EFFECTS OF POLY CULTURE SHRIMP, *Litopenaeus vannamei* WITH KEELED MULLET, *Liza carinata* AT DIFFERENT DENSITIES COMPARED TO THE MONOCULTURE SYSTEM ON PHYSICO-CHEMICAL WATER QUALITY

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ABSTRACT: The present study was conducted to evaluate the effect of polyculture shrimp, *Litopenaeus vannamei* with keeled mullet, *liza carinata* at different densities compared to the monoculture system on Physico-Chemical water quality. In a complete randomized design, 15 glass aquaria (80×30×40 cm - 96 L) randomly distributed into in 5 treatments group (in triplicates). Each aquaria was stocked with 12 aquatic animals. In first experimental group was stocked with *L. carinata* only as monoculture (T₁; Fish 100%). Similarly, second experimental group was stocked with *L. vannamei* only as monoculture (T₂; Shrimp 100%). Experimental treatments of T3-T5 groups were stocked with both *L. carinata* and *L. vannamei* in polyculture at densities of (fish 25%: shrimp 75%), (fish 50%: shrimp 50%) and (fish 75%, shrimp 25%), respectively. Over the 12-weeks period, all water quality parameters were observed within the acceptable range for both *L. carinata* and *L. vannamei* either monoculture or polyculture systems. The results showed that water salinity was ranged between 30.15 to 32.30ppt, water temperature from 25.32 to 30.90°C, dissolved oxygen(6.17 to 7.09 mgL⁻¹) and pH (7.07 to 7.83) without any statistical differences (P ≥ 0.05). The concentration of phosphorous (PO₄) ranged from 0.005±0.02 - 0.009±0.002 mg/l. The highest PO₄ values was recorded for (T₁) followed (T₅). The highest TAN values was recorded for (T₁) followed (T₅), while the lowest values were recorded in either T₃ or T₂. The same trend was observed for NO₃. The concentration of NO₂ ranges from 0.001 to 0.09 mg/L. The results of present study suggested that a clear effect of mixed culture of *L. carinata* with *L. vannamei* in polyculture system to purify the water pond through food residues or undigested food and improve physico-chemical water quality.

Key word: Polyculture, monoculture, water quality, shrimp, keeled mullet.

INTRODUCTION

Aquaculture continues to pioneer the advancement of intensive cultivation technology in order to increase the production and to meet people's protein needs. The use of various natural products in aquaculture as immune stimulants has been reported to be effective in reducing the evidence of disease in fish and shrimp aquaculture and increasing production (Manoppo et al., 2015; Sharawy et al., 2020).

Intensive development of the aquaculture industry has been accompanied by an increase in environmental impacts. Aquaculture has negative environmental, social and economic impacts in the absence of appropriate control programs. Ecosystems are not always as fragile as could be considered, instead, they have a remarkable capacity of resiliency (Frankie and Hershner, 2003).

The production process generates substantial amounts of polluted effluent, containing uneaten feed and feces (Piedrahita, 2003; Sugiura et al.,...
High levels of nutrients cause environmental deterioration of the receiving water bodies (Thompson et al., 2002).

Shrimp farming has been historically related to negative environmental impacts including alteration of wetlands, land subsidence, pollution of agricultural lands and coastal waters by pond effluents and sludge, increased of pathogens into coastal environment, and subsequent loss of goods and services generated by natural common property resources (Paez-Osuna, 2001; Paez-Osuna et al., 2003; Azad et al., 2009).

Several studies have concentrated on the design and development of alternative farming systems for the integrated culture of aquatic organisms (Pacheco-Vega et al., 2018). Researchers have been experimenting with co-culturing shrimp with a number of species, including tilapia (Muangkeow et al., 2007; Yuan et al., 2010), milkfish (Jaspe et al., 2011), mullet (Costa et al., 2013), and seaweeds (Lombardi et al., 2006; Cruz-Suárez et al., 2010). In most cases, water quality, overall production, and survival were improved compared to monoculture (Liu et al., 2014).

The polyculture system is highly productive and can be very lucrative, with a low environmental impact (Vinatéa, 1999; Valenti, 2002).

The polyculture as integrated practiced system in aquaculture via stocking of fish species of different food habits proved to be an important management tool in utilizing efficiently the natural food resources in the fish pond. Synergistic interactions among fish species are manifested by higher growth and yield in poly-culture than in monoculture. The bases for these interactions are the increase of available food resources and the improvement of environmental conditions (Shaker et al., 2013). Although, polyculture is not yet common practice. The perceived low profitability of extensive aquaculture systems, in which polyculture are mostly performed is considered to be a downside.

Hoang et al. (2020) concluded that the combination of shrimp and fish in polyculture and biofloc has additive effects at the level of animal production and synergistic effects at the level of some water quality parameters. Akiyama and Angawati (1999) reported that the polyculture of penaeid shrimps with omnivorous fishes such as tilapia showed an improvement in water quality as fish fed on organic wastes (Cruz et al., 2008).

Martinez-Porcas et al. (2010) reported that shrimp polyculture is not yet a common practice among farmers; however, this activity represents an important alternative to solving and minimizing some of the problems that shrimp aquaculture has faced in the past two decades (environmental pollution, diseases, and decreasing prices).

The intensive monoculture shrimp faces two major problems. Firstly, water quality deterioration caused by a high concentration of metabolites and secondly, low nutrient utilization efficiency and high water exchange within or outside the pond system (Avnimelech, 2007). Wastewaters, containing high nitrogen and phosphorus concentrations, are often discharged directly into canals and rivers leading to oxygen depletion and eutrophication (Anh et al., 2010). This has raised several concerns about the persistence of toxic compounds in aquatic environments and in harvested animals as well (Business, 2003). However to reduce the outbreak or spread of shrimp disease and water quality degradation, many remediating actions have been suggested. One of the most practical methods is Integrated Multi-Trophic Aquaculture (IMTA) system as polyculture which caters for an enhanced nutrient recycling relative to conventional farming systems, as species with different trophic levels are used, providing also an opportunity for diversification and increased yield of both crustaceans and fish, according to (Troell et al., 2009; Barrington et al., 2010), as well as appears to prevent shrimp disease outbreaks (Liu et al., 2014).

Water must be tested with different physical-chemical parameters. Selection of parameters for testing of water is solely depends upon for what purpose we going to use that water and what extent we need its quality and purity. Water does content different types of floating, dissolved, suspended and microbiological as well as bacteriological impurities. Some physical test should be performed for testing of its physical appearance such as temperature,
color, odour, pH, turbidity, TDS etc, while chemical tests should be perform for its BOD, COD, dissolved oxygen, alkalinity, hardness and other characters (Patil et al., 2012).

This study was conducted to determine the effect of the polyculture of shrimp, Litopenaeus vannamei with Keeled mullet, Liza carinata at different densities on water quality compared to the monoculture system of both Liza carinata and litopenaeus vannamei.

MATERIALS AND METHODS

Experimental Design

The present study was carried out in Fish Rearing Laboratory at National Institute of Oceanography and Fisheries (NIOF), Gulfs of Suez & Aqaba’s Branch, Suez Governorate, Egypt. The experimental period of 12 weeks started during September to November 2019.

Shrimp, Litopenaeus vannamei post larvae (Pl) with an average initial body weight of 0.33±0.01 g were obtained from Birkat Ghalion - Kafr El Sheikh Governorate, Egypt, while the fry of keeled mullet, Liza carinata with an average initial body weight of 5.60 ± 0.11 g were obtained from El Hag-Zaghloul farm, Suez Governorate, Egypt. The fish and shrimp Pl’s were stocked separately into three glass aquaria (each with 96 L) at Fish Rearing Laboratory, Gulfs of Suez & Aqaba’s Branch, National Institute of Oceanography and Fisheries (NIOF), Suez, Egypt. Both of fish and shrimp Pl’s were acclimated separately for two weeks to laboratory conditions.

In a complete randomized design, 15 glass aquaria (80x30x40 cm - 96 L) randomly distributed into in 5 treatments group (in triplicates). Each aquaria was stocked with 12 aquatic animals. In first experimental group was stocked with L. carinata only as monoculture (T1; Fish 100%). Similarly, second experimental group was stocked with L. vannamei only as monoculture (T2; Shrimp 100%). Experimental treatments of T3-T5 groups were stocked with both L. carinata and L. vannamei in polyculture at densities of (fish 25%; shrimp 75%), (fish 50%; shrimp 50%) and (fish 75%, shrimp 25%), respectively.

Aquaria’s were cleaned and disinfected before the experimental trails. The system were installed in an environmental-controlled laboratory and held under natural light (12:12 h light: dark schedule). Continuous aeration was provided by an air blower, Heaters were placed in the glass aquaria to obtain the optimum temperature for both fish and shrimp.

Experimental Tank Management

Fish in all treatments were fed commercial diet (35 % crude protein and 5.98 % crude fat, Skretting Egypt Company, Belbies, Egypt). Fish and shrimp were fed at a rate of 5% and 7% of the live body weight, respectively in monoculture system, while in polyculture system shrimp was not fed and fish only fed at a rate of 5% of the live body weight. The daily ration was divided into two equal amounts and offered two times a day (08:30, and 15:00 h). Samples from each replicate aquaria were weighed biweekly and the amount of daily allowance was adjusted accordingly.

Water Quality

Water temperature (°C), dissolved oxygen (DO, mg/l), pH, salinity (ppt), total ammonia nitrogen (TAN, mg/l), nitrite nitrogen (NO₂), nitrate nitrogen (NO₃) and phosphate (PO₄) were monitored during the trial, to maintain water quality at the optimum range for fish and shrimp. Water temperature was recorded daily at 13.00 h using a mercury thermometer suspended at 30-cm depth. DO was measured at 05.00 h using YSI model 56 oxygen meter and pH at 09.00 h by using a pH meter. Salinity, TAN, NO₂, NO₃, and PO₄ using multi-spectrophotometers (JENWAY 6100) were measured three times a week according to APHA (1998).

Statistical Analysis

Data were statistically analyzed by ANOVA using One-way software (Spss 26.0 for windows). Duncan’s multiple range test was used to compare differences between treatment means when significant F values were observed (Duncan, 1955), at \( P \leq 0.05 \) level.
RESULTS AND DISCUSSION

Physical Water Parameters

Over the 12-weeks period, all physical water quality parameters were observed within the acceptable range for both *L. carinata* and *L. vannamei* either monoculture or polyculture systems (Van Wyk and Scarpa, 1999). The results showed that water salinity was ranged between 30.15 to 32.30 ppt, water temperature from 25.32 to 30.90°C, dissolved oxygen (6.17 to 7.09 mg L\(^{-1}\)) and pH (7.07 to 7.83) without any statistical differences (\(P \geq 0.05\)) (Figs. 1-4).

Physical parameters of water play a significant role in the biology and physiology of aquatic animals. The results in this study showed that was range pH values (7.07 to 7.83) in all treatments. Both species, fish and shrimp, tolerate pH varying between 6.0 and 9.0 (Boyd, 1990; Arana, 1997), while the ideal and satisfactory pH ranges for fish farming varies from 7.0 to 8.5, and from 6.5 to 9.5 (Sipáuiba-Tavares, 1994), marine shrimp ideal pH ranges from 8.0 to 8.5 (Igarashi, 1995), and water temperature from 25.32 to 30.90°C, within the range recommended by Brock and Main (1994).

The results in present study indicate that water Salinity was ranged between 30.15 to 32.30 ppt. Aghuzbeni et al. (2017) found that, the integrated culture of shrimp and mullet has shown to be successful in productive and water quality ways. Some studies on the polyculture of penaeid shrimps with omnivorous fishes such as tilapia showed an improvement in water quality as fish fed on organic wastes (Akiyama and Angawati, 1999; Cruz et al., 2008). (Fitzsimmons, 2001) demonstrated that beneficial effects of culturing shrimp with other aquatic species result in positive conditions on the primary and secondary species (Jaspe et al., 2011). Improving pond water quality by controlling phytoplankton growth, reducing the accumulation of organic matter, antibacterial effect and the prevalence of viruses (Jatobá et al., 2011). Juarez-Rosales et al. (2019) reported that the white shrimp (10 org/m\(^{2}\)) can be co-cultured with Nile tilapia at a stocking high density (4 org/m\(^{2}\)), leading to improved water quality.

Chemical Water Parameters

The results noted that elevated values were recorded for all chemical parameters at the beginning of the experiment due to higher concentration in the watersource used, then decreased in the second week.

Regarding to the mono and polyculture systems, an increase in chemical water parameters was observed at the end of the experiment in *L. carinata* monoculture system as a result of increased weight of fish (not shown) and consequently increased waste output (dissolved outputs, faces and uneaten feeds) compared to either *L. vannamei* monoculture or experimental polyculture systems.

Phosphorous (PO\(_4\))

The result showed that the concentration of phosphorous (PO\(_4\), Fig. 5) ranged from 0.05 ± 0.02 - 0.009±0.002 mg/L. The highest PO\(_4\) values was recorded for (T1) followed (T5), while the lowest values were recorded in either (T2) or (T3).

Total ammonia nitrogen (TAN), nitrite (NO\(_2\)) and nitrate (NO\(_3\))

The result showed that the concentration of TAN (Fig. 6) ranged from 0.02 - 0.72 mg/L. The highest TAN values was recorded for (T1) followed (T5), while the lowest values were recorded in either T3 or T2. The same trend was observed for NO\(_2\)(NO\(_3\)-N, Fig. 7). The concentration of NO\(_2\) (NO\(_2\) -N) ranges from 0.001 to 0.09 mg/L, with highest values recorded for T1 compared to other experimental treatments (Fig. 8).

Water chemical quality parameters in all treatments stayed in a suitable range for white shrimp and mullet growth (Van Wyk and Scarpa, 1999). The chemical water quality parameters including TAN, nitrite, nitrate, phosphate were significantly different between treatments which was significantly influenced by type of culture aquatic animals especially polyculture system.

Polyculture system that is mixing of two or more species does not require significant extra investment money or human efforts because the secondary species are simply added within the same space of pond. Generally, many benefits have been achieved in shrimp polyculture systems when using fish, bivalves and seaweeds. The benefits include the diminution of ecological
Fig. 1. Water salinity values in experimental treatment over a 12-week period

Fig. 2. Water temperature (°C) recorded in experimental treatment over a 12-week period

Fig. 3. Water dissolved oxygen (mg/l) values recorded in experimental treatment over a 12-week period
Fig. 4. Water pH values recorded in experimental treatment over a 12-week period

Fig. 5. Water PO₄₃⁻ (mg/l) values recorded in experimental treatment over a 12-week period

Fig. 6. Water TAN (mg/l) values recorded in experimental treatment over a 12-week period
impacts and maintenance of water quality which subsequently improve total biomass of shrimp \cite{Muangkeowet2007, Troell2009}. Tampy et al. \cite{1988}, reported that polyculture of *Chanos chanos* and *Penaeus monodon* increased the mean weight values of harvested shrimps. In the present study, the concentration of TAN, nitrite, and nitrate was recorded higher in monoculture *L. carinata* (T1) and polyculture *L. carinata* with *L. vannamei* (T5), associated with reduced the concentration of TAN and nitrite, and lowest in polyculture (T3), (T4), and monoculture shrimp (T2) and therefore there is a relationship between the number of fish and shrimp in the pond, according to what he mentioned, Liu et al. \cite{2014}, reported that it appears that polyculture may have a possibility to improve shrimp efficiency and water quality. Although the mullet is present with shrimp, the shrimp tends to grow similar to the monoculture, and the mullet grows better in polyculture. It is not clear in which way mullet contributes to shrimp growth (independent from the presence of flocks). The results showed is a clear effect of mixed culture in shrimp ponds as it works to purify the water pond through food residues or undigested food. Hoang et al. \cite{2018} indicate that gray mullet can be co-cultured with white
shrimp at the fish stocking density of 10% shrimp biomass to improve water quality, overall productivity and nutrient utilization efficiency.

**Conclusion**

There are a positive relationship between the number of fish in all treatment and the values of Total ammonia nitrogen, Nitrite, Nitrate and Phosphate. While there are a reverse relationship between the number of shrimp in all treatment and the values of Total ammonia nitrogen, Nitrite, Nitrate and Phosphate.

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تأثیر الاستزراع المتعدد الأنواع بين الجمیري الفانامی Litopenaeus vannamei بتکثافات مختلفة مقارنة بنظام الاستزراع الأحادي على جودة المياه الفیزیانیة والکیمیانیة

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تأثیر الاستزراع المتعدد الأنواع بين الجمیري الفانامی Litopenaeus vannamei بتکثافات مختلفة مقارنة بنظام الاستزراع الأحادی Litopenaeus vannamei على جودة المياه الفیزیانیة والکیمیانیة.

أجريت الدراسة الحالية لتقيیم تأثیر استزراع الجمیري Litopenaeus vannamei بتکثافات مختلفة مقارنة بنظام الاستزراع الأحادی Litopenaeus vannamei على جودة المياه الفیزیانیة والکیمیانیة في تمصير عشوائی كامل، تم توزیع 15 حوض زجاجی (80 × 30 × 40 سم - 96 لتر) بشكل عشوائی في 5 معاکلات تجربیة (ثلاثة مکثفات لكل معاملة). تم تزیین كل حوض بعد 12 حیوان مانی. في المجموعة التجربیة الاولیة تم تربیة أسماک الجمیري Litopenaeus vannamei بنظام الاستزراع الأحادی (T1)، وبالمثل، تم تربیة الجمیري Litopenaeus vannamei في المجموعة التجربیة الثانیة بنظام الاستزراع الأحادی (T2). بالنسبة إلى المعاملات التجربیة من الثلاثة إلى المجاورة (T3-T5)، فقد تم تربیة كل من أسماک Litopenaeus vannamei والجمیري Litopenaeus vannamei في نظام استزراع متعدد الأنواع بتکثافات (25% سهیلی: 75% جمیری)، (50% سهیلی: 50% جمیری) وتکثافات (25% سهیلی: 75% جمیری)، على التوالي. خلال فترة تربیة لمدة 12 أسبوعا، لوحظت جميع معاکرات جودة المياه ضمن المتراع المقبول لكل من أسماک Litopenaeus vannamei والجمیري Litopenaeus vannamei سواء كانت أحادیة النوع أو متعددة الأنواع أظهرت النتائج أن ملوحة الماء تراوحت بين 30.15 إلى 32.30 جزء في المليون ودرجة حرارة الماء من 24.32 إلى 30.90 درجة مئیة والذخائر المذاب (0.17 إلى 0.90 مجم/ لتر) ودرجة الحموضة (7.07 إلى 8.3) دون أي فروق ذات دلالة إحصائیة (0.05) تراوح تكریز الفوسفور (P) من 0.05±0.02 إلى 0.06±0.009 مجم/ لتر. تم تسجیل اعلى قیم الفوسفور (P) في المعاکلات (T1) لـ (TAN) تلتها (T5) بينما سجلت ادنی قیم في (T3) TAN. ولوحظ نفس الالتجاع بالسلاسل اکسید النتروجین (NO3) تراوح تكریز الفوسفور (P) من 0.00 إلى 0.09 مجم/لتر. أشارت نتائج الدراسة الحالية إلى وجود تأثیر واضح لاستزراع المتعدد بين أسماک Litopenaeus vannamei والجمیري Litopenaeus vannamei في نظام الاستزراع متعدد الأنواع لتثقيف میاه الحوض من بقايا الطعام أو الطعام غير المهضوم وتهدیم جودة المياه الفیزیانیة والکیمیانیة.

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