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Effects of addition of red tilapia (*Oreochromis* spp.) at different densities and sizes on production, water quality and nutrient recovery of intensive culture of white shrimp (*Litopenaeus vannamei*) in cement tanks

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ABSTRACT

An experiment was conducted in 21 outdoor cement tanks (2.5 × 2 × 1.2 m) from 8 December 2005 to 3 March 2006 to determine the effects of adding red tilapia (*Oreochromis* spp.) at different densities and sizes on production, water quality and nutrient recovery in intensive culture tanks of white shrimp (*Litopenaeus vannamei*). Shrimp postlarvae of 0.06 g were stocked into all tanks at a density of 60 postlarvae m^{-2}, while either small (13.8 ± 0.2 g) or large (41.9 ± 0.3 g) mono-sex tilapia fingerlings were stocked into the shrimp tanks two weeks later at low (0.4 fish m^{-2}), medium (0.8 fish m^{-2}) or high (1.2 fish m^{-2}) density. Water depth in all tanks was maintained at 1 m and salinity at 20 ppt. Water loss due to evaporation was compensated weekly. The experiment was conducted in a 2 × 3 factorial design, while three additional tanks for shrimp monoculture were set as a control. All treatments and the control were randomly allocated to tanks in triplicate each. Shrimps were fed three times daily with commercial pellets using feeding trays made with metal frame and nylon mesh (0.6 × 0.6 × 0.05 m) at the same feeding rates as those for the control. No separate feed was given to tilapia.

The highest shrimp survival rate of 66.8% was obtained in the small–low density tilapia treatment, which was significantly higher than those in other treatments and the control. The small–low density tilapia treatment had the highest shrimp yield and lowest feed conversion ratio, which was similar to those in the control and the large–low and small–medium density tilapia treatments, but significantly better than those in other treatments. Factorial analyses revealed that the increase of tilapia density from 0.4 to 1.2 fish m^{-2} and size from 13.8 to 41.9 g negatively affected shrimp production performance but remarkably increased the combined production of shrimp and tilapia. Polyculture incorporated 36.0–49.5% of the total nitrogen input and 14.2–26.5% of the total phosphorous input into shrimp and tilapia, which were significantly higher than those (27.1% and 8.9%) in the monoculture, respectively. The nutrient recovery efficiency increased with increased tilapia stocking size and density. Polyculture with small tilapia stocked at low density had the best economic performance among all treatments and control, and significantly better than small–high, large–medium and large–high density tilapia treatments.

It was concluded that addition of red tilapia at suitable stocking densities and sizes into intensive white shrimp monoculture can improve productivity, profitability, nutrient utilization and environmental friendliness of shrimp monoculture. The suitable stocking density and size of red tilapia identified in this study were 0.4 fish m^{-2} and 13.7 g respectively. Red tilapia could be stocked at higher density and larger size up to 1.2 fish m^{-2} and 42 g respectively to maximize system productivity and minimize nutrient waste without affecting shrimp survival, but economic performance could be negatively affected. Shrimp–tilapia polyculture should be promoted to improve sustainability of shrimp culture.

1. Introduction

Shrimp farming has been a major aquaculture activity and an investment objective over the past two to three decades. Production increased from 87,831 metric tons (MT) in 1981 to 3,164,384 MT in

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2006 (FAO, 2008). However, the expansion of intensive shrimp culture has raised environmental concerns due to intensive nutrient accumulation in culture systems and lack of effective waste treatments (Pruder, 1992; Phillips et al., 1993; Briggs and Funge-Smith, 1994; Boyd and Clay, 1998; Fast and Menasveta, 2000; Lin, 2000; Jackson et al., 2003). The nutrients and organic matter, if not treated before dispersal, may potentially result in low dissolved oxygen (DO), hyper-nutrification and eutrophication, as well as sedimentation in receiving waters. In addition to environmental issues, the discharge of untreated pond effluent represents an economic loss of costly nutrients, thereby reducing farm profitability (Burford et al., 2001).

Polyculture of Chinese carps with different food habits has been practiced in China for centuries (Lin, 1969, 1982). With the introduction of Chinese carps to many countries, polyculture has become a common practice in other parts of the world (Hepher and Milstein, 1989). The rationale is that fish species in an ideal polyculture pond occupy different niches and possess feeding habits which are different from and complementary to each other, therefore are able to utilize food available in the pond more efficiently than single species. It is commonly believed that polyculture gives higher production than monoculture in extensive and semi-intensive systems (Jhingran, 1982; Lin, 1982) and is considered to be more ecologically-sound than monoculture (Mackay and Lodge, 1983). Other advantages of polyculture include less metabolic waste accumulation/pollution and possibly higher economic return.

Marine shrimp are benthic animals spending most of their life in contact with the sea bottom (Dall et al., 1990) and have wide-ranging food habits in natural systems. They have been described as omnivorous scavengers, opportunistic omnivores, detritus feeders, carnivores, and predators (Bailey-Brock and Moss, 1992). They consume detrital aggregates, including bacteria and meiofauna, including protozoa, micro-algae, zooplankton, macrobenthos and other items (Dall, 1968; Chong and Sasekumar, 1997; Moriarty, 1997). Shrimp in intensive culture ponds also derive significant benefits from small suspended and settleable solids in culture waters (Leber and Pruder, 1988; Moss et al., 1992; Moss, 1995; Burford et al., 2004). The widely diverse feeding behaviors offer possibility to culture shrimp in polyculture as either the main species or a secondary species.

Shrimp polyculture is an old practice and might have evolved from early extensive shrimp systems in which fish species such as milkfish (*Chanos chanos*) and mullet (*Mugil* spp.) were incidentally or intentionally introduced and harvested as extra crops to shrimp (Jhingran, 1982). Further development could have involved purposeful introduction of shrimp into fish or Gracilaira ponds (Gomez, 1981; Chiang, 1992) as an additional source of income. The research on and practice of shrimp polyculture with other species such as shrimp (Chamberlain et al., 1981; Hariati et al., 1998; Mitra and Patra, 2001), milkfish (Eldani and Primavera, 1981; Pudadera and Lim, 1982; Apud, 1985; Kuntiyo and Baliao, 1987; James, 1996), mullets (James, 1996), tilapias (*Oreochromis* spp.) (Samonte et al., 1991; Wang et al., 1998; Tian et al., 2001), bivalves (Hunt, 1991; Hopkins et al., 1993; Tian et al., 2001) were done with the purpose of increasing overall production and controlling water quality. However research and culture practices were mainly based on extensive and semi-intensive systems. Few attempts have been made to polyculture shrimp at an intensity level comparable to that of modern intensive monoculture. There is a need to develop culture technology and intensive polyculture systems with increased waste assimilating capacity to transfer the excessive nutrients into harvestable aquatic products and to avoid uncontrolled effluent discharge.

Tilapia are one group of the most widely cultured fishes due to their general hardiness, ease of breeding, rapid growth, tolerance to wide range of environmental conditions, adaptation to both fresh and brackish water environment, resistance to diseases, ability to efficiently convert organic and domestic wastes into high quality protein, amenability to handling and captivity, and tasty flavor (Stickney et al., 1979; Balarin and Haller, 1982; Suresh and Lin, 1992). They have proven to be ideal species for polyculture (Hepher and Pruginin, 1981; Yakupitigage et al., 1991). Tilapia are among very few domesticated finfish species that feed on natural foods of low trophic level, such as detritus and plankton, and they can grow in saline water after proper acclimation, so they appear to be the most appropriate choice for a shrimp–fish polyculture system. Akiyama and Anggawati (1998) reported that yields of shrimp increased when red tilapia (*Oreochromis* spp.) were stocked into black tiger shrimp (*Penaeus monodon*) ponds. They believed that red tilapia might have assisted shrimp performance by improving and stabilizing water quality and by foraging and cleaning the pond bottom and by having a probiotic type effect in the pond environment. However more structured experiments are needed to confirm these findings. Two experiments on intensive shrimp–tilapia polyculture were conducted by Yi et al. (2002) in Thailand, which proved that positive interactions and mutual benefits did exist between black tiger shrimp and Nile tilapia (*O. niloticus*). Both shrimp yield and feed conversion ratio (FCR) were improved by presence of Nile tilapia in the system. However, questions still remain on how shrimp respond to different stocking densities and sizes of tilapia and what stocking density and size results in the largest improvement in shrimp production performance.

To answer these questions, an experiment was conducted at the Asian Institute of Technology in Thailand from 8 December 2005 to 3 March 2006. The objective was to assess the effects of adding red tilapia at different densities and sizes on shrimp growth, production, water quality and nutrient recovery in intensive culture of white shrimp (*Litopenaeus vannamei*).

2. Materials and methods

White shrimp postlarvae (PL) of 0.06 g were stocked into rectangular outdoor cement tanks ($2.5 \times 2 \times 1.2$ m) at 60 PLs m^{-2}. Either small (13.8 ± 0.2 g) or large (41.9 ± 0.3 g) mono-sex red tilapia fingerlings were added to shrimp tanks two weeks later at low (0.4 fish m^{-2}), medium (0.8 fish m^{-2}) or high density (1.2 fish m^{-2}) to form polyculture treatments. The experiment thus was conducted using a 3×2 factorial design with tilapia stocking density and size as two factors. Three additional tanks with shrimp monoculture were used as a control. All treatments (density–size combinations) and the control were randomly distributed among tanks with three replicates per treatment. Shrimp in all tanks were fed three times daily for 12 weeks with commercial shrimp pellets (40%, 38%, 35% and 35% crude protein for feed #1, #2, #3 and #4 respectively, Pokphand Aquatech Co., Ltd., Thailand) using feeding trays ($0.6 \times 0.6 \times 0.05$ m) made with metal frame and nylon mesh. Apparent feed consumption in trays in control tanks was closely observed to determine and adjust the feed amount applied (Salame, 1993). The same feed amount as that for control tanks was applied to all other tanks. Water depth in all tanks was maintained at 1 m and salinity at 20 ppt. Water loss due to evaporation was compensated weekly. There was no water exchange throughout the experimental period. Each tank was aerated using 9 spherical air stones with a diameter of 2″ suspended 10 cm above the bottom. The aeration system was supported by an air blower.

Water temperature, DO and pH were measured in situ once every two weeks at dawn using a DO meter (YSI Model DO-100) and a pH meter (YSI Model pH-200), respectively. Water in tanks was sampled once every two weeks at 0900 h for analyses of total alkalinity, total ammonia nitrogen (TAN), nitrate nitrogen (NO_{-3}–N), nitrite nitrogen (NO_{-2}–N), total Kjedahl nitrogen (TKN), total phosphorous (TP), specific reactive phosphorous (SRP), chlorophyll α, total suspended solid (TSS) and total volatile suspended solid (TVSS) using standard methods (APHA, AWWA, WPCF, 1995).