Biodiversity and contribution of natural foods in tiger shrimp (*Penaeus monodon*) aquaculture pond system: A review

Muyassar H. Abualreesh

Department of Marine Biology, Faculty of Marine Sciences, King Abdualaziz University, Jeddah, Saudi Arabia. Corresponding author: M. H. Abualreesh, mabulreesh1@kau.edu.sa

Abstract. The aquaculture industry has been developing in many countries during the past decade due to its potential economic value. The methods of aquaculture vary from extensive to intensive rearing systems. Extensive and semi-intensive systems depend on natural processes, while intensive systems require additional inputs like feeding, management, and capital. Generally, in any kind of aquaculture system, the water, natural food availability, and bottom soil conditions often promote good productivity in ponds and, hence, a higher production. The quality of culture pond ecosystems also depends on the processes of natural biodiversity such as living macro and microorganism presence in the pond. The organisms (phytoplankton, zooplankton, benthos, bacteria, and fungi) are the most important natural organisms in the aquaculture pond ecosystems. Some of them have been well documented in the shrimp aquaculture industry as having a high protein content, vitamins, minerals, and other essential elements for the growth of cultured species. Some organisms like *Bacillus* and some soil fungi act as bio-remediators or decomposers. However, the significance of each item in the culture pond ecosystem has not yet been determined in the culture stage of aquaculture production. Therefore, considering the above, this paper provides an update on the associated natural organisms and their roles in aquaculture systems, and their contribution in production.
Key Words: benthos, diversity, natural organisms, plankton, production.

Introduction. Shrimp aquaculture has been established in numerous countries across the past decade, providing commercial and social benefits (Anand et al 2019). Among the cultured species of shrimp, tiger shrimp (*Penaeus monodon*) is a highly valuable species for coastal aquaculture in many countries, particularly in Asia. In these areas, tiger shrimp is chosen due to its availability, fast growth, resilient quality, and high value (Muangyao et al 2020). The most common tiger shrimp production practices are either extensive, semi-intensive or intensive cultures. The extensive and semi-intensive systems completely depend on natural productivity, the biodiversity available in the pond ecosystems, while intensive systems require auxiliary inputs and capital (Reis et al 2020).

Biological diversity or biodiversity such as aquatic macro and microphytes (phytoplankton), zooplankton, benthos and few beneficial bacteria or fungi are important natural organisms in aquaculture ponds (Pong-Masak & Pirzan 2006). They are rich in protein, vitamins, minerals, and others essential growth elements. In extensive ponds, cultured organisms like shrimp are completely dependent on natural foods, while additional feed is given in semi-intensive culture systems (Abu Hena & Hishamuddin 2012). There is not much information on natural food availability, such as biodiversity, and the role of natural organisms in the wellbeing of the tiger shrimp aquaculture ponds.

In recent years, the advancements in aquaculture support the progress of particular aspects of *P. monodon* aquaculture, but major challenges still persist. Some shrimp farmers note that aquaculture is more of an art rather than science. This may be due to the incomplete understanding of some aspects, like eco-biological factors of culture ponds, especially on natural food availability, food preference and microbes, along with sediments condition and water quality throughout the culture period (Boyd & Thunjai 2003; Abu Hena et al 2018). Therefore, to better understand the dynamic roles of cosmopolitan biodiversity and natural foods present in tiger shrimp aquaculture pond ecosystems, this review was carried out to understand the fundamental and practical aspects. This review should contribute positively towards improving natural biodiversity and knowledge for the production of tiger shrimp, and for the management of semi-intensive or extensive organic aquaculture ponds in host countries.

Roles of Plankton and Plants in *P. monodon* Aquaculture Ponds. All aquaculture candidates are smaller in size at the early stage of culture, and mostly depend on biological/natural diets, especially plankton (phytoplankton and zooplankton), even though ready diets are supplied. Many phytoplankton species are highly nutritious for aquaculture species, such as *Chaetoceros* sp., *Tetraselmis* sp., *Isochrysis* sp., *Skeletonema* sp., *Spirulina* sp. and *Chlorella* sp. (Thong 2017). These species are beneficial and important to shrimp health and nourishment during early life stages. Many phytoplankton species also generate omega-3 fatty acids that have multiple health benefits (Cui et al 2019). The diversity of phytoplankton that occupies the tiger shrimp aquaculture ponds includes Bacillariophyta, Chlorophyta, Cyanophyta, Cryptophyta, Ochrophyta and Pyrrophyta (Ara et al 2018). Hadi et al (2016) recorded 112 species, while Cremen et al (2007) found a total of 103 algal taxa in nine classes of phytoplankton from the tiger shrimp aquaculture ponds in the tropics (Figure 1).

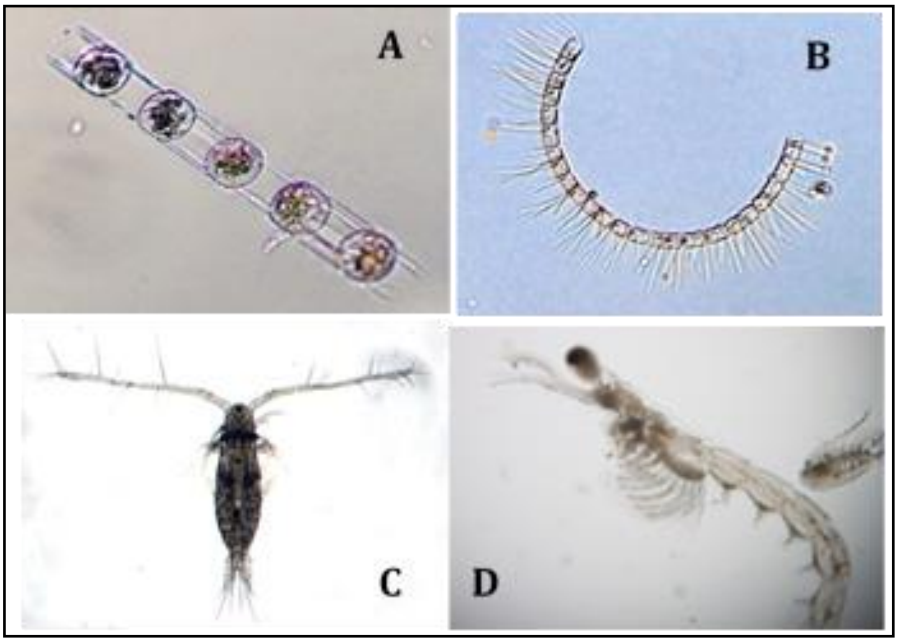

Figure 1. Some of the important phytoplankton (A) *Skeletonema* sp., (B) *Cheatocerous* sp. and zooplankton (C) *Acartia* sp., (D) *Lucifer* found in tiger shrimp (*Penaeus monodon*) aquaculture ponds (original images).

The major groups of zooplankton in tiger shrimp aquaculture ponds are copepods, rotifers, Sergestidae, *Lucifer* spp., gastropod larvae, bivalve larvae, pelagic polychaetes, nematodes, crustacean nauplii, insects and mysidacea (Ara et al 2018; Figure 1). Many cultured species are omnivores in the initial phases of their life history and eat what is available in the environment (Table 1). As a natural diet, phytoplankton and zooplankton serve an important role in the food chains of culture pond ecosystems by transferring energy from phytoplankton to the culture species. The inorganic and organic nutrients from shrimp metabolic wastes, uneaten feed and dead plankton undergoes microbial mineralization and are used by phytoplankton for growth and development. The phytoplankton further provides food for assemblages of pond zooplankton, which is limited by the presence of the shrimp population in the aquaculture ponds (Figure 2).

Table 1
Food habits of *Penaeus monodon* in ponds and in the wild in different development stages (source: Pascual 1988)

Life stages	*Food*	*Location*	*References*
Zoea to mysis	Phytoplankton	Philippines	Villaluz et al (1969)
Mysis to post larvae	Zooplankton Small crustaceans	Philippines	Villaluz et al (1969)
Post larvae	Small crabs, shrimps moluscs, polychaetes, ophiuroids, fish, debris, sand, silt, mixed plankton, benthic diatoms, small neck clam	Philippines Japan	Marte (1980) Hudinaga & Kittaka (1966)
Adults	Crustacean, annelids, algae, mud, unidentified matter, molluscs, crustaceans, fish remains	Sudan India Philippines	El Haq (1984) Thomas (1972) Marte (1982)

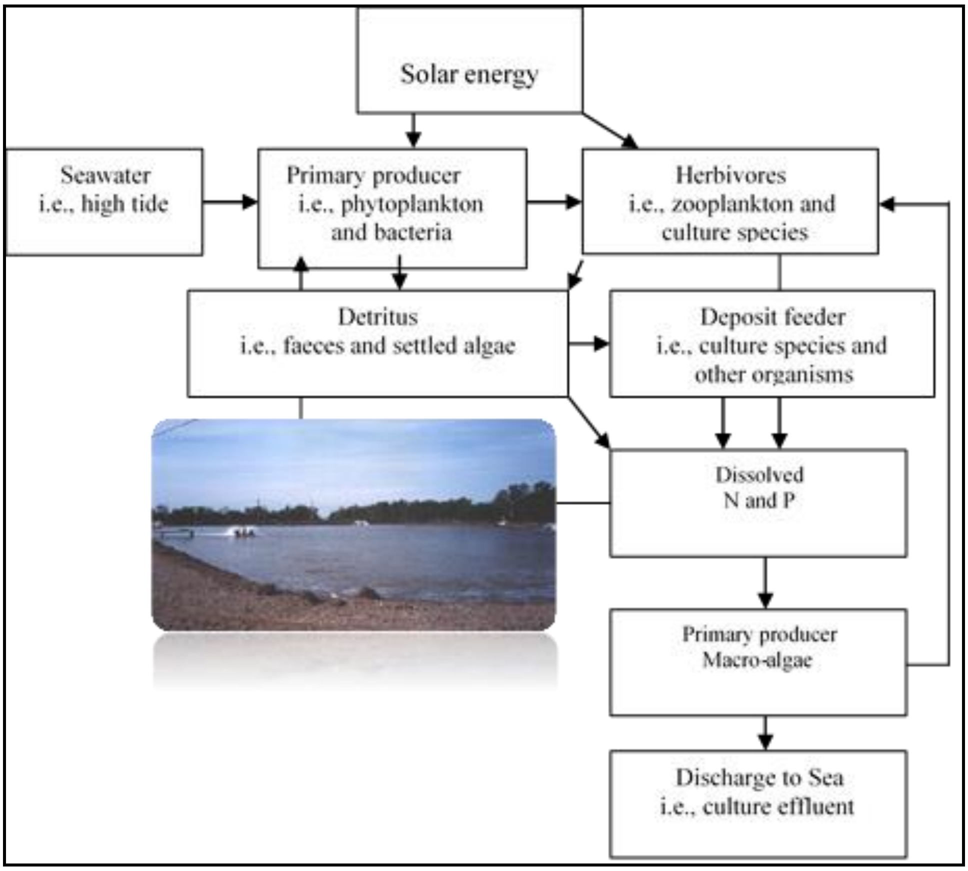

Figure 2. A speculated food web model in an extensive and semi-intensive tiger shrimp (*Penaeus monodon*) aquaculture pond ecosystem (modified from Hadi et al 2016; Thong 2017; Ara et al 2018).

In general, almost all shrimp farms are operated in earth ponds, which contain biota of nutritional values to shrimp (Sarkera et al 2021). Aquatic microphytes such as *Navicula* sp. and *Pleurosigma* sp. serve as food sources for shrimps (SEAFDEC 2000). Primavera & Gacutan (1989) stated that the aquatic macrophytes *Ruppia maritima* and *Najas* *graminea* are commonly found in extensive ponds and serve as food for shrimps. The shrimp assimilation efficiency for *R. maritima* (70-76%) is higher than for *N. graminea*. In another study, Bombeo-Tuburan et al (1993) found better shrimp survival and growth in ponds with *R. maritima* and plankton than in ponds with filamentous green algae.

At the initial stage of the culture period, tiger shrimp prefer to consume microphytes or/and small zooplankton together with detritus as a diet, and they change their food habit with growth, while density of zooplankton in the ponds increases at the last stage of the culture period (Figure 3). De Abreu et al (2019) stated that diatoms are a better natural food for shrimp than other algae. Diatoms have high levels of poly-unsaturated fatty acids, which are known to enhance shrimp growth. They are easily digested since their cell walls have a series of perforations through which enzymes can penetrate (SEAFDEC 2000). Apart from diatoms, the presence of zooplankton or animal remains produce high growth of shrimps. As a common group, copepods are a significant food resource in addition to diatoms. Studies by Rasdi & Qin (2016) discovered those zooplanktons are important food for penaeid shrimp, while they penetrate into the detrital food web in the culture pond. In addition, zooplankton has a high moisture content, and higher protein (50-75%) than other live foods like phytoplankton (30%) (NRC 1977). Previous studies on zooplankton in shrimp ponds have noticed that there are complex assemblages with rapid temporal changes in zooplankton structure (Preston et al 2003).

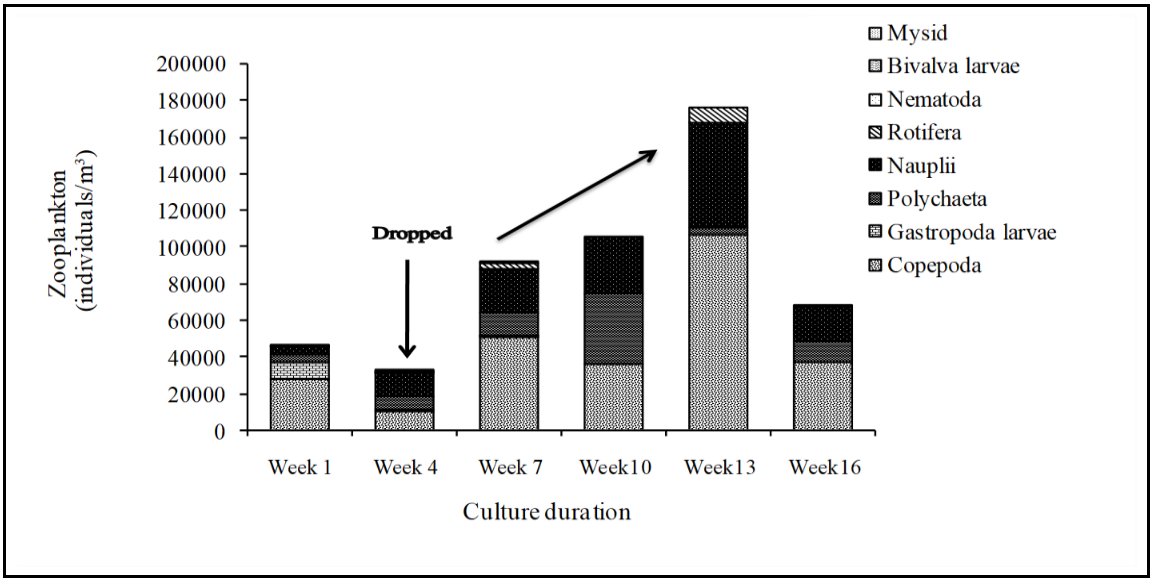

Figure 3. Population and fluctuation of zooplankton in *Penaeus monodon* aquaculture ponds (source: Abu Hena & Hishamuddin 2014).

The biota in shrimp aquaculture ponds is a significant source of nutrition and food value for the growth of shrimp (Ajiboye et al 2011). The feeding behavior of tiger shrimp changes throughout their life stages. Adult and juvenile shrimp stomach contains mostly detritus, algae (plant macrophytes and phytoplankton), meiobenthos and macrobenthos (Leh & Sasekumar 1984; Shishehchian & Yusoff 1999). In addition, penaeid shrimp can select its food depending on the locality and availability of food items and pray-predator size ratio (Figure 4). Panikkar (1952) observed that the food of young penaeids consisted of organic detritus, while Abu Hena & Hishamuddin (2012) noted that the food of *P. monodon* foregut contains crustaceans, polychaetes, molluscs, small fish and plant matters (Figure 4).

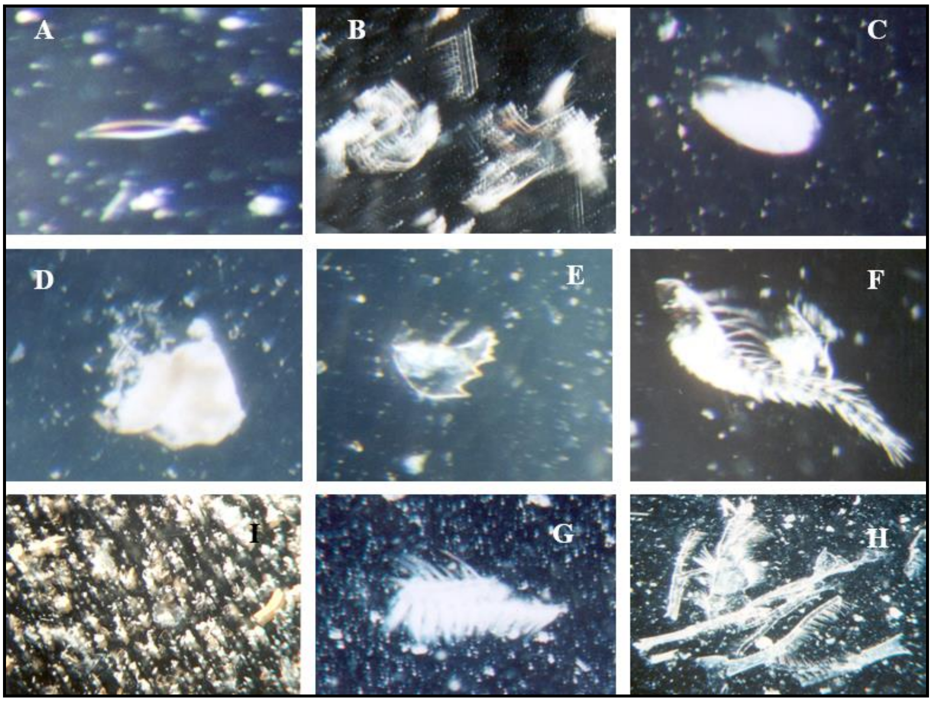

Figure 4. Body parts of natural food organisms found in the stomach of *Penaeus monodon* during the culture period: (A) phytoplankton (4th week; x32); (B) crustacean appendages (7th week; x8); (C) ostracodes (7th week; x16); (D) gastropod (10th week; x20); (E) crustacean mouth part (10th week; x16); (F) polychaetes (10th week; x20); (I) rotifer (13th week; x12); (G) polychaetes (16th week; x10); (H) mysid (crustacean) appendage (16th week; x10); source: Abu Hena & Hishamuddin (2012).

Benthos in *P. monodon* Aquaculture Ponds. Macro and meiobenthos grow naturally in aquaculture ponds. The major groups of macrobenthos are comprised of gastropods, polychaetes, bivalves, insects and crab larvae, while meiobenthos is usually represented by harpacticoid copepods, nematodes, gastropods, bivalves, insects and polychaetes (Figure 5). These communities perform an essential part in ponds, especially with regard to trophic linkage, food resources, shrimp health development, efficiency of pond and nutrient driving. They have a high content of proteins, fats, cellulose, lignin, starch, waxes and oils (Kungvankij et al 1986). The benthic faunal structures in the culture pond differ based on numerous issues like pond preparation, management and chemicals used. The benthic organisms are absent in poorly prepared ponds (Shariff et al 2001).

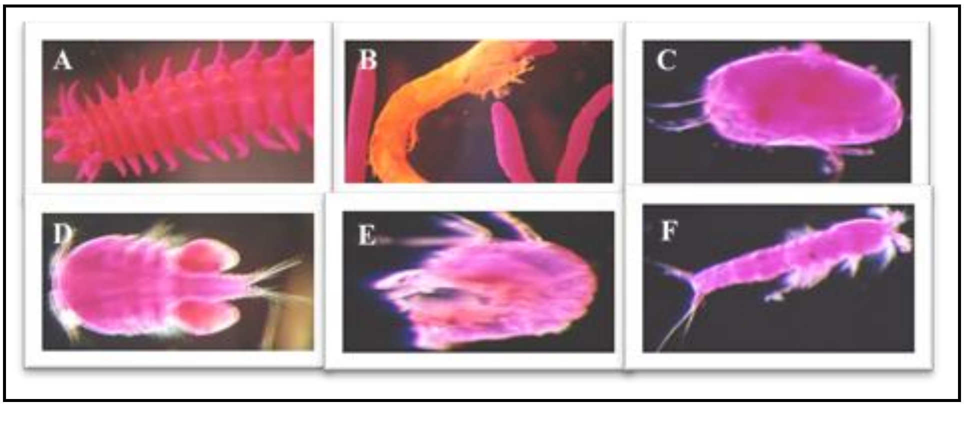

Figure 5. Some of the macrobenthos (A) *Namalycostis abiuma* (x8); (B) *Notomastus* sp. (x10); (C) *Cypridina* sp. (x25); and meiobenthos (D) *Tisbe* sp. (x25); (E) *Tegastes* sp. (x40); (F) *Euterpina* sp., found in *Penaeus monodon* aquaculture ponds (source: Abu Hena et al 2006).

Previous studies revealed that macro and meiobenthos are essential to many cultured species throughout their entire life stages. Warwick (1987) found that almost all juvenile stages of cultured species feed on benthic meiofauna when it is available. Studies by Abu Hena et al (2006) found that 64.72-91.87% of macrobenthos decreased in the total number of species sampled in ponds during the culture period (Figure 6). The depletion indicated that shrimp could have intensively preyed upon the consumable benthic fauna (<1 cm in length for gastropods). Shishehchian & Yusoff (1999) also observed a decrease of total benthic faunal density in ponds where shrimp are fed with additional foods and assumed that predation by shrimp is a potential cause for lessening benthic fauna. Tidwell et al (1995) observed that the total number of macrobenthos decreased in ponds by 67%, when fishmeal, vitamin and minerals were excluded from shrimp diets. It is likely that macrobenthos are suitable prey for juvenile and adult *P. monodon* when they are available in culture ponds. Likewise, many other macrobenthos that exist in the pond, including insects, polychaetes, bivalves and ostracods are known to be preyed-on by shrimp (Maguire et al 1984; Nunes & Parsons 2000).

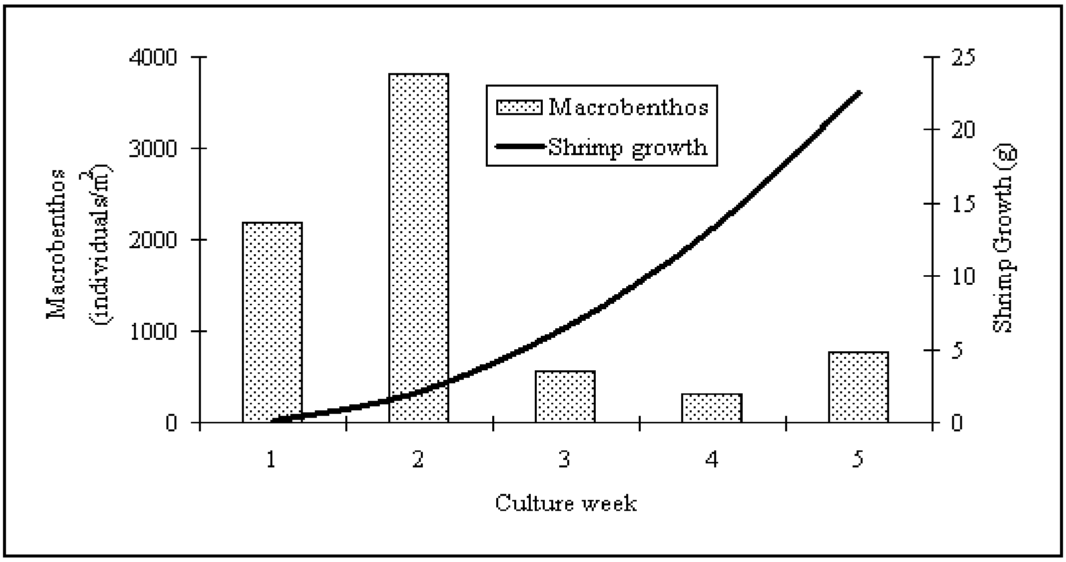

Figure 6. Relationship between total macrobenthos and *Penaeus monodon* growth in aquaculture ponds (sources: Abu Hena 2005; Abu Hena et al 2006).

It is well documented that in any aquatic ecosystem, almost all benthic faunas are comprised of deposit feeders, and their food consists of bacteria, fungi, micro algae, and organic detritus (Snelgrove et al 1997). There is a trophic relationship among these organisms in aquaculture pond ecosystems with cultured species. In aquatic ecosystems, bacteria are a major food source for protozoan (Finlay et al 1996), meiofauna (Alongi 1997) and macrofauna (Levinton 1995). On the other hand, macrofauna may prey on meiofauna, and meiofauna can prey on juvenile macrofauna (Bell & Coull 1980). The grazing of bacteria by protozoan, meiofauna and macrofauna can increase or decrease bacterial activity, and thus, re-mineralization of organic matter (Hargrave 1976). Moriarty et al (1987) documented that the abundance of benthic fauna in shrimp ponds influences the microorganism biomass, such as bacteria. A significant reduction of bacterial biomass occurs with the increase in benthic fauna, suggesting that the grazing of a larger benthic fauna stimulates bacterial growth.

Microbes and *P. monodon* Aquaculture Ponds. Like in other aquatic ecosystems, microorganisms in aquaculture ponds such as bacteria (Figure 7) and fungi (Figure 8) play an important role in decomposition and nutrient cycle (Moriarty 1986; Ismaun 2006). Generally, an aquatic habitat contains a great number of microorganisms in many different taxonomic and physiological groups (Langis et al 1988). Schroeder (1978) stated that microbial concentration and activity on the pond bottom are greater than in the water column, and the rate of degradation on pond bottom is higher than in the overlying water. However, the dynamics of bacterial populations in ponds depends on pond preparation, feeding materials, water quality and faeces of the cultured species.

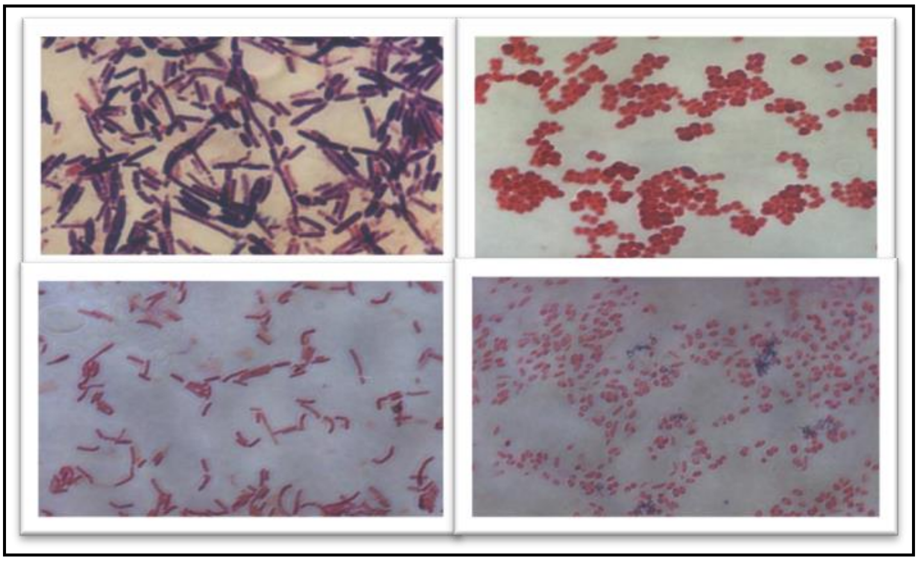

Figure 7. Bacteria from tiger shrimp (*Penaeus monodon*) aquaculture pond ecosystems; mainly gram-positive bacilli, cocci, gram-negative rod (original photo).

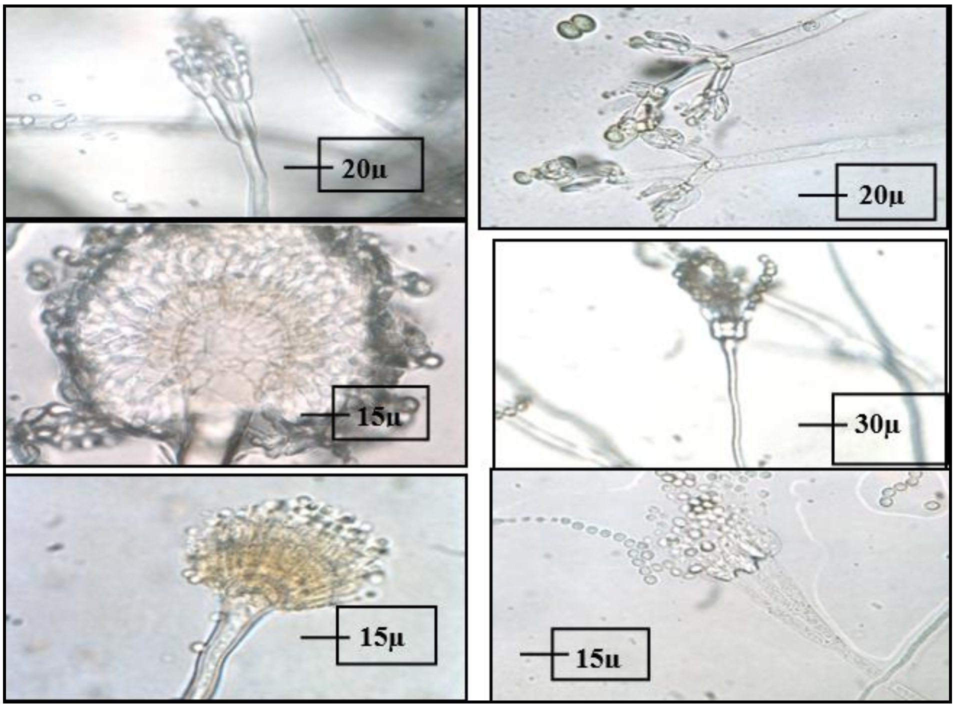

Figure 8. Fungi from tiger shrimp (*Penaeus monodon*) aquaculture pond sediments; mainly *Penicillium*, *Aspergillus* and *Trichoderma* (original photo).

The growth of microorganism is a key issue in the commercial production of tiger shrimp and other marine species. Moriarty (1997a) stated that microorganisms, mostly bacteria and fungi, utilize organic materials as nutrients to construct microbial assemblages. They provide a natural means of eliminating pollution and, thus, create a beneficial microbial environment, besides inhibiting the growth of harmful microbes (Keawchum 1994). These assemblages promote the survival rates of culture species like shrimp. In addition, heterotrophic microorganisms work as decomposers and mineralizers in culture ponds.

They consume oxygen and release CO_2 and ammonium, while oxidizing organic matter. Bacteria and fungi can also be found among the symbionts and parasites of culture species. Sometimes, they are pathogenic and responsible for disease outbreaks of culture organisms (SEAFDEC 1988). Fungi such as *Saprolegnia* sp., *Aphanomyces piscicida*, *Ichthyophonus hoferi* and *Fusarium solani* can be pathogenic, causing diseases to culture organisms (SEAFDEC 1988; Hatai 1998). Clifford & Cook (2002) stated that certain bacteria and fungi could also provoke white spots on the shrimp cuticle. They also suggested that mineral imbalances in the water could induce the formation of calcified white spots on the exoskeleton.

Shrimp is usually reared in ponds where microbial food webs are an integral part of the environment and have a direct influence on productivity (Moriarty 1986). Moriarty (1997b) stated that the health of culture species in aquaculture depends primarily upon their inherent resistance to microbial invasion and the biological equilibrium between competing beneficial and detrimental microorganisms. However, in culture ponds, the water quality and control of diseases are interdependent and linked to microbial activities. As an example, respiration is often predominantly due to heterotrophic decomposers, which need organic food. This microbial process affects water quality factors such as dissolved oxygen and toxic metabolites such as ammonia, nitrite and sulfide. Through the activity of the heterotrophic decomposers, nitrogen and phosphorus are recycled to stimulate primary production in the pond. The recent advances in microbial ecology enable the study of the community composition and activities of the microbes in shrimp culture pond ecosystems. The results of these studies are now being applied in aquaculture, for example beneficial bacterial strains such as bacterium or probiotics mixed with artificial feed (Uma 1999; Devaraja et al 2002). Fuller (1989) stated that probiotics or bacterium are living microbial feed supplements, which beneficially influence the host by improving intestinal balance.

Conclusions. Several factors have been identified to influence the well-being of aquaculture species, and the overall status of tiger shrimp ponds. Some of the factors investigated need further study to establish their significance; natural organisms or pond biodiversity is an important factor. The composition of biodiversity or natural food availability in aquaculture ponds represents an important source of nutrition for shrimp, at least during the early culture period, but needs more study to determine the standard level that should be present in a culture pond before stocking the culture species. Reduction of the pond biodiversity could occur due to intensive predation by different culture organisms. However, the exact contribution of benthic organisms to the growth of *P. monodon* is still unknown in aquaculture ponds. Therefore, future studies are needed to understand the presence of benthos in ponds and their contribution to the weight gain, protein, fatty acid and lipid contents intake throughout the culture period. The maintenance of natural foods is important in any culture system to achieve higher production with lower operational costs. Since aquaculture pond ecosystems are heavily loaded through excess nitrogenous products over culture periods, selected non-photogenic microbes are important to be tested for the utilization of high organic materials in ponds. Thus, these microbes can improve the culture pond environment and open new subjects of research in aquaculture.

Acknowledgements. This work was supported by the Department of Marine Biology, Faculty of Marine Sciences, King Abdualaziz University, KSA.

Data Availability Statement. No new data were produced or analyzed in this review. Most of the literature regarding the treated subject was sourced from scientific journals and databases, being interpreted and analyzed. However, the conclusions are created on the author's understanding of the available studies.

Conflict of Interest. The author declares that there is no conflict of interest.

References

Abu Hena M. K., 2005 Mariculture pond ecology with emphasis on environmental quality and production of *Penaeus monodon* (Fabricius). Dissertation, Universiti Putra Malaysia, Seri Kembangan, Selangor, Malaysia, 210 p.

Abu Hena M. K., Hishamuddin O., 2012 Food selection preference of different ages and sizes of black tiger shrimp, *Penaeus monodon* Fabricius, in tropical aquaculture ponds in Malaysia. African Journal of Biotechnology 11(22):6153-6159.

Abu Hena M. K., Hishamuddin O., 2014 Zooplankton community structure in the tiger shrimp (*Penaeus monodon*) culture pond at Malacca, Malaysia. International Journal of Agriculture & Biology 16(5):961-965.

Abu Hena M. K., Hishamuddin O., Boyd C. E., 2018 Physical and chemical characteristics of soil from tiger shrimp aquaculture pond at Malacca, Malaysia. Journal of Applied Aquaculture 30(1):47-62.

Abu Hena M. K., Hishamuddin O., Misri K., Abdullah F., Loo K. K., 2006 Benthic faunal composition of *Penaeus monodon* Fabricius culture pond in west coast of peninsular Malaysia. Journal of Biological Sciences 4(5):631-636.

Ajiboye O. O., Yakubu A. F., Adams T. E., Olaji E. D., Nwogu N. A., 2011 A review of the use of copepods in marine fish larviculture. Reviews in Fish Biology and Fisheries 21:225-246.

Alongi D. M., 1997 Coastal ecosystem processes. CRC Press, Boca Raton, 419 p.

Anand P. S. S., Balasubramanian C. P., Christina L., Kumar S., Biswas G., De D., Ghoshal T. K., Vijayan K. K., 2019 Substrate based black tiger shrimp, *Penaeus monodon* culture: Stocking density, aeration and their effect on growth performance, water quality and periphyton development. Aquaculture 507:411-418.

Ara S., Kamrujjaman M., Kabir K. A., Naser M. N., 2018 Nutrients impacts on the abundance of plankton in *Penaeus monodon* (Fabricius 1798) shrimp ponds at Dumuria, Bangladesh. Bangladesh Journal of Zoology 46(2):167-175.

Bell S. S., Coull B. C., 1980 Experimental evidence for a model of juvenile macrofauna-meiofauna interactions. In: Tenore K. R., Coull B. C. (eds), Marine Benthic Dynamics, University of South Carolina, USA, pp. 179-192.

Bombeo-Tuburan I., Guanzon N. G. Jr., Schroeder G. L., 1993 Production of *Penaeus monodon* (Fabricius) using four natural food types in an extensive system. Aquaculture 112(1):57-65.

Boyd C. E., Thunjai T., 2003 Concentrations of major ions in waters of inland shrimp farms in China, Ecuador, Thailand, and the United States. Journal of the World Aquaculture Society 34(4):524-532.

Clifford H. C., Cook H. L., 2002 Disease management in shrimp culture ponds. Aquaculture Magazine 28(4):18-26.

Cremen M. C. M., Martinez-Goss M. R., Corre Jr. V. L., Azanza R. V., 2007 Phytoplankton bloom in commercial shrimp ponds using green-water technology. Journal of Applied Phycology 19:615-624.

Cui Y., Thomas-Hall S. R., Schenk P. M., 2019 *Phaeodactylum tricornutum* microalgae as a rich source of omega-3 oil: Progress in lipid induction techniques towards industry adoption. Food Chemistry 297:124937.

de Abreu J. L., Brito L. O., de Lima P. C. M., da Silva S. M. B. C., Severi W., Gálvez A. O., 2019 Effects of addition of *Navicula* sp. (diatom) in different densities to postlarvae of shrimp *Litopenaeus vannamei* reared in a BFT system: Growth, survival, productivity and fatty acid profile. Aquaculture Research 50(8):2231-2239.

Devaraja T. N., Yusoff F. M., Shariff M., 2002 Changes in bacterial populations and shrimp production in ponds treated with commercial microbial products. Aquaculture 206(3-4):245-256.

El Hag E. A., 1984 Food and food selection of the Penaeid prawn *Penaeus monodon* (Fabricius). Hydrobiologia 110:213-217.

Finlay B. J., Corliss J. O., Esteban G., Fenchel T., 1996 Biodiversity at the microbial level: The number of free-living ciliates in the biosphere. The Quarterly Review of Biology 71(2):221-237.

Fuller R., 1989 Probiotics in man and animals. Journal of Applied Bacteriology 66(5):365-378.
Hadi N. A., Naqqiuddin M. A., Zulkifli S. Z., Abu Hena M. K., Hishamuddin O., Ismail A., 2016 Phytoplankton diversity in tiger shrimp pond in Merlimau, Malacca. Seminar Ekologi Malaysia, pp. 223-226.
Hargrave B. T., 1976 The central role of invertebrate faeces in sediment decomposition. In: The roles of terrestrial and aquatic organisms in decomposition processes. Anderson J. M., Mafayden A. (eds), 17th Symposium British Ecological Society, Blackwell, Oxford, pp. 301-321.
Hatai K., 1998 Diseases caused by aquatic fungi. Proceeding of the Asia-Pacific Mycological Conference on Biodiversity and Biotechnology, Hua Hin, 6-9 July 1998, Thailand, 28 p.
Hudinaga M., Kittaka J., 1966 Local and seasonal influences on the large-scale production method for penaeid shrimp larvae. Bulletin of the Japanese Society of Scientific Fisheries 41(8):843-854.
Ismaun H., 2006 Aerobic bacteria abundance and mineral element status in aged and new culture ponds of tiger shrimp (*Penaeus monodon*). Dissertation, Universiti Putra Malaysia, Seri Kembangan, Selangor, Malaysia, 135 p.
Keawchum S., 1994 Impacts of substrate and commercial bacteria on the growth performance of shrimp (*P. monodon)* in intensive closed and open culture systems. MSc thesis proposal, Asian Institute of Technology, Bangkok, 92 p.
Kungvankij B. J., Pudadera J. R., Tirio J. R., Potesta I. O., Chua T. E., 1986 An improved traditional shrimp culture technique for increasing pond yield. NACA, RLCP, FAO, SEAFDEC.
Langis R., Proulx D., de la Noue J., Couture P., 1988 Effects of a bacterial biofilm on intensive *Daphnia* culture. Aquaculture Engineering 7(1):21-38.
Leh C. M. U., Sasekumar A., 1984 Feeding ecology of prawns in shallow waters adjoining shores. Proceedings of Asian Symposium of Mangrove Environment Research and Management, University Malaya, pp. 331-353.
Levinton J., 1995 Bioturbators as ecosystem engineers: a control of the sediment fabric, inter-individual interactions and material fluxes. In: Linking species and ecosystems. Jones C. G., Lawton J. H. (eds), Chapman and Hall, New York, pp. 29-36.
Maguire G. B., Gibbs P. J., Collett L. C., 1984 The macrobenthic fauna in brackish water prawn farming ponds at Port Stephens, New South Wales. Australian Zoology 21(5):445-458.
Marte C. L., 1980 The food and feeding habit of *Penaeus monodon* Fabricius collected from Makato River, Aklan, Philippines (Decapoda Natantia). Crustaceana 38(3):225-236.
Marte C. L., 1982 Seasonal variation in food and feeding of *Penaeus monodon* Fabricius (Decapoda, Natantia). Crustaceana 42(3):250-255.
Moriarty D. J. W., 1986 Bacterial productivity in ponds used for culture of penaeid prawns. Microbial Ecology 12(3):259-269.
Moriarty D. J. W., 1997a The role of microorganisms in aquaculture ponds. Aquaculture 151: 333-349.
Moriarty D. J. W., 1997b Methodology for determining biomass and productivity of microorganisms in detrital food webs. In: Moriarty D. J. W., Pullin R. S. V. (eds) Detritus and Microbial Ecology in Aquaculture. ICLARM Conference Proceedings 14, pp. 4-31.
Moriarty D. J. W., Cook H. L., Hassan R., Thanabal M., 1987 Primary production and meiofauna in some penaeid prawn aquaculture ponds at Gelang Patah. Malaysian Agriculture Journal 54:37-51.
Muangyao P., Fukami K., Songsangjinda P., Predalumpaburt Y., 2020 Stimulation by gutweed to increase the abundance of insect larvae as food for shrimp aquaculture in Thailand. Aquaculture 519:734740.
NRC (National Research Council), 1977 Nutrient Requirements of warm water fishes. National Academy of Sciences, Washington D. C., 78 p.

Nunes A. J. P., Parsons G. J., 2000 Effects of the Southern brown shrimp, *Penaeus subtilis*, predation and artificial feeding on the population dynamics of benthic polychaetes in tropical pond enclosures. Aquaculture 183(1-2):125-147.

Panikkar N. K., 1952 Possibilities of future expansion of fish and prawn cultural practices in India. Current Science 21(2):29-33.

Pascual F. P., 1988 Status of shrimp nutrition and development in Southeast Asia. Nutrition Workshop, Sponsored by IDRC, June 6-11, 1988, Bangkok, Thailand.

Pong-Masak P. R., Pirzan A. M., 2006 Macrozoobenthos community at the pond culture area in Malakosa coastal, Parigi Moutong, Central of Sulawesi. Biodiversitas 7(4):354-360.

Preston N. P., Coman F. E., Fry V. M., 2003 Shrimp pond zooplankton dynamics and the efficiency of sampling effort. Aquaculture Research 34(5):374-381.

Primavera J. H., Gacutan R. Q., 1989 Preliminary results of feeding aquatic macrophytes to *Penaeus monodon* juveniles. Aquaculture 80(1-2):189-193.

Rasdi N. W., Qin J. G., 2016 Improvement of copepod nutritional quality as live food for aquaculture: A review. Aquaculture Research 47(1):1-20.

Reis J., Novriadi R., Swanepoel A., Jingping G., Rhodes M., Davis D. A., 2020 Optimizing feed automation: improving timer-feeders and on demand systems in semi-intensive pond culture of shrimp *Litopenaeus vannamei*. Aquaculture 519:734759.

Sarker M. M., Hossain M. B., Islam M. M., Abu Hena M. K., Idris M. H., 2021 Unraveling the diversity and assemblage of phytoplankton in homestead ponds of central coastal belt, Bangladesh. Aquaculture Research 52:167-184.

Schroeder G. L., 1978 Autotrophic and heterotrophic production of micro-organisms in intensely-manured fish ponds, and related fish yields. Aquaculture 14(4):303-325.

SEAFDEC, 1988 Diseases of prawns in the Philippines. SEAFDEC Asian Aquaculture 10(1):1-7.

SEAFDEC, 2000 Environmental friendly shrimp farming. SEAFDEC Asian Aquaculture 22(3):6-8.

Shariff M., Yusoff F. M., Devaraja T. N., Srinivasa Rao P. S., 2001 The effectiveness of a commercial microbial product in poorly prepared tiger shrimp, *Penaeus monodon* (Fabricius), ponds. Aquaculture Research 32(3):181-187.

Shishehchian F., Yusoff F. M., 1999 Composition and abundance of macrobenthos in intensive tropical marine shrimp culture ponds. Journal of the World Aquaculture Society 30(1):128-133.

Snelgrove P., Blackburn T. H., Hutchings P. A., Alongi D. M., Grassle J. F., Hummel H., King G., Koike I., Lambshead P. J. D., Ramsing N. B., Solis-Weiss V., 1997 The importance of marine sediment biodiversity in ecosystem processes. Ambio 26(8):578-583.

Thomas M. M., 1972 Food and feeding habits of *Penaeus monodon* Fabricius from Korapuzha estuary. Indian Journal of Fisheries 19(1-2):202-204.

Thong P. Y., 2017 Phytoplankton in aquaculture ponds: Friend or foe? Global Aquaculture Advocate. Available at: aquaculturealliance.org.

Tidwell J. H., Webster C. D., Sedlacek J. D., Weston P. A., Knight W. L., Hill Jr. S. S., D’Abramo L. R., Daniels W. H., Fuller M. J., Montanez J. L., 1995 Effects of complete and supplemental diets and organic pond fertilization on production of *Macrobrachium rosenbergii* and associated benthic macroinvertebrate populations. Aquaculture 138(1-4):169-180.

Uma A., 1999 Feed probiotics for sustainable aquaculture. SEAFDEC Asian Aquaculture 21(2):13-15.

Villaluz D. K., Villaluz A., Ladrera B., Sheik M., Gonzaga A., 1969 Reproduction, larval development and cultivation of sugpo (*Penaeus monodon* Fabricius). Philippines Journal of Science 98(3-4):205-233.

Warwick R. M., 1987 Meiofauna: their role in marine detrital systems. In: Detritus and microbial ecology in aquaculture. Moriarty D. J. W., Pullin R. S. V (eds), ICLARM Conference Proceedings 14, International Centre for Living Aquatic Resources Management, Manila, Philippines, pp. 282-292.

Received: 14 March 2021. Accepted: 27 April 2021. Published online: 27 June 2021.
Authors:
Muyassar Hamid Abualreesh, Department of Marine Biology, Faculty of Marine Sciences, King Abdualaziz University, P. O. Box 80207, 21589 Jeddah, Saudi Arabia, e-mail: mabulreesh1@kau.edu.sa

How to cite this article:
Abualreesh M. H., 2021 Biodiversity and contribution of natural foods in tiger shrimp (*Penaeus monodon*) aquaculture pond system: A review. AACL Bioflux 14(3):1715-1726.