GROWTH PERFORMANCE OF PACIFIC WHITE SHRIMP (*Penaeus vannamei*) WITH SILVER POMPANO UNDER POLYCULTURE SYSTEM

Thesis submitted in part fulfillment of the requirements for the degree of ***Master of Fisheries Science in Aquaculture*** *to the Tamil Nadu Dr.J.Jayalalithaa Fisheries University, Nagapattinam*

K. BALAJI, B.F.Sc.,
ID.No. U-17-TN-03-002-M-F-029 (AQC)

DEPARTMENT OF AQUACULTURE FISHERIES COLLEGE AND RESEARCH INSTITUTE
TAMIL NADU DR. J. JAYALALITHAA FISHERIES UNIVERSITY
THOOTHUKUDI – 628 008

2019

ABSTRACT

Title	**:**	**Growth performance of Pacific white shrimp (*Penaeus vannamei*) with silver pompano under polyculture system**
Name of the student	**:**	**K.Balaji**
Degree	**:**	**M.F.Sc (Aquaculture)**
Chairman	**:**	**Dr. J. Stephen Sampath Kumar**
Department	**:**	**Department of Aquaculture**
College	**:**	**Fisheries College and Research Institute, Thoothukudi**
Year and University	**:**	**2019, Tamil Nadu Dr. J. Jayalalithaa Fisheries University**

The present study was undertaken to investigate the possibilities of undertaking polyculture of Pacific white shrimp (*Penaeus vannamei*) with silver pompano under different stocking densities in indoor polyculture system. The best stocking density that can be arrived at in the indoor system was further tried in outdoor polyculture system.

Indoor experiment was conducted in 15 cement tanks (1.8 m^3) each to have triplicate for each treatment. Pacific white shrimp juvenile (ABW: 0.43± 0.047 g) were procured from an approval hatchery and reared in the raceway tank for 20 days before stocking in the experiment tanks. After rearing the shrimp juveniles were stocked at a density of 60/m^2 in all four treatments and in one control tank. Silver pompano seeds (ABW2.17 ± 0.2083 g) were procured from RGCA, Kerala and reared in raceway tank for 20 days and then stocked at four different stocking densities (T_1 - 3/m^2, T_2 - 6/m^2, T_3 - 9/m^2 and T_4 – 12/m^2). Feeding was done only to Pacific white shrimp twice a day (10.00 a.m and 2.00 p.m) with commercial shrimp feed as per the feeding schedule of the feed company. Sampling was done once in 10 days for shrimp and fortnightly for fish and the bio-growth parameters were observed and recorded. Water quality parameters were recorded every day.

Highest weight gain and ADG for *P. vannamei* were observed in control tank (6.51 ± 0.0173 g) which is not statistically significant. The percentage weight gain, SGR and SR 1489.25 ±39.30%, 4.61 ± 0.042g and 97%, respectively for *P. vannamei* were the highest for T_1. Highest weight gain, percentage of weight gain and SGR 4.96 ± 0.0751 g, 263.65 ± 13.389 g and 2.15 ± 0.061g, respectively for silver pompano were observed in T_3 which are not statistically significant. The highest survival rate of silver pompano was observed in T_1 (100%).

The highest net biomass production (877.45 ± 7.572 g) was recorded in T_1. In total production, the highest percentage of *P. vannamei* was obtained from T_1 (96.5%). Good FCR and FCE 1.16 ± 0.007 and 86.56 ± 0.49 respectively were observed in T_3.

The outdoor experiment was carried out in two HDPE lined ponds of size 30 m^3 (10 m x 3 m x 1m) for the best performed stocking density in indoor trial study (shrimp-60/m^2 and pompano-3/m^2) for validation. *P. vannamei* (0.028± 0.003 g) and silver pompano (0.364± 0.066 g) were stocked and reared for 60 days. Bio-growth parameters and water quality parameters were analyzed every 10 days and daily respectively. The growth performances in both the trials were assessed in terms of mean weight gain, specific growth rate (SGR), feed conversion ratio (FCR), feed efficiency ratio (FER), survival rate (SR) and total production.

In outdoor system, the total biomass was observed to be 16560.37 ± 8.515 g. The FCR and FCE were better than that of indoor system for the same stocking density of fishes and shrimp.

The results showed that silver pompano stocked at 3/m^2 along with *P. vannamei* did not affect the growth and production of *P. vannamei,* instead it helped in enhancing total biomass production. Although there is an increase in the fish density, the mean body weight of shrimp was not affected. But the biomass was increased and the profit enhanced.

CERTIFICATE

This is to certify that the thesis entitled, **"Growth performance of Pacific white shrimp (*Penaeus vannamei*) with silver pompano under polyculture system"** submitted in part fulfillment of the requirements for the degree of **Master of Fisheries Science** in **Aquaculture** to the Tamil Nadu Dr. J. Jayalalithaa Fisheries University, Nagapattinam is a record of bonafide research work carried out by **Mr. K.Balaji, ID. No. U-17-TN-03-002-M-F-029 (AQC)** under my supervision and guidance and that no part of this thesis has been submitted for the award of any other degree, diploma, fellowship or similar titles or prizes and that part of the thesis has been published in peer reviewed journal(s) and copy / copies appended.

Place : Thoothukudi
Date :

Dr. J. Stephen Sampath Kumar
(CHAIRMAN)

RECOMMENDED

EXTERNAL EXAMINER

APPROVED BY

Chairman : **Dr. J. Stephen Sampath Kumar**

Members : **1. Mr. K.S.Vijay Amirtharaj**

2. Dr. P.Padmavathy

Additional Member: **Mr. Ranjith Manley**

Place :

Date :

ACKNOWLEDGMENTS

I express my profound and heartiest thanks to the Chairman of the Advisory Committee, **Dr. J. Stephen Sampath Kumar**, Director i/c, Directorate of Sustainable Aquaculture, Thanjavur, for his valuable guidance in executing and completing this study successfully. His care has greatly helped not only to improve my thought but also stimulated me with a bigger passion towards Aquaculture. His continuous support of doing this research work, patience, motivation, enthusiasm and immense knowledge have helped in many ways. His guidance helped me throughout of my research and writing this thesis.

I acknowledge the support and helps extended by **Mr. K.S.Vijay Amirtharaj**, Assistant Professor and Head i/c MRFF, Tharuvaikulam, throughout my work as Member of Advisory Committee.

I thank **Dr. P. Padhmavathy,** Associate Professor and Head, Department of Aquatic Environment Management and Member of the Advisory Committee who has always inspired, encouraged and supported me during the course of the study.

I am grateful to **Mr. Ranjith Manley,** Adjunct Faculty, TNJFU and Additional Member for his support and suggestions to carry out my work.

I sincerely thank **Dr. P. Velayutham,** Dean i/c, Fisheries College and Research Institute, Thoothukudi for his support during the period of my study. It is my pleasure to acknowledge my gratitude to the university authorities and thanks to the University for the Financial Assistance provided.

I sincerely thank **Dr. G. Aruloli,** Assistant Professor, MRFF, Tharuvaikulam

and R. Kumaresan, Deputy Librarian for their help in literature collection.

I thank **Mr. K. Murugan (Attender), Mr. Shanmuga Velayutham (Worker), Mr. Benedict (Worker), Mr. Subburaj / Mr. Radha Krishnan / Mr. Johnson (Securities of Tharuvaikulam)** for their helps and assistance.

I owe my sincere thanks to my friends namely **Mr. P. Karthick Raja, Mr. M. Subash Chandra Boss, Mr. R. Tamilselvan, Mr. S. Sathish, Mr. K. Kathiresan, Miss. K. Keerthiga, Miss. Vanlalhriatpuii chawngthu** and all my classmates for their help and also **I thank my seniors Mr. D. Kaviyarasu** and **Mr. K. Masilan,** for their support and guidance.

I sincerely thank my juniors **Mr. Ranjithkumar, Mr. Tamilarasan, Mr.Ponsrinivasan, Mr. Nethaj, Mr. Jeyaprakash, Mr. NirmalRaj, Mr.Sivaganesh, Mr. Kaviin, Mr. Kumarakannan, Mr. Paul Nathanial, Mr. Dheeran, Miss. Dhivyakumari, Miss. Abisha, Miss. Abinaya, Miss. Nandhana, Miss. Vennila, Miss. Sherly, Miss. Dharani** and **Miss. shaji** for their help during my research.

I also thank my friend **Miss. V. Vennila** who has unwaveringly stood beside me over the years of my study.

There are no matching words to express my heartfelt indebtedness to my beloved parents and brother for their moral support, kind understanding and unflinching encouragement with an astonishing forbearance throughout my study period.

(K.BALAJI)

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

I.INTRODUCTION

World farmed crustacean production during 2016 was 7.86 million tonnes (MT) (FAO, 2018). Of this 4.86 million tonnes (MT) was by penaeids. Among the penaeids, *Penaeus vannamei* stood first in the global production with 4.15 MT (FAO, 2018). Pacific white shrimp (*P. vannamei*), a native species of Pacific Ocean is an important source of foreign exports in many developing countries of Asia and Latin America. In 2016, among the crustaceans, *P. vannamei* showed hike in production, with 53% of growth rate over the last year (FAO, 2018).

India's production of *P. vannamei* shrimp has increased from 5,01,297 MT in 2016 to 6,22,327 MT in 2017-18. This has registered an increase of 24% over the last year production and the overall shrimp export during 2017-18 was 6,91,748 MT (MPEDA, 2018). This has clearly indicated that this progressive increase in shrimp production was supported by *P. vannamei* production (over 89.96% of the total shrimp production) even though there was a chance for culturing other shrimp varieties in the country.

P. vannamei is native to the Pacific coast of Mexico and central and South America extending to south up to Peru, in areas where water temperatures are normally over 20^{o}C throughout the year (Wyban and Sweeny, 1991: Rosenberry 2002). Introductions of *P. vannamei* to Asia began in 1978 to 1989, when it was introduced to the Philippines first and in 1988 to Mainland in China. In 1996, mainland China and Taiwan started commercial production of *P. vannamei* and from there, aquaculture production expanded rapidly to other nations in Asia, including

Thailand, Indonesia, Vietnam, Malaysia and India (Rosenberry, 2004; Briggs et al., 2004).

The first commercial shipment of Specific Pathogen Free (SPF) *P. vannamei* broodstock from America to Asia was from Hawaii to Taiwan province of China in 1996 (Wyban, 2002). *P. vannamei* has the potential to grow as fast as *P. monodon* (at upto 3g/week) up to 20g under intensive culture conditions. Although it will keep growing beyond 20g, its growth may slow (particularly males) to 1g/wk once above 20 g weight (Wyban and Sweeny, 1991). Therefore, this shrimp is grown up to 20 g and preferred for harvesting.

P. vannamei tolerates a wide range of salinities from 0.5 to 45 ppt. *P. vannamei* inhabits in waters that range in salinity from 1 to 40 ppt (Smith and Lawrence, 1990; Bray et al., 1994; Samocha et al., 2001). However, better growth and survival were found to be at 7 to 34 ppt, but grows particularly well at low densities when the salinity was around 10 to 15 ppt (Wyban and Sweeny, 1991).

The stocking density of *P. vannamei* is 60/m^2 as per Coastal Aquaculture Authority (CAA) regulations. Athough *P. vannamei* can tolerate a wide range of temperature, it grows best between 23 to 30^{o}C comprising the majority of the tropical and sub tropical-world, with the optimum for growth being 30^{0}C for small (1g) and 27^{0}C for larger (12 to 18 g) shrimp. They can also tolerate temperature lower than 15^{0} C and upto 37^{0}C, but at reduced growth rates (Wyban and Sweeny, 1991). *P. vannamei* requires a low protein diet (20 to 35%) during culture when compared to *P. monodon* and *P. styilirostris* (36 to 42%) and are able to utilize natural productivity of shrimp ponds, even under intensive culture conditions (Wyban and Sweeny, 1991).

The silver pompano, *Trachinotus blochii* is a common Carangid fish in the tropical belt and particularly in Indian coast. It is a high-value fish due to its tasty meat and appealing appearance. Fry production was started in 1989 in Taiwan. Since then, culture of silver pompano has been carried out continuously and profitably not only in Taiwan but also in China and Singapore too. Pompano juveniles live in small schools, while adults are usually solitary. Adults feed primarily on sand molluscs and other hard-shelled invertebrates. During farming, they can be weaned to feeds such as floating pellets, sinking pellets and by-catch waste. The pompano species tolerate a wide range of salinities (McMaster et al., 2003). They are resistant to low dissolved oxygen and handling stress, readily consume pelleted rations, successfully breed in captivity (Weirich, 2006), and are excellent candidates for aquaculture in a variety of systems (McMaster et al., 2004). This species prefers warm tropical waters, with a tolerance from 25–29°C. They can grow fast in salinities below 20 ppt and poorly in full seawater. Pompano are not tolerant of low temperature. It is pelagic, very active and is able to acclimatize and grow well even at a lower salinity of about 10 ppt and hence suitable for farming in the vast low saline waters of our country besides its potential for sea cage farming.

1.1 Farming methods

Shrimps are mostly farmed under monoculture. Intensification can be done without many problems under monoculture system. However, there are specific fishes to be addressed for monoculture production of shrimps. One such issue is the waste production and disposal in the ponds. The shrimp aquaculture industry faces several problems due to feces and food wastes. Shrimp excreta and excess feed waste lead to contamination and possible damages of the near shore water. Polyculture offers huge benefits like alternative to minimize or eventually solve these problems. However, polyculture is not commercially used by the shrimp farmers.

Polyculture is referred to as multi-trophic aquaculture, co-culture or simply integrated aquaculture (Bunting, 2008). There are three general types of polyculture, viz direct polyculture, cage-cum-pond polyculture and sequential polyculture (Yi and Fitzsimmons, 2004). Direct polyculture refers to two or more species mixed in the same culture unit without partitioning. This type of polyculture does not need significant extra economical or human effort in investment because the secondary species are simply added within the same culture unit of the main species. Thus, there is no need for more space.

Cage-cum-pond polyculture is related to direct polyculture because different species are cultured together in the same tank or pond, but one of the animal are stocked within cages, limiting their space within the cages and there is no physical contact with the main organism (Yi and Fitzsimmons, 2004). Sequential polyculture is a system where the main and subordinate species are separated by different culture systems. Simple example of this system is the shrimp effluents flow towards the subordinate species culture system. Unfortunately, these types of polyculture systems need many investments.

1.2. Shrimp – fish polyculture

Shrimp polyculture is a sustainable aquaculture production method and has been shown experimentally to improve yield, decrease the environmental impact, re-utilize wastes and reduce the entry of pathogen organisms in shrimp aquaculture. However, there are some considerations that need to be solved before practicing polyculture, such as economic and human effort investment, compatibility of the species (feeding habits and environmental requirements), food competition, space, size of the organisms and decreasing oxygen levels.

Polyculture contributes to minimizing the environmental impact of farm effluents, particularly the nitrogenous wastes, which are further converted into toxic metabolites. Subordinate species or secondary species in the polyculture system feed on and assimilate most of the wastes generated from shrimp aquaculture. A higher efficiency of nitrogen waste utilization has been observed in polyculture systems compared with monoculture systems, with a consequent decrease in nitrogen level and improvement in water quality and diminution of the environmental impact resulting from effluent discharges (Zhen-xiong et al., 2001). It could be observed that wastes from aquaculture are assimilated through the food web within pond by subordinate species and natural pond biota in the polyculture systems (Yokoyama et al., 2002). There is also evidence that polyculture improves productivity, decomposition of nitrogenous wastes according to Hooper et al., (2005) Balvanera et al., (2006) Douglass et al., (2008).

1.3 Present focus

Shrimp farming is an emerging sector, in terms of global production and also employment opportunities. Present problems in shrimp farming are lack of profitable technologies for sustainable aquaculture production. Nowadays disease outbreaks have caused a significant decrease in the profit and heavy loss to the farmers in recent years. Alternative methods like polyculture of shrimp with fishes can ensure yield, and decreasing the disease causative agents and maintaining the water quality in optimum condition.

Marine fin fishes such as cobia, silver pompano, grouper, sea bass, milkfish, pearl spot, etc. are nowadays cultured in cages and coastal ponds. They help in increasing the marine aquaculture production. Therefore, shrimp culture along with fishes in polyculture is felt profitable if the stocking densities are standardized. Keeping in view of the need to standardize the polyculture of Pacific white shrimp with silver pompano, the present study is planned to contemplate the following objectives:

i. To conduct growth experiment of Pacific white shrimp (*P. vannamei)* with silver pompano under different stocking densities in indoor system

ii. To conduct growth experiment of Pacific white shrimp (*P. vannamei)* with silver pompano under outdoor system with best stocking ratio obtained from indoor trial

iii.. To monitor and record water quality parameters of the rearing system

II. REVIEW OF LITERATURE

Polyculture is culture of two or more species differing in their feeding behavior, habits and ecological requirements to effectively increase the production in the same pond (Zimmermann and New, 2000). It also refers to two or more species mixed in the same aquaculture unit without partitioning (Martínez-Porchas et al., 2010). Lanza-Espino et al., (1991) defined polyculture as adding one or more subordinate species to the culture system involving one main species.

Fishes that are used in aquaculture can utilize a wide range of feeding niches. They can be carnivorous, benthivorous, omnivorous, planktivorous and herbivorous (Bosma and Verdegem, 2011). Fishes in an ideal polyculture pond occupy different niches and possess feeding habits which are different from one another but complementary to each, thereby they are able to utilize food available in the pond more efficiently than by a single species (Yuan et al., 2010).

Shrimp farming is an emerging sector, which has been growing at a rate of 14.88% annually (MPEDA, 2018) Shrimp farming has now developed into an important export-oriented food industry especially in South Asian countries (Chakraborty, 2001). There are many problems that are often influencing the production and profit. Some of the identified problems are lack of sustainable technologies, adverse environmental impacts, competition for resources with other activities and disease outbreaks which have caused a significant decrease in the production of shrimp in recent years (FAO, 2014). Therefore, an assurance for the farmers is essential in order to prevent the economic losses to them. As pointed out by Hepher and Pruginin (1981) polyculture can help to increase the productivity through efficient utilization of natural food available resources available.

Shrimp polyculture is an age-old practice and might have evolved from early extensive shrimp farming in which fishes such as milkfish (*Chanos chanos*) and mullet (*Mugil sps*.) were incidentally or intentionally introduced and harvested as extra crops to shrimp (Jhingran, 1982). In the past decades, there were reports on the crustacean polyculture, demonstrating in some cases that it is not only profitable but also a sustainable activity, both in freshwater and marine systems (Irz and Mckenzie, 2003). Rodrigues and Zimmermann (1998) reported that 74% of research works on polyculture of crustacean were done in freshwater prawns in combination with planktivorous fishes. The remaining 26% of research works on polyculture were done with *M. rosenbergii* along with a wide variety of other species. It might be true as polyculture has been mostly a technology in freshwater aquaculture. In the reports concerning the polyculture of freshwater prawns with fishes, it has been pointed out that the production cost of prawn may be lowered by the correct choice of fish species and their stocking rates (Valenti and New, 2000). Therefore, it is evident that polyculture can help in reducing the production cost thereby the profit margin can be increased.

2.1. History of polyculture

It is observed that Chinese aquaculture practices are very old and ancient. They have often stocked multiple species of carps together in ponds to take advantage of the fertilized water and natural foods (Brick and Stickney, 1979), each of the species stocked occupied its own ecological niche. Another form of polyculture that has a long history in China is rice–fish culture (Kangmin, 1988). By modifying rice ponds to provide a refuge for fishes when the rice field is dewatered enabling the rice farmer to have two types of crops. Polyculture of Chinese carps with different food habits has been practiced in China for centuries (Lin, 1969 and Hao-Ren, 1982). With, the introduction of Chinese carps too many countries, polyculture has become a common practice in other parts of the world (Hepher and Milstein, 1989).

Today, polyculture is done with a wide variety of species than those that have been used in olden days in China, and there have been nuances modern approaches developed in the polyculture of fishes. According to Brick and Stickney (1979) the species used in polyculture systems need to be compatible, that is, they need to grow well without interfering with one another. In some exceptional polyculture systems, as explained by them combinations of species are used to maintain the unwanted fish growth and survival. There have also been instances where fish have been stocked in marine cages to consume parasites as it can be observed in the stocking of wrasse (family Labridae) to control sea lice in Atlantic salmon cages in Norway (Sayer et.al., 1996). Similarly, sea cucumbers (class Holothuriidae) are stocked in salmon net pens to feed on feces, fouling organisms, and unconsumed feed in fish cage culture (Ahlgren, 1998).

Paclibare et al., (2002) illustrated tilapia-shrimp polyculture systems as TIPS (Tilapia Introduction to Prawn System) developed by FYD International on Negros Island in the Philippines. The system was developed in 95 ha of ponds on Negros Island in 2002 and expanded further in other islands in 2003. By 2008, in Philippines, more than 60% of the shrimp farms employed tilapia – shrimp polyculture (Cruz, et al., 2008). Farming tilapia and shrimp together, improves shrimp health and increases profits (Yuan, et al., 2010; Hernandez-Barraza, et al., 2012). Shrimp production has been found to be higher in polycultures than in monocultures (Li and Dong, 2002).

2.2. Importance of polyculture

Belton and Little (2008) demonstrated that integrated aquaculture practices, such as polyculture, can contribute to minimizing the environmental impact of farm effluents, particularly those related to nitrogenous wastes, which could be further converted into toxic metabolites. The subordinate species can feed and assimilate most of the wastes generated from shrimp aquaculture. A higher efficiency of nitrogen utilization has been observed in polyculture systems compared with monoculture systems (Zhen-xiong et al., 2001).

The benefits of polyculture as already mentioned include the mitigation of ecological impacts and amelioration of yield and environmental quality (Chien and Liao, 1995; Martínez - Porchas et al., 2010; Yuan et al., 2010; Bosma and Verdegem, 2011). Polyculture is considered as an effective strategy to minimize waste in the farm system. Several benefits have been reported in shrimp polyculture systems when using fish and other aquatic organisms as subordinate species, despite the fact that polyculture is not yet a common practice (Martinez-Porchas et al., 2010). It has been demonstrated that beneficial effects of culturing shrimp with other shellfish, macroalgae and tilapia as other aquatic species led to positive conditions on the primary as well as secondary species, besides, it improves the pond water quality by controlling phytoplankton growth, reducing the accumulation of organic matter, antibacterial effects and the prevalence of viruses (Jatoba et al., 2011). According to Hepher and Pruginin (1981), the beneficial effect of polyculture is due to dissolved oxygen stability, reduction of predators and coprophagy.

It has been reported that polyculture increased the yield of fish over monoculture at similar stocking densities by reducing inter-specific resource competition and probably by mutual enrichment of diet through synergy (Hossain and Islam, 2006). Lilyestrom et al., (1987) contended that polyculture appeared to have no adverse effects on the survival, growth or yield of either species in channel catfish (*Ictalurus punctatus*) with freshwater prawn polyculture system. In freshwater prawn-fish polyculture system, cannibalism amongst prawn did not seem to be exacerbated by the presence of other fishes or crustaceans (Valenti and New, 2000).

Studies on polyculture and mix-culture of shrimp with different species of Tilapia (hybrid red tilapia, *O. niloticus* and *O. urolepis hornorum*), milkfish (*C. chanos*), mullet (*M. cephalus* and *M. platanus*), rabbit fish (*Siganus fuscescens* and *Siganus guttatus*), angelfish (*Pterophyllum scalare*) and river puffer (*Takifugu* *obscurus*) have been made with positive results (Tendencia et al*.,* 2004; Jang et al*.,* 2007; Yuan et al*.,* 2010; Jaspe et al*.,* 2011; Hernandez-Barraza et al*.,* 2012; Costa et al*.,* 2013; Luong et al*.,* 2014; Ribeiro et al*.,* 2014; Apun-Molina et al*.,* 2015; Aghuzbeni et al., 2016). Polyculture adds a secondary or subordinate species and improves the performance of the main cultured species by enhancing water quality as per the observation of Wang and Lu, (2016) and Tian et al., (2001). Therefore, polyculture fits the principles of sustainable aquaculture. It reduces the environmental impact of the farming activity, increases producer profitability and provides benefits associated with advanced ecological stability and function by optimizing use of available resources (Wohlfarth et al., 1985; McKinnon et al., 2002).

2.3. Shrimp polyculture systems

2.3.1. Shrimp with Tilapia

In a polyculture pond, tilapia and shrimp can utilize different niches in the culture system (Yi et al., 2002). Akiyama and Anggawati (1998) registered about two decades back that the polyculture of shrimp and tilapia had increased the production of shrimp, with tilapia production as a secondary benefit. In addition to that, Saelee (2002) reported that excess feed usage in a polyculture system than in a shrimp monoculture system did not have any adverse effect on water quality, due to the grazing of available natural food by Nile tilapia, which was the secondary species in the pond that helped in stabilizing the water quality. Yi et al., (2002) also found that the addition of Nile tilapia into shrimp ponds with shrimp as the main species could improve feed utilization efficiency, better economic returns and less environmental pollution. Tendencia et al., (2006) has gone to the extent of expressing that the presence of genetically improved farmed tilapia (GIFT) can reduce the luminous bacteria population and increase shrimp survival. It could be true as it was endorsed by Nagashima (2001) and Tendencia (2006a;b;c) who witnessed antibacterial activity against luminous bacteria and gram-negative bacteria in the mucus of some species of grouper, tilapia, milkfish, sea bass and rabbitfish. Thus, the presence of a secondary species like tilapia was found to inhibit growth of luminous bacteria and positively affect shrimp survival.

Tilapia production in shrimp ponds was noticed to be expanding in many countries of Southeast Asian and Latin America, including Thailand, Mexico, Peru, Ecuador, Brazil and also among other countries (Fitzsimmons, 2001). Polyculture of shrimp with tilapia species may provide an opportunity to develop a sustainable aquaculture system as pointed by Fitzsimmons (2001).

2.3.2 Shrimp with Milkfish *(C. chanos)* and Mullet *(M. cephalus)*

Eldani and Primavera (1981) and Marichamy and Rajapackram (1982) reported that shrimp culture with mullet and milkfish had benefits in the removal of nitrogenous wastes from the shrimp ponds. Mullet is potentially a good candidate for polyculture with shrimp due to its commercial value and high resistance to wide range of temperature and salinity (Pakrasi et al., 1975). In many countries, mullets are cultured in association with fish and other organisms as polyculture as witnessed by Pakrasi et al., (1975). The rearing of grey mullets in combination with milkfish, Indian major carps and shrimps in the coastal tanks of West Bengal has been described by them elaborately. Mullet is a filter feeder, which usually swims near the top of the water as school and swallows the scum of the water surface (Anil et al., 2010). The economic feasibility of polyculture of the giant tiger shrimp with mullet was further investigated by them. All these reports clearly indicate that shrimp performance is enhanced by the presence of a secondary species.

2.3.3. Blue Shrimp (*Penaeus stylirostris*) with sea cucumber (*Holothuria scabra*)

Study on polyculture of blue shrimp with sea cucumber was conducted in New Caledonia (Purcell et al., 2006 and Bell et al., 2007). Results of this study indicated that co-culture of sea cucumber (*H. scabra*) juveniles and blue shrimp (*P. stylirostris*) in earthen ponds was feasible, without any adverse impact on shrimp production. In contrary to the above observation, Bell et al., (2007) reported that grow-out production of *P. stylirostris* with *H. scabra* in pond was not viable. They further studied that such a production system with high stocking density of sandfish juvenile had no significant effects on growth and survival of shrimp. However, shrimp had a significant negative impact on survival and growth of sandfish in sand-bottom tanks. Furthermore, all sandfish were dead or moribund after a month of grow-out trial in ponds. Therefore, there might be some adverse effects also in such polyculture systems, which might be species specific.

2.3.4 Blue shrimp (*P. stylirostris*) with gold lined rabbit fish *(Siganus lineatus)*

The shrimp industry in New Caledonia according to the reports available has not been highly profitable but has persisted mainly because of the lucrative, niche market for *P. stylirostris* in Japan. Goldlined rabbitfish, *S. lineatus*is is considered a potential candidate for polyculture with blue shrimp in earthen ponds due to it is herbivorous feeding habits, adaptive nature in captivity and strong belief of its capability to inhibit the growth of Vibrio. *S. lineatus* can well adapt and grow in a closed culture system where dissolved oxygen is above 2mg/L and eutrophication is limited. This species was less competitive among individuals in high stocking density and was able to grow at low temperature during the cold season (Luong et al., 2014). The reports suggest a positive grow-out of blue shrimp and Gold lined Rabbit fish (Tendencia et al., 2006 a)

2.3.5. Black tiger shrimp (*P. monodon)* with Red Tilapia

Akiyama and Anggawati (1998) have mentioned that yields of shrimp increased when red tilapia (*Oreochromis* spp.) were stocked into black tiger shrimp (*P. monodon*) ponds. Red tilapia was reported to have influenced shrimp performance by improving and stabilizing water quality and foraging and cleaning the pond bottom. According to them it was a probiotic type effect in the pond environment.

Two experiments on intensive black tiger shrimp–tilapia polyculture was 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*). Shrimp yield and feed conversion ratio (FCR) were improved by the presence of Nile tilapia in the system. These findings support the concept of polyculture with tilapia for penaeid shrimps.

2.3.6. Penaeid Shrimp with bivalves

There are reports on the polyculture of different aquatic species, like Pacific oyster, *Crassostrea gigas* and black clam, *Chione fluctifraga* and fish (*Oreochromis urolepis hornorum*) with shrimps (Martinez-Cordova and Martinez-Porchas 2006; Tendencia et al., 2006). They also witnessed improvement in the shrimp production. Similar results of polyculture of Indian white shrimp (*P. indicus*) with *C. gigas* and *C. fluctifraga* showed that the presence of mollusks had a beneficial effect on the production of shrimp (Martinez-Cordova and Martinez-Porchas 2006,).

2.3.7. Penaeid Shrimp with pompano (*Trachinotus carolinus*)

Shrimp culture with omnivorous species with carnivorous tendencies is very scanty. Gomez et al., (1982) evaluated polyculture of pompano (*T. carolinus*) and shrimp (*P. brasiliensis*) in concrete tanks fed with two different artificial diets.Combination of species such as Pompano (*T. carolinus)* for encouraging results demonstrating its potential due to its high price in the market together with demand was felt feasible (Trimble, 1980).Pompano and penaeid shrimp have a high commercial value and their polyculture was investigated very long back in Alabama (Tatum and Trimble, 1978) and Texas (Rossberg and Strawn 1980). However, there were low survival rates. But in a later case, Trimble (1980) managed polyculture production ponds in Alabama with high survival and positive economic returns.

2.4. Feeding in polyculture system

Penaeid shrimps spend most of their life in contact with the bottom sediment (Dall et al., 1990) and have wide-range of food habits in natural systems. They have been described as omnivores, scavengers, detritus feeders, carnivores, and predators (Bailey-Brock and Moss, 1992; Rothlisberg, 1998). Their diverse feeding behaviors offer possibility to culture shrimp in polyculture as either the main species or a secondary species (Jackson and Ozbay, 2008; Yuan et al., 2010).They consume detrital aggregates, including bacteria and meiofauna, protozoa, micro-algae, zooplankton, macro benthos and other items (Dall, 1968; Chong and Sasekumar, 1981; Moriarty, 1997).

Polyculture of shrimp without bottom feeding secondary species allows the shrimps to obtain their sufficient share of the pelleted feed, as naturally a certain proportion of the feed will sink to the bottom. In addition, it allows the shrimp to graze on bacterial films on the bottom substrate and ultimately results in better growth performance (Hossain and Islam, 2006). Roberts and Kuris (1990) recommended that the stocking density of shrimps and fishes in the polyculture system varies from region to region and farm to farm. Shrimps may be predators depending on the size of the fishes as observed and recorded by Roberts and Kuris (1990).

Silver pompano (*T. blochii*) has already been considered a suitable candidate for mariculture due to its easy adaptation to culture systems, acceptance of formulated feeds, and fast growth rates (Chavez et al., 2011). The silver pompano is a pelagic and active species that is easy to domesticate and culture in tropical and subtropical marine waters.

Several studies have been conducted to assess the culture of this species (Gopakumar et al., 2011; 2012; Nazar et al., 2012; Kalidas et al., 2012). Like other marine species, successful culture of pompano requires high dietary crude protein

(CP), with a diet containing 45% CP being the minimum requirement for growth of juvenile pompano (Lazo et al., 1998). Pompano are highly active marine species and it has been suggested that the appropriate diet for successful growth of juvenile pompano requires a high level of digestible energy (DE) to support metabolic and growth demands (Weirich et al., 2009)

Different studies indicate that feeding management practices affect growth and feed conversion ratio of the cultured species (Wang and Lu, 2016; Cho et al., 2003) and reduce size class variation (Jobling, 1994). Moreover, feeding regimes optimizing feeding frequency and feeding rate may minimize feed wastage and lead to an improvement in environmental safety, greater size-class homogeneity and economic return (Dwyer et al., 2002; Tucker et al., 2006; Cho et al., 2003; Kim et al., 2007; Booth et al., 2008). Insufficient feeding frequency leads to poor growth and high mortality, especially in intensive systems (Carneiro and Mikos, 2005). Sporadic feeding and low feeding rates may contribute to reduced growth as well as increased hunger, intra specific aggression, and increased rate of cannibalism according to Folkvord and Ottera, (1993). However, increasing feeding frequency requires more labor and increases production costs (Carneiro and Mikos, 2005).

Fishes require food to supply the energy they need for movement and all other functions, and as the “building blocks for growth”. Unfortunately, the maximum growth and the lowest feed conversion ratios do not coincide at the same feeding rate. The lowest feed conversion occurs at feeding rates below those at which maximum growth occurs (Silva et al., 1995; Goddard, 1996). Thus, it is evident that there is a range of possible feeding rates, which depend on whether maximum growth, optimal food conversion, or a balance between the two is sought.

Fish carcass composition is a good indicator of physiological condition but it is relatively time consuming to routinely measure (Ali et al., 2005). Feeds and feeding are among the major factors influencing carcass composition and fish quality. Eating quality therefore is an important determinant of the overall impression of a food (Ochang et al., 2007). Overall, proper feeding frequency and feeding rates vary with fish size, rearing system, temperature and feed quality (Ruohonen et al., 1998).

The available literature suggests a possible production enhancement in the polyculture systems for Penaeid shrimps. Pacific white shrimp is the present day highly preferred species for the Indian coastal aquaculture and therefore investigation for production enhancement is the need of the hour as suggested by Wyban and Sweeny, (1991). Considering the emerging marine finfish aquaculture, Silver pompano combined shrimp polyculture might be a real boost to the aqua-culturists in India.

III. MATERIALS AND METHODS

The present study was undertaken with an objective of determining the growth performance of Pacific white shrimp, (*P. vannamei)* with silver pompano *(T. blochii)* (Plate 1) under polyculture system at different stocking densities in indoor condition. Further, outdoor grow out study was conducted for the best performing stocking density selected from the indoor trial conducted.

3.1 Raceway rearing of Pacific white shrimp

Pacific white shrimp Post Larvae (PL8) were purchased from Coastal Aquaculture Authority Approved (CAA) Dolphin Shrimp Hatchery, Melamunthal, Ramnadhapuram. The shrimp seeds were tested for occurance of White Spot Syndrome Virus (WSSV), Enterocyctocean Hepato Peneaii (EHP), and Vibrio (*V. paraheamoliticus*) in a commercial laboratory located at Marakkanam before purchase. The shrimp seeds were stocked in raceway cement tank of $18m^3$ capacity for initial rearing of Pacific white shrimp seeds, before starting the experimental study for acclimatization and make them fit for experimental condition (Plate 2). Raceway cement tank was cleaned, disinfected with bleaching power and dried for 3 days prior to use. Feeding was done with commercial feed for two times (10.00 a.m and 2.00 p.m) a day as per the feeding regime of the commercial feed company. Vigorous and continuous aeration was given in the raceway tank with the help of an air compressor. Excess feed and fecal matter were removed regularly from the tank through siphoning to maintain the water quality.

3.2 Raceway rearing of silver pompano

Raceway cement tank (18m^3 capacity) was used for initial rearing of silver pompano fry before stocking them in starting the experimental study. Silver pompano fry (500) was purchased from CMFRI, Mandapam, Ramnadhapram. After 3 hours of transportation in oxygen filled HDPE bags and brought to the MRFF, Tharuvaikulam, Raceway tank was cleaned, disinfected with bleaching power and dried for 3 days prior to stocking. Pompano fry were reared for a period of one week for acclimatization to make them fit for stocking in experimental condition. Vigorous and continuous aeration was given in the raceway tank with the help of an air compressor. Feeding was done two times (10.00 a.m and 2.00 a.m) a day using commercial fish feed until satiation. Excess feed and fecal matter were removed from the tank through siphoning.

3.3 Experiment set up

3.3.1 Indoor experiment

The indoor growth experiment was carried out in Mariculture Research Farm Facility (MRFF), an Unit of Department of Aquaculture located at Tharuvaikulam coastal village, Thoothukudi District. A total of 15 cement tanks each with a capacity of 1.8m^3 were used for this trial study (Pic 3 a of Plate 3). They were 4 sets of treatment tanks and 1 set of control tanks in triplicate. Before starting the experiment, these cement tanks were washed with seawater, freshwater and disinfected with bleaching powder. Air dried and filled with clear filtered sea water pumped from the sea bores. All the 15 cement tanks were provided with proper aeration facility to ensure proper water quality in the tanks.

3.3.2 Outdoor Experiment

The outdoor growth experiment was done in two HDPE lined ponds (Pic 3 b of Plate 3) of size $30m^3$ (10 m x 3 m x 1m) at the same location. The experiment was done as one treatment with duplicate. The trial ponds were prepared for stocking after sun drying, sludge removal and by water flushing. After preparation, the ponds were filled with clean filtered seawater and the water was treated by chlorination. Both the ponds were provided with proper aeration by ring blowers.

3.4 Indoor polyculture trial Pacific white shrimp and silver pompano

Raceway reared Pacific white shrimp with an initial body weight of 0.43± 0.047g and silver pompano with an ABW of 2.17 ± 0.2083 g were stocked successively in cement tanks. Pacific white shrimps were stocked at a density of $60/m^2$ as per CAA recommendation in all 4 treatments and 1 control tank prior to fish stocking uniform size silver pompano seeds were selected and stocked at 4 different stocking densities in four treatment tanks and control tank was left with only shrimp. Pacific white shrimps were fed with commercial crumble feed with a protein content of 35 % (Pic 4 a of Plate 4). Pacific white shrimps were fed with as per commercial feed regime. The stocking density details of pacific white shrimp and silver pompano seeds in the cement tanks were given in Table 3.1. Harvesting was done at the end of 60 days of indoor trial (Pic 4 b of Plate 4). The experiment tanks were monitored daily and the water quality parameters were assessed. The dead shrimps and waste generated in the tanks were siphoned off. If there are any unusual behavior of fish or shrimp, that was attended to immediately.

Table 3.1. Stocking details and experiment code of Pacific white shrimp (*P. vannamei*) and silver pompano fingerlings under polyculture in indoor system.

	Silver pompano		Pacific white shrimp	
Treatment	Stocking density/m^2	Numbers Stocked	Stocking Density/m^2	Numbers Stocked
Treatment 1(T_1)	3/m^2	7	60/m^2	135
Treatment 2(T_2)	6/m^2	14	60/m^2	135
Treatment 3(T_3)	9/m^2	21	60/m^2	135
Treatment 4(T_4)	12/m^2	28	60/m^2	135
Control (C)	0	0	60/m^2	135

3.5 Outdoor polyculture of Pacific white shrimp and silver pompano

Raceway reared Pacific white shrimp with an initial body weight of 0.028 ± 0.0032g and silver pompano with an ABW of 0.364± 0.0655g were stocked at the best stocking density obtained from indoor ponds. The ponds were supplied with aeration through ring blowers and Pacific white shrimp were fed with commercial crumble feed (protein content of 35 %) as per the feeding chart given. The stocking density details of Pacific white shrimp PL and silver pompano seeds in the treatment and duplicate pond are given in Table 3.2. Harvesting was done at the end of 60 days of outdoor trial (Pic 5 of plate 5)

Table 3.2 Stocking details of Pacific white shrimp (*P. vannamei*) and silver pompano fingerlings under polyculture in outdoor system

	Silver pompano		Pacific white shrimp	
	Stocking density	Numbers Stocked	Stocking density	Numbers Stocked
Treatment	$3/m^2$	90	$60/m^2$	1800

3.6. Water quality parameters

During the experiment period, water quality parameters such as Temperature, Dissolved Oxygen, pH and salinity were recorded daily and Ammonia–N, and Alkalinity were measured once in 3 days. Water temperature was measured using a thermometer with an accuracy of 0.1^oC in the afternoon and evening. The pH of rearing water was measured using the laboratory model Elico pH meter. Modified Winkler's titration method (APHA, 2005) was adopted to estimate the dissolved oxygen once in a day. Total alkalinity was determined as per the method described in APHA, (2005).

3.7 Sampling

The sampling was done once in 10 days for shrimp and fortnightly for silver pompano. Length and weight for Pacific white shrimp and silver pompano were recorded during sampling (Plate 6 a and 6 b of Plate 6).

3.8 Bio-Growth Parameters

Following parameters were calculated based on the formula

1. Weight gain (Wg) = (Mean final weight - Mean initial weight)
2. Biomass = ABW X No.of fishes
3. Average daily weight gain (ADG) = Final weight – Initital weight / days of culture
4. Daily weight gain percentage = ADWG/initial weight of fishes X 100
5. Net Biomass Production = Final Biomass obtained – Initial Biomass stocked
6. Specific Growth Rate (SGR) = (Ln final weight – Ln initial weight) x 100/ Days
7. Food Conversion Ratio (FCR)= Total feed (g) / Weight gain (g)
8. Food Conversion Efficiency (FCE) = Net Biomass Production/ Total feed given X 100
9. Survival Rate (SR) = No of fishes survived / No of fishes stocked x 100

3.9 Statistical Analysis

The data obtained during experiment was statistically analyzed with one way ANOVA and Students “t” test.

IV.RESULTS

4.1. Growth studies on *P. vannamei* with silver pompano at different stocking densities under polyculture in indoor system

The growth parameters of *P. vannamei* and silver pompano cultured under polyculture in indoor system are presented in Table 4.1 and 4.2

4.1.1. Growth of *P. vannamei*

P. vannamei in the control group reached the high ABW of 6.97±0.04g, which was followed by shrimps in T_1 group. However, there was a minor variation in the ABW of shrimps of stocking, which is not statistically significant. The shrimps in the T_4 group had reached the lowest ABW among the treatments (Table 4.1).

P. vannamei attained maximum mean weight gain of 6.51±0.02g in the control group (C). Among treatments, *P. vannamei* attained maximum final mean weight gain of 6.45 ± 0.05g in the Treatment 1(T_1) and followed by 6.26±0.04g in Treatment 4(T_4) as given in Table 4.1. The least weight gain (6.23±0.06g) was noticed in the *P. vannamei* of treatment 2(T2).

The percentage weight gain estimated against the initial ABW of shrimps showed great variation among the treatments. Percentage of weight gain in *P. vannamei* was the highest (1489.25±39.3%) shrimps of T_1 and the lowest percentage of weight gain (1153.24 ± 665.83%) of *P. vannamei* was observed in T_2 (Table 4.1). The highest Specific Growth Rate in *P. vannamei* was recorded in T_1

Table: 4.1 Bio-gowth parameters of *P. vannamei* during culture with silver pompano under polyculture in indoor system *(P < 0.05)

Treatment	Parameters (Mean ± SD value)							
	Experiment Animal	Mean Initial weight (g)	Mean Final weight (g)	Mean Weight Gain(g)	Percentage of weight Gain-PWG (%)	Average Daily Growth-ADG(g)	Specific Growth Rate SGR(%/day)	Survival Rate (%)
Control	Shrimp	$0.47^{a} \pm 0.03$	$6.97^{a} \pm 0.04$	$6.51^{a} \pm 0.02$	$1,381.34^{b} \pm 73.62$	0.1083^{a}	$4.4884^{b} \pm 0.08$	95
T_1	Shrimp	$0.43^{b} \pm 0.01$	$6.88^{b} \pm 0.05$	$6.45^{a} \pm 0.05$	$1489.252^{a} \pm 39.30$	0.1074^{a}	$4.61^{a} \pm 0.04$	97
T_2	Shrimp	$0.54^{a} \pm 0.01$	$6.76^{c} \pm 0.06$	$6.23^{b} \pm 0.06$	$1153.24^{b} \pm 665.83$	0.104^{b}	$4.21^{a} \pm 0.02$	94
T_3	Shrimp	$0.48^{a} \pm 0.04$	$6.73^{c} \pm 0.08$	$6.25^{c} \pm 0.07$	$1318.52^{b} \pm 108.78$	0.104^{b}	$4.41^{b} \pm 0.13$	92
T_4	Shrimp	$0.43^{b} \pm 0.03$	$6.69^{c} \pm 0.01$	$6.26^{c} \pm 0.04$	$1472.08^{a} \pm 105.46$	0.104^{b}	$4.58^{a} \pm 0.12$	89

Table: 4.2 Bio-gowth parameters of silver pompano during cultured with *P. vannamei* under polyculture in indoor system *(P < 0.05)

	Parameters (Mean ± SD value)							
Treatment	Experiment Animal	Mean Initial weight (g)	Mean Final weight (g)	Mean Weight Gain(g)	Percentage of weight Gain- PWG (%)	Average Daily Growth- ADG(g)	Specific Growth Rate SGR-(g)	Survival Rate (%)
T_1	Fish	2.10 ± 0.15	7.05 ± 0.04 a	4.95 ± 0.18	239.26 ± 23.78	0.083	2.03 ± 0.12	100
T_2	Fish	2.04 ± 0.07	6.92 b	4.88 ± 0.07	240.45 ± 11.88	0.0813	2.0398 ± 0.06	93
T_3	Fish	1.89 ± 0.06	6.84 ± 0.02 b	4.96 ± 0.07	263.65 ± 13.39	0.083	2.15 ± 0.06	95
T_4	Fish	1.94 ± 0.13	6.75 ± 0.02 c	4.81 ± 0.14	251.17 ± 23.01	0.08	2.09 ± 0.11	92

(4.61±0.04g) was observed in T_1 and the lowest SGR (4.21 ± 0.02 g) was recorded in T_2 (Table 4.1).

The maximum Average Daily Growth (ADG) value (0.11g) was obtained in the *P. vannamei* in the control group(C). Minimum ADG of 0.01g and 0.01g were observed in T_3 and T_4, respectively (Table 4.1).

The highest survival rate for *P. vannamei* was observed in T_1 (97%) and followed by control group (95%) and the lowest survival rate of *P. vannamei* was observed in T_4 (89%).

Growth patterns of *P. vannamei* recorded during the polyculture with different densities of silver pompano in indoor system are depicted in Fig 4.1 As it can be observed, *P. vannamei* registered positive growth patterns for all the treatments. Also all are almost same level up to DOC 40 days. In all treatments, growth was consistently increasing and touched the maximum. Among all treatments, the shrimps in Control group reached the highest (6.97±0.03g) and followed by shrimps of T_1(6.88±0.05g) on the 60th day of observation. The shrimps of T_4 registered least growth in the 60th day of this experiment.

4.1.2. Growth of silver pompano

There were drastic variations among the silver pompano of different groups attaining their final ABW. The fishes in T_1 reached a higher ABW (7.05±0.04g) than

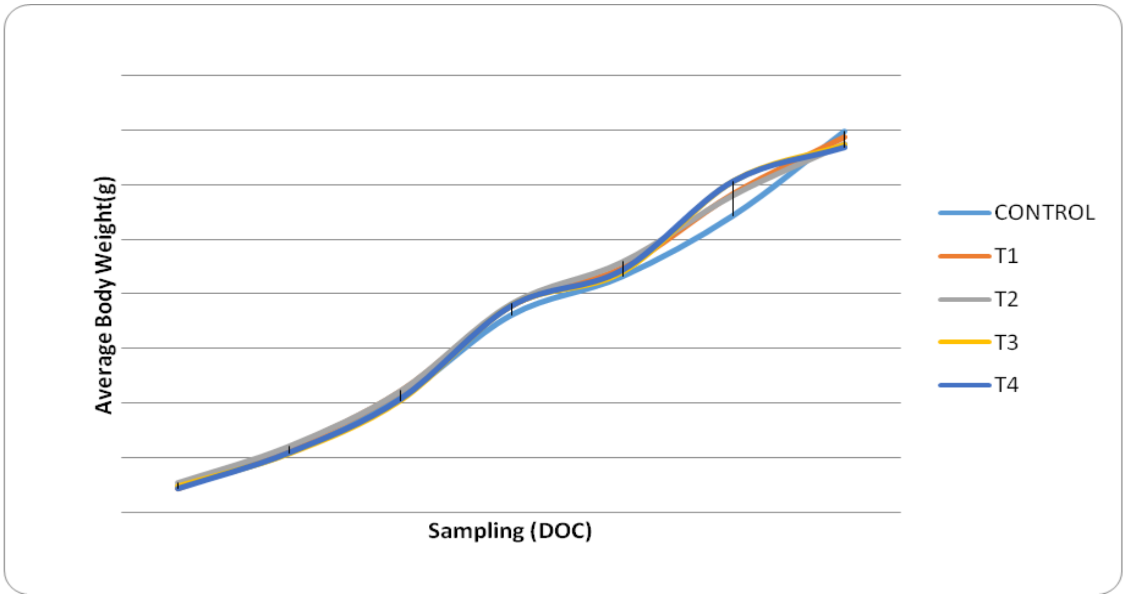


Fig 4.1 Growth patterns of *P. vannamei* during the polyculture with different densities of silver pompano in indoor system.

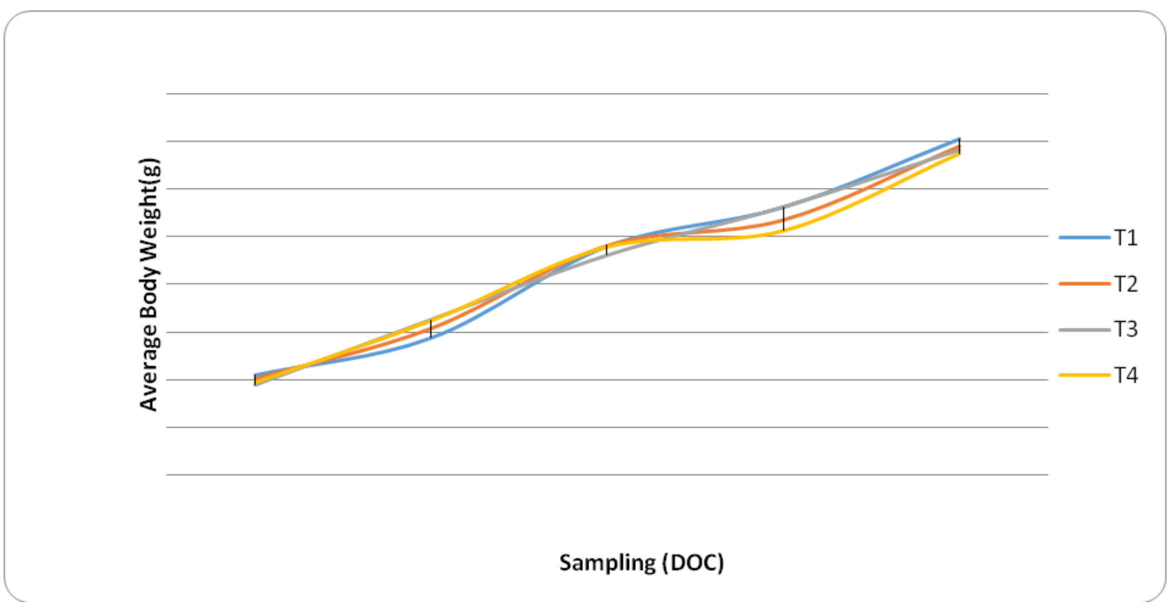


Fig 4.2 Growth patterns of silver pompano during the polyculture with *P. vannamei* in indoor system

that of other treatments. The other treatments (T_2 T_3 and T_4) did not show any higher variation is the final ABW as can be noticed in Table 4.2 and Fig 4.2.

Silver pompano attained maximum mean body weight gain of 4.96±0.07g in the Treatment 3 (T_3) and followed by T_1 (4.95±0.18g). The minimum weight gain was 4.81±0.14g observed in the silver pompano of T_4 (Table 4.2).

Percentage of weight gain in silver pompano was the highest (263.65±13.39%) in T3 group. The minimum percentage of weight gain (239.26±23.78%) was obtained in the treatment of T_1 (Table 4.2). In silver pompano the maximum SGR of 2.09±0.11g was noticed in the T_4 group and the minimum SGR of 2.03±0.12g was with fishes in T_1 was tabulated in Table 4.2

The ADG of silver pompano was found to be maximum (0.08g) in two treatments such as T_1 and T_3 seen Table 4.2

There were differences in the survival rate of silver pompano and the highest survival rate of silver pompano was observed in T_1 (100%), followed by T_3 (95%) and the lowest survival rate was observed in T_4 (92%) (Table 4.2).

Growth patterns of silver pompano recorded during the polyculture with *P. vannamei* in Indoor system were depicted in Fig 4.2 There was a fluctuation of growth in silver pompano in the treatments. The growth was consistently increasing until 30 DOC and there was a slow growth occurred after 30th day.

However, after 45th DOC, the growth was increasing. This was observed in all treatments. Maximum growth was obtained in T_1 (7.05±0.04g) and followed by T_2

(6.92g) on 60th day of this experiment which was given in Fig 4.2 and Table 4.2 Minimum growth was obtained in 60 days of this experiment in T_4 (6.75±0.02g) and followed by T_3 (6.84 ± 0.02g) which was depicted in Fig 4.2 and Table 4.2

4.1.3 Biomass production and feed conversion parameters of *P. vannamei* and silver pompano under polyculture system in indoor system

The biomass production and feed utilization parameters of *P. vannamei* and silver pompano under polyculture system in indoor system are presented in Table 4.3. The net biomass production of *P. vannamei* was the highest in T_1 (842.78±7.21g) which is followed by control group (835.66±2.17g). The lowest net biomass production for *P. vannamei* was observed in T_4 (752.25±5.83g) (Table 4.3).The highest biomass production of silver pompano was observed in T_4 (121.27g) and followed by T_3 (97.25±1.57g). The lowest biomass production of silver pompano was observed in T_1 (34.67±1.24g) (Table 4.3).

The highest total net combined biomass production of *P. vannamei* and silver pompano (877.45±7.57g) was recorded in T_1 and followed by T_4 (873.51±6.75g).The lowest total net biomass production (835.66±2.17g) was observed in control group which had only shrimps (Table 4.3).

When the feed consumption parameters were compared with net biomass production, it was observed that the mean feed intake was maximum observed in T_1 (1171.66±8.4g) and the minimum mean feed intake (1009±11.17g) was in the T_3. Since there was higher feed intake, the T_1 group had poor FCR

Table: 4.3 Production and feed conversion parameters of *P. vannamei* and silver pompano cultured under polyculture in indoor system

	Parameters (Mean ± SD value)								
Treatment	Experiment animal	Mean Initial Biomass (g)	Mean Final Biomass (g)	Net Biomass production (g)	Total Net Biomass production(g)	Percentage of contribution (%)	Total feed given (g)	FCR	FCE (%)
Control	Shrimp	63.9±3.51	899.56±4.79	835.66±2.17	835.66±2.17	100	1034.49±5.51	1.24	80.78±0.31
T_1	Fish	14.7±1.05	49.37±0.3	34.67±1.24	877.45±7.57	3.95	1171.66± 8.4	1.34	74.89±0.11
	Shrimp	58.5±1.19	901.28 ±6.46	842.78±7.21		96.05			
T_2	Fish	28.51±1.01	89.92 ± 0.04	61.40± 0.98	847.87±6.34	7.25	1074.21± 9.63	1.27	78.93±0.18
	Shrimp	72.9±0.78	859.37 ± 7.7	786.47± 7.32		92.75			
T_3	Fish	39.62± 1.38	136.87 ±0.35	97.25±1.57	873.28±7.17	11.14	1009± 11.17	1.16	86.56±0.49
	Shrimp	64.8±5.11	840.83± 9.31	776.03±8.66		88.86			
T_4	Fish	54.32±6.04	175.59±0.46	121.27	873.51±6.75	13.88	1093.9±2.88	1.25	79.85±0.41
	Shrimp	58.05± 4.05	810.30±2.13	752.25±5.83		86.12			

1.34 against the best conversion rate of 1.16 in T_3. Next to T_3 which showed good Food Conversion Ratio (FCR) followed the control group had better FCR (1.24). The poor FCR was observed in T_1 (1.34) (Table 4.3).

This data could be further processed against the food conversion efficiency of the animals in polyculture. Maximum Food Conversion Efficiency (FCE) was recorded in T_3 (86.56±0.49) followed by the control group (80.78±0.31). The lowest FCE was observed in T_1 (74.89±0.11%) and followed by T_2 (78.93±0.18%) as seen in Fig 4.3

4.1.4. Biomass contribution of shrimp and fish in the production of indoor system

Percentage contribution of *P. vannamei* and silver pompano is the production under polyculture in indoor system at 4 different treatments which was depicted in Fig 4.4. As there was no fish component, the entire production in control group was with shrimp alone (100%). It can be seen further that there is a positive relation between the share of fishes and their stocking density. It is obtained that the additional species could enhance the production as it is evidenced in the net biomass production.

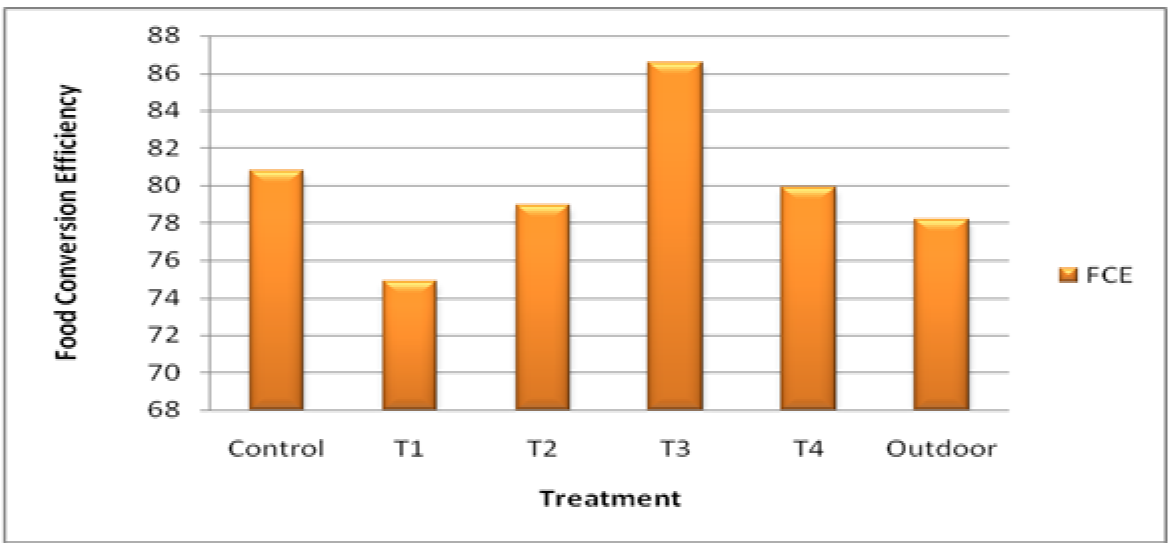


Fig 4.3 Food conversion efficiency of of *P. vannamei* and silver pompano(combined) polycultured in indoor and outdoor polyculture systems

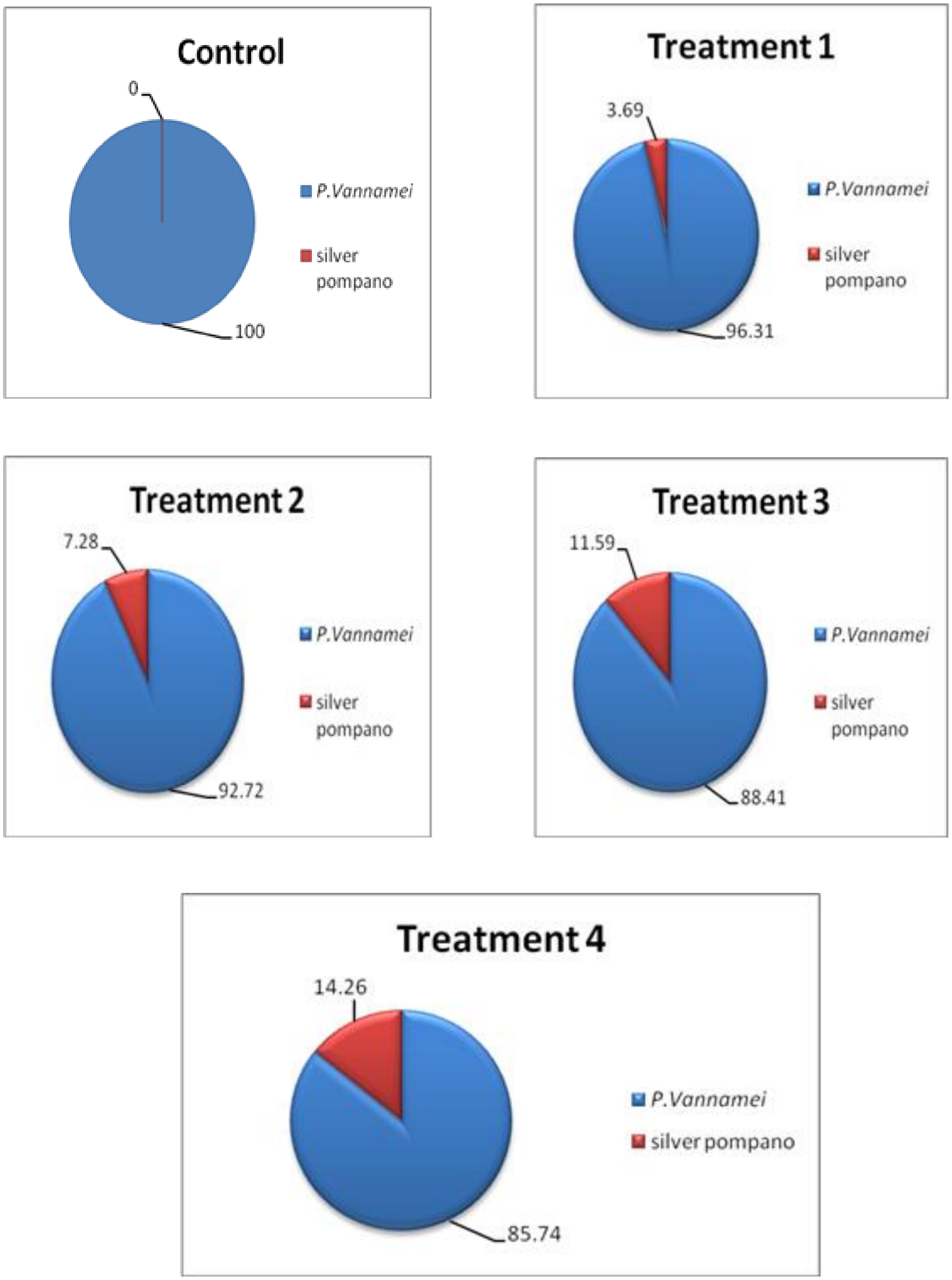


Fig 4.4 Percentage contribution of *P. vannamei* and silver pompano under polyculture in Indoor system

4.1.5. Water quality parameters during the experiment period

The water quality parameters (mean ± SD) of indoor system such as temperature, pH, dissolved oxygen, alkalinity, secchi depth, salinity and ammonia, are presented in Table 4.4 Water temperature of the indoor system, was found to be 25.89±0.1°C (mean ± SD). The maximum water temperature was 26.2°C and the minimum water temperature was found to be 24.5°C. Salinity (mean ± SD) was 37.33±0.33 (mg/l) during the experiment. Dissolved oxygen (mean ± SD) level of the indoor system was observed to be 5.56±0.18mg/l. The p^H was 8.42±0.05 and the highest value was 8.45 and the lowest value of p^H was 8.2. The Alkalinity level was 131.33±1.49 mg/l during the study. Secchi disc depth (mean ± SD) was observed to be of 22.22±0.81(cm). In the indoor tanks Ammonia (mean ± SD) values were 0.01mg/l during the study period (Table 4.4).

4.2. Growth studies on *P. vannamei* with silver pompano under polyculture in outdoor system

The estimated growth parameters of *P. vannamei* and silver pompano cultured under polyculture in outdoor system are presented in Table 4.5. The biomass Production and feed conversion parameters of this outdoor system are presented in Table 4.6. The growth patterns of shrimp and fish are depicted in Fig 4.5 and Fig 4.6.

4.2.1. Growth of *P. vannamei* and silver pompano

In the outdoor ponds, *P. vannamei* reached a mean body weight of 9.91g within the rearing period of 60 days. During the same time silver pompano reached

Table: 4.4 Range of Water quality parameters during indoor system

Parameters (mean ± SD)	
Water quality parameters	**Value**
Temperature	25.89±0.11(^{0}C)
Salinity	37.33±0.33(mg/l)
Alkalinity	131.33±1.49(mg/l)
Dissolved oxygen	5.56 ± 0.18(mg/l)
Secchi depth	22.22±0.81(cm)
p^H	8.42±0.05
Ammonia	0.01(mg/l)

Table: 4.5 Bio-gowth parameters of *P. vannamei* and silver pompano cultured under polyculture in outdoor system

	Parameters (mean ± SD)							
Treatment	Experiment Animal	Mean Initial weight (g)	Mean Final weight (g)	Mean Weight Gain(g)	Percentage of weight Gain PWG (%)	Average Daily Growth ADG(g)	Specific Growth Rate SGR-(g)	Survival Rate (%)
T	Fish	0.36	6.82 ± 0.03	6.46 ± 0.03	1793.06 ± 9.72	0.108	4.90	95
	Shrimp	0.02	9.91	9.89	49,425 ± 25	0.165	10.34	90

the mean body weight of 6.82±0.03g. Percentage weight gain of *P. vannamei* (49,425±25%) was observed in this treatment which was given in Table 4.5.

Specific Growth rate of *P. vannamei* was (10.34g) and that of silver pompano was 4.90±0.01g. Average Daily Growth (ADG) of *P. vannamei* was 0.165g and silver pompano was 0.108g. The survival rate was 90% for *P. vannamei* and 95% for silver pompano.

Growth pattern of *P. vannamei* recorded during the polyculture with silver pompano in outdoor system which was given in Fig 4.5. The growth was steadily increasing with an ADG of 0.16g up to 60th day. The silver pompano also had the same growth trend (Fig 4.6)

The growth of *P. vannamei* and silver pompano is statistically significant in outdoor polyculture system as it could be presented in Table 4.6.

4.2.2. Biomass production and feed conversion parameters of *P. vannamei* and silver pompano in outdoor system

The biomass production and feed conversion parameters of *P. vannamei* and silver pompano under polyculture system in outdoor pond are given in Table 9. The Net biomass production of *P. vannamei* and silver pompano was 16,560.37±8.51g which is combination of both shrimp and fish. The total feed consumed was 21180.85±10.69g leading to an FCR of 1.28 and FCE of 78.19%. The percentage contribution of fish and shrimp are depicted in Fig 7 and it can be observed that silver pompano has contributed to 3.32% of the total biomass production.

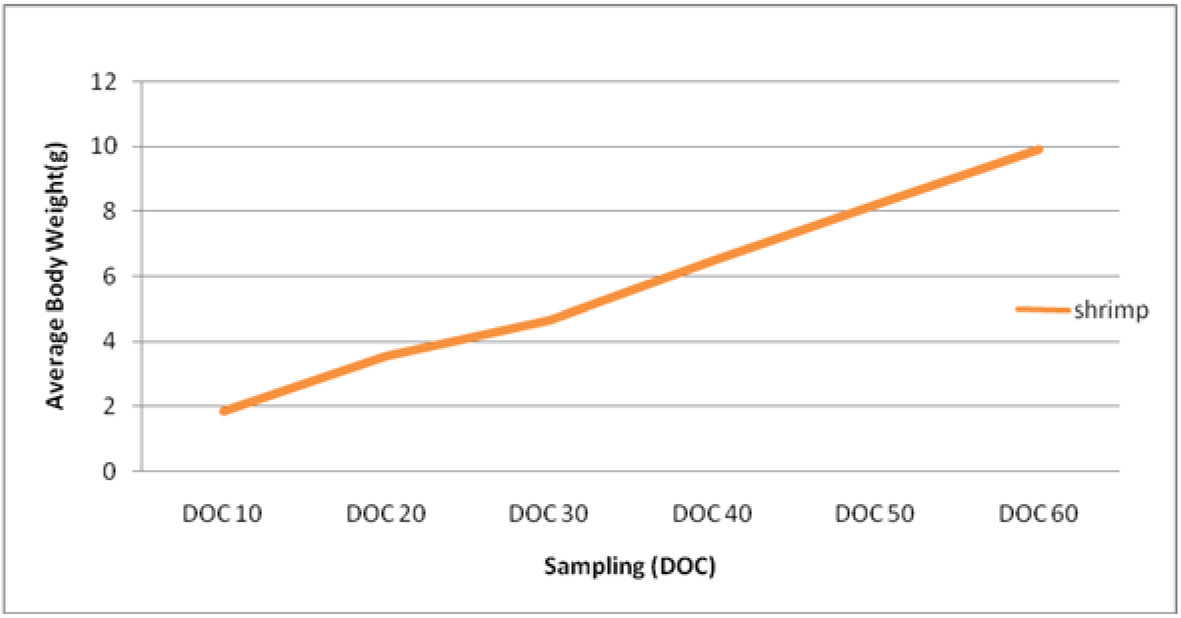


Fig 4.5 Growth pattern of *P. vannamei* during the polyculture with silver pompano in outdoor system

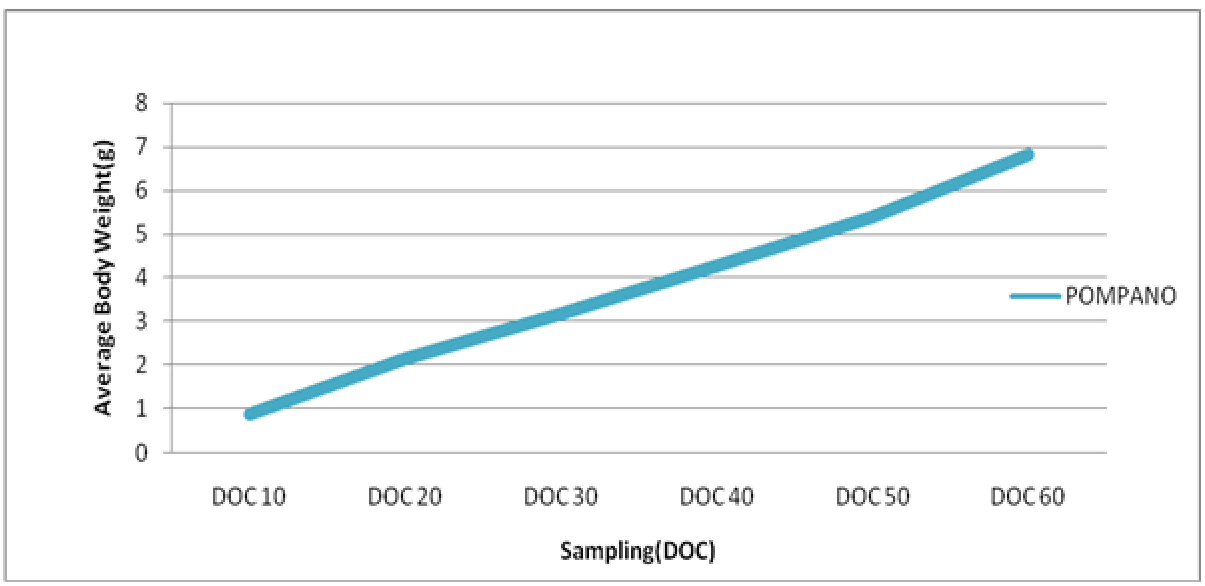


Fig. 4.6 Growth pattern of silver pompano during the polyculture with *P. vannamei* in outdoor system

Table: 4.6 ANOVA for growth and production parameters of *P. vannamei* with silver pompano cultured under polyculture in outdoor system *(P < 0.05)

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	***P-value***	*F crit*
Rows	102.6542	6	17.10903	24.91261	**0.000542**	4.283866
Columns	9.794579	1	9.794579	14.26197	**0.009218**	5.987378
Error	4.120571	6	0.686762			
Total	116.5693	13				

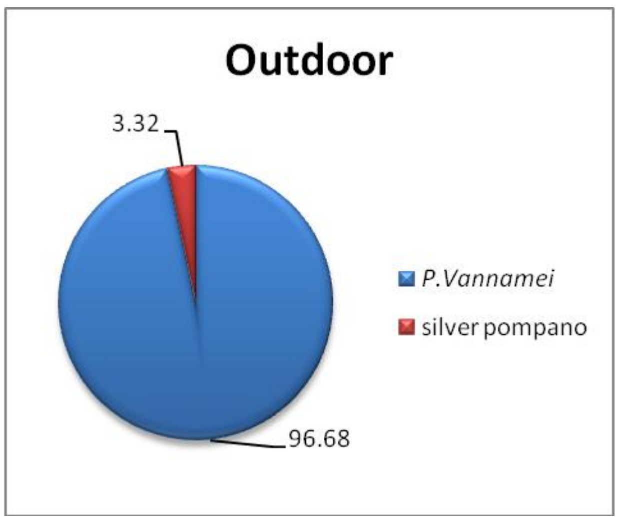


Fig 4.7 Percentage contribution of *P. vannamei* and silver pompano under polyculture in outdoor system

Table: 4.7 Production and feed conversion parameters of *P. vannamei* and silver pompano cultured under polyculture in outdoor system

	Parameters (mean ± SD)								
Treatment	Experimental Animal	Mean Initial Biomass (g)	Mean Final Biomass (g)	Net Biomass production (g)	Total Net Biomass production(g)	Percentage of contribution (%)	Total feed given (g)	FCR	FCE (%)
T	Fish	32.4	582.67 ± 0.41	549.85 ± 0.41	16560.37 ± 8.51	3.32	21180.85 ± 10.69	1.28	78.19
	Shrimp	36	16010.1 ± 5.12	16002 ± 8.1		96.68			

Table: 4.8 Comparison of indoor and outdoor culture of *P. vannamei* and silver pompano under polyculture system

	Stocking density Numbers/m^2		Net Biomass production (g/m^2)		Percentage of contribution (%)		FCR		FCE (%)		Survival rate (%)	
species	**Indoor**	**outdoor**	**Indoor**	**outdoor**	**Indoor**	**outdoor**	**Indoor**	**outdoor**	**Indoor**	**outdoor**	**Indoor**	**outdoor**
Shrimp	60	60	374.57	533.4	96.05%	96.68%	1.34	1.28	74.89	78.19	97%	90%
Fish	3	3	15.41	18.33	3.95%	3.32%					100%	95%

The comparison of indoor and outdoor culture of *P. vannamei* and silver pompano is presented in Table 4.8. As it can be seen from the Table 4.8, there are similarities in FCR and FCE in both treatments. However, the survival and net biomass production/m^2 are much better in outdoor system than that of indoor polyculture system. Surprisingly, the percentage contribution of fish in the total net biomass production was almost same in both the cases. The outdoor system gave a shrimp production of 533.4 g/m^2 against the indoor system, which yielded only 374.57 g/m^2.

Water quality parameters as recorded in outdoor system are presented in Table 4.9. During outdoor culture, the temperature was 29.44±0.24 (^{0}C), Alkalinity was 156.22±3.26 (mg/l), Dissolved oxygen was 5.67±0.19 (mg/l), p^H was 8.45±0.04, Secchi depth was 15.11± 0.61cm. Ammonia was 0.017(mg/l) throughout the culture system (Table 4.9).

Table: 4.9 Ranges of Water quality parameters during outdoor system

Parameters (mean± SD)	
Water quality parameters	**Value**
Temperature	29.44±0.24(^{0}C)
Salinity	38.11±0.35(mg/l)
Alkalinity	156.22±3.26(mg/l)
Dissolved oxygen	5.67±0.19(mg/l)
Secchi depth	15.11±0.61(cm)
p^H	8.45±0.04
Ammonia	0.017(mg/l)

V.DISCUSSION

In the present study, there was highest ADG for *P. vannamei* reared in the control group (C) and the next highest was with *P. vannamei* in T_1 group. The difference was not statistically significant between two groups indicating the T_1 performed much similar to control group. This signifies exhibits no negative Impact of silver pompano at 3/m^2 as the ADG of shrimp. This finding is similar to that of Yuan et al., (2010); Hernandez Barraza et al., (2012) who said that polyculture of tilapia with shrimp together, improved shrimp health and enhanced profits compared to monoculture.

In the present experiment, it was seen that shrimp production was higher in the T_1group than that of control group. This difference is statistically significant between two groups indicating that T_1 performed better than control group. These results are similar to that of Li and Dong (2002) who said that Shrimp production was generally higher in polyculture system than in monoculture system. It may be the reason of silver pompano influence the shrimp growth and improved production.

Akiyama and Anggawati (1998) observed that polyculture of shrimp–tilapia culture improved survival rates of black tiger shrimp by 4% and 13% at tilapia stocking densities of 0.2 and 0.3 fish/m^2, respectively. In the present study similar results could be observed that silver pompano - *P. vannamei* polyculture increased the *P. vannamei* survival rates in T_1. The survival (97%) was higher than *P. vannamei* monoculture (control group). It might be due to the ability of silver pompano that can feed excess feed and reduce the ammonia level and maintain the water quality in optimum condition that leads to increasing the shrimp survival rate and enhanced production.

In the present experiment silver pompano was stocked after stocking the shrimp thereby the cannibalism by the fish was avoided. This was earlier stated by Yi et al., (2002). They conducted two experiments and did not find any significant improvement of shrimp survival by tilapia stocked at 0.25 and 0.5 fish/m^2 in intensive black tiger shrimp ponds. It was said, that the small stocking size of tilapia ranged from 5.5 g to 8 g used in the experiments of Yi et al., (2002) got good result. The lower size fishes would have had less beneficial effect.

In the present study, there was no disease in shrimps harvested in treatment groups compared to control group. This signifies the positive impact of silver pompano which did not affect shrimp health and survival in treatment tanks. This finding related to that of Akiyama and Anggawati (1998) mentioned that red tilapia with black tiger shrimp ponds might have a probiotic effect which helped to improve the pond environment and hence shrimp survival, but provided no conclusive proof.

Yi et al., (2002) reported that shrimp in polyculture ponds, where feed rations were determined by feed consumption conditions in individual ponds, had similar growth rates to monoculture ponds. But, in the present study there is a smaller difference in feed rations compared to control group. In polyculture tanks, the FCR was more similar to that of control tanks indicating that shrimp probably compensated intake of food, when in the presence of silver pompano in higher stocking density.

High stocking density of silver pompano did cause a smaller significant variation in feed ration and FCE. Stocking of secondary animal in the shrimp pond might have influenced shrimp growth rate. This may be a reason for fluctuation in feed rations and shrimp growth.

In the present study, there is increase in shrimp production in (T_1) although there was presence of silver pompano. The FCR was higher than the control. This difference was statistically not significant between control groups. This result similar to that of Akiyama and Anggawati (1998) who reported that red tilapia enhanced black tiger shrimp production in polyculture ponds stocked with tilapia at the density of 0.2/m^2 and 0.3/m^2, but increased FCR by 10%.

In the present study it was observed that silver pompano ADG was almost similar in all the treatments and there is no difference statistically between the groups. This finding is similar to that of Yuan et al., (2010) who reported that stocking size of tilapia or density did not affect daily weight gain which was similar at all tilapia stocking densities. The result in the present study showed that silver pompano is a very good candidate species for polyculture with shrimps and therefore this polyculture practices can be recommended.

In the polyculture system, water quality parameters deserve special attention as pointed by Muangkeow et al., (2007) and Troell et al., (2009) the secondary species, preferably a finfish is always found to help in maintaining the water quality in the polyculture ponds. The same was found true in the present study.

Lowest net biomass production of shrimp was observed in T_4 followed by T_3. But the shrimp production was not decreased in T_1 and T_2. This signifies the negative impact of high stocking density of silver pompano and shrimp growth. There is statistically significant difference between treatments. Yuan et al., (2010) also showed negative partial net returns due to addition of tilapia and pointed out that increased tilapia stocking density and size in these treatments negatively affected overall profitability mainly due to reduced shrimp production. This shows that low density of silver pompano (T_1) would not affect the shrimp growth and overall production of shrimps

There was good FCR observed in (T_3) followed by control group. But no significant difference was observed between treatment groups. This result agrees to that of Saelee (2002) who reported that the polyculture of shrimp and Nile tilapia in low salinity waters showed FCR that was almost equal to 2 and was higher than that in the monoculture (1.6). The better FCR in the study obtained might be due to the combination of fish and shrimp biomass taken together, which was believed to be due to be no feed given.

The ADG of silver pompano was almost same in all the treatment tanks. These findings are similar to that of Cruz *et al.,* (2008) who said that shrimp gets benefit from tilapia in two ways. At first, shrimp were fed on organic waste and second, because of bio-perturbation of sediments. Different studies showed that there is the positive effect of Nile tilapia on shrimp performance. This could be due to the addition of undigested food particles excreted by Nile tilapia that served as direct as food for the shrimp (Gonzales-Corre, 1988).

There was an increase in the biomass production in all treatment tanks compared to control group. That might be due to the secondary species (silver pompano) contributing the shrimp production. This finding is similar to that of

Akiyama and Anggawati (1998) who said that the polyculture of shrimp and tilapia had increased the production of shrimp, with tilapia production as a secondary benefit. Secondary animal always is beneficial in increasing the production.

When the best performed treatment in the indoor system was repeated in the outdoor system, the production parameters were found to be magnified. However, the percentage contribution of fish was found to be almost similar in both systems. This result was also similar to that of Baylon (1996) who said that polyculture of shrimp with milkfish resulted to significantly higher phytoplankton content compared to monoculture. This present study shows that the silver pompano might have fed on excess feed and shrimp excreta that would have led to better water quality in optimum condition.

Both indoor and outdoor system had the optimum level of water quality parameters were maintained throughout the study. This finding are similar to that of Muangkeow et al., (2007); Troell et al., (2009) who told that polyculture had the advantage of diminution of ecological impacts and maintenance of water quality which subsequently improved total biomass of shrimp. In the present study, mean water temperatures in tanks during indoor and outdoor ponds were optimum, which would have supported shrimp survival, growth and FCR. However, this finding was not in agreement with that of Yuan et al., (2010) who reported that mean water temperature in tanks were 24.6°C during the experimental period. This low water temperature might have had some negative effects on shrimp survival, growth and food conversion ratio (Wyban et al., 1995).

Tian *et al*. (2001a) suggested that most varieties of tilapia are omnivorous in feeding habit and also filter feeders, which are capable of improving water quality in ponds (Diana *et al*., 1991; Jingrong *et al*., 1993; Zhang *et al*., 1999).

Polyculture of shrimp with silver pompano in the present study was found to be an alternative approach for shrimp farming, which could ultimately lead to a more sustainable shrimp farming.

VI. SUMMARY AND CONCLUSION

Polyculture of aquatic species is mostly done in freshwater farming. However, its application in mariculture is also felt essential considering the need to effectively use different resources. Combination of shrimp and other marine fin-fishes gain attention because of the demand for marine fin fishes. There were some reports specifying the advantages of shrimp – fish polyculture in other countries. Therefore, an experiment was planned with polyculture of shrimp and silver pompano in both indoor and outdoor grow-out systems. Polyculture trials were conducted with *P. vannamei* and silver pompano (*T. blochii*) to assess its growth at different stocking densities in indoor and outdoor grow-out systems.

Pacific white shrimp Post Larvae (PL 8) were procured from Coastal Aquaculture Authority (CAA) Approved hatchery and silver pompano fry from RGCA, Pozhiyoor. Before starting the experiment, Pacific white shrimp Post Larvae and silver pompano fry were reared in raceway nursery system for a period of 20 days to acclimatize and make them fit for stocking in experiment condition. In raceway system, Pacific white shrimp and pompano were fed with commercial feed for two times a day. After 20 days uniform size shrimp juvenile and fish young ones were segregated and taken for the polyculture in cement tanks.

Indoor experiment was conducted for a period of 60 days in 15 cement tanks each with a capacity of 1.8m^3. The experiment set up comprised of triplicates of 4 sets of treatment tanks and 1 set of control tanks. Pacific white shrimps (ABW: 0.43± 0.047g) were stocked at a density of $60/m^2$ as per CAA recommendation in all four treatments and in one control tank. Silver pompano seeds (ABW: 2.17 ± 0.2083g) were stocked at four different stocking densities (T_1 - $3/m^2$, T_2 - $6/m^2$, T_3 - $9/m^2$ and T_4-$12m^2$) in treatment tanks. After the shrimp stocking, fishes were stocked in to the experiment tank. The control tank was having only shrimp. Feeding was done only to Pacific white shrimp two times (10.00 am & 2.00 pm) a day with commercial shrimp feed as per the feeding schedule of the feed company. Sampling was done once in 10 days and the bio-growth parameters were observed and recorded. Water quality parameters were recorded every day.

Highest weight gain and ADG for *P. vannamei* were observed in control tank (6.51 ± 0.0173 g) which is not statistically significant. The percentage weight gain, SGR and SR for *P. vannamei* were the highest for T_1 (1489.25 ±39.30%, 4.61 ± 0.042g and 97%, respectively). Highest weight gain, percentage of weight gain and SGR for silver pompano were observed in T_3 (4.96 ± 0.0751 g, 263.65 ± 13.389 g and 2.15 ± 0.061 g respectively) which are not statistically significant. The highest survival rate of silver pompano was observed in T_1(100%).

The highest net biomass production (877.45 ± 7.572 g) was recorded in T_1. In total production, the highest percentage of *P. vannamei* was obtained from T_1group (96.5%). Good FCR and FCE were observed in T_3 (1.16 ± 0.007 and 86.56 ± 0.49%, respectively). The results showed that silver pompano stocked at $3/m^2$ along with *P. vannamei* did not affect the growth and production of *P. vannamei,* instead it helped in enhancing total biomass production.

The outdoor experiment was carried out in two HDPE lined ponds of size 30m^3 (10 m x 3 m x 1m) and the best performed stocking density in indoor trial study was taken for outdoor grow-out trial based on the results from the first experiment (shrimp-60/m^2 and pompano-3/m^2) in order to validate the result obtained in the indoor experiment. This trial was also done for a period of 60 days. Bio-growth parameters and water quality parameters were analyzed every 10 days and daily, respectively.

In outdoor system, the total biomass production was 16560.37 ± 8.515 g. When compared to indoor and outdoor culture, there are similarities in FCR and FCE in both treatments. However, the survival and net biomass production/m^2 are much better in outdoor system than that of indoor polyculture system. Surprisingly, the percentage contribution of fish in the total net biomass production was almost same in both the cases. The outdoor system gave a shrimp production of 533.4 g/m^2 against the indoor system, which yielded only 374.57 g/m^2.

In this study the growth performance of Pacific white shrimp (*P. vannamei)* was not affected by silver pompano under different stocking densities such as 3/m^2, 6/m^2, 9/m^2 and 12/m^2 in indoor system. Among the treatments, silver pompano stocking density at 3/m^2 along with *P. vannamei* helped in enhancing total biomass production.

In the outdoor experiment it was found that the mean body weight of shrimp was higher than that of indoor culture. The FCR and FCE were found to be not affected.

VII REFERENCES

Aghuzbeni SH, Hajirezaee S, Matinfar A, Khara H, Ghobadi M., 2016. A preliminary study on polyculture of western white shrimp (*Litopenaeus vannamei*) with mullet (*Mugil cephalus*): an assessment of water quality, growth parameters, feed intake efficiency and survival. Journal of applied animal research, 1-5.

Ahlgren, M.O., 1998. Consumption and assimilation of salmon net pen fouling debris by the red sea cucumber *Parastichopus californicus*: implications for polyculture. *Journal of the World Aquaculture Society*, *29*(2), 133-139.

Akiyama, D.M. and Anggawati, A.M., 1998. Growing tilapia with shrimp increased shrimp production, tended to improve pond condition. *Aquaculture Asia*, *3*(2), 18-19.

Ali, M.Z., Hossain, M.A. and Mazid, M.A., 2005. Effect of mixed feeding schedules with varying dietary protein levels on the growth of sutchi catfish, *Pangasius hypophthalmus* (Sauvage) with silver carp, *Hypophthalmichthys molitrix* (Valenciennes) in ponds. *Aquaculture Research*, *36*(7), 627-634.

Anil, S.K., Gunalan, B., Jetani, K.L., Trivedi, G.K. and Soundarapandian, P., 2010. Determine the economic feasibility of the polyculture system (giant tiger shrimp and mullet). *African Journal of Basic and Applied Sciences*, *2*(3-4), 124-127.

APHA. 2005. Standard methods for the examination of water and wastewater. APHA, Washington DC.

Apún-Molina, J.P., Santamaría-Miranda, A., Luna-González, A., Ibarra-Gámez, J.C., Medina-Alcantar, V. and Racotta, I., 2015. Growth and metabolic responses of whiteleg shrimp *Litopenaeus vannamei* and Nile tilapia *Oreochromis niloticus* in polyculture fed with potential probiotic microorganisms on different schedules: Crecimiento y respuesta metabólica del camarón blanco Litopenaeus vannamei y tilapia del Nilo *Oreochromis niloticus* en policultivo alimentado con microorganismos probióticos potenciales en diferentes frecuencias. *Latin american journal of aquatic research*, *43*(3), 435-445.

Bailey-Brook, J.H., 1992. Penaeid taxonomy, biology and zoogeography. *Marine shrimp culture: principles and practices*, 9-23.

Balvanera, P., Pfisterer, A.B., Buchmann, N., He, J.S., Nakashizuka, T., Raffaelli, D. and Schmid, B., 2006. Quantifying the evidence for biodiversity effects on ecosystem functioning and services. *Ecology letters*, *9*(10), 1146-1156.

Baylon, C., 1996. Polyculture and crop rotation in brackish-water shrimp ponds: effect on soil and water quality. *Aquaculture Research and Sustainable Development in Inland and Coastal Regions in South-East Asia*, 160-167.

Bell, J.D., Agudo, N.N., Purcell, S.W., Blazer, P., Simutoga, M., Pham, D. and Della Patrona, L., 2007. Grow-out of sandfish *Holothuria scabra* in ponds shows that co-culture with shrimp *Litopenaeus stylirostris* is not viable. *Aquaculture*, *273*(4), 509-519.

Belton, B. and Little, D., 2008. The development of aquaculture in central Thailand: domestic demand versus export-led production. *Journal of Agrarian Change*, *8*(1), 123-143.

Booth, M.A., Tucker, B.J., Allan, G.L. and Fielder, D.S., 2008. Effect of feeding regime and fish size on weight gain, feed intake and gastric evacuation in juvenile Australian snapper *Pagrus auratus*. *Aquaculture*, *282*(1-4), 104-110.

Bosma, R.H. and Verdegem, M.C., 2011. Sustainable aquaculture in ponds: principles, practices and limits. *Livestock science*, *139*(1-2), 58-68.

Bray, W.A., Lawrence, A.L. and Leung-Trujillo, J.R., 1994. The effect of salinity on growth and survival of *Penaeus vannamei*, with observations on the interaction of IHHN virus and salinity. *Aquaculture*, *122*(2-3), 133-146.

Brick, R.W. and Stickney, R.R., 1979, March. Polyculture of Tilapia aurea and *Macrobrachium rosenbergii* in texas 1. In *Proceedings of the World Mariculture Society* (Vol. 10, No. 1-4, 222-228). Oxford, UK: Blackwell Publishing Ltd.

Briggs, M., Funge-Smith, S., Subasinghe, R., Phillips, M., 2004. Introductions and movement of *Penaeus vannamei* and *P. stylirostris* in Asia and Pacific. RAP public. 10, 1-92.

Bunting, S.W., 2008. Horizontally integrated aquaculture development: exploring consensus on constraints and opportunities with a stakeholder Delphi. *Aquaculture International*, *16*(2), 153-169.

Carneiro, P.C.F. and Mikos, J.D., 2005. Feeding frequency and growth of silver catfish, Rhamdia quelen, fingerlings. *Ciência Rural*, *35*(1), 187-191.

Chakraborty, C., 2000. *Biology Hatchery and Culture Technology of Tiger Prawn and Giant Freshwater Prawn*. Daya Books.

Chavez, H.M., Fang, A.L. and Carandang, A.A., 2011. Effect of stocking density on growth performance, survival and production of silver pompano, *Trachinotus blochii,*(Lacépède, 1801) in marine floating cages. *Asian Fisheries Science*, *24*(3), 321-330.

Chien, Y.H. and Liao, J.C., 1995. Integrated approch to shrimp growout system design. In *Proceedings of the special session on shrimp farming. World Aquaculture Society, Baton Rouge, LA* (167-179).

Cho, S.H., Lim, Y.S., Lee, J.H., Lee, J.K., Park, S. and Lee, S.M., 2003. Effects of feeding rate and feeding frequency on survival, growth, and body composition of Ayu post-larvae *Plecoglossus altivelis*. *Journal of the World Aquaculture Society*, *34*(1), 85-91.

Chong, V.C. and Sasekumar, A., 1981. Food and feeding habits of the white prawn *Penaeus merguiensis*. *Marine ecology progress series*, *5*(20), pp.185-191.

Costa, L.C.D.O., Xavier, J.A.A., Neves, L.F.D.M., Azambuja, A.M.V.D., Wasielesky Junior, W. and Figueiredo, M.R.C., 2013. Polyculture of *Litopenaeus vannamei* shrimp and *Mugil platanus* mullet in earthen ponds. *Revista Brasileira de Zootecnia*, *42*(9), 605-611.

Cruz, P.S., Andalecio, M.N., Bolivar, R.B. and Fitzsimmons, K., 2008. Tilapia–shrimp polyculture in Negros Island, Philippines: a review. *Journal of the World Aquaculture Society*, *39*(6), 713-725.

Dall, W., 1968. Food and feeding of some Australian penaeid shrimp. *FAO Fisheries Report*, *2*, 251-258.

Dall, W., Hill, B.J., Rothlisberg, P.C. and Staples, D.J., 1990. The Biology of the Penaeidae (Advances in Marine Biology, Vol. 27).

Diana, J.S., Dettweiler, D.J. and Lin, C.K., 1991. Effect of Nile tilapia (*Oreochromis niloticus*) on the ecosystem of aquaculture ponds, and its significance to the trophic cascade hypothesis. *Canadian Journal of Fisheries and Aquatic Sciences*, *48*(2), 183-190.

Douglass, J.G., Duffy, J.E. and Bruno, J.F., 2008. Herbivore and predator diversity interactively affect ecosystem properties in an experimental marine community. *Ecology letters, 11(6),* 598-608.

Dwyer, K.S., Brown, J.A., Parrish, C. and Lall, S.P., 2002. Feeding frequency affects food consumption, feeding pattern and growth of juvenile yellowtail flounder (*Limanda ferruginea*). *Aquaculture*, *213*(1-4), 279-292.

Eldani, A. and Primavera, J.H., 1981. Effect of different stocking combinations on growth, production and survival of milkfish (*Chanos chanos* Forskal) and prawn (*Penaeus monodon* Fabricius) in polyculture in brackishwater ponds. *Aquaculture*, *23*(1-4), 59-72.

FAO, F., 2014. Agriculture Organization, 2014. *Cereal Supply and Demand Brief-5 July 2012*.

Fitzsimmons, K., 2001. Polyculture of tilapia and penaeid shrimp. *Global Aquaculture Advocate*, *4*(3), 43-44.

Folkvord, A. and Otterå, H., 1993. Effects of initial size distribution, day length, and feeding frequency on growth, survival, and cannibalism in juvenile Atlantic cod (*Gadus morhua L.*). *Aquaculture*, *114*(3-4), 243-260.

Food And Agriculture Organization Of The United Nations., 2018. State Of World Fisheries And Aquaculture 2018 (SOFIA) Meeting the Sustainable Development Goals. Food & Agriculture Org.

Goddard S., 1996. Feed Management in Intensive Aquaculture, Chapman & Hall, New York, 194

Gomez, A. and Scelzo, M.A., 1982. Polyculture experiments of pompano *Trachinotus carolinus* (Carangidae) and spotted red shrimp *Penaeus brasiliensis* (Penaeidae) in concrete ponds, Margarita Island, Venezuela. *Journal of the World Mariculture Society*, *13*(1-4), 146-153.

Gonzales-Corre, K., 1988. Polyculture of the tiger shrimp (*Penaeus monodon*) with the Nile tilapia (*Oreochromis niloticus*) in brackish water fish ponds.

In *Proceedings of the second international symposium on Tilapia in Aquaculture, Manila, Philippines* (15-20).

Gopakumar, G., Nazar, A.A., Jayakumar, R., Tamilmani, G., Kalidas, C., Sakthivel, M., Ramesh Kumar, P., Rao, G., Premjoti, R., Balamurugan, V. and Ramkumar, B., 2012. Broodstock development through regulation of photoperiod and controlled breeding of silver pompano, *Trachinotus blochii* (Lacepede, 1801) in India. *Indian Journal of Fisheries*, *59*(1), 53-57.

Hao-Ren, L., 1982. Polycultural system of freshwater fish in China. *Canadian Journal of Fisheries and Aquatic Sciences*, *39*(1), 143-150.

Hepher, B. and Pruginin, Y., 1981. *Commercial fish farming*(No. 639.311/H483).

Hepher, B., Milstein, A., Leventer, H. and Teltsch, B., 1989. The effect of fish density and species combination on growth and utilization of natural food in ponds. *Aquaculture Research*, *20*(1), 59-71.

Hernández-Barraza, C., Loredo, J., Adame, J. and Fitzsimmons, K.M., 2012. Effect of Nile tilapia (*Oreochromis niloticus*) on the growth performance of Pacific white shrimp (*Litopenaeus vannamei*) in a sequential polyculture system. *Latin American Journal of Aquatic Research*, *40*(4).

Hooper, D.U., Chapin, F.S., Ewel, J.J., Hector, A., Inchausti, P., Lavorel, S., Lawton, J.H., Lodge, D.M., Loreau, M., Naeem, S. and Schmid, B., 2005. Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. *Ecological monographs*, *75*(1), 3-35.

Hossain, M.A. and Islam, M.S., 2006. Optimization of stocking density of freshwater prawn *Macrobrachium rosenbergii* (de Man) in carp polyculture in Bangladesh. *Aquaculture Research*, *37*(10), 994-1000.

Hossain, M.A., Ali, M.Z., Rahman, M.M. and Kader, M.A., 2006. Evaluation of mixed-feeding schedules with varying dietary protein content on the growth performance and reduction of cost of production for sutchi catfish, *Pangasius hypophthalmus* (Sauvage) with silver carp, *Hypophthalmichthys molitrix* (Valenciennes). *Journal of applied aquaculture*, *18*(1), 63-78.

Irz, X. and Mckenzie, V., 2003. Profitability and technical efficiency of aquaculture systems in pampaanga, philippines. *Aquaculture Economics & Management*, *7*(3-4), 195-211.

Jackson, A.R. and Ozbay, G.U.L.N.I.H.A.L., 2008. Ecological sustainability in shrimp culture. *World*.

Jang, I.K., Jun, J.C., Jo, G.J., Cho, Y.R., Seo, H.C., Kim, B.L. and Kim, J.S., 2007. Polyculture of fleshy shrimp *Fenneropenaeus chinensis* and white shrimp *Litopenaeus vannamei* with river puffer *Takifugu obscurus* in shrimp ponds. *Journal of Aquaculture*, *20*(4), 278-288.

Jaspe, C.J., Caipang, C.M. and Elle, B.J.G., 2011. Polyculture of white shrimp, *Litopenaeus vannamei* and milkfish, *Chanos chanos* as a strategy for efficient utilization of natural food production in ponds. *Animal Biology & Animal Husbandry*, *3*(2), 96 104.

Jatobá, A., do Nascimento Vieira, F., Buglione-Neto, C.C., Mourino, J.L.P., Silva, B.C., Seiftter, W.Q. and Andreatta, E.R., 2011. Diet supplemented with probiotic for Nile tilapia in polyculture system with marine shrimp. *Fish physiology and biochemistry*, *37*(4), 725-732.

Jhingran, V.G., 1982. Fish and Fisheries of India (revised and enlarged 2nd edition).

Jingrong, R., Kewen, R., Shaomei, W. and Quxia, L., 1993. Effect of Nile tilapia on plankton community and primary productivity of freshwater microcosms. *Chinese Journal of Applied Ecology*, *1*.

Jobling, M., 1994. Respiration and metabolism. *Fish bioenergetics*, *8*, 121-146.

Kalidas, C., Sakthivel, M., Tamilmani, G., Ramesh Kumar, P., Nazar, A.A., Jayakumar, R., Jothi, P. and Gopakumar, G., 2012. Survival and growth of juvenile silver pompano *Trachinotus blochii* (Lacepède, 1801) at different salinities in tropical conditions. *Indian Journal of Fisheries*, *59*(3), 95-98.

Kangmin, L., 1988. Rice-fish culture in China: A review. *Aquaculture*, *71*(3), 173-186.

Kim, K.D., Kang, Y.J., Kim, K.W. and Kim, K.M., 2007. Effects of feeding rate on growth and body composition of juvenile flounder, Paralichthys olivaceus. *Journal of the World Aquaculture Society*, *38*(1), 169-173.

Lanza Espino, G.D.L. and Andrade, L., 1991. *La acuicultura en palabras*. García Calderón, José Luis, coaut..

Lazo, J.P., Davis, D.A. and Arnold, C.R., 1998. The effects of dietary protein level on growth, feed efficiency and survival of juvenile Florida pompano (*Trachinotus carolinus*). *Aquaculture*, *169*(3-4), 225-232.

Li, D. and Dong, S., 2002. Summary of studies on closed-polyculture of penaeid shrimp with tilapia and molluscans. *Oceanologia et Limnologia Sinica*, *33*(1), 90-96.

Lilyestrom, C.G., Romaire, R.P. and Aharon, P., 1987. Diet and Food Assimilation by Channel Catfish and Malaysian Prawns in Polyculture as Determined by Stomach Content Analysis and Stable Carbon Isotope Ratios. *Journal of the World Aquaculture Society*, *18*(4), 278-288.

Lin, S.Y., 1969. The feeding habits of silver, bighead, and mud carp. Joint Commission on Rural Reconstruction. *Fish Ser*, *8*, 49-66.

Luong, T.C., Hochard, S., Royer, F., Lemonnier, H. and Letourneur, Y., 2014. Feasibility of polyculture of blue shrimp *Litopenaeus stylirostris* and goldlined rabbitfish *Siganus lineatus* in a mesocosm system. *Aquaculture*, *433*,340-347.

Marichamy, R. and Rajapackiam, S., 1982. The culture of milkfish, mullet and prawn in an experimental marine fish farm at Tuticorin.

Marine Products Export Development Authority, Annual report, 2018.

Martinez-Cordova, L.R. and Martinez-Porchas, M., 2006. Polyculture of Pacific white shrimp, *Litopenaeus vannamei*, giant oyster, *Crassostrea gigas* and black clam, *Chione fluctifraga* in ponds in Sonora, Mexico. *Aquaculture*, *258*(1-4), 321-326.

Martínez-Porchas, M., Martínez-Córdova, L.R., Porchas-Cornejo, M.A. and López-Elías, J.A., 2010. Shrimp polyculture: a potentially profitable, sustainable, but uncommon aquacultural practice. *Reviews in Aquaculture*, *2*(2), 73-85.

McKinnon, D.A., Trott, L.L., Alongi, D.D. and Davidson, A.A., 2002. Water column production and nutrient characteristics in mangrove creeks receiving prawn farm effluent. *Aquaculture Research-pages: 33: 55-73*.

McMaster, M.F., Kloth, T.C. and Coburn, J.F., 2003. Prospects for commercial pompano mariculture. *Aquaculture America 2003*.

Moriarty, D.J., 1997. The role of microorganisms in aquaculture ponds. *Aquaculture*, *151*(1-4), 333-349.

Muangkeow, B., Ikejima, K., Powtongsook, S. and 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*(1-4), 363-376.

Nagashima, Y., Sendo, A., Shimakura, K., Shiomi, K., Kobayashi, T., Kimura, B. and Fujii, T., 2001. Antibacterial factors in skin mucus of rabbitfishes. *Journal of fish biology*, *58*(6), 1761-1765.

Nazar, A.A., Jayakumar, R., Tamilmani, G., Sakthivel, M., Kalidas, C., Ramesh Kumar, P., Anbarasu, M., Sirajudeen, S., Balamurugan, V., Jayasingh, M. and Gopakumar, G., 2012. Larviculture and seed production of the silver pompano, *Trachinotus blochii* (Lacepede, 1801) for the first time in India. *Indian Journal of Fisheries*, *59*(3), 83-87.

Ochang, S.N., Fagbenro, O.A. and Adebayo, O.T., 2007. Influence of dietary palm oil on growth response, carcass composition, haematology and organoleptic properties of juvenile Nile tilapia, Oreochromis niloticus. *Pakistan Journal of Nutrition*, *6*(5), 424-429.

Paclibare JO, Usero RC, Somga JR, Visitacion RN. Integration of finfish in shrimp (*Penaeus monodon*) culture: an effective disease prevention strategy. In Disease Control in Fish and Shrimp Aquaculture in Southeast Asia-Diagnosis and Husbandry Techniques: Proceedings of the SEAFDEC-OIE Seminar-Workshop on Disease Control in Fish and Shrimp Aquaculture in Southeast Asia-Diagnosis and Husbandry Techniques, 4-6 December 2001, Iloilo City, Philippines 2002 (151-171). Aquaculture Department, Southeast Asian Fisheries Development Center.

Pakrasi, B.B., Basu, N.C. and BANERJI, R., 1975. Role of grey mullets in polyculture in coastal tanks of West Bengal. *Bull. Dept. Mar. Sci. Univ. Cochin*, *7*(1), 31-40.

Purcell, S.W., Patrois, J. and Fraisse, N., 2006. Experimental evaluation of co-culture of juvenile sea cucumbers, *Holothuria scabra* (Jaeger), with juvenile blue shrimp, *Litopenaeus stylirostris* (Stimpson). *Aquaculture research*, *37*(5), 515-522.

Ribeiro, F.D.A.S., Diógenes, A.F., Cacho, J.C.S., de Carvalho, T.L. and Fernandes, J.B.K., 2014. Polyculture of Freshwater Angelfish *Pterophyllum scalare* and Pacific white shrimp *Litopenaeus vannamei* in low-salinity water. *Aquaculture research*, *45*(4), 637-646.

Roberts, J.K. and Kuris, A.M., 1990. Predation and control of laboratory populations of the snail Biomphalaria glabrata by the freshwater prawn Macrobrachium rosenbergii. *Annals of Tropical Medicine & Parasitology*, *84*(4), 401-412.

Rodrigues, L.H.A. and Zimmermann, F., 1998. A decision support system for an organic farm. In *Proceedings of 7th International Conference on Computers in Agriculture, Orlando, FL, USA*.

Rosenberry, B., 2002. World shrimp farming 2001. Number 14, Published by Shrimp News International, San Diego, CA, USA. 316 pp.

Rosenberry, B., 2004. World shrimp farming 2003, number 16. Shrimp News International, San Diego, California, USA.

Rossberg, K.S. and Strawn, R.K., 1980, March. Comparative growth and survival of brown shrimp cultured with Florida pompano, black drum and striped mullet. In *Proceedings of the World Mariculture Society* (Vol. 11, No. 1-4, 219-225). Oxford, UK: Blackwell Publishing Ltd.

Rothlisberg, P.C., 1998. Aspects of penaeid biology and ecology of relevance to aquaculture: a review. *Aquaculture*, *164*(1-4), 49-65.

Ruan, J., K. Rong, S. Wang, and Q. Liu, 1992. Effect of Nile tilapia on plankton community and primary productivity of freshwater microcosms. *Chinese J. Appl. Ecol*. 4(1), 65–73

Ruohonen, K., Vielma, J. and Grove, D.J., 1998. Effects of feeding frequency on growth and food utilisation of rainbow trout (*Oncorhynchus mykiss*) fed low-fat herring or dry pellets. *Aquaculture*, *165*(1-2), 111-121.

Saelee, W., 2002. Shrimp-tilapia polyculture in low salinity water. *Unpublished M. Sc. Thesis, Asian Institute of Technology, Thailand*.

Samocha, T.M., Davis, A.D., Lawrence, A.L., Collins, C.R. and Van Wyk, P., 2001. Intensive and super-intensive production of the Pacific white *Litopenaeus vannamei* in greenhouse-enclosed raceway systems. Book of Abstracts. *Aquaculture*, *573*, 183.

Sayer, M.D. and Costello, M.J., 1996. Wrasse: biology and use in aquaculture.

Silva, S.D., Anderson, T.A. and Sargent, J.R., 1995. Fish nutrition in aquaculture. *Reviews in Fish Biology and Fisheries*, *5*(4), 472-473.

Smith, L.L., 1990. Feasibility of penaeid shrimp culture in inland saline ground-water-fed ponds. *Tex J Sci*, *42*, 3-12.

Tatum, W.M. and Trimble, W.C., 1978, March. Monoculture and polyculture pond studies with pompano (*Trachinotus carolinus*) and penaeid shrimp (*Penaeus aztecus*, *P. duorarum,* AND *P. setiferus*) in alabama, 1975–1977 1. In *Proceedings of the annual meeting-World Mariculture Society* (Vol. 9, No. 1-4, 431-446). Oxford, UK: Blackwell Publishing Ltd.

Tendencia, E.A., dela Peña, M.R. and Choresca Jr, C.H., 2006a. Presence of snapper, seabass, and siganid inhibits growth of luminous bacteria in a simulated shrimp culture system. *Aquaculture*, *260*(1-4), 54-60.

Tendencia, E.A., dela Peña, M.R. and Choresca Jr, C.H., 2006c. Effect of shrimp biomass and feeding on the anti-*Vibrio harveyi* activity of Tilapia sp. in a simulated shrimp–tilapia polyculture system. *Aquaculture*, *253*(1-4), 154-162.

Tendencia, E.A., dela Peña, M.R., Fermin, A.C., Lio-Po, G., Choresca Jr, C.H. and Inui, Y., 2004. Antibacterial activity of tilapia Tilapia hornorum against *Vibrio harveyi*. *Aquaculture*, *232*(1-4), 145-152.

Tendencia, E.A., Fermin, A.C., dela Peña, M.R. and Choresca Jr, C.H., 2006b. Effect of *Epinephelus coioides*, *Chanos chanos*, and GIFT tilapia in polyculture with *Penaeus monodon* on the growth of the luminous bacteria *Vibrio harveyi*. *Aquaculture*, *253*(1-4), 48-56.

Tian, X., Li, D., Dong, S., Liu, G., Qi, Z. and Lu, J., 2001. Water quality of closed polyculture of penaeid shrimp with tilapia and constricted tagelus. *Ying yong sheng tai xue bao= The journal of applied ecology*, *12*(2), 287-292.

Tian, X., Li, D., Dong, S., Yan, X., Qi, Z., Liu, G. and Lu, J., 2001. An experimental study on closed-polyculture of penaeid shrimp with tilapia and constricted tagelus. *Aquaculture*, *202*(1-2), 57-71.

Trimble, W.C., 1980, March. Production trials for monoculture and polyculture of white shrimp (*Penaeus vannamei*) or blue shrimp (*P. stylirostris*) with Florida pompano (*Trachinotus carolinus*) in Alabama, 1978–1979. In *Proceedings of the World Mariculture Society* (Vol. 11, No. 1-4, 44-59). Oxford, UK: Blackwell Publishing Ltd.

Troell, M., Joyce, A., Chopin, T., Neori, A., Buschmann, A.H. and Fang, J.G., 2009. Ecological engineering in aquaculture potential for integrated multi-trophic aquaculture (IMTA) in marine offshore systems. *Aquaculture*, *297*(1-4), 1-9.

Tucker, B.J., Booth, M.A., Allan, G.L., Booth, D. and Fielder, D.S., 2006. Effects of photoperiod and feeding frequency on performance of newly weaned Australian snapper *Pagrus auratus*. *Aquaculture*, *258*(1-4), 514-520.

Valenti, W.C. and New, M.B., 2000. Grow-out systems-monoculture. *Freshwater prawn culture: the farming of Macrobrachium rosenbergii*, 157-176.

Wang J., Li D., Dong S., Wang K. and Tian X. (1998) Experimental studies on polyculture in closed shrimp ponds: I. Intensive polyculture of Chinese shrimp (*Penaeus chinensis*) with tilapia hybrids. Aquaculture 163, 11–27

Wang, M. and Lu, M., 2016. Tilapia polyculture: a global review. *Aquaculture research*, *47*(8), 2363-2374.

Weirich, C.R., Wills, P.S., Baptiste, R.M., Woodward, P.N. and Riche, M.A., 2009. Production characteristics and body composition of Florida pompano reared to market size at two different densities in low-salinity recirculating aquaculture systems. *North American Journal of Aquaculture*, *71*(2), 165-173.

Wohlfarth, G.W., Hulata, G., Karplus, I. and Halevy, A., 1985. Polyculture of the freshwater prawn *Macrobrachium rosenbergii* in intensively manured ponds, and the effect of stocking rate of prawns and fish on their production characteristics. *Aquaculture*, *46*(2), 143-156.

Wyban, J. and Sweeney, J.N., 1991. *Intensive shrimp production technology: the Oceanic Institute shrimp manual*.

Wyban, J., 2002. White shrimp boom continues. *Global Aquaculture Advocate*, pp.18-19.

Wyban, J., Walsh, W.A., Godin, D.M., 1995. Temperature effect on growth, feeding rate and feed conversion of the pacific white shrimp (Penaeus vannamei). Aquaculture 138, 267–279

Yi, Y. and Fitzsimmons, K., 2004. Tilapia-shrimp polyculture in Thailand. *New dimensions in farmed tilapia. Proceedings of ISTA*, *6*, pp.777-790.

Yi, Y., Saelee, W., Naditrom, P. and Fitzsimmons, K., 2002. Stocking densities for tilapia-shrimp polyculture in Thailand. *Twentieth Annual Technical Report, Pond dynamics/Aquaculture Collaborative Research Support Program, Oregon State University, Corvallis, Oregon*.

Yokoyama, H., Higano, J., Adachi, K., Ishihi, Y., Yamada, Y. and Pichitkul, P., 2002. Evaluation of shrimp polyculture system in Thailand based on stable carbon and nitrogen isotope ratios. *Fisheries science*, *68*(4), 745-750.

Yuan, D., Yi, Y., Yakupitiyage, A., Fitzimmons, K. and Diana, J.S., 2010. 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. *Aquaculture*, *298*(3-4), 226-238.

Zhang, H., Li, D. and Wang, Y., 1999. The impacts of tilapia polyculture in shrimp ponds on the structure of plankton communities. *Journal of Fisheries Sciences*, *6*(4), 114-116.

Zhen-xiong, Q., De-shang, L., Man-ping, Z. and Shuang-lin, D., 2001. Comparative studies on nitrogen budgets of closed shrimp polyculture systems. *Chinese Journal of Oceanology and Limnology*, *19*(3), 233-242.

Zimmermann, S. and New, M.B., 2000. Grow-out systems polyculture and integrated culture. *Freshwater prawn culture: the farming of Macrobrachium rosenbergii*, 187-202.

Plate 1

Pic 1. Experiment animals of *P.vannamei* and *T.blochii*

Plate 2

Pic 2. Stocking of seeds in raceway unit for acclimatization

Plate 3

Pic 3 a. Experiment tanks used for polyculture of *P.vannamei* and silver pompano in Indoor system

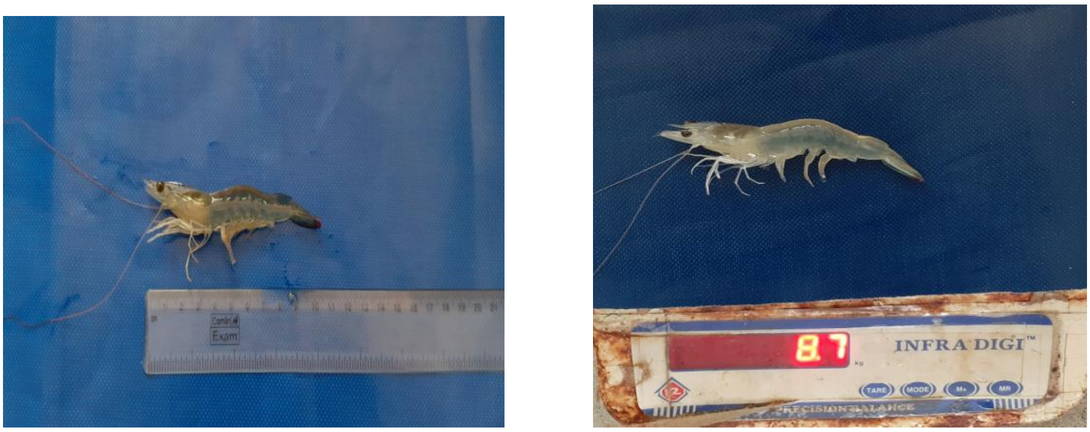
Pic 3 b. Experiment ponds used for polyculture of *P.vannamei* and silver pompano in outdoor system

Plate 4

Pic 4 a . Feeding the experiment animals

Pic 4 b. Harvesting of *P.vannamei* and silver pompano in indoor polyculture system

Plate 5



Pic 5 a. Sampling of *P.vannamei* during the experiment

Pic 5 b. Sampling of silver pompano during the experiment

Plate 6

Pic 6. Harvesting of *P.vannamei* and silver pompano in outdoor polyculture system