The impact of tiger shrimp, *Penaeus monodon* Fabricius, postlarvae stocking density on production in traditional tambak systems in East Java, Indonesia

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Abstract
The effects of stocking density [range: 2.0–5.5 postlarvae (PL) m\(^{-2}\)] and water quality on the production of a traditional tambak tiger shrimp, *Penaeus monodon* Fabricius, culture system on one farm in Probolinggo, East Java, were studied during one culture period of 126 days using eight ponds. Production characteristics were recorded and water quality parameters monitored. Production was quadratically influenced by stocking density. The optimum density was 4.8 PL m\(^{-2}\), which corresponds with a production per crop of around 300 kg ha\(^{-1}\). Production was also quadratically related to mean shrimp body weight at harvest, while there was an inverse relationship between production and bottom organic matter, indicating that shrimp biomass diminishes the amount of organic matter accumulating at bottom of the tambak.

Introduction
In East Java, Indonesia, 45 000 ha of tambak exist, the majority being exploited extensively (Hariati, Wiadnya, Prajitno, Sukkel, Boon & Verdegem 1995). The tambak system of intertidal brackish water ponds is centuries old (Schuster 1952), and is used for both finfish and shrimps. Whereas intensive shrimp-farming systems in Asia and Latin America are well documented (Sindermann & Lightner 1988), and the subject of numerous research projects, studies on extensive culture practices are rare, and little or no effort is put into improving their management. This is in spite of the fact that 50% of shrimp production in East Java is produced extensively, providing labour and income to more than 7000 households (Hariati et al. 1995).

Tambak shrimp production depends on several variables, one of them being stocking density. For intensive tambak production in East Java, Hariati, Wiadnya, Sukkel, Boon & Verdegem (1996) observed a positive correlation between PL stocking density and production, the optimum density being \(\approx 45\) postlarvae (PL) m\(^{-2}\), which corresponds to a production of 14.3 t year\(^{-1}\) (1 t = 1000 kg). It is important to find out whether a similar relationship exists in extensive tambak systems, considering PL are the principal cost factor for extensive farms in Indonesia. Traditional tambak management relies on primary productivity without the application of artificial feeds. The principal source of nutrients in extensive systems is the estuarine water entering the tambak at high tide. Intensive shrimp farms discharge nutrient-loaded water to the adjacent estuaries (Philips, Kwei Lin & Beveridge 1993).
and therefore, it is most likely the discharge will influence the production in extensively managed ponds.

The present study was conducted to estimate an optimal stocking density of PL for shrimp production in extensively managed tambak systems. Therefore, common traditional culture practices were used, with a major exception: hatchery-produced PL were stocked instead of relying on wild PL. In addition, the impact of shrimp biomass on algae biomass and the accumulation of bottom organic matter, respectively, were monitored during one production cycle.

**Materials and methods**

**Ponds**

The experiment was carried out in Probolinggo, a city along the northern coast of East Java (Hariati et al. 1996), at the Brawijaya University experimental farm, which was constructed for traditional tambak culture. Eight ponds, ranging in size from 2500 to 3500 m² (Table 1), were filled at high tide by gravity flow to a water level of 65 cm, which was subsequently maintained at each high tide. Before filling, all pond bottoms were tilled and fertilized with 48 kg ha⁻¹ of each of the following
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Figure 2 Relationship between production (kg ha⁻¹ per crop) and stocking density [individual postlarvae (PL) m⁻²].

Table 2 Overall means (above) and standard deviations (below) of physico-chemical characteristics of eight traditional tambak ponds

<table>
<thead>
<tr>
<th>Pond code</th>
<th>STD (no. m⁻²)</th>
<th>Temp.¹ (°C)</th>
<th>Salinity (%)</th>
<th>DO-SAT¹ (%)</th>
<th>DO¹ (mg L⁻¹)</th>
<th>pH</th>
<th>Turbidity (NTU)</th>
<th>OM¹ (% dm)</th>
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¹STD, stocking density; temp., temperature; DO-SAT, dissolved oxygen saturation (%); DO, dissolved oxygen; OM, bottom organic matter.

Fertilizers: triple super phosphate, urea and N-P-K fertilizer.

Stocking

Two weeks after pond preparation, the ponds were stocked with tiger shrimp, *Penaeus monodon* Fabricius, PL-15, obtained from a commercial hatchery at Situbondo, East Java. Stocking densities of 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0 and 5.5 individuals m⁻² were assigned randomly to eight ponds. Prior to stocking, PL quality was tested using morphological and viability characteristics. Commercially produced PL batches were only
stocked in the experiment if a random sample of 10 PL-4 did not show abnormalities and if no mortalities were observed after 6 days stocking in a closed plastic bag at room temperature. Shrimps were not fed during the 126-day culture period.

**Shrimp performance**

Shrimp were sampled fortnightly starting 56 days after stocking. A lift-net (‘ancho’: 1.0 m × 1.0 m square tray, located at the pond bottom, which could be lifted by a rope) was used. Per sample day, the overall mean individual shrimp weight was estimated using all shrimps available on the anchos. At harvest, the mean shrimp body weight per pond was calculated by dividing the biomass by the number of individuals caught. The percentage survival rate (SR) was estimated by dividing the number of individuals harvested by the number of individuals stocked.

**Physico-chemical parameters**

Starting on the day of stocking, ponds were sampled fortnightly at 0700 h for temperature (°C), salinity (%), pH, dissolved oxygen (p.p.m.) and bottom organic matter (% of dry matter). The last parameter was determined by burning 1 g of oven-dry sediment (16 h at 80°C) for 4 h at 450–500°C. Chlorophyll a content was estimated spectrophotometrically (DR-2000 turbidity program 750) after successively water sampling, concentration of
algae by sieving, and extraction of the pigments in acetone.

Histopathology

Eight weeks after stocking, five shrimp from each pond were sampled and fixed in Davidson and glutaraldehyde, respectively, for histo/cytopathological examination using a combined haematoxylin-eosin/phloxine staining technique and routine TEM technique for electromicroscopical examination of tissue showing abnormalities in the light-microscopical examination.

Statistics

Relationships between stocking density, and (1) production (biomass harvested) and (2) physico-chemical parameters were established using curvilinear regression analysis (STATISTIX 1985).

Results

Shrimp performance

Production characteristics are reviewed in Table 1. Ponds were harvested 126 days after stocking, with the exception of one pond (B2) which was emergency harvested 106 days after stocking because of a sudden onset of mortality. Considering the shorter culture period, pond B2 was excluded from the analysis. There was a curvilinear relation between production and mean body weight at harvest (Fig. 1; \( r = 0.86, P = 0.068 \)) and stocking density (Fig. 2; \( r = 0.92, P = 0.024 \)); Survival rate varied between 49% and 25%, and declined with increasing stocking density for the more densely stocked ponds.

Physico-chemical parameters

During the experiment, dissolved oxygen levels never dropped below critical levels. Overall means of the physico-chemical parameters measured are reviewed in Table 2. In contrast to temperature and pH, large differences between ponds were observed in overall means of salinity, dissolved oxygen and organic matter. In all ponds, the soil organic matter content increased dramatically after day 84 (Fig. 3). There was a negative relationship between accumulation of organic matter on the bottom and shrimp production (Fig. 4, \( r = -0.87, P = 0.010 \)). Salinity and production were curvilinearly related (Fig. 5, \( r = 0.95, P = 0.009 \)).

Histopathology

In a number of hepatopancreatic cells, one or more fluorescing eosinophilic inclusion bodies (Fig. 6a) were observed. Under EM, many intranuclear virions were observed, whether these were in nuclear polyhedrons or not (Fig. 6b). No evidence was found for the presence of pathogenic bacteria in the tissues, nor in the digestive tract.

Discussion

A maximum production of 292 kg ha\(^{-1}\) per crop was calculated at a salinity of 22‰ (Fig. 5). This is similar to the maximum production of 312 and
The detection of eosinophilic and fluorescent intranuclear inclusion bodies clearly demonstrated that a monodon baculo virus (MBV) infection was present (Lightner, Bell, Redman, Mohney, Natividad, Rukyani & Poernomo 1992). In spite of this infection, the production obtained was double the average production reached in extensively managed tambak systems in East Java. MBV is probably endemic in coastal waters of East Java (Hariati et al. 1995). It remains to be proven whether stocking MBV-free PL would yield a higher production in the same production environment. Experiments with MBV-infected and specific-pathogen-free PL, respectively, might provide relevant information.

Shrimp were not fed during the experiment, and accumulation of bottom organic matter during the culture period was caused by precipitation of detritus and micro-organisms from the water column and by production from benthic fauna including the shrimps. Chlorophyll a measurements were not different between ponds, indicating that primary production in the ponds was similar. The decreased concentration of bottom organic matter in ponds with the highest shrimp production could have been caused by consumption of organic matter by the shrimp. Shrimp under starving conditions are detritus feeders with cannibalistic or coprophagous tendencies which supplement the nutritionally poor quality of detritus (Pascual 1985; Ulrich, Vollmer, Stöcker & Storch 1992). Further investigation is needed to determine if the nutrients necessary to maintain pond productivity were provided by the tidal water entering the pond, the bottom or a combination of both. If tidal waters are the principal nutrient source, large areas of traditional ponds can help to neutralize high organic loads discharged from intensive farms. The ponds used in the present experiment were located in an area with numerous intensive farms (Hariati et al. 1995).

Typical aquaculture ponds have a carbon fixation rate of 2–6 g C m⁻² day⁻¹ (Brune & Drapcho 1991). Biomass from dead algae is the main input to the detritus layer at the pond bottom. Assuming a conversion efficiency of 1% from algae biomass to shrimp tissue, a production of 110–335 kg ha⁻¹ per crop can be reached, which concurs with the range of productions reached in the present study. Nevertheless, primary production rates were not measured in the present study. It would be interesting to establish a direct relation between carbon fixation rates and shrimp production.

307 kg ha⁻¹ per crop reached for a stocking density of 4.8 individuals m⁻² (Fig. 2) or a mean individual body weight at harvest of 23.9 g (Fig. 1), respectively. Reported yields from traditional, extensively managed tambak ponds in East Java were on average 150 kg ha⁻¹ per crop (Hariati et al. 1995), which is half the 300 kg ha⁻¹ per crop obtained in the present study at a stocking density of 4.5 individuals m⁻². Reference to traditional tambak management is difficult because most farmers operating traditional ponds rely on tidal water movements for PL to enter their ponds, whether or not these are supplemented with PL caught in estuaries or channels next to the farm. Under such practices, farmers have no control over initial stocking densities or the quality of the PL.

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allowing an estimate of the apparent conversion efficiency from algae to shrimp biomass in a traditional system. According to the present experiment, it is unlikely to achieve a harvest of more than 300 kg per crop in unfed traditional ponds.

The survival rate of the PL stocked in the present study (Table 1) was on average 31% lower than in ponds under intensive management (Hariati et al. 1996). Whereas, in intensive systems, there is a positive relation between survival rate and production, this could not be confirmed for extensive systems. A possible explanation could be the cannibalistic behaviour of detritus-feeding shrimp (Ulrich et al. 1992). Cannibalism should be more pronounced at higher densities, when the natural feed supply per individual is limited as partially indicated by decreasing survival rates with increasing stocking densities between 3.5 and 5.5 PL m\(^{-2}\) (Table 1).

The mean body weight at harvest in extensively (present experiment) and intensively managed ponds (Hariati et al. 1996) seems to be similar. The latter had a mean stocking density of 35–70 PL m\(^{-2}\) and a culture period of 120 days. Hopkins, Hamilton, Sandifer, Browdy & Stokes (1993) also found that shrimp growth in culture systems ranging from high stocking densities with high water exchange rates to low stocking densities with low water exchange rates was similar. The latter favours the mixing of intensive and extensive culture systems, as yields from extensively managed ponds can be sold together with the animals harvested from intensive systems. Especially in East Java, where large tambak systems exist (Hariati et al. 1995), and at present numerous tambak ponds are abandoned, more attention should be paid to improving extensive culture practices. Besides the possibility to partially use nutrients discharged from intensive farms, extensive systems can also be profitable. When stocking about 4.5 good-quality PL m\(^{-2}\), preparing the tambak as well as possible prior to stocking and applying a minimum amount of fertilizer, the practice can be highly profitable. Fertilizers are a minor cost. Considering the present (December 1996) PL price of 10 Rupiah apiece, and farm prices of 20 000 Rupiah kg\(^{-1}\) for consumption animals, a benefit of 5.8 million Rupiah (about US$ 2 340) per ha per crop can be obtained. Therefore, it is advisable to support the owners of traditional ponds to borrow a relatively small amount of money to purchase good-quality PL. Furthermore, seeding costs might be further minimized if a natural PL recruitment to tambak ponds of 1–2 individual m\(^{-2}\) is taken into account. The latter means adding only 2–3 'hatchery' PL m\(^{-2}\) to obtain a stocking density of 3–5 PL m\(^{-2}\).

In addition, considering that 95% of East Java's entire tambak area is currently exploited extensively or abandoned, the application of research results from small efforts like the present study on extensive systems could double current production levels. In contrast, even when disregarding research costs, a doubling of production levels from intensive systems is highly unlikely.

**Acknowledgments**

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