



Special Issue: Innovations in Sustainable Fisheries, Marine Resources, and Food Systems for Food Security and Human Well-being

Water Quality and Plankton Dynamics in *Litopenaeus vannamei* Pond Culture Systems

Aryani Rahmawati^{1*}, Asep Awaludin Prihanto², Moh. Khusaini³ and Anthon Efani⁴

¹Doctoral Program on Environmental Science, School of Postgraduate, Brawijaya University, Malang, Indonesia; ²Department Fishery Product Technology, Faculty of Fisheries and Marine Science, Brawijaya University, Malang, Indonesia; ³School of Postgraduate, Brawijaya University, Malang, Indonesia; ⁴Departement. Fisheries Agrobusiness, Faculty of Fisheries and Marine Science, Brawijaya University.

Abstract | Shrimp pond ecosystems are highly dynamic environments in which water quality and biological communities play a critical role in determining culture stability and productivity. This study aimed to evaluate temporal variations in water quality parameters, microbial indicators, and plankton composition in intensive pond-based culture systems of *Litopenaeus vannamei* across consecutive production phases. Monitoring was conducted in multiple pond units through routine measurements of physicochemical parameters, water transparency, bacterial and *Vibrio* abundance, and plankton communities throughout the culture period. The results revealed distinct temporal fluctuations in pH, dissolved oxygen, and water clarity, accompanied by corresponding variations in bacterial and *Vibrio* populations. Plankton community structure shifted over time, reflecting changes in nutrient dynamics and organic matter accumulation within the ponds. These findings demonstrate that ecological conditions in shrimp ponds are not static but evolve in response to culture progression. Continuous ecological monitoring is therefore essential to support adaptive pond management strategies and to maintain environmental stability in intensive *Litopenaeus vannamei* culture systems.

Received | March 31, 2026; **Accepted** | June 22, 2026; **Published** | October 22, 2026

***Correspondence** | Aryani Rahmawati, Doctoral Program on Environmental Science, School of Postgraduate, Brawijaya University, Malang, Indonesia; **Email:** Aryanirahmawati1983@gmail.com

Citation | Rahmawati, A., A.A. Prihanto, M. Khusaini and A. Efani. 2026. Water Quality and Plankton Dynamics in *Litopenaeus vannamei* Pond Culture Systems. *Sarhad Journal of Agriculture*, 42(s2): 10-17.

DOI | <https://dx.doi.org/10.17582/journal.sja/2026/42.s2.10.17>

Keywords | Shrimp ponds, Water quality, Plankton, *Vibrio*, Aquaculture ecology



Copyright: 2026 by the authors. Licensee ResearchersLinks Ltd, England, UK.

This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

Introduction

Shrimp aquaculture has become one of the fastest-growing food production sectors worldwide, with *Litopenaeus vannamei* dominating global cultivation due to its high adaptability and economic value (Tacon *et al.*, 2020). Intensive pond systems are widely applied to meet production demands, yet these

systems are inherently unstable because water quality is strongly influenced by biological activity, organic loading, and microbial proliferation (Emerenciano *et al.*, 2017; Paez-Osuna, 2001). Fluctuations in physicochemical parameters, particularly pH and dissolved oxygen, are common in shrimp ponds and often linked to the metabolic activity of plankton communities and decomposition of organic matter

(Liu *et al.*, 2018; Wasielesky *et al.*, 2013).

Pond ecosystems supporting shrimp culture function as semi-closed environments where nutrient accumulation and microbial processes continuously reshape water conditions (Avnimelech, 1999; Burford *et al.*, 2003). These ecological shifts may influence not only water stability but also the abundance of opportunistic pathogens such as *Vibrio* spp., which are widely recognized as major threats to shrimp health and survival (De Schryver and Vadstein, 2014; Xiong, 2018). Therefore, understanding the temporal dynamics of water quality and biological indicators is essential for sustainable shrimp farming.

Despite extensive research on shrimp production, many studies primarily focus on growth performance and feeding efficiency rather than the ecological processes occurring within ponds (Samocha *et al.*, 2004; Ray *et al.*, 2010). Investigations addressing plankton succession and microbial dynamics often rely on experimental or short-term datasets, which may not fully represent real farming conditions (Hu *et al.*, 2015; Zhang *et al.*, 2016). Moreover, routine farm monitoring data, although abundant, are rarely utilized as scientific evidence to describe ecological patterns in operational shrimp ponds (Krummenauer *et al.*, 2014; Anh *et al.*, 2010).

This gap limits the understanding of how water quality and biological communities fluctuate naturally during shrimp culture cycles under commercial management. Continuous pond monitoring provides valuable insight into ecosystem behavior, including plankton dominance shifts, diel pH variation, oxygen depletion, and microbial proliferation (Lin and Chen, 2001; Lancelot and Mathot, 1987). Such information is crucial to anticipate environmental instability and disease risk in intensive shrimp culture systems.

This study was conducted to provide a descriptive ecological assessment of pond water quality, plankton dynamics, and microbial indicators in *Litopenaeus vannamei* culture systems using field-based monitoring data collected during shrimp production cycle phases. The research aims to highlight how physicochemical fluctuations are linked to biological processes within shrimp ponds and to provide practical insights for improving environmental management in pond-based aquaculture.

Despite the widespread application of water quality monitoring in shrimp aquaculture, many studies rely on snapshot measurements that do not adequately capture temporal ecological dynamics throughout the production cycle. In intensive *Litopenaeus vannamei* pond systems, limited attention has been given to the combined temporal behavior of physicochemical parameters, microbial indicators, and plankton community structure as an integrated ecological unit. As a result, the understanding of how pond ecosystems evolve during culture progression remains incomplete. This study addresses this gap by systematically monitoring temporal changes in water quality, bacterial and *Vibrio* abundance, and plankton composition across consecutive culture phases. The objective is to provide an ecological perspective that supports adaptive management and environmental stability in intensive shrimp pond systems.

Materials and Methods

This study employed a longitudinal monitoring approach to capture temporal ecological dynamics in intensive *Litopenaeus vannamei* pond culture systems. Observations were conducted across consecutive production phases in multiple pond units to ensure representativeness of routine farming conditions. Monitoring focused on key physicochemical parameters, microbial indicators, and plankton communities that are widely recognized as indicators of pond ecological status. This approach allows for the identification of temporal patterns and interactions among water quality, microbial load, and plankton dynamics during the culture period.

Study area and pond system

The study was conducted in a commercial-scale pond aquaculture facility culturing *Litopenaeus vannamei* under semi-intensive management. Earthen ponds were operated using similar preparation and water management protocols throughout consecutive production cycle phases. Pond ecosystems in shrimp farming are recognized as dynamic aquatic agro-systems strongly influenced by organic loading, plankton productivity, and microbial processes (Boyd and Tucker, 2012; Edwards, 2015).

Physicochemical water quality measurements

pH was measured twice daily (morning and afternoon) using a portable digital pH meter to capture diel fluctuations associated with photosynthesis and

respiration in shrimp ponds (Boyd and Tucker, 2012; Zhang *et al.*, 2019). Dissolved oxygen (DO) was measured in the early morning using a calibrated DO meter, as minimum oxygen levels typically occur before sunrise due to plankton and microbial respiration (Edwards, 2015). Water transparency was monitored using a Secchi disk to indicate plankton density and suspended solids (Boyd and Tucker, 2012).

Microbial (*Vibrio*) Monitoring

Water samples were collected aseptically and analyzed for total *Vibrio* abundance using standard microbiological plating techniques on selective media. *Vibrio* populations are widely used as indicators of microbial imbalance and disease risk in shrimp ponds (Primavera *et al.*, 2018; Nguyen *et al.*, 2022). Elevated *Vibrio* loads are often associated with high organic matter and unstable environmental conditions (Zhang *et al.*, 2019; Edwards, 2015).

Plankton identification

Water samples were collected from each pond and examined microscopically to identify dominant phytoplankton groups. Plankton composition serves as a biological indicator of nutrient dynamics and ecological condition in shrimp ponds (Boyd and Tucker, 2012). Shifts between green algae and blue-green algae were recorded to evaluate trophic changes and bloom dynamics (Edwards, 2015).

Data handling and interpretation

Monitoring data were compiled descriptively to evaluate ecological trends across production cycle phases. Observational analysis was applied to interpret fluctuations in physicochemical, microbial, and plankton indicators without experimental

manipulation, a method widely used in pond ecosystem studies (Primavera *et al.*, 2018).

Results and Discussion

The results illustrate that water quality and biological components in shrimp ponds exhibit clear temporal variability rather than remaining stable throughout the culture period. Changes in physicochemical parameters were closely followed by shifts in microbial abundance and plankton composition, indicating strong ecological coupling within the pond system.

Water quality dynamics in pond-based culture systems of *Litopenaeus vannamei* exhibited clear temporal fluctuations across the observed production cycle phases, reflecting the highly dynamic nature of shrimp pond ecosystems. Variations in physicochemical parameters such as pH and dissolved oxygen (DO), together with changes in microbial abundance and plankton composition, indicated ongoing ecological shifts throughout the culture period (Table 1). Such variability is typical in semi-intensive and intensive shrimp ponds, where nutrient loading and biological processes continuously alter water conditions (Boyd and Tucker, 2012; Edwards, 2015).

The pH values recorded during the culture period showed daily and cyclical variation between morning and afternoon measurements (Figure 1). This pattern is strongly associated with photosynthetic activity and respiration of phytoplankton communities in the ponds. Higher afternoon pH levels observed in several pond units suggest active phytoplankton photosynthesis, which consumes carbon dioxide and increases alkalinity during daylight hours. Similar pH

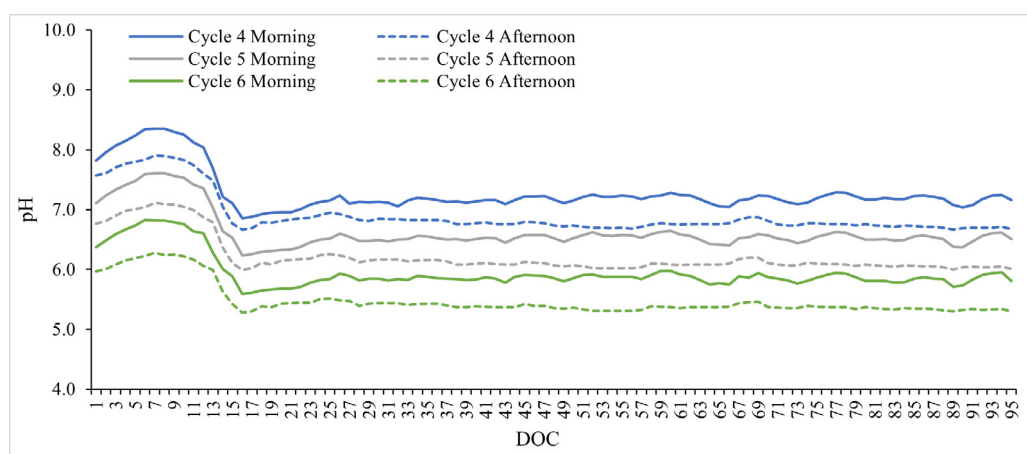


Figure 1: Daily fluctuations of pH (morning and afternoon) in *Litopenaeus vannamei* ponds during production cycle phases.

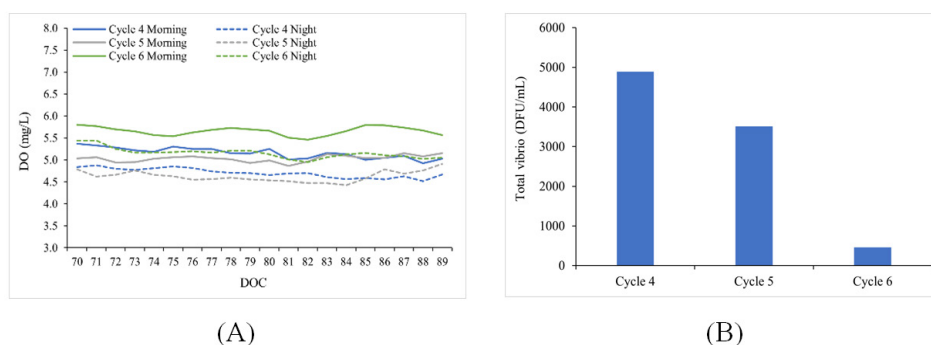


Figure 2: Variations in dissolved oxygen (A) and *Vibrio* abundance (B) in shrimp ponds across production cycle phases.

Table 1: Summary of physicochemical water quality parameters (pH and DO) in *Litopenaeus vannamei* ponds

DOC	pH		DO (mg/L)									
	Cycle 4		Cycle 5		Cycle 6		Cycle 4		Cycle 5		Cycle 6	
	Morn- ing	After- noon	Morn- ing	After- noon	Morn- ing	After- noon	Morning	Night	Morning	Night	Morning	Night
70	7.2	6.8	6.6	6.1	5.9	5.4	5.4	4.8	5.0	4.8	5.8	5.4
71	7.2	6.7	6.5	6.1	5.8	5.4	5.3	4.9	5.1	4.6	5.8	5.4
72	7.1	6.7	6.5	6.1	5.8	5.4	5.3	4.8	4.9	4.7	5.7	5.3
73	7.1	6.7	6.4	6.1	5.8	5.4	5.2	4.8	5.0	4.8	5.7	5.2
74	7.1	6.8	6.5	6.1	5.8	5.4	5.2	4.8	5.0	4.7	5.6	5.2
75	7.2	6.8	6.5	6.1	5.9	5.4	5.3	4.9	5.1	4.6	5.5	5.2
76	7.2	6.8	6.6	6.1	5.9	5.4	5.3	4.8	5.1	4.5	5.6	5.2
77	7.3	6.8	6.6	6.1	5.9	5.4	5.3	4.7	5.0	4.6	5.7	5.2
78	7.3	6.8	6.6	6.1	5.9	5.4	5.2	4.7	5.0	4.6	5.7	5.2
79	7.2	6.7	6.6	6.1	5.9	5.3	5.1	4.7	4.9	4.6	5.7	5.2
80	7.2	6.8	6.5	6.1	5.8	5.4	5.3	4.7	5.0	4.5	5.7	5.1
81	7.2	6.7	6.5	6.1	5.8	5.4	5.0	4.7	4.9	4.5	5.5	5.0
82	7.2	6.7	6.5	6.1	5.8	5.3	5.0	4.7	5.0	4.5	5.5	5.0
83	7.2	6.7	6.5	6.0	5.8	5.3	5.2	4.6	5.1	4.5	5.5	5.1
84	7.2	6.7	6.5	6.1	5.8	5.4	5.1	4.6	5.1	4.4	5.7	5.1
85	7.2	6.7	6.6	6.1	5.8	5.3	5.0	4.6	5.0	4.6	5.8	5.2
86	7.2	6.7	6.6	6.1	5.9	5.3	5.0	4.6	5.0	4.8	5.8	5.1
87	7.2	6.7	6.5	6.1	5.8	5.3	5.1	4.6	5.2	4.7	5.7	5.1
88	7.2	6.7	6.5	6.0	5.8	5.3	4.9	4.5	5.1	4.8	5.7	5.0
89	7.1	6.7	6.4	6.0	5.7	5.3	5.0	4.7	5.2	4.9	5.6	5.1

oscillations have been widely reported in shrimp ponds and are considered key indicators of plankton productivity and metabolic balance (Boyd and Tucker, 2012; Zhang *et al.*, 2019).

Dissolved oxygen levels also displayed notable fluctuations, particularly between early morning and daytime observations (Figure 2). Morning DO reductions in some sampling periods indicate oxygen depletion caused by nighttime respiration of plankton and microbial communities, a common phenomenon in ponds with high organic matter accumulation.

Conversely, increased DO during daytime corresponds to phytoplankton photosynthesis, which enhances oxygen availability. These dynamics highlight the strong coupling between biological activity and oxygen balance in shrimp culture ponds (Araujo *et al.*, 2025).

Microbial monitoring revealed variability in total *Vibrio* abundance across ponds and production cycle phases (Table 2). Elevated *Vibrio* counts during certain periods are commonly associated with increased organic matter, feed residues, and unstable

Table 2: Distribution of *Vibrio* counts observed during shrimp culture cycles.

DOC	Total vibrio (DFU/mL) Cycle 4									
	Pond 1	Pond 2	Pond 3	Pond 4	Pond 5	Pond 6	Pond 7	Pond 8	Pond 9	Pond 10
9	100	125	415	230						
23	4040	10300	2270	9530	800	8320	1520	3090	2780	1670
35	6340	2140	3850	2500	2070	6700	7960	3880	12590	3320
39	2910	8870	1360	1580	2280	5580	4030	12350	5450	3200
46	5070	7550	7000	12930	5830	4150	5070	7080	3990	7590
54	9220	5340	8600	9280	10080	7820	7580	1480	3940	9280
60	6700	3480	3040	400	380	2560	4620	2180	980	2880
65	4850	7180	2110	830	1370	5480	1700	1950	3460	2020
73	10730	4050	3830	4600	6190	7800	3170	5350	2920	3550
79	5590	2550	3080	2590	5210	3930	6250	4020	4820	9400
87	8780	7350	6700	4540	2860	3500	4450	9340	4990	3700
93	6620	8530	7170	5080	4910	6350	3520	6300	7420	8180
99	5460	4940	6400	3230	2370	4240	3730	5160	5030	4710
DOC	Total vibrio (DFU/mL) Cycle 5									
	Pond 1	Pond 2	Pond 3	Pond 4	Pond 5	Pond 6	Pond 7	Pond 8	Pond 9	Pond 10
17	620	1495	1025	1485	595	1385	12			
26	1330	2010	1580	670	1210	200	1810	1230	1310	80
36	4460	950	3360	2800	1210	1760	1000	780	2130	910
45	12840	13990	9880	6650	5910	3940	4710	8470	5030	2130
53	9330	7590	9190	9140	4810	3080	6660	2390	2460	690
66	7900	7040	7620	4960	0	5840	10160	8860	11780	5050
85	2580	3660	2900	2620	2730	1460	1340	300	2250	260
98	770	3260	910	620	970	920	2530	1010	590	3350
DOC	Total vibrio (DFU/mL) Cycle 6									
	Pond 1	Pond 2	Pond 3	Pond 4	Pond 5	Pond 6	Pond 7	Pond 8	Pond 9	Pond 10
15	100		10				820	660		10
27	30	510	790	60	920	1520	1290	220	1560	1110
43	690	10	520	840	190	290	50	1040	50	0
50	240	120	70	0	10	150	260	100	750	10
88	800	740	60	30	650	460	350	60	750	470
111	780	610	380	800	900	600	510	490	100	290

water quality, which create favorable conditions for opportunistic bacteria. The observed *Vibrio* dynamics align with previous studies indicating that microbial populations in shrimp ponds are closely linked to environmental parameters and nutrient enrichment (Primavera *et al.*, 2018; Nguyen *et al.*, 2022). These fluctuations emphasize the importance of continuous microbial surveillance in intensive *Litopenaeus vannamei* farming to prevent disease outbreaks.

Plankton composition varied markedly throughout the culture period, with shifts in dominant phytoplankton

groups reflecting changing nutrient conditions and pond trophic status (Table 3). The occurrence of green algae and blue-green algae indicates nutrient-rich environments typical of shrimp ponds receiving regular feed inputs. While moderate phytoplankton presence supports natural food availability and oxygen production, excessive blooms may destabilize water quality and increase bacterial proliferation (Edwards, 2015). Therefore, plankton dynamics serve as both ecological indicators and management signals in pond-based shrimp culture.

Table 3: Distribution of dominant plankton groups observed during shrimp culture cycles.

Class	Percentage	Type	Abundance (x10 ⁴)
Cycle 4			
Green alga	54%	Chlorella	46
Blue green alga	25%	Pseudonabaena	17
		Anabaena	3
		Oscillatoria	1
		Gymnodinium	1
Dinoflagelata	14%	Lepidodinium	10
		Heterocapsa	1
		Melosira	2
Diatome	6%	Cyclotella	3
Etc	0%		
Protozoa	1	Euglena	1
Density			85
Cycle 5			
Green alga	14%	Chlorella	5
		Dunaliella	1
		Oocystis	1
Blue green alga	65%	Pseudonabaena	26
		Oscillatoria	4
		Microcystis	1
		Anabaena	1
Dinoflagelata	6%	Gymnodinium	1
		Peridinium	1
		Hemidinium	1
Diatome	10%	Melosira	5
Etc	0%		
Protozoa	2	Uronychia	1
		Ciliata	1
Density			49
Cycle 6			
Green alga	17%	Chlorella	7
		Dunaliella	1
Blue green alga	30%	Pseudonabaena	13
		Oscillatoria	1
Dinoflagelata	11%	Gyrodinium	1
		Gymnodinium	1
		Paradoxum	3
		Heterosigma	3
Diatome	24%	Akashiwo	11
		Biddulphia	11
Etc	13%	Astasia	3
		Cryptomonas	3
Protozoa	2	Uronychia	1
		Vorticella	1
Density			46

Overall, the combined physicochemical, microbial, and plankton data demonstrate that shrimp ponds function as complex and fluctuating agro-aquatic ecosystems. Variability in water quality across production cycle phases is not merely incidental but reflects biological feedback processes inherent to *L. vannamei* pond farming. These findings reinforce that maintaining pond stability requires continuous monitoring and adaptive management to balance nutrient input, plankton growth, and microbial load (Hasan and New, 2013; Costa-Pierce *et al.*, 2019).

Conclusions and Recommendations

The monitoring data demonstrated that pond ecosystems used for the culture of *Litopenaeus vannamei* experienced continuous and interconnected fluctuations in physicochemical and biological parameters throughout the production cycle phases. Variations in pH and dissolved oxygen reflected the metabolic activities of plankton communities and the accumulation of organic matter typical of shrimp ponds. Shifts in plankton composition and periodic increases in *Vibrio* abundance indicated that ecological instability can emerge even under routine pond management. These findings confirm that water quality dynamics are closely linked to biological processes within shrimp ponds and highlight the importance of integrated ecological monitoring to maintain a balanced culture environment. Based on these observations, it is recommended that shrimp pond management incorporate routine assessment of both physicochemical and microbial indicators to anticipate ecological shifts that may compromise pond stability. Early detection of plankton blooms and elevated *Vibrio* levels should be used as practical warning signals for implementing corrective measures such as aeration adjustment, water exchange, and organic load control. Furthermore, standardized documentation of water quality and biological monitoring across production cycle phases is essential to support adaptive management and improve sustainability in pond-based *Litopenaeus vannamei* aquaculture systems. These findings emphasize that routine and continuous ecological monitoring is a key requirement for adaptive management in intensive shrimp aquaculture, enabling early detection of unfavorable environmental trends and supporting sustainable production performance.

Acknowledgements

The authors gratefully acknowledge the support provided by the Postgraduate school University of Brawijaya, for facilitating this research.

Novelty Statement

This study provides a temporally integrated ecological assessment of intensive *Litopenaeus vannamei* pond systems by simultaneously tracking physicochemical dynamics, microbial indicators (including *Vibrio* abundance), and plankton community shifts across consecutive production phases. Unlike previous studies that often evaluate these components in isolation or at single time points, this research captures their synchronized temporal variability within operational ponds. The findings offer novel insights into how short-term ecological fluctuations reflect underlying nutrient dynamics and organic matter accumulation, strengthening the ecological basis for adaptive water quality management in intensive shrimp aquaculture systems.

Authors' Contribution

Aryani Rahmawati: Performing the research, formal analysis of the data, wrote the original manuscript draft.

Asep Awaludin Prihanto: Led the conceptualization of the research, contributed to the methodology, reviewing and editing the manuscript, reviewed the final manuscript for publication.

Moh. Khusaini: Academic supervision, assisted in data handling and interpretation.

Antho Efan: Contributed to the formal analysis of the data, and reviewed the final manuscript.

Generative AI and AI-assisted technology statement

The authors declare that no generative AI and AI assisted technology was used in the creation of this manuscript.

Conflict of interest

The authors have declared no conflict of interest.

References

Anh, P.T., C. Kroeze, S.R. Bush and A.P.J. Mol. 2010. Water pollution by intensive brackish shrimp farming in south-east Vietnam: Causes

and options for control. *Agric. Water Manag.*, 97(6): 872-882. <https://doi.org/10.1016/j.agwat.2010.01.018>

Araujo, A.N., C.F. San Andres, K.Q. Nguyen., T.L. Corby, M.A. Rhodes, J.C. Garcia, L.A. Roy, J. Stoeckel and D.A. Davis. 2025. Effects of minimum dissolved oxygen setpoints for aeration in semi-intensive pond production of Pacific white shrimp (*Litopenaeus vannamei*). *Aquaculture*, 594: 741376. <https://doi.org/10.1016/j.aquaculture.2024.741376>

Avnimelech, Y. 1999. Carbon/nitrogen ratio as a control element in aquaculture systems. *Aquaculture*, 176(3-4):227-235. [https://doi.org/10.1016/S0044-8486\(99\)00085-X](https://doi.org/10.1016/S0044-8486(99)00085-X)

Boyd, C.E., and C.S. Tucker. 2012. Pond aquaculture water quality management. Springer, New York.

Burford, M.A., P.J. Thompson, R.P. McIntosh, R.H. Bauman and D.C. Pearson. 2003. Nutrient and microbial dynamics in high-intensity shrimp ponds. *Aquac.*, 219(1-4): 393-411. [https://doi.org/10.1016/S0044-8486\(02\)00575-6](https://doi.org/10.1016/S0044-8486(02)00575-6)

Costa-Pierce, B.A., F. Chopin, S. Robinson, R. Neori, A.H. Buschmann and I. Fang. 2019. Sustainability of integrated multi-trophic aquaculture. *Rev. Aquac.*, 11(1): 1-22.

De Schryver, P. and O. Vadstein. 2014. Ecological theory as a foundation to control pathogenic invasion in aquaculture. *ISME J.*, 8(12): 2360-2368. <https://doi.org/10.1038/ismej.2014.84>

Edwards, P. 2015. Aquaculture environment interactions: Past, present and likely future trends. *Aquac.*, 447: 2-14. <https://doi.org/10.1016/j.aquaculture.2015.02.001>

Emerenciano, M., G. Gaxiola and A. Cuzon. 2017. Biofloc technology (BFT): A review for aquaculture application and animal food industry. *Biomass Bioener.*, 99: 42-52.

Hasan, M.R. and M.B. New. 2013. On-farm feeding and feed management in aquaculture. *FAO Fish. Aquac. Tech. Pap.*, 583: 1-67.

Hu, Z., J.W. Lee, K. Chandran, S. Kim and P.L. Sharma. 2015. Influence of microbial communities on shrimp pond stability. *Aquac. Res.*, 46(7): 1722-1734.

Krummenauer, D., F. Poersch, M. Cavalli and W. Wasielesky. 2014. Superintensive culture of white shrimp in biofloc systems. *Aquac. Eng.*, 59:35-39.

Lancelot, C., and S. Mathot. 1987. Dynamics of

- phytoplankton in nutrient-rich waters. *Mar. Ecol. Prog. Ser.*, 40: 197-204.
- Lin, Y.C., and J.C. Chen. 2001. Acute toxicity of ammonia on shrimp in relation to salinity. *J. Exp. Mar. Biol. Ecol.*, 259(1): 109-119. [https://doi.org/10.1016/S0022-0981\(01\)00227-1](https://doi.org/10.1016/S0022-0981(01)00227-1)
- Liu, K.F., H.C. Chuang and C.S. Chen. 2018. Diurnal variations of dissolved oxygen and pH in shrimp ponds. *Aquac. Environ. Interact.*, 10: 155-164.
- Paez-Osuna, F. 2001. The environmental impact of shrimp aquaculture. *Environ. Manag.*, 28(1): 131-140. <https://doi.org/10.1007/s002670010212>
- Nguyen, K.A.T., T.T.H. Nguyen, H.V. Tran and M.C.J. Verdegem. 2022. Production performance and sustainability of shrimp farming systems. *Aquac. Rep.*, 22: 100955.
- Primavera, J.H., M.J.H. Leбата, H.L. Altamirano and J.P. Faye. 2018. Mangroves and aquaculture: A re-examination of blue revolution. *Ocean Coast., Manag.*, 152: 1-7.
- Ray, A.J., K.S. Dillon and J.M. Lotz. 2010. Water quality dynamics in intensive shrimp ponds. *Aquac.*, 300(1-4): 15-21.
- Samocha, T.M., A.L. Lawrence and J.P. Jones. 2004. Sustainable shrimp farming in ponds. *Aquac. Res.*, 35(1): 10-20.
- Tacon, A.G.J., M.R. Hasan and R.P. Subasinghe. 2020. Global overview of shrimp aquaculture. *Rev. Fish. Sci. Aquac.*, 28(3): 290-308.
- Wasieliesky, W., D. Atwood, A. Stokes and C.L. Browdy. 2013. Effect of natural productivity on shrimp ponds. *Aquac. Res.*, 44(2): 318-327.
- Xiong, J. 2018. Progress in the gut microbiota in shrimp aquaculture. *Aquaculture.*, 495:368-374.
- Zhang, M., L. Sun, S. Liu and J. Qiu. 2016. Microbial community dynamics in shrimp ponds. *Aquac.*, 455: 9-17.
- Zhang, W., Y. Liu, J. Tian, H. Wang and S. Zhang. 2019. Growth performance and environmental effects of intensive shrimp farming. *Aquac. Res.*, 50(9): 2478-2489.