in the North adjoining to My Xuyen and Long Phu districts in the Soc Trang province.

1.4.2. Topography

Vinh Chau belongs to Soc Trang and Bac Lieu territory. The soil profile characteristics are clay (55-60 %), mud (19-20 %), and sand (21-22 %). There are three main soil groups identified in the area, all classified with humic, flavic and salic specifics, which are characteristic for marine inundation areas.

1.4.3. Hydrology

Seawater enters the area directly from the East Sea (South China Sea). Semi-diurnal tidal regime affects the area directly from the East Sea with a large magnitude (i.e. 2.5 m to 4.5 m).

Salinity of the area fluctuates in time (Fig. 3) and the highest salinities are recorded from May to June (the end of the dry season). However, because this period coincides with the rainy season, salinity in the area remains quite low. Moreover, as *Artemia* ponds are usually

shallow (Brands, 1992), and heavy rains quickly dilute the pond salinity, pond culture of *Artemia* is not feasible during the rainy season.

2. OVERVIEW OF ARTEMIA CULTURE IN SOUTHERN VIET NAM

2.1. Review of *Artemia* cyst production in Viet Nam

First inoculation of *Artemia* in the central area of Vietnam took place in 1982 (Vu Do Quynh and Nguyen Ngoc Lam, 1987) with *Artemia* strains from Macau (Brazil), Great Salt Lake (USA) and China. However, in Vinh Chau and Bac Lieu (southern Vietnam, East coast of the Mekong Delta) first inoculation attempts were made in 1984 (De Graaf, 1985) and successful cyst production was recorded with San Francisco Bay (CA-USA, SFB) *Artemia* only in 1986 (Rothuis, 1986).

In the period between 1986 and 1990 different culture systems, e.g. the static system, flow-through system, and pond management procedures were developed. Late 1989 and early 1990 a few salt farmers in the area were selected to introduce *Artemia* into their salt farms for cyst production. Cyst production was successful and resulted in higher profits (3-5 folds) for farmers compared to the low income from traditional salt works. These results stimulated the salt-cooperatives and more farmers to engage in *Artemia* culture. In 1991, more than 2,700 kg of raw cysts were collected from 40 ha of culture area, which made the product available for commercialization. By 2001 the number of production sites increased to approximately 1,200 ha along Vinh Chau and Bac Lieu coastal lines, yielding almost 50 tons of raw cysts (College of Aquaculture and Fisheries, Can Tho University, unpublished data). With the boom of shrimp farming in 2002, many salt farmers switched their salt operation into shrimp culture. Also the drop of the selling price of raw cysts led a number of farmers back to their traditional salt production. In recent years this region has now turned into an important supplier of high-quality cysts (see Table 2).

Table 1: Overview of the weather conditions in Vinh Chau (Soc Trang province)

Month	Air temperature (°C)		Sun-hours (hrs/wk)	Rain-fall (mm/month)	Humidity (%)	Evaporation (mm/wk)
	max	min				
JAN	30.47±0.49	22.02±0.53	87±7	4.43±5.42	79.11±1.72	34.73±2.45
FEB	31.51±0.55	22.06±0.64	87±6	17.60±24.89	78.56±0.96	34.44±3.18
MAR	32.71±0.33	23.29±0.72	96±7	13.88±13.57	77.11±1.54	43.05±4.82
APR	34.27±0.55	24.58±0.51	90±6	39.60±30.97	77.22±0.78	40.78±4.08
MAY	33.32±0.65	24.77±0.17	67±4	235.29±155.53	82.56±1.60	27.98±4.01
JUN	31.83±0.47	24.65±0.28	53±4	301.87±66.66	86.83±1.01	20.36±3.18

JUL	31.29±0.90	24.27±0.18	58±9	370.38±104.41	87.83±0.66	19.71±2.88
AUG	30.58±0.31	24.12±0.15	52±7	387.71±75.94	88.50±1.26	18.01±2.17
SEP	30.59±0.54	24.22±0.15	51±10	377.76±86.37	89.28±0.95	16.94±2.69
OCT	30.38±0.47	24.22±0.30	55±12	316.16±88.81	88.17±1.96	15.66±1.46
NOV	30.27±0.45	23.69±0.34	68±14	125.70±51.61	85.22±2.65	20.62±5.05
DEC	29.88±0.62	22.53±0.23	72±13	45.60±49.01	83.00±1.32	23.56±3.07

(Source: Meteorological field station, Soc Trang province)

Table 2: Cyst quality of Vinh Chau *Artemia* (SFB origin, source: Aquaculture and Fisheries Sciences Institute, University of Cantho, Viet Nam)

Cyst diameter	235.2 ± 1.3 µm
Hatching efficiency (HE)	> 300,000 Nauplii/g
Moisture content	< 5 %
Hatching percentage (24 h ; 28°C)	> 90 %
HUFA (highly unsaturated fatty acid)	≈ 17 mg/g

2.2. General description of a traditional salt street and an *Artemia* culture system

2.2.1. Description of a traditional salt street

Salt production in Vinh Chau and Bac Lieu follows the traditional system, the so-called solar salt works, in which each salt street includes a reservoir, primary and secondary evaporation ponds, storage ponds, and finally crystallizers for salt precipitation. In such a salt street, crude salt is being produced by evaporation of seawater under the influence of solar radiation. The system is illustrated in Fig. 4 and operates as follows: seawater of 35 g/l from the reservoir will flow by gravity into the next basin, evaporation pond 1. Evaporation takes place and salinity reaches 70 g/l within a couple of days depending on temperature, wind speed, water viscosity, etc. Next, this saline water will be transferred into evaporation pond 2, and eventually to the following basins for further evaporation. This process continues until salinity reaches 170 to 250 g/l, approximately. Finally, high saline water or brine will be fed into crystallizers, in which, within 10 to 15 days, sodium chloride salt precipitates, completing a full production cycle. The first complete cycle, i.e. from seawater intake up to salt precipitation in the crystallizers, takes approximately 45 days. Towards the end the dry season, when temperature has increased and more salty water becomes available, the following batches for salt precipitation are shorter. Normally 4 to 6 salt production cycles are completed during the dry season in this area.

2.2.2. General description of Artemia culture in Vinh Chau saltworks

The Artemia culture system in Vietnam is referred to as “semi-intensive” (Tackaert and Sorgeloos, 1991) and static (Vu Do Quynh and Nguyen Ngoc Lam, 1987). The term “semi-intensive” is used to denote small seasonal man-managed systems in which brine shrimp are inoculated at high densities (> 20 nauplii/l). Ponds are managed intensively following the methodology outlined in Sorgeloos et al. (1986), i.e. inoculation of selected strains, manipulation of primary and secondary production, predator control, etc.

In the previously described salt street, Artemia can be introduced into ponds where salinity reaches 80 g/l to 120 g/l. Most of the Artemia ponds in Vinh Chau and Bac Lieu salt works are situated in the second evaporation ponds, i.e. where salinity varies from 90 to 150 g/l (see Fig.4). An Artemia pond of 0.5 to 0.7 ha is manageable. A pond with its axis directed towards the local wind orientation is necessary for more oxygen diffusion into the water column. Wind action also helps to drive the floating cysts into the pond corners from where they can be harvested. As salt ponds are usually shallow, excavation of the pond bottom and/or heightening the pond dikes to increase the pond volume are necessary. In every culture system, a “kitchen pond” to produce green water as feed for Artemia, is recommended. Green water is pumped from a common fertilization pond and if needed mixed with brine to maintain high salinity levels (> 80 g/l) in the culture ponds (Vu Do Quynh and Nguyen Ngoc Lam, 1987; Baert et al., 1997). Two to three weeks after inoculation, Artemia commonly starts to reproduce. Two reproduction modes (i.e. ovoviviparous and oviparous) are observed in SFB Artemia. High production of cysts usually occurs in February to March as water temperature is less than 35°C. Towards the end of the dry season, high water temperature and food limitation cause a population collapse. Sometimes ponds are re-inoculated but higher water levels are then needed in order to avoid excessive water temperatures. In average, cyst production in Vinh Chau varies from less than 5 kg/ha/month to 40 kg/ha/month, depending on the culture system (extensive vs. semi-intensive, respectively), and the climatic conditions.

Recently, the culture techniques have been gradually improved into intensive culture techniques, in which the main concepts are the following: (1) excavated ponds as to increase the water column to at least 50 cm, (2) stocking density up to 100 nauplii/l, (3) management of green water to stimulate more suitable algae (e.g. diatoms and green algae) at appropriate concentrations prior to outflow to the Artemia pond, (4) additional feeding with marine shrimp feed (circa 40 % protein) and finally (5) aeration of the pond waters in order to promote higher survival, growth and reproduction rates. Interestingly, such a system now can yield cyst productions up to 150-200 kg raw cysts (wet weight) per hectare and per season (90-120 days) and thus considerably improve the farmer's income (US \$ 7,000 to 10,000 per household per season).

3. CONCLUSION

Because of its wide tolerance the *Artemia franciscana* (SFB) strain was intentionally introduced at the beginning and now it has shown its ability to adapt to a new habitat in the solar salt works in the Mekong delta. This combined salt-cum-Artemia production has become a very lucrative business with major socio-economic ramifications in the coastal area of Vinh Chau – Bac Lieu in the Mekong Delta of Vietnam: over 500 families of salt farmers have improved their income with more than 5,000 US \$ per household and per dry

season with the production and sales of brine shrimp (cysts and since recently also adult brine shrimp biomass harvested towards the end of the dry season through the first months of the rainy season). Although cyst harvests amount to about 50 tons in a dry season of 3 to 4 months, these meet less than 10 % of the present demand for Artemia cysts by the Vietnamese aquaculture industry. Local availability of top-quality Artemia cysts has allowed Vietnam to become the first in the world to develop commercial mud crab hatcheries (as umbrella Artemia can be used to replace rotifers at start feeding).

As the profitability of seasonal solar salt production is under much pressure in many countries around the world integrated salt with brine shrimp production should be further explored: it can make this artisanal sector, often involving many thousands of households, again profitable (with brine shrimp Artemia as extra by-product and thanks to its filter-feeding activity producing a higher NaCl quality) and furthermore contribute to the expansion of local fish and shellfish farming activities.

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