

Modified extensive pond culture of *Litopenaeus vannamei* for sustainable shrimp culture in the Philippines

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Abstract. The shrimp culture industry provides huge revenues to most aquaculture producing countries, but it is also beset with problems that hamper its sustainability. In the present study, we described a modified extensive pond culture method for white shrimp, *Litopenaeus vannamei* in the Philippines during the wet and dry months. One hectare earthen ponds were prepared and added with organic and/or inorganic fertilizers to stimulate natural food production. The ponds were stocked with *L. vannamei* postlarvae (PL) at a density of 4 PL m⁻². A zero-water exchange system of pond management was done during the first two months of culture followed by a bi-weekly water exchange until harvest. No artificial feeding was given during the culture period, instead, the ponds were applied with inorganic fertilizer every month to ensure continuous supply of natural food. During the culture period, the shrimps appeared healthy and no disease outbreaks were observed. All the physico-chemical parameters of the water in the pond were within the optimum range required for shrimp farming and the phytoplankton population was predominantly green microalgae (Chlorophyta). The shrimps were harvested after 3 to 3.5 months of culture or when they reached an average body weight of 13-15 g, with moderate to high survival rates depending on the prevailing climatic conditions.

Key Words: modified extensive, shrimp culture, shrimp, *Litopenaeus vannamei*.

Introduction. Aquaculture production has grown tremendously in the past years and is expected to continue during the next few years. Crustacean aquaculture followed the same trend in which its annual production reached almost 5 million tons in 2006 (FAO 2009). Penaeid shrimps account for the bulk of production in terms of volume and value of production. The rapid expansion of shrimp aquaculture has resulted in serious consequences mostly related to environmental impacts and over-dependence on the use of fish meal as the main protein ingredient in shrimp feeds (Tacon 2002; Porchas-Cornejo et al 2011). Several management strategies have been developed to minimize the impacts of intensive shrimp aquaculture, including the use of low or zero water exchange, recirculating systems, adoption of alternative feed ingredients and feeding strategies, polyculture/crop rotation techniques and the use of natural feed (Martinez-Cordova et al 1998; Thakur & Lin 2003; Casillas-Hernández et al 2007; Muangkeow et al 2007; Chi et al 2009; Krummenauer et al 2010; Markey et al 2010; Porchas-Cornejo et al 2011).

The adequate management and use of the natural biota in shrimp ponds as techniques in farming have been found to be cost-effective methods in reducing the risk of environmental degradation (Martinez-Cordova et al 2002; Martínez-Córdova & Peña-Messina 2005; De Schryver et al 2008). This is achieved through lesser use of supplemental feeding thereby decreasing the organic load of the effluent that is being released back to the waterways. The modified extensive method in shrimp farming suits these criteria in which there is lower stocking density of the shrimp and the cultured stock relies mainly on natural food production. It has been demonstrated that in semi-intensive ponds, the natural food present can support up to 75% of the nutritional

requirements of the stock (Anderson et al 1987; Jory 2000). If the stocking density is reduced then natural food production could completely meet the food demands of the shrimps during culture.

Among the natural food present in the pond, the benthic organisms and zooplankters are the preferred food items of shrimps (Rubrigh et al 1981; Martínez-Córdova & Peña-Messina 2005), however, the numbers tend to decline towards the end of the culture period. Hence shrimp ponds are fertilized either with organic or inorganic fertilizers to ensure continuous growth of natural food (Martinez-Cordova et al 1998).

There are several shrimp species that are being cultured in ponds, and the farming of the white shrimp, *Litopenaeus vannamei* (Boone, 1931) is increasing rapidly because this species of shrimp has fast growth rates, thus, reducing its culture period. Aside from being a good potential species in aquaculture, white shrimp has been included by the Greenpeace International in its seafoods red list in 2010 (<http://www.greenpeace.org/international/seafood/red-list-of-species>). An aquatic commodity that is included in the red list means that this particular species is being sold in markets around the world that has a high risk of being obtained from unsustainable resources. White shrimp is not endemic in the Philippines and it was only recently that the Philippine government lifted its ban on the importation of this shrimp in the country (Civin-Aralar et al 2009). At present, there have been culture initiatives for white shrimps in various parts of the country.

Preliminary trials on the cage culture of white shrimp at various stocking densities in a shallow eutrophic lake showed that growth was significantly affected by the stocking density, whereas survival rate was not (Civin-Aralar et al 2009). The shrimps were grown in low salinity conditions, yet they attained harvestable sizes (range: 11-23 g) at 95 days of culture, depending on the stocking density. In terms of the growth performance of white shrimps in ponds, there have been few studies that documented pond trials for this species. Most shrimp farmers relied on their previous pond culture experiences with tiger shrimp, *Penaeus monodon* and used this technical knowledge when farming white shrimps. Hence, this study aimed to provide the detailed pond culture practices for white shrimp using the modified extensive method. More specifically, this study determined the grow-out performance of white shrimp during the dry and wet months subsisting entirely on natural food in the pond. In addition, the different biological and physico-chemical parameters of the water were assessed to find out the optimum levels of each parameter that are required for the pond culture of this shrimp species.

Materials and Methods

Experimental ponds and their preparation. A 1-ha earthen pond was used for the modified extensive culture of white shrimp, *L. vannamei*. Pond preparation activities during the dry months were different during the wet months. During the dry months, the ponds were sundried for 30 days, compacted and the dikes repaired of leaks and seepage. Hydrated lime was added at 500 kgs per hectare followed by the broadcasting of chicken manure as organic fertilizer at a rate of 3 tons per hectare. Brackishwater was added to the pond either through the use of pumps or gravity flow at a depth of 5-10 cm and applied with teaseed powder at a concentration of 20 ppm to kill fish larvae and juveniles. The pond is left for a few days until luxuriant growth of periphyton (benthic assemblages of both zoo- and phytoplankters that serve as natural food) is observed. After two weeks when the amount of natural food present in the pond is at its maximum density, the water level is gradually increased to 30 cm then finally to 60-70 cm in time for stocking of the shrimp postlarvae.

During the wet months, immediately after harvest the pond is flushed with brackishwater to remove high amounts of organic material. After flushing, brackishwater is added into the pond at a depth of 10 cm and applied to with teaseed powder. This was followed by the addition of inorganic fertilizer (ammonium phosphate and urea) at a rate of 50 kg per hectare. The addition of inorganic fertilizers facilitates the growth of filamentous green algae, which are dominant during the rainy months. After two weeks,

the water level is increased to 30 cm and a second application of inorganic fertilizer is done at the same dosage. The water level is then increased to 60-70 cm prior to stocking.

Stocking of shrimps. Stocking is usually done early in the morning between 6-7 AM, when the air temperature is not so high. Forty thousand (40,000) disease-free shrimp postlarvae (PL 12) were procured from a commercial hatchery in Central Philippines. Prior to shipment, the postlarvae in the hatchery were acclimated to the salinity of the pond in order to prevent salinity stress during stocking. Upon reaching the pond site, the transport bags are opened and allowed to float on the pond water. Once the temperature of the transport bags is similar to the pond water, the contents of the transport bag are gradually mixed with the water from the pond and the larvae are slowly released to the pond. During stocking, initial readings for salinity, water temperature and dissolved oxygen are recorded.

Natural feeding and pond management. The shrimps relied solely on natural food that grew inside the pond throughout the culture period. In order to maintain stable production of natural food in the pond, inorganic fertilizers (ammonium phosphate and urea) were added monthly at a rate of 20 kg per hectare. The fertilizers are dissolved in water and broadcasted directly to the pond after water exchange.

During the first two months of culture, there was zero-water exchange. The pond is only filled with water during the high tide to maintain the desired water level. From the third month until harvest, water exchange was done every spring tide (usually every two weeks) by gravity flow.

Aeration was provided only on emergency cases, and this occurred during the latter part of the culture period. One horsepower paddle wheel aerator was installed in the pond and operated from 4 AM until 8 AM, when dissolved oxygen level in the pond was low or when the shrimps were observed to swim up the water surface and stayed along the sides of the ponds.

Water sampling and analyses. Water samples were collected once a week for the analyses of ammonia, alkalinity and water pH in the laboratory. Dissolved oxygen, temperature, salinity and water depth were measured on the field twice weekly. Water samples for phytoplankton counts were taken every two weeks.

Salinity was measured using Atago refractometer, while temperature and dissolved oxygen were determined using the YSI model DO meter. Water pH was determined using a digital pH pen. Ammonia and total alkalinity were determined following standard procedures (Strickland & Parsons 1972; APHA 1989).

For the quantitative determination of phytoplankton population in the pond, water samples (100 ml) were collected in plastic containers, concentrated and added with 1% Lugol's iodine solution as preservative (Casé et al 2008). Direct enumeration was done using Neubauer hemocytometer counting chamber and a compound microscope. Phytoplankton was identified at the genus level and enumerated following the keys and illustrations of Prescott (1962).

Results and Discussion. The growth of the shrimps during the dry and wet months is shown in Figure 1. During the dry months the shrimps were harvested at 87 days of culture (DOC) at an average body weight of 15.96 g. On the other hand, during the wet months, the shrimps attained harvestable size of 14.98 in 100 DOC. Other production parameters are shown in Table 1. Survival rate of the cultured stock was 70% and 24.8% during the dry and wet months, respectively. The rate of growth of the shrimps was 1.28 g per week during the dry months and 1.05 g per week during the wet months. All throughout the duration of the culture period, the shrimps subsisted on the natural food present in the pond, hence, there were no additional commercial feed inputs. Guerrero-Galván et al (1999) reported better growth and higher production of *L. vannamei* in semi-intensive (stocking density of 14-20 PLs m⁻²) ponds during the dry months than in the rainy months. Our results conformed with their studies even if we used a modified semi-extensive system. Because of better growth rates during the dry months, the number of days in culturing the shrimps was shorter during this time than with the rainy months. In addition, the growth rate of the shrimp in the present study was higher in the

dry months than in the wet months, and these findings were similar to those obtained by Guerrero-Galván et al (1999). Regardless of the climatic conditions, we obtained higher growth rates than those done in previous studies (Hopkins et al 1993; Teichert-Coddington et al 1994; Guerrero-Galván et al 1999), and this could be explained by the differences in pond culture management and stocking densities. As to harvest weights, our reported values for both the dry and wet months were comparable to those obtained by Hopkins et al (1991) at 14-19 g and by Guerrero-Galván et al (1999) at 11-16 g.

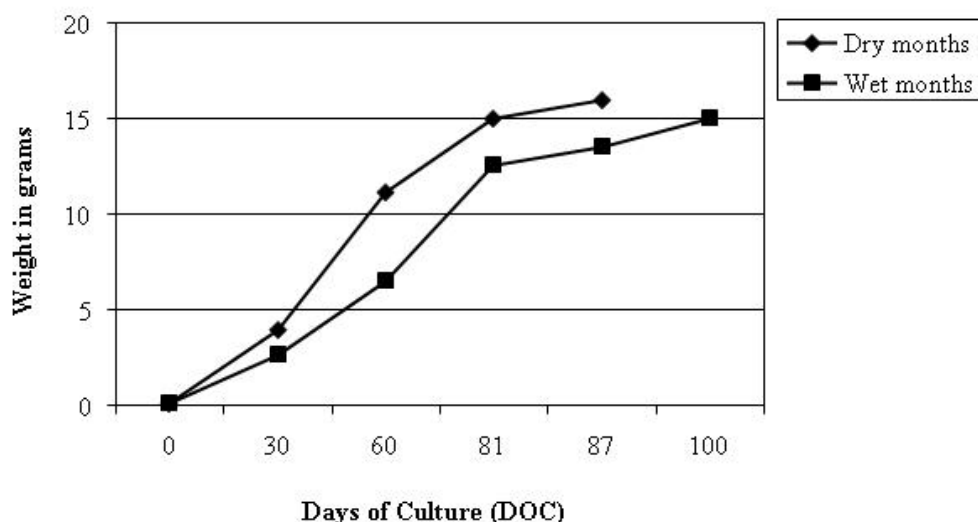


Figure 1. Growth of white shrimps during the dry and wet months in a modified extensive pond culture system.

Table 1

Production of white shrimps in a modified extensive pond culture system during the dry and wet months

	Days of Culture	Weight at harvest (g)	Growth rate (g/wk)	Survival Rate (%)
Dry months	87	15.96	1.28	70.0
Wet months	100	14.98	1.05	24.8

We also obtained higher survival rate of the shrimps during the dry months than in the wet months. There is no single factor that could explain this difference because the trial was done in one pond for both climatic conditions. We have observed that the shrimps were apparently healthy, such that there was no luminous bacteria infestation as well as no outbreak of white spot disease. Hence, the low survival could not be implicated on the presence of diseases. During the wet months, there was the abundance of migratory birds in the area and the low survival was due to predation rather than mortality due to diseases or due to fluctuations in environmental conditions such as changes in salinity levels and suspended solids. Additional studies should be done to compare pond performance of white shrimp in both dry and wet months by having more or less similar management approaches so that the differences could be attributed to environmental

factors rather than biases in human intervention. For comparison, Guerrero-Galván et al (1999) obtained higher survival of white shrimps in ponds during the wet months than in the dry months. If seasonal changes are correlated with fluctuations in salinity, then studies done by Ogle et al (1992) and Yan et al (2007) showed that white shrimps had better survival at higher salinities (similar to the dry months) than at lower salinities (similar to the wet months). Salinity levels have also direct effect on the composition of natural food, *i.e.*, during the dry months when salinity is high, the natural food population in the pond is dominated by periphyton benthic organisms, whereas during the wet months, which is characterized by lower salinity levels, the natural food in the pond is predominantly filamentous green algae. Between the two food types, shrimps have better preference on the benthic periphyton assemblages (Rubrigh et al 1981).

The different water quality parameters of the shrimp pond during the culture period is shown in Table 2. The salinity levels during the dry months ranged from 30 to 42 ppt, while it ranged 20 to 30 ppt in the wet months. All the other water quality parameters were more or less similar during the dry and wet months. The values of these water quality parameters were optimum for shrimp culture and were comparable to previous studies on the culture of white shrimp whether in semi-intensive/intensive ponds (Martinez-Cordova et al 1998; Guerrero- Galván et al 1999; Casillas-Hernández et al 2007; Krummenauer et al 2010; Porchas-Cornejo et al 2011) or in cages/tanks (Cuvin-Aralar et al 2009). Because we used a modified extensive level of pond management, we did not observe erratic changes in the water quality as compared to semi- or intensive culture system where wide fluctuations in the water quality of the pond would likely occur towards the latter part of the culture period as observed by Casillas-Hernández et al (2007). In addition, there was no feed input throughout the duration of the culture period, hence, there was less risk of organic matter build-up in the pond due to the presence of uneaten feeds, thereby reducing the load of nitrogen metabolites and suspended solids. The only intervention that took place was the addition of both hydrated lime and dolomite to the pond at a rate of 100 kg ha⁻¹ when total alkalinity of the water was below 70 ppm. By having a total alkalinity of at least 70 ppm, the natural food production in the pond was stable and regular molting of the shrimps was observed.

Table 2

Range of water quality parameters in the shrimp ponds during the dry and wet months

	Dry months	Wet Months
Salinity (ppt)	30 – 42	20 - 30
Temperature (°C)	24.8 – 31.1	24.8 – 31.1
Dissolved Oxygen (ppm)	3.1 – 6.6	3.1 – 6.6
pH	7.9 – 8.8	7.9 – 8.8
Ammonia-N (ppm)	0.01- 0.28	0.01 – 0.28
Alkalinity (ppm)	56.3 – 126.7	56.3 – 126.7

The profile of the natural food population in terms of the number of phytoplankton cells/organisms in the pond during the culture period is shown in Figure 2. The total phytoplankton count was more or less stable during the entire culture period, although lower counts were observed towards the latter part of the culture. This is not surprising because as the shrimps grow bigger, their demand for food and the quantity being eaten also increased. Although bigger-sized shrimps seldom feed on the microscopic phytolankters, the latter serve an important link of the food chain that eventually ensure

continuous supply of natural food for the shrimps. For example, Martinez-Cordova et al (1998) found that polychaetes were the most abundant benthic organisms in ponds cultured with white shrimps. These polychaetes feed on zooplankters which in turn subsist on phytoplankton. Zooplankton population affects the dynamics of the phytoplankton composition due to the grazing activity of the former (Coman et al 2003). It can be inferred that the more phytoplankters are present in the pond, that will likely result in higher numbers of polychaetes, that serve as food for the shrimps. Based on the production at harvest, the natural food production in the pond could support a biomass of up to 400 kg, as long as the growth of the natural food is regularly maintained through the addition of inorganic fertilizers.

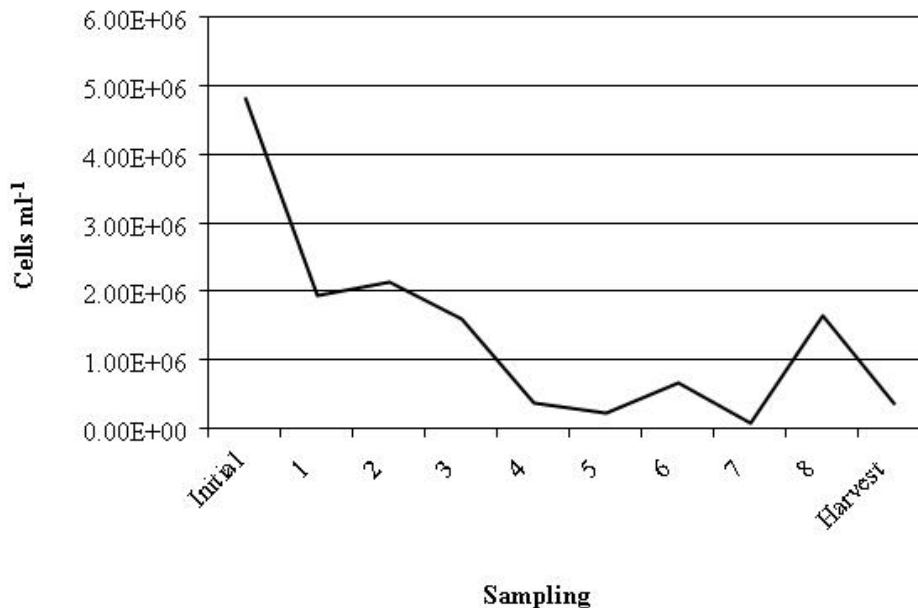


Figure 2. Total phytoplankton in shrimp pond using a modified extensive culture system.

During the culture period, the natural food in the pond was dominated by the members of Chlorophyta (green algae), specifically *Chlorella* sp. (Figure 3). The percentage composition of this phytoplankton in the shrimp pond ranged 64.3 to 97.2%. The other minor phytoplankton populations include the Cyanophyta (blue-green algae) and the Chrysophyta (golden algae and diatoms). However, towards the latter part of the culture period, the populations of the blue-green algae increased particularly the percentage composition of *Oscillatoria* sp., *Chroococcus* sp., *Aphanocapsa* sp. and *Microcystis* sp. Casé et al (2008) observed that as the culture of white shrimps progressed, the plankton composition in the pond is dominated by cyanobacteria/blue-green algae, protozoans and rotifers. Such increase in the populations of this group of phyto- and zooplankton is due to higher loads of nutrients in the ponds. Similar trend was also observed in this study, however the composition of blue-green algae in the shrimp pond did not exceed the population of the green microalgae, hence, possible deleterious effects of the growth of blue-green algae are kept at the minimum. We can also speculate that the presence of high populations of *Chlorella* sp in the pond could be a contributing factor why the incidence of diseases particularly due to luminous *Vibrios* was low. This observation was based on laboratory studies that showed inhibition of luminous *Vibrio harveyi* in the presence of *Chlorella* sp in the water (Tendencia & dela Peña 2003; Huervana et al 2006). However, in pond conditions these results are not yet conclusive and additional studies are needed to determine the relationship between abundance of *Chlorella* sp. and inhibition of luminous *Vibrios* and other pathogenic agents.

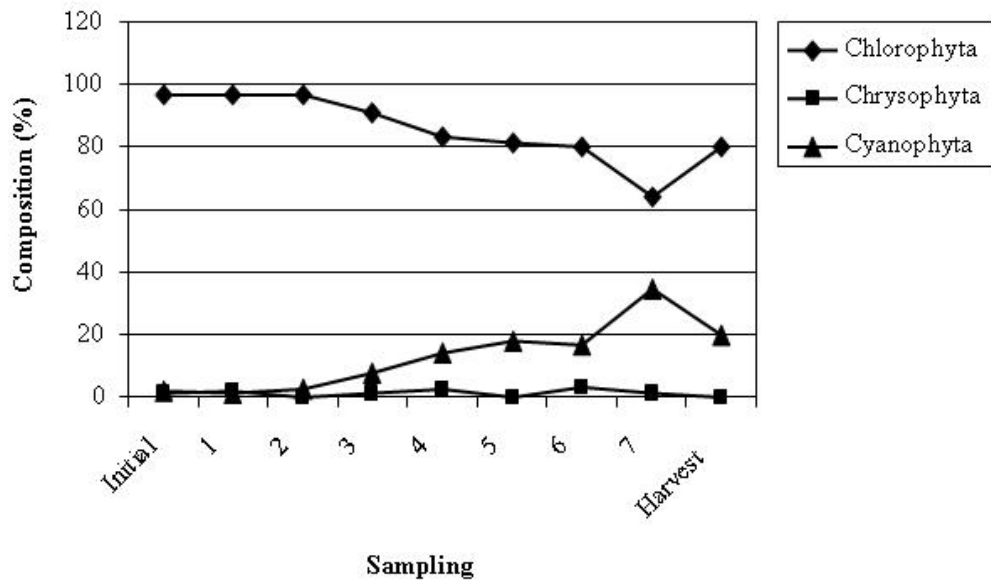


Figure 3. Percentage composition of phytoplankton population in a modified extensive shrimp pond.

Conclusions. In summary, we have described a modified extensive pond culture method without supplemental feeding for the rearing of white shrimps in the Philippines both during the dry and wet months. This method ensures sustainability in shrimp farming because of its low inputs, low risk of disease problems and environmental degradation. Natural feeding that is complemented by fertilization with inorganic fertilizers could support a shrimp biomass up to nearly 400 kg. Higher survival, production and shorter culture period was observed during the dry months. Regardless of the time of culture, the shrimps attained harvestable size (13-15 g) in 80-100 days of culture. Water quality parameters were stable and did not fluctuate towards the latter part of the culture period. The phytoplankton population is dominated by green microalgae, particularly the *Chlorella* sp., which could have inhibitory effects against pathogenic agents.

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References

- Anderson R. K., Parker P. L., Lawrence A. A., 1987 A $^{13}\text{C}/^{12}\text{C}$ tracer study of the utilization of presented feed by a commercially important shrimp *Penaeus vannamei* in a pond grow-out system. *J World Aquac Soc* **18**:148.
- APHA (American Public Health Association), 1989 Standard methods for the examination of water and wastewater, 17th ed. Port City Press, Baltimore, pp. 10-203.
- Casé M., Leca E. E., Leitão S. N., Anna E. E. S., Schwamborn R., Junior A. T. M., 2008 Plankton community as an indicator of water quality in tropical shrimp culture ponds. *Mar Pollution Bull* **56**:1343-1352.
- Casillas-Hernández R., Nolasco-Soria H., Garcia-Galano T., Carrillo-Farnes O., Paez-Osuna F., 2007 Water quality, chemical fluxes and production in semi-intensive Pacific white shrimp (*Litopenaeus vannamei*) culture ponds utilizing two different feeding strategies. *Aquac Eng* **36**:105-114.

- Chi S., Tan B., Mai K., Zheng S., 2009 Growth and feed efficiency of juvenile shrimp *Litopenaeus vannamei* fed formulated diets containing different levels of poultry by-product meal. *J Ocean Univ China* **8**:399-403.
- Coman F. E., Connolly R. M., Preston N. P., 2003 Zooplankton and epibenthic fauna in shrimp ponds: factors influencing assemblages dynamics. *Aquac Res* **34**: 359-371.
- Cuvin-Aralar M. L. A., Lazartigue A. G., Aralar E. V., 2009 Cage culture of the Pacific white shrimp *Litopenaeus vannamei* (Boone, 1931) at different stocking densities in a shallow eutrophic lake. *Aquac Res* **40**:181-187.
- De Schryver P., Crab R., Deforidit T., Boon N., Verstraete W., 2008 The basics of bio-flocs technology: the added value for aquaculture. *Aquaculture* **277**:125-137.
- FAO, 2009 The State of World Fisheries and Aquaculture 2008. Food and Agriculture Organization of the United Nations. Rome, Italy. 196 p.
- Guerrero-Galván S. R., Páez-Osuna F., Ruiz-Fernández A. C., Espinoza-Angulo R., 1999 Seasonal variation in the water quality and chlorophyll *a* of semi-intensive shrimp ponds in a subtropical environment. *Hydrobiologia* **391**:33-45.
- Hopkins J. S., Stokes A. D., Browdy C. L., Sandifer P. A., 1991 The relationship between feeding rate, paddle-wheel aeration rate and expected dawn dissolved oxygen in intensive shrimp ponds. *Aquac Eng* **10**:281-290.
- Hopkins J. S., Hamilton R. D., Sandifer P. A., Browdy C. L., Stokes A. D., 1993 Effect of water exchange rate on production, water quality, effluent characteristics and nitrogen budgets of intensive shrimp ponds. *J World Aquac Soc* **24**:304-320.
- Huervana F. H., dela Cruz J. J. Y., Caipang C. M. A., 2006 Inhibition of luminous *Vibrio harveyi* by "green water" obtained from tank culture of tilapia, *Oreochromis mossambicus*. *Acta Ichthyol Piscat* **36**:17-23.
- Jory D. E., 2000 General concerns for managements of biota in progress shrimp ponds. *Aquac Mag* **26**:76-80.
- Krummenauer D., Cavalli R. O., Ballester E. L. C., Wasielesky W. Jr., 2010 Feasibility of Pacific white shrimp *Litopenaeus vannamei* culture in southern Brazil: effects of stocking density and a single or a double CROP management strategy in earthen ponds. *Aquac Res* **41**:240-248.
- Markey J. C., Amaya E. A., Davis D. A., 2010 Replacement of poultry by-product meal in production diets for the Pacific white shrimp, *Litopenaeus vannamei*. *J World Aquac Soc* **41**:893-902.
- Martínez-Córdova L., Campaña-Torres A., Porchas-Cornejo M., 2002 Promotion and contribution of biota in low water exchange ponds farming blue shrimp, *Litopenaeus stylirostris* (Stimpson). *Aquac Res* **33**:27-32.
- Martínez-Córdova L., Peña-Messina E., 2005 Biotic communities and feeding habits of *Litopenaeus vannamei* (Boone, 1931) and *Litopenaeus stylirostris* (Stimpson, 1974) in monoculture and polyculture semi-intensive ponds. *Aquac Res* **36**:1075-1085.
- Martinez-Cordova L. R., Villareal-Colmenares H., Porchas-Cornejo M. A., 1998 Response of biota to aeration rate in low water exchange ponds farming white shrimp, *Penaeus vannamei* Boone. *Aquac Res* **29**:587-593.
- Muangkeow B., Ikejima K., Powtongsook S., Yi Y., 2007 Effects of white shrimp, *Litopenaeus vannamei* (Boone), and Nile tilapia, *Oreochromis niloticus* L., stocking density on growth, nutrient conversion rate and economic return in integrated closed recirculation system. *Aquaculture* **269**:363-376.
- Ogle J. T., Beaugez K., Lotz J. M., 1992 Effects of salinity on the growth and survival of *Penaeus vannamei*. *Gulf Res Rep* **8**:415-421.
- Porchas-Cornejo M. A., Martinez-Cordova L. R., Ramos-Trujillo L., Hernandez-Lopez J., Martinez-Porchas M., Mendoza-Cano F., 2011 Effect of promoted natural feed on the production, nutritional, and immunological parameters of *Litopenaeus vannamei* (Boone, 1931) semi-intensively farmed. *Aquac Nutr* **17**:e622-e628.
- Prescott G. W., 1962 Algae of the Western Great Lakes with an Illustrated Key to the Genera of Desmids and Freshwater Diatoms. Brown, Dubuque, LA.

- Rubright J. S., Harrel J. S., Holcomb H. W., Parker J. C., 1981 Response of planktonic and benthic communities to fertilizer and feed applications in shrimp mariculture ponds. *J World Mariculture Soc* **12**:281-299.
- Strickland J. D. H., Parsons T. R., 1972 A practical handbook of seawater analysis. *Bull Fish Res Bd Can* 167, 310 p.
- Tacon A. G. J., 2002 Thematic review of feed and feed management practices in shrimp aquaculture. A report for FAO, World Bank, WWF and NACA, Kanehoe, HI.
- Teichert-Coddington D. R., Rodriguez R., Toyofuku W., 1994 Cause of cyclical variation in Honduran shrimp production. *World Aquac* **25**:57-61.
- Tendencia E. A., dela Peña M., 2003 Investigation of some components of the greenwater system which makes it effective in the initial control of luminous bacteria. *Aquaculture* **218**:115-119.
- Thakur D. P., Lin C. K., 2003 Water quality and nutrient budget in closed shrimp (*Penaeus monodon*) culture systems. *Aquac Eng* **27**:159-176.
- Yan B., Wang X., Cao M., 2007 Effects of salinity and temperature on survival, growth and energy budget of juvenile *Litopenaeus vannamei*. *J Shellfish Res* **26**:141-146.
- *** <http://www.greenpeace.org/international/seafood/red-list-of-species>.

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