Fisheries Journal, 15 (1), 360-374 (2025)
http://doi.org/10.29303/jp.v15i1.1402

IMTA (INTEGRATED MULTI-TROPHIC AQUACULTURE) SYSTEM APPLICATION IN WINDU SHRIMP CULTIVATION PRODUCTIVITY (LITERATURE REVIEW)

Aplikasi Sistem IMTA (Integrated Multi-Trophic Aquaculture) dalam Produktivitas Budidaya Udang Windu (Telaah Pustaka)

Yuli Andriani[1*], Aulia Putri Kapsari Hafel[2], Annisa Nur Maharani[2], Melati Taufanputri[2], Ayi Yustiati[1]

[1]Department of Fisheries, Padjadjaran University, [2]Master of Fisheries Study Program, Padjadjaran University

Bandung Sumedang Highway KM.21, Hegarmanah, West Java

*Corresponding Author: aulia20020@mail.unpad.ac.id

(Received February 4th 2025; Accepted February 25th 2025)

ABSTRACT

The IMTA cultivation system is a cultivation system that combines several commodities with different trophic levels. In an effort to increase the productivity and sustainability of shrimp cultivation, the Pond-Water Integration (IMTA) system has emerged as a solution in the field of cultivation. Tiger shrimp cultivation using the IMTA system is a combination of two or three cultivation commodities, where nutritional/feed waste from higher level animals is consumed by lower level thropic animals. This research aims to determine the influence of the IMTA system on the growth of tiger prawns. The method used in this research is exploratory descriptive from various literature and research results that have been published, either from books, national journals or international journals. Based on a comparison of the results of previous research, it can be concluded that the IMTA system has a significant effect on the growth of tiger prawns, there are real differences in growth such as weight gain, relative growth rate, and survival rate of tiger prawns (*P. monodon*).

Key words: Cultivation, Growth, IMTA, Productivity, Tiger Prawns

ABSTRAK

Sistem budidaya IMTA merupakan sistem budidaya yang menggabungkan beberapa komoditas dengan tingkat trofik berbeda. Dalam upaya meningkatkan produktivitas dan keberlanjutan budidaya udang, sistem *Integrated Multi-Trophic Aquaculture* (IMTA) telah muncul sebagai solusi dalam bidang budidaya. Budidaya udang windu dengan sistem IMTA yaitu mengkombinasikan dua atau tiga komoditas budidaya, dimana limbah nutrisi/pakan dari hewan tingkat tinggi dikonsumsi oleh hewan tingkat rendah. Penelitian ini bertujuan untuk mengetahui bagaimana pengaruh sistem IMTA dalam pertumbuhan udang windu. Metode yang digunakan dalam penelitian ini yaitu deskriptif eksploratif dari berbagai literatur dan hasil-hasil penelitian yang telah dipublikasikan, baik dari buku, jurnal nasional ataupun jurnal internasional. Berdasarkan perbandingan dari hasil penelitian terdahulu dapat ditarik kesimpulan bahwa sistem IMTA berpengaruh nyata dalam pertumbuhan udang windu terdapat perbedaan nyata terhadap pertumbuhan seperti penambahan bobot, laju pertumbuhan relatif, dan tingkat kelulushidupan udang windu (*P. monodon*).

Kata Kunci: Budidaya, Pertumbuhan, IMTA, Produktivitas, Udang Windu

INTRODUCTION

The shrimp farming industry has become one of the most important sectors in global aquaculture, providing an essential source of animal protein for the human population worldwide. However, the growth of this industry is not without its growing challenges, including health, environmental, and economic issues. One approach that has emerged to improve the sustainability and efficiency of shrimp farming is through the implementation of an integrated farming system, or what is known as Integrated Multi-Trophic Aquaculture (IMTA). The IMTA concept involves combining the cultivation of several species of organisms simultaneously in one integrated farming system, by utilizing the natural interactions between these species. The IMTA system is an aquaculture practice that uses more than one species of biota that have an ecological mutualistic relationship in the same area or system at the same time (Rejeki *et al.,* 2016).

Tiger shrimp is one of the potential aquaculture commodities for Indonesia, because it has export opportunities so that it generates foreign exchange for the country. In addition, tiger shrimp is a local species, naturally there is a diversity of parent varieties that can be used as a source of germplasm. Indonesia was once the world's largest shrimp producer and exporter since the National Shrimp Program was launched in 1982 (Dahuri, 2013). Tiger shrimp (*Peinaeius monodon*) is one of the shrimp species that has the highest economic value in the shrimp farming industry compared to other shrimp commodities (Azizah *et al.,* 2018). Tiger shrimp (*Peinaeius monodon*) has profitable biological and economic attributes, including relatively fast growth, wide tolerance to salinity, and high market demand (Mustafa *et al.,* 2021). Therefore, this shrimp is still one of the target species to be cultivated by farmers in brackish water.

Research on the effect of IMTA system on tiger prawn growth has been an interesting subject for researchers and aquaculture practitioners. This approach promises the potential to improve the sustainability and efficiency of tiger prawn farming through optimizing resource utilization and reducing environmental impacts. However, although much research has been done in this area, there is still a need for a deeper understanding of how IMTA system specifically affects tiger prawn growth. Therefore, research that systematically examines the influence of the IMTA system on the growth of tiger prawns has significant value in supporting the balance of better cultivation techniques and to support the sustainability of the global shrimp farming industry.

This paper aims to explore and analyze in depth the influence of the IMTA system on the growth of tiger prawns. It is hoped that this paper can provide new insights and innovative solutions for stakeholders in the shrimp farming industry, and contribute to the balance of more sustainable and efficient cultivation practices.

RESEARCH METHODS

This article contains a literature review on the influence of the IMTA system on the growth of tiger prawns and was reviewed from March to May 2024. The method used in compiling this journal is the literature study method (systematic review), namely collecting data from various library sources, reading, recording, and managing research materials (Zeid, 2008). The data used in the journal comes from various literature and research both from national and international journals: Research Gate, Directory of Open Access Journals and Google Scholar. Keywords used to search for relevant discussion topics include IMTA, tiger prawns, productivity, cultivation, and growth. In this way, the theoretical framework can be arranged in accordance with the main material of the discussion.

RESULT

Several empirical studies support the benefits of the IMTA system on the productivity of tiger prawn cultivation. The IMTA system provides various benefits that can significantly increase the productivity of tiger prawn cultivation. With improved water quality, better nutrition, reduced feed costs, reduced disease, diversified production, and environmental sustainability, IMTA is a more efficient and environmentally friendly approach to shrimp cultivation. The implementation of IMTA can provide significant economic and environmental benefits, supporting long-term sustainability and profitability in the aquaculture industry. Some literature studies on the implementation of the IMTA concept and its influence on the productivity of tiger shrimp cultivation are shown in Table 1.

Table 1. Implementation of IMTA and Its Influence on the Productivity of Tiger Shrimp Cultivation

No	Combination of Biota in the System	Results and Impact
1	Milkfish and tiger prawns and mussels and rice	- Produces high survival in each biota. The survival of tiger prawns is around (88.9 ± 1.91%), milkfish is around (98.9 ± 1.90%) and green mussels (85.6 ± 1.90%) (Hamsiah *et al.,* 2021) - Produces NH_3 content, Rice significantly reduces 25.4% NH_3 in shrimp ponds (Li *et al.,* 2019). - Produces Specific Growth Rate (SGR) and Morphomeitric Characteristic Growth (PKM) of tiger prawns ($p < 0.05$) higher than monoculture, polyculture, and IMTA-non-rice systems (Alifia *et al.,* 2023)
2	Tiger prawns, seaweed	- The survival of tiger prawns reared with *Gracillaria* sp. seaweed is in the range of 56.67-78.75% with the growth of tiger prawns with an absolute weight of 1.67 grams; relative growth rate value of 36.36 (Azizah *et al.,* 2018) - Tiger shrimp integrated with seaweed *Sargassum polycistum* and *G. veirrucosa* produced survival rates of 84.7% and 88.7% respectively with a weight of 1.33-1.66 respectively (Izzati, 2011) - Produces stable water quality due to the use of seaweed with a nitrate content of 0.017 mg/L to 0.0803 mg/L, nitrite of 0.002-0.42 mg/L, and ammonia levels of 0.017-0.591 mg/L (Azizah *et al.,* 2018)
3	Tiger prawns, green mussels	- Produces relative growth of tiger shrimp as large as 28.89 ± 0.20% / day (Evania *et al.,* 2018). - The efficiency of nutrient absorption of green mussels as large as 62.1% N and is able to remove 13.5 mg N particles per day per individual (Srisunont & Babeil, 2016)

DISCUSSION

Characteristics and Biology of Tiger Prawns

Tiger prawns are known as black tiger, tiger shrimp, or tiger prawn. The term tiger appears because the pattern of its body is in the form of tiger-like stripes, but the color is bluish green. Tiger prawns in local languages are also called panceit shrimp, bago shrimp, lotong, liling shrimp, baratan shrimp, palaspas shrimp, teipus shrimp, and useirweidi shrimp (Purnamasari, 2008). Classification of tiger prawns according to Armanda (2009) as follows:

Kingdom : Animalia
Phylum : Arthropoda
Subphylum : Crustaceiaei
Order : Malacostraca
Suboorder : Deindrobranchiata
Family : Peinaeiidaei
Genus : Peinaeius
Species : Peinaeius monodon

Morphologically, the shrimp body consists of two parts, the head and chest (cephalothorax) and the abdomen. In the head to chest section there are other body parts in pairs. In order from the front to the back are the small antennae (anteinnula), the head fin (scophoceirit), the large antennae (anteinna), the jaws (mandibles), the jaw accessory organs (maxilla), and the walking legs (peireiiopoda). In the abdomen there are five pairs of pleiopods. The end of the 6th segment towards the back forms the tip of the tail (teilson). Below the base of the tip of the tail there is the anus. Male shrimp are usually larger, have a slender body, the lower abdominal chamber is narrow, while female shrimp are fat because their abdominal chamber is wider. The morphology of tiger shrimp (P. monodon) can be seen in Figure 1.

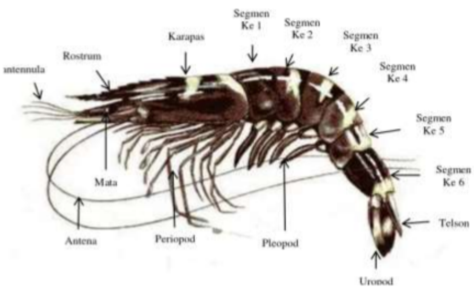

Figure 1. Morphology of tiger prawns Source: (Setiyo, 2020)

As a member of the crustacean group, the entire body of the shrimp is covered by a hard shell containing chitin except for the joints between segments, which allows the shrimp to move more flexibly (Suyanto & Takarina, 2009). Tiger shrimp have 19 pairs of appendages. Five pairs are found on the head, the first anteinula and the second anteinula function for smelling and balance. The mandible is for chewing, and the maxilla is for helping to eat and breathe. The last three pairs of appendages are part of the mouth (Murtidjo, 2007). Tiger prawns are classified as euryhaline animals, namely they can live in seas with high salt content to brackish waters with very good salt content or aquatic animals that can live in a range of salt content of 3-45% (optimal growth at a salinity of 15-30%). These animals are active at night, while during the day they prefer to immerse themselves in shaded places or mud (Murtidjo, 2007). Shrimp have nocturnal characteristics, meaning that shrimp actively move and look for food in dark or dim conditions (Suyanto & Takarina, 2009). In looking for food, shrimp rely more on chemical senses than visual senses. Tiger prawns have cannibalistic behavior at high stocking densities and inadequate feed intake (Siboro *et al.,* 2014).

Tiger prawns are known for their large size and high meat protein content compared to the protein content of *P. vannameii* (Narasimhan *et al.,* 2013). Tiger prawns have a savory taste and high nutritional content so that they are widely consumed by the community (Chodrijah & Faizah, 2018) and are a favorite for shrimp farmers in various parts of the world. From a biological perspective, tiger prawns are omnivorous, which means they eat various types of food including phytoplankton, zooplankton, and detritus. Meireika has a life cycle that includes egg, larva, postlarva, juvenile, and adult stages.

Water Quality of Tiger Prawn Cultivation

One of the factors that is thought to determine the success of shrimp cultivation production is water quality management, because shrimp are aquatic animals whose entire life, health and growth depend on the quality of water as their living medium. In line with the opinion of Dauda *et al.*(2019), that good water quality in a cultivation system is a key factor that correlates with the growth performance of organisms. Therefore, water quality management during the maintenance process needs to be considered. Tiger prawns like relatively clear waters and are not resistant to industrial or household or agricultural pollution (pesticides). The reason is, dirty living environment and muddy water bottom can inhibit the growth of tiger prawns. Other limiting factors for tiger prawn growth are temperature and dissolved oxygen.

Based on the research of Evania *et al.* (2018), measurements of several water quality parameters of the maintenance media were carried out as supporting data during the research. The water quality parameters measured include dissolved oxygen, temperature, pH, salinity, ammonia, nitrate and nitrite. Based on the observation results, the water quality data is still in a condition suitable for tiger prawn cultivation activities. Based on research conducted on tiger shrimp maintenance ponds at the post-larva stage (PL30), the dissolved oxygen (DO) content ranged from 4.32 ppm to 5.97 ppm. This value indicates that the oxygen content in the tiger shrimp maintenance media is still in a decent condition to support the growth of tiger shrimp. This is in accordance with the statement of Syukri (2016) that the concentration of dissolved oxygen during tiger shrimp post-larva maintenance ranges from 3-8 ppm. This value is still optimal and quite good in supporting the growth of post-larva shrimp.

The water temperature in the maintenance pond ranges from 27°C to 31°C. This value indicates that the water temperature is still within the normal range that can be tolerated by post-larvae of tiger prawns. Temperature is one of the abiotic factors that can affect the activity, oxygen consumption, metabolism rate, survival and growth of tiger prawns. This is in accordance with the statement of Syukri (2016), the range of good water temperature for the growth of post-larvae of tiger prawns is between 26°C - 32°C. According to Pratama *et al.* (2017), water temperature can affect survival, growth, reproduction, behavior, molting and metabolism.

The pH value of the water ranges from 7.7 to 8.7. The pH value of the water obtained is still considered good for post-larvae of tiger prawns. This is supported by the statement of Syukri (2016), the pH of the waters that are suitable for the growth of post-larvae of tiger prawns is between 6.5 and 9.0. The pH range is still suitable for post-larvae of tiger prawns breeding activities and supports the growth and survival of post-larvae of tiger prawns.

The salinity value obtained ranges from 29 ppt to 46 ppt. This value indicates that the salinity in the maintenance pond is suitable for the growth and survival of tiger prawns. This is reinforced by Arsad *et al.* (2017), that shrimp can survive at salinity that is not too high, which is between 10 - 30 ppt and shrimp can grow well at salinity of 5 - 45 ppt.

Evania *et al.* (2018), in his research conducted various treatments with different ammonia concentrations. The ammonia concentration in treatment A (green mussel stock density 0 units) ranged between 0.027 - 0.901 mg/L while in treatment B (green mussel stock density 30 units), treatment C (green mussel stock density 45 units), treatment D (green mussel stock density 60 units) and treatment E (green mussel stock density 75 units) ranged between 0.057 - 0.531 mg/L. Treatment A (green mussel stock density 0 units) showed the highest ammonia content in water compared to other treatments, but the concentration was still quite good for tiger shrimp. High ammonia content in the pond can be dangerous for tiger shrimp. Shrimp will experience stress and even death if the concentration of ammonia in the water is too high. Ammonia is formed due to the decomposition process of uneaten feed residue, shrimp feces and other organic materials in the water. This is in accordance with the statement of Hastuti (2011), ammonia is formed due to the decomposition process of organic compounds of feed residue that accumulates at the bottom of the pond. Uneaten feed residue, shrimp feces and other organic materials will undergo a breakdown into NH3 in the form of gas. Biologically, this process does not only stop here, in nature ammonia will undergo a decomposition into nitrate (NO3) a harmless form in the nitrification process. This can be strengthened by Komarawidjaja (2008) that high levels of ammonia in ponds can be influenced by pH, temperature and salinity.

The nitrite concentration obtained in treatment A (green mussel stocking density 0 units) ranged between 0.002 - 0.123 mg/L while in treatment B (green mussel stocking density 30 units), treatment C (green mussel stocking density 45 units), treatment D (green mussel stocking density 60 units) and treatment E (green mussel stocking density 75 units) ranged between 0.003 - 0.171 mg/L. The nitrite concentration between treatments did not differ much and was still considered good for tiger shrimp. This is because the nitrite concentration in waters is usually found in small amounts because nitrite is unstable. This can be strengthened by Kanwilyanti *et al.* (2013), that the good nitrite content for the growth of tiger shrimp is less than 0.8 mg/L.

Nitrate is not toxic to the life of tiger shrimp when compared to ammonia and nitrite. Nitrate is the main form of nitrogen compounds in water and is the main nutrient for the growth of aquatic plants and algae. Nitrate is the end result of the nitrification process so that nitrate concentration should increase. The nitrate concentration obtained in treatment A (green mussel distribution density 0 units) ranged between 1,036 - 2,172 mg/L while in treatment B (green mussel distribution density 30 units), treatment C (green mussel distribution density 45 units), treatment D (green mussel distribution density 60 units) and treatment E (green mussel distribution density 75 units) ranged between 0,553 - 2,479 mg/L. Treatments B, C, D and E showed higher nitrate levels compared to treatment A (green mussel distribution density 0 units). This is explained by Leistari (2012) that nitrate is very soluble in water and is stable which is produced from the perfect oxidation process of nitrogen compounds in water. Nitrate is the main nutrient for the growth of algae. The concentration of nitrate in waters is influenced by the nitrification process.

Amiein *et al.* (2021), has conducted research on a modern technology system which is considered better when compared to a modern technology system because the traditional technology system produces relatively beautiful pond productivity, which is around 25-70 kg/ha/cycle. This is more beautiful when compared to the tiger shrimp cultivation guidelines set by Keipmein KP No. 76 of 2016, which is 100-300 kg / ha / cycle. According to Djawad *et al.* (2019), traditional technology can be caused by continuous land use and poor cultivation management, especially due to high ammonia and H_2S water quality.

Tiger Prawn Cultivation

Tiger prawn (*Peinaeius monodon*) cultivation is one of the aquaculture sectors that has high economic potential, but requires the implementation of integrated technology and management to achieve success. The initial stage in this cultivation begins with the selection of a strategic location, such as a coastal area with access to clean water that has quality parameters according to the needs of the shrimp. The parameters measured are taken from the criteria of land suitability, namely soil lightness, tides, soil thickness, pyrite depth, clay content, soil pH, organic carbon content, water clarity, temperature, salinity level, water pH, annual rainfall, and the length of the dry season (Mustafa, 2012). According to the research of Efrizal *et al.* (2015), the coastal area of Deisa Tanjung, Sungai Limau District, Padang Pariaman Regency, West Sumatra, has great potential for balancing coastal cultivation, including tiger shrimp (*Peinaeius monodon*), with a potential area reaching 35 hectares and around 8.75 hectares that are suitable for use. This location is supported by mangrove vegetation that increases fertility through humus from mangrove leaf litter, as well as flat topography that allows high salinity during high tide.

Water quality management is one of the determining factors for the success of tiger shrimp cultivation. Based on research by Muliyadi *et al*. (2022), water quality management in ponds is very important in determining the health, growth, and survival rate of shrimp. This research shows that optimal water quality can be achieved through the application of biotechnology, such as inoculation of commercial decomposing bacteria into the maintenance media. In the study, the water quality parameters observed included dissolved oxygen (DO), temperature, salinity, and pH. The results showed that a dose of 20 ml/l multibacteria was effective in improving water quality and supporting the growth and survival of tiger shrimp. Good water quality is characterized by DO values between 5.13 - 5.25 mg/l, temperature 28.09 - 30.22°C, salinity 28.00 - 29.11 ppt, and pH 7.7. The study also noted that the optimal water temperature ranges from 20-30°C to support shrimp metabolic activity and increase oxygen consumption. Research by Supriatna *et al.* (2020), stated that good water quality conditions not only affect shrimp growth but also reduce the risk of disease. Poor water quality can cause stress and death in tiger shrimp. Therefore, water quality management must be carried out continuously by monitoring these parameters routinely to ensure that conditions remain within a safe range for shrimp.

Feeding is another aspect that is no less important because feed plays a direct role in supporting growth, health, and production efficiency. Feed provides essential nutrients, such as protein, lipids, carbohydrates, vitamins, and minerals, which are needed for the metabolism process, tissue growth, and shrimp immunity. According to Halveir (2002), tiger shrimp generally get optimum growth by providing feed containing 30-60% protein. Based on research by Hasbullah *et al.,* (2020), good feed for tiger shrimp (*Peinaeius monodon*) cultivation must meet the needs of essential nutrients such as protein, lipids, and essential fatty acids. In the study, the combination of marine worms (*Marphysa* sp.) and squid (*Loligo* sp.) feed with a proportion of 60% and 40% was proven to be more effective than the combination of feed including marine worms, squid, and oysters (*Crassostreia* sp.). The combination resulted in a higher average fecundity (382,248±6,971.50 eggs) and a better hatching rate (78.47%±1.93). Marine worms contribute to the maturity of shrimp gonads through the content of protein, fat, and steroid hormones that influence egg balance, while squid provides essential fatty acids such as DHA and EPA that support reproductive success. This study shows that a balanced feed formulation that suits the biological needs of shrimp is very important to increase productivity and cultivation success. Based on research by Ocktovian *et al*. (2024), the recommended frequency of feeding is 4 to 8 times a day. This study shows that feeding 8 times a day produces higher absolute growth and average daily growth compared to higher frequencies, namely 2, 4, or 6 times a day. The frequency of feeding 10% of the daily biomass weight is an ideal size so that shrimp do not experience a lack of feed or excess feed, even with the method of feeding four times a day allows shrimp not to fight in finding food so that it does not cause cannibalism which can reduce survival rates (Zainuddin *et al.,* 2017).

Routine maintenance including monitoring the health of tiger prawns (*Peinaeius monodon*), pest control, and biosecurity implementation is very important in tiger prawn cultivation, because these factors contribute directly to shrimp health and the quality of the pond environment, which ultimately affects shrimp productivity and survival. Diseases that generally infect shrimp are caused by viruses and bacteria. The bacteria that are often the cause of infection are Vibrio, which can trigger Vibriosis disease and often result in high mortality rates (Fleigeil, 2012; Ina-Salwany *et al*., 2019). Controlling the spread of this disease is very important to support the sustainability of cultivation, with one strategy that can be applied is biosecurities (Palić *et al.,* 2015). The application of biosecurities in the cultivation of tiger shrimp (*Peinaeius monodon*) is very important to minimize the risk of spreading diseases that can interfere with productivity. According to Ariadi *et al.* (2022), one of the important steps implemented is the installation of netting in the water inlet channel to prevent the entry of carrier animals such as crabs and wild fish that can carry diseases. In addition, workers are required to wash their feet with disinfectant solution before entering the pond area, as an effort to sterilize disease germs. The results of the implementation of biosecurity indicate that the cultivation environment becomes more sterile and water quality is maintained, which has a positive impact on increasing shrimp harvest productivity. This study confirms that strict biosecurity implementation not only protects shrimp health but can also be used as a reference for standard operating procedures in intensive shrimp cultivation. In the research of Leistatun *et al.* (2020), showed that the application of biosecurity consistently can control diseases in shrimp seeds. The application of biosecurity includes environmental sanitation, the use of netting to prevent carrier animals, washing workers' feet before entering the pond area, quarantine of new broodstock, handling of solid and liquid waste, personnel and vehicle regulations, water changes using treated reservoir water, the use of probiotics to reduce pathogenic bacteria, regulation of seed density, and routine fish health screening. The results of the analysis show that the application of biosecurity consistently can prevent the spread of bacterial diseases such as Vibriosis and AHPND. These steps not only improve shrimp health but also maintain the quality of the pond environment.

IMTA System in Tiger Prawn Cultivation

IMTA is a fish farming practice that involves mutualistic relationships between organisms at lower trophic levels, such as organisms that feed on dissolved suspensions in water (suspension feeders) at higher trophic levels, such as fish, so that waste nutrients from one species can become a source of nutrient input for other organisms (Reiid *et al.,* 2007; Troeill *et al.,* 2003). The effectiveness of IMTA has been proven in both freshwater and marine waters by combining various types of organisms (FAO, 2009).

The IMTA system cultivation is a cultivation approach carried out by integrating the cultivation of species that in their growth require additional feed (feed species), such as finfish, species that are able to extract inorganic materials such as seaweed, and species that are able to extract organic materials such as suspension feeding organisms (suspension and deposition of feed), so that it can minimize the negative effects of the aquaculture industry in its natural ecosystem. The IMTA application aims to reduce the release of aquaculture waste, and has advantages that may include reducing ecological impacts, increasing the diversification of aquaculture products, and increasing the social acceptance of the aquaculture system, so that the IMTA application contributes to the sustainability of aquaculture.

The IMTA system is a cultivation system that uses commodities with different trophic levels. The use of the IMTA system can help maintain the balance of the ecosystem because each species has different functions such as carnivores, heirbivores, and filter feeders so that the balance of the ecosystem can be maintained properly. The principle of the IMTA system is to recycle waste from the cultivation process produced by the main species into a source of energy and nutrients for other commodities so as to produce products that can be harvested and can reduce environmental impacts (Rein *et al.,* 2012). IMTA is implemented in order to reduce negative impacts on the environment, such as high organic matter, excessive redox values of water and soil, and high ammonia and nitrite in water. It is expected that with the presence of various organisms in one water column, it can have a positive impact on the environment, and furthermore can guarantee the sustainability of cultivation production.

One of the applications of the IMTA system is in tiger prawn cultivation. Tiger prawn cultivation with the IMTA system combines two or three cultivation commodities, where nutrient waste or feed from higher animals is consumed by lower animals. This integration combination can be done by combining fish or shrimp cultivation with seaweed and shellfish, where in addition to consuming nutrient waste from farmed fish feed, seaweed and shellfish can also absorb waste to increase growth rates (Chopin & Robinson, 2004). According to Yuniarsih *et al.* (2014), the commodities selected for IMTA are adjusted to their function in the ecosystem and are commodities with important economic value. If the selection of cultivation species is correct, then the IMTA system will reduce the organic and inorganic content of nitrogen and carbon in water and soil. In addition to the selection of cultivation species, another important thing that needs to be considered is the stocking density. The stocking density of tiger prawns (*Peinaeius monodon*) is an important factor in the IMTA system. Determining the optimal stocking density ensures a balance between shrimp production and the ability of other organisms in the IMTA system to absorb waste, thereby maintaining water quality and the health of the cultivation ecosystem. Hidayat *et al.* (2014), stated that the denser the microorganisms in the maintenance pond can cause competition in the movement space and getting oxygen so that the shrimp become stressed and even die. Another statement by Prihantoro *et al.* (2014), that the higher the density, the more competition in getting oxygen and movement space will be. This is reinforced by Purnamasari *et al.* (2017), the level of shrimp survival can decrease because high stocking density will increase shrimp competition in getting food, movement space, living space and oxygen. According to Deiwi *et al.* (2020), the appropriate stocking density for tiger prawns is 100 individuals/m3 to produce a balanced C/N ratio.

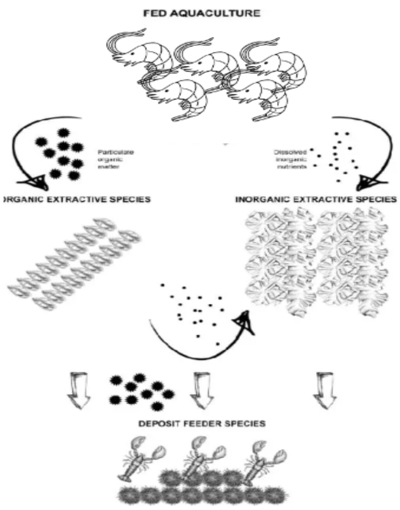

Figure 2. Representation of the IMTA system with feeding species and species extracting both organic and inorganic, as well as sediment-feeding species.
Source: Rosa *et al.,* (2020)

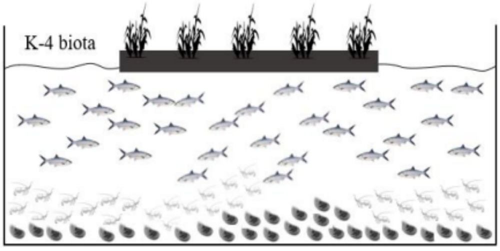

Figure 3. Illustration of the IMTA system in milkfish, tiger prawns and mussels.
Source: Hamsiah *et al.,* (2021)

Zhang *et al*. (2019) and Knowler *et al*. (2020), grouped four IMTA species based on their trophic levels, namely feed species (feed species, such as shrimp or fish), organic particle extractive species (suspension feeder and filter feeder species, such as mussels, sea cucumbers, sea urchins), and inorganic extractive species (seaweed and other plants). Increasing the number of species with different trophic levels can improve growth performance in each species (Campanati *et al.,* 2022; Neideirlof e*t al.,* 2021). In the study of Alifia *et al.* (2023), it was explained that the presence of species with various trophic levels was the most relevant reason for higher growth (LPS and PKM) of tiger shrimp in the IMTA-rice system. Four organisms with different and complete trophic levels are found in the IMTA-rice system that produces the highest growth of tiger prawns. In this system, tiger prawns and tilapia are the feieid species, bloodfish are utilized as the feieid suspension, sea cucumbers as the feieid deposit, and rice as the inorganic material absorber plant. The compatible synergy of these four species in utilizing nutrient waste seems to create a conducive environmental condition so that the physiological process of tiger prawns supports their growth.

IMTA System on Tiger Shrimp Cultivation Productivity

IMTA system has various positive effects on tiger shrimp cultivation productivity. Organisms such as macroalgae and bivalves in the IMTA system can absorb organic and inorganic waste from water, including nitrogen and phosphorus, produced by tiger shrimp. This helps maintain better water quality, reduces stress on shrimp, and improves their growth. With the presence of various trophic levels in the system, the ecosystem becomes more balanced and stable, which supports better living conditions for shrimp. Waste from shrimp that becomes a source of nutrients for other organisms (such as algae and bivalves) creates a more efficient nutrient cycle.

In addition, additional organisms involved in the IMTA system, such as plankton or organic detritus, can be an additional source of food for tiger shrimp. The provision of this additional natural food can enrich tiger shrimp and support better growth and contribute to survival. This is reinforced by the research of Hamsiah *et al.* (2021), that leftover feed, feces, and excretion results from the three cultivated aquatic animals, namely milkfish, tiger shrimp and mussels can trigger the growth of natural food in the form of plankton and klekap (Pantjara & Heindradjat, 2011). Tiger prawns feed on detritus and other small organisms (Aubin *et al.,* 2015) as well as food that sinks to the bottom of the waters. The availability of sufficient food for the biota in this study is also thought to contribute to survival.

The presence of organism variation in the IMTA system also reduces direct competition between tiger shrimp in competing for resources. Organism variation can also create a more stable environment, reducing environmental stress that can inhibit the growth of tiger shrimp. Additional organisms in the IMTA system, such as mussels or filter media molluscs, can help clean the water from organic particles and reduce the level of contamination. A cleaner and more stable environment can create better conditions for the growth of tiger shrimp. In accordance with the principle of IMTA, namely the utilization of organic waste utilized by biota in one container. The decomposition of organic waste can be utilized as a growth of phytoplankton which will later be utilized by green mussels as natural food (Astriana, 2015). Green mussels are able to survive and reproduce in high environmental pressure without feeding and have important roles as biofilters that can improve environmental quality (Eshmat *et al.,* 2014).

Previous studies have also confirmed that the integration of various species in the IMTA system allows for increased crop yields through optimization of resources and waste management (Chopin *et al.,* 2010). In addition, research by Troeill et al. (2009), shows that the IMTA system can improve economic stability and sustainability through production diversification. According to Neiori *et al.* (2007), the use of different species with complementary ecological functions supports sustainability and productivity in aquaculture systems.

In addition to the direct benefits to shrimp growth, the IMTA system can also provide opportunities for diversifying income by selling additional products such as seaweed or small fish that are farmed. However, as with all aquaculture systems, there are also potential challenges and risks that must be considered in implementing an IMTA system. These include potential competition for resources, disease risks, and attention to the ecological balance of the system. Therefore, careful planning, implementation, and management are essential to ensure that the IMTA system has a positive impact on shrimp growth and environmental sustainability.

CONCLUSION

The principle of the IMTA system is to recycle cultivation waste from the main species as a source of energy and nutrients for other commodities so that it can produce harvestable products and reduce environmental impacts. The IMTA system, as in tiger shrimp cultivation, utilizes organisms such as macroalgae and bivalves to absorb organic and inorganic waste, and filter materials such as keiran to clean the water. Although there are challenges such as resource competition, disease risks, and ecological balance, IMTA provides many benefits. Based on a comparison of several studies, it can be concluded that the IMTA system has a significant effect on the productivity of tiger shrimp cultivation. Research shows that tiger prawns in the IMTA-rice system have better morphometric characteristics and survival rates than other systems (Alifia *et al.,* 2023; Hamsiah *et al.,* 2021). In addition, the combination with green mussels showed a significant increase in the growth rate of tiger prawns (Evania *et al.,* 2018).

ACKNOWLEDGEMENTS

The author would like to thank all parties who have helped and supported the author so that he can complete this paper well. The author also would like to thank the supervisors, family, relatives, and friends who have helped the author during the writing process.

REFERENCES

Alifia, F., Heriansah, Arnold, K., Selvianita, & Reski, W. (2023). Performa Pertumbuhan Udang Windu (*Penaeus monodon*) Sistem Ko-Kultur Hewan Akuatik dan Padi di Air Payau. *Juvenil*, 4(4), 299-310. https://doi.org/10.21107/juvenil.v4i4.20844.

Amien, M., Widiatmaka, Kukuh, N., Setyo, P., & Wiwin, A. (2021). Analisis Kualitas Lingkungan dan Produktivitas Tambak Budidaya Udang Windu Sistem Teknologi Tradisional di Kabupaten Bulungan. *Indonesian Journal of Fisheries Science and Technology* 18(2), 93-104. https://doi.org/10.14710/ijfst.18.2.93-104.

Ariadi, H., Mardiana, T. Y., & Linayati, L. (2022). Aplikasi Penerapan Biosecurity Pada Kegiatan Budidaya Udang di PT. Manunggal Setia Makmur, Kabupaten Probolinggo.

Jurnal Komunitas : *Jurnal Pengabdian Kepada Masyarakat*, 4(2), 167–170. https://doi.org/10.31334/jks.v4i2.1852.

Armanda, F. (2009). Studi Pemanfaatan Buah Jeruk Nipis (*Citrus Aurantifolia Swingle*) Sebagai Chelator Logam Pb Dan Cd Dalam Udang Windu (*Penaeus Monodon*). Skripsi. Universitas Sumatera Utara, Medan.

Arsad, S., Atika, P., & Dhira, K. (2017). Studi Kegiatan Budidaya Pembesaran Udang Vaname (*Litopenaeus vannamei*) dengan Penerapan Sistem Pemeliharaan Berbeda*. Jurnal Ilmiah Perikanan dan Kelautan*. 9(1), 1- 14. https://doi.org/10.20473/jipk.v9i1.7624.

Astriana, B. H. (2015). Konseptual modul dinamika nitrogen dalam sistem Integrated Multi-Trophic Aquaculture (IMTA) menggunakan *Penaeus monodon*, *Crassostrea* sp. dan *Gracilaria* sp. *BioWallacea*, 1(3), 159–165.

Aubin, J., Baruthio, A., Mungkung, R., & Lazard, J. (2015). Environmental performance of brackish water polyculture system from a life cycle perspective: A Filipino case study. Aquaculture, 435, 217–227. https://doi.org/10.1016/j.aquaculture.2014.09.019.

Azizah, I., Sri, R., Restiana, W. (2018). Performa Pertumbuhan Udang Windu (*Penaeus monodon*) yang Dibudidayakan Bersama Rumput Laut (*Gracilaria* sp.) dengan Padat Tebar yang Berbeda Menerapkan Sistem Integrated Multi-Trophic Aquaculture (IMTA). *Jurnal Sains Akuakultur Tropis*. 2(2): 1-11. https://doi.org/10.14710/sat.v2i2.2725.

Campanati, C., Willer, D., Schubert, J., & Aldridge, D. C. (2022). Sustainable intensification of aquaculture through nutrient recycling and circular economies: More fish, less waste, blue growth. *Reviews in Fisheries Science and Aquaculture*, 30(2), 143–169. https://doi.org/10.1080/23308249.2021.1897520.

Chodrijah, U., & Faizah, R. (2018). Beberapa aspek biologi udang windu (*Penaeus Monodon)* (Fabricus, 1789) di Perairan Tarakan, Kalimantan Utara*. BAWAL Widya Riset Perikanan Tangkap*, 10(1),49. http://dx.doi.org/10.15578/bawal.10.1.2018.49-55.

Chopin, T., & Robinson, S. (2006). Rationale for developing integrated multi-trophic aquaculture (IMTA): an example from Canada. Fish Farmer, 20-21.

Chopin, T. (2010). Integrated multi-trophic aquaculture. 195-217.

Dahuri, R. (2013). Usaha pertambakan Udang Vannamei Prospektif BPEN. Jakarta.

Dauda, A. B., Ajadi, A., Tola-Fabunmi, A. S., & Akinwole, A. O. (2019). Waste production in aquaculture: Sources, components and managements in different culture systems. *Aquaculture and Fisheries*, 4(3), 81–88. https://doi.org/10.1016/j.aaf.2018.10.002.

Dewi, A., Sri, R., & Titik S.(2020). Pengaruh Kepadatan Udang Windu Yang Berbeda Pada Konsep IMTA Terhadap Rasio C/N Dalam Media Air Budidaya. *Jurnal Sains Akuakultur Tropis*, 4, 148-155. https://doi.org/10.14710/jphtcr.v%25vi%25i.6876.

Djawad, M. Iqbal., Bachrianto, Rosmala Dewi, Rahmat Y.P. (2019). Penelitian Peningkatan Produktivitas Produktivitas Udang Windu di Sulawesi Selatan. Badan Penelitian dan Pengembangan Daerah Pemerintah Provinsi Sulawesi Selatan.

Efrizal, Elfrida, & Ikhsan. (2015). Studi Ekologi Lokasi untuk Potensi Budidaya Pantai di Kawasan Pesisir Desa Tanjung Kecamatan Sungai Limau Kabupaten Padang Pariaman Sumatera Barat. Prosiding Semirata 2015 Bidang MIPA BKS-PTN Barat, Universitas Tanjungpura Pontianak, 145–153.

Eshmat., M. Ervany, G. Mahasri & B. S. Rahardja. (2014). Analisis Kandungan Logam Berat Timbal (Pb) dan Cadmium (Cd) pada Kerang Hijau (*Perna Viridis L.*) di Perairan Ngemboh Kabupaten Gresik Jawa Timur. *Jurnal Ilmiah Perikanan dan Kelautan*, 6(1), 101 – 108. https://doi.org/10.20473/jipk.v6i1.11387.

Evania, C., Sri, R., & Restiana, W. (2018). Performa Pertumbuhan Udang Windu (*Penaeus monodon*) yang Dibudidayakan Bersama Kerang Hijau (*Perna viridis*) dengan Sistem IMTA. *Jurnal Sains Akuakultur Tropis*, 2(2), 44-52.

https://doi.org/10.14710/sat.v2i2.2984.
FAO. (2009). The State of World Fisheries and Aquaculture 2008. FAO of the United Nations, Rome, xvi + 176 p.
Flegel TW. (2012). Historic emergence, impact and current status of shrimp pathogens in Asia. J. Invertebr. Pathol, 110,166–173.
Halver, J. E., & Ronald, W. H. (2002). Fish Nutrition (pp. 672–699). Academic Press.
Hamsiah, Indra, C., Heriansah, W., Wayan, K., & Arnold, K. (2021). Kelulushidupan Biota Pada Sistem Integrated Multi Trophic Aquaculture (IMTA) - padi. *Jurnal Sumberdaya Akuatik Indopasifik*, 5(2), 127–136. https://doi.org/10.46252/jsai-fpik-unipa.2021.Vol.5.No.2.119.
Hasbullah, D., Haruna, & Syarifuddin, L. (2020). Uji Perlakuan Komposisi Pakan yang Berbeda Terhadap Produktivitas Induk Udang Windu Strain Aceh di BPBAP Takalar. Dalam Seminar Ilmiah Nasional Fakultas Perikanan dan Ilmu Kelautan Universitas Muslim Indonesia (pp. 1–16). Universitas Muslim Indonesia.
Hastuti, Y.P. (2011). Nitrifikasi dan Denitrifikasi di Tambak. *Jurnal Akuakultur Indonesia*, 10(1) : 89 – 98. https://doi.org/10.19027/jai.10.89-98.
Hidayat, Riyan., A. Sudaryono & D. Harwanto. (2014). Pengaruh C/N Ratio Berbeda terhadap Efesiensi Pemanfaatan Pakan dan Pertumbuhan Udang Windu (*Penaeus monodon*) pada Media Bioflok. *Journal of Aquaculture Management and Technology*, 3(4) : 166 – 173.
Ina-Salwany, M. Y., Al-Saari, N., Mohamad, A., Mursidi, F. A., Mohd-Aris, A., Amal, M. N. A., Kasai, H., Mino, S., Sawabe, T., & Zamri-Saad, M. (2019). Vibriosis in Fish: A Review on Disease Development and Prevention. *Journal of Aquatic Animal Health*, 31(1), 3–22. https://doi.org/10.1002/aah.10045.
Izzati, M. (2011). The Role of Seawees Sargassum polycystum and Gracilaria verrucosa on Growth Performance and Biomass Production of Tiger Shrimp. *Journal of Coastal Development*, 14(3), 235–241.
Kanwilyanti, S., A. Suryanto & Supriharyono. (2013). Kelimpahan Larva Udang di Sekitar Perairan Pt. Kayu Lapis Indonesia, Kaliwungu, Kendal. *Diponegoro Journal Of Maquares Management Of Aquatic Resources*, 2(4) : 71 – 80. https://doi.org/10.14710/marj.v2i4.4270.
Knowler, D., Chopin, T., Martínez-Espiñeira, R., Neori, A., Nobre, A., Noce, A., & Reid, G. (2020). The Economics of Integrated Multi-Trophic Aquaculture: Where Are We Now and Where Do We Need To Go? Reviews in Aquaculture, 12(3), 1250–1268. https://doi.org/10.1111/raq.12399.
Komarawidjaja, W. (2008). Pengaruh Perbedaan Dosis Oksigen Terlarut (DO) pada Degradasi Amonium Kolam Kajian Budidaya Udang. *Jurnal Hidrosfir*, 1(1) : 32 – 37.
Lestantun, A., Anggoro, S., & Yulianto, B. (2020). The Role of Biosecurity to Control The Diseases of Vannamei Seed in Banten. Dalam Prosiding Seminar Nasional (pp. 53–58).
Lestari, F. (2012). Sebaran Nitrogen Anorganik Terlarut di Perairan Pesisir Kota Tanjung Pinang, Kepulauan Riau. *Jurnal Dinamika Maritim*, 5(2) : 88 – 96.
Li, F., Feng, J., Zhou, X., Xu, C., Haissam Jijakli, M., Zhang, W., & Fang, F. (2019). Impact of Ricefish/Shrimp Co-Culture on the N2O Emission and NH3 Volatilization in Intensive Aquaculture Ponds. *Science of the Total Environment*, 655, 284–292. https://doi.org/10.1016/j.scitotenv.2018.10.440.
Muliyadi, A., Supriyanto, E., & Ramadhan, A. (2022). Pengaruh Inokulasi Bakteri Pengurai terhadap Kualitas Air dan Pertumbuhan Udang Windu (*Penaeus monodon*) di Tambak. *Jurnal Perikanan dan Kelautan*, 13(2), 115-123.
Murtidjo, B. A. (2007). Benih Udang Windu Skala Kecil. Cetakan ke-5. Yogyakarta: Kanisius.
Mustafa, A. (2012). Kriteria Kesesuaian Lahan Untuk Berbagai Komoditas di Tambak. *Media*

Akuakultur, 7(2). http://dx.doi.org/10.15578/ma.7.2.2012.108-118.

Narasimhan, N., Maharajothi, P., Ravichelvan, R., Sukumaran, M., Ravichandran, R., & Rengarajan, R. (2013). Biochemical Studies on Protein Content in Different Tissues of Selected Shrimps *Penaeus monodon* and *Penaeus vannamei*. *International Journal of Pure and Applied Zoology*, 1(1), 92-96.

Nederlof, M. A. J., Verdegem, M. C. J., Smaal, A. C., & Jansen, H. M. (2021). Nutrient Retention Efficiencies in Integrated Multitrophic Aquaculture. *Reviews in Aquaculture*, 1–19. https://doi.org/10.1111/raq.12645.

Neori, A., & Nobre, A. M. (2012). Relationship between trophic level and economics in aquaculture. *Aquaculture Economics & Management*, 16(1), 40-67. http://dx.doi.org/10.1080/13657305.2012.649046.

Ocktovian, H., Nasmia, & Serdiati, N. (2024). Frekunsi Pemberian Pakan yang Berbeda terhadap Pertumbuhan dan Rasio Konversi Pakan Udang Vaname (*Litopenaeus vannamei*). *Juvenil*, 5(3), 324-335. https://doi.org/10.21107/juvenil.v5i3.27168.

Palić, D., Scarfe, A. D., & Walster, C. I. (2015). A Standardized Approach for Meeting National and International Aquaculture Biosecurity Requirements for Preventing, Controlling, and Eradicating Infectious Diseases. *Journal of Applied Aquaculture*, 27, 185–219. https://doi.org/10.1080/10454438.2015.1084164.

Pantjara, B., & Hendradjat, E. A. (2011). Produksi Bandeng Melalui Aplikasi Pupuk Organik. *Jurnal Riset Akuakultur*, 6(2), 253.

Pratama, A., Wardiyanto & Supono. (2017). Studi Performa Udang Vaname (*Litopenaeus vannamei*) yang Dipelihara dengan Sistem Semi Intensif pada Kondisi Air Tambak dengan Kelimpahan Plankton yang Berbeda pada Saat Penebaran. *Jurnal Rekayasa dan Teknologi Budidaya Perairan*. 6(1): 643-651.

Prihantoro, A.C., S. Wahyo, Y.T. Adiputra, R. Diantri & Wardiyanto. (2014). Pengaruh Padat Tebar terhadap Pertumbuhan dan Kualitas Udang Windu (*Penaeus monodon*) pada Sistem Nurseri. *Jurnal Ilmu Perikanan dan Sumberdaya Perairan*. 253 – 257.

Purnamasari, G. H. (2008). Analisis Permintaan Benur Udang Windu Di Kecamatan Pasekan, Kabupaten Indramayu, Jawa Barat.

Purnamasari, Indah., D. Purnama & M.A.F. Utami. (2017). Pertumbuhan Udang Vaname (*Litopenaeus vannamei*) di Tambak Intensif. *Jurnal Enggano*. 2(1) : 58 – 67. https://doi.org/10.31186/jenggano.2.1.58-67.

Reid, G., Robinson, S.M.C., Chopin, T., Mullen, J., Lander, T., Sawhney, M., MacDonald, B., Haya, K., Burridge, L., Page, F., Ridler, N., Boyne-Travis, S., Sewuster, J., Marvin, R., Szemerda, M. & Powell, F. (2007). Recent development and challenges for open-water, integrated multi-trophic aquaculture (IMTA) in the Bay of Fundy, Canada. In: Aquaculture Canada 2007. Proceedings of Contributed Papers. C. Couturier, E. Boucher & A. Vickerson (eds). Aquaculture Association of Canada Special Publication No. 13 (in press).

Rejeki, S., Ariyati, R. W., & Widowati, L. L. (2016). Application of integrated multi tropic aquaculture concept in an abraded brackish water pond. *Jurnal Teknologi*, 78(4–2), 227–232. https://doi.org/10.11113/jt.v78.8213.

Ren, J.S., Dozey, J.S., Plew, D.R., Fang, J., & Gall, M. (2012). An ecosystem model for optimising production in integrated multi-trophic aquaculture system. *Journal Eco-logical Modelling*, 246, 34-46. https://doi.org/10.1016/j.ecolmodel.2012.07.020.

Rosa, J., Lemos, M. F. L., Crespo, D., Nunes, M., Freitas, A., Ramos, F., Leston, S. (2020). Integrated multitrophic aquaculture systems – Potential risks for food safety. Trends in Food Science and Technology, 96 (July 2019), 79–90. https://doi.org/10.1016/j.tifs.2019.12.008.

Siboro, G. F., Melki, & Isnaini. (2014). Laju Pertumbuhan Udang Windu (*Penaeus Monodon*), Ikan Bandeng (*Chanos Chanos*), dan Rumput Laut (*Eucheuma Cottonii , Gracilaria* Sp) Pada Budidaya Polikultur Dengan Padat Tebar Yang Berbeda Di Desa Sungai Lumpur Kabupaten OKI Sumatera Selatan. 6(1): 46–55.

Srisunont, C., & Babel, S. (2016). Estimating the carrying capacity of green mussel cultivation by using net nutrient removal model. *Marine Pollution Bulletin*, 112(1– 2), 235–243. https://doi.org/10.1016/j.marpolbul.2016.08.012.

Supriatna, H., Setiawan, A., & Rachman, A. (2020). Analisis Kualitas Air dan Pertumbuhan Udang Windu (*Penaeus monodon*) di Tambak dengan Sistem Resirkulasi. *Jurnal Ilmu Perikanan*, 8(1), 45-52.

Suyanto, Rachmatun & E. P. Takarina. (2009). Panduan Budidaya Udang Windu. Penebar Swadaya : Jakarta.116 hal.

Syukri, M. (2016). Pengaruh Salinitas Terhadap Sintasan dan Pertumbuhan Larva Udang Windu (*Penaeus monodon*). *Jurnal Galung Tropika*. 5(2) : 86 – 96. https://doi.org/10.31850/jgt.v5i2.166.

Troell, M., Halling, C., Neori, A., Chopin, T., Buschmann, A.H., Kautsky, N. & Yarish, C. (2003). Integrated mariculture: asking the right questions. *Aquaculture*, 226: 69-90. https://doi.org/10.1016/S0044-8486(03)00469-1.

Troell, M., Joyce, A., Chopin, T., Neori, A., Buschmann, A. H., & 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. https://doi.org/10.1016/j.aquaculture.2009.09.010.

Yuniarsih, E., Nirmala, K., & Radiarta, I N. (2014). Tingkat penyerapan nitrogen dan fosfor pada budidaya rumput laut berbasis IMTA (integrated multi-trophic aquaculture) di Teluk Gerupuk, Lombok Tengah, Nusa Tenggara Barat. J. Ris. *Akuakultur*, 9(3), 487-501. http://dx.doi.org/10.15578/jra.9.3.2014.487-500.

Zainuddin, Z., Haryati, H., & Aslamyah, S. (2017). Pengaruh Berbagai Sumber Karbohidrat Pakan Terhadap Pertumbuhan dan Sintasan Juvenil Udang Vannamei *Litopenaeus vannamei*. *Agrokompleks*, 16(1), 7-11. https://doi.org/10.22146/jfs.9150.

Zed, M. (2008). Metode penelitian kepustakaan. Yayasan Obor.

Zhang, J., Zhang, S., Kitazawa, D., Zhou, J., Park, S., Gao, S., & Shen, Y. (2019). Biomitigation based on integrated multitrophic aquaculture in temperate coastal waters: Practice, assessment, and challenges. *In Latin American Journal of Aquatic Research* (Vol. 47, Issue 2). http://dx.doi.org/10.3856/vol47-issue2-fulltext-1.