Jurnal Teknologi Perikanan dan Kelautan Vol. 16 No. 4 November 2025: 351-359
DOI: https://doi.org/10.24319/jtpk.16.351-359

ISSN 2087-4871
EISSN 2549-3841

CONDITION FACTOR AND SIZE VARIATION OF CATFISH FRY REARING IN A SUPER-INTENSIVE UFBs-RAS SYSTEM

KONDISI FAKTOR DAN KERAGAMAN UKURAN BENIH IKAN LELE PADA PEMELIHARAAN SUPER INTENSIF DALAM SISTEM UFBs-RAS

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(Received January 17, 2025; Revised July 23, 2025; Accepted August 24, 2025)

ABSTRACT

Catfish (*Clarias gariepinus*) is one of the leading aquaculture commodities in Indonesia, with a production volume reaching 1.01 million tons, accounting for approximately 15% of the national aquaculture output in 2020. The availability of high-quality fry is crucial for the sustainability of catfish farming. This study aims to evaluate the effect of high stocking densities on survival rate, condition factor, and size variation of catfish fry reared in UFBs-RAS. This research was conducted at PUI-PT Nano Powder Functional Universitas Padjadjaran (Jatinangor) from October to November 2023. The study tested catfish fry with lengths of 3–4 cm and weights of 1.2–1.4 g with four densities (10 fish/L, 15 fish/L, 20 fish/L, 25 fish/L). The results indicated that stocking density did not significantly affect the survival rate (P>0.05), but it did have a significant effect on length and weight variation (P<0.05). The condition factor did not show significant differences (P>0.05) between stocking density treatments. Overall, a density of 25 fish/L yielded the best performance within the UFBs-RAS. Therefore, this density is recommended as the optimal stocking rate for catfish fry rearing in this system. These findings suggest that the application of the UFBs-RAS system provides a strategic solution for the aquaculture industry to enhance the efficiency of catfish fry rearing at high stocking densities while maintaining optimal water quality and growth performance, thereby supporting productivity and sustainability in intensive aquaculture systems.

Keywords: catfish, stocking density, super-intensive aquaculture, UFBs-RAS, water quality

ABSTRAK

Ikan lele (*Clarias gariepinus*) merupakan salah satu komoditas unggulan dalam sektor akuakultur di Indonesia, dengan produksi mencapai 1,01 juta ton atau sekitar 15% dari total produksi akuakultur nasional pada tahun 2020. Ketersediaan benih berkualitas menjadi faktor kunci dalam menjaga kesinambungan budidaya lele. Penelitian ini bertujuan untuk mengkaji pengaruh padat tebar tinggi terhadap tingkat kelangsungan hidup, faktor kondisi dan keragaman ukuran benih ikan lele dalam sistem UFBs-RAS. Penelitian ini dilakukan di PUI-PT Nano Powder Fungsional Unviersitas Padjadjaran (Jatinangor), selama Oktober–November 2023. Benih ikan lele yang diuji memiliki ukuran panjang 3–4 cm dan berat 1,2–1,4 g dengan empat tingkat kepadatan (10 ekor/L, 15 ekor/L, 20 ekor/L, 25 ekor/L). Hasil dari penelitian menunjukkan bahwa antar perlakuan padat tebar pada sistem UFBs-RAS tidak terdapat perbedaan nyata (P>0,05) terhadap tingkat kelangsungan hidup, hasil analisis sidik ragam menunjukkan bahwa perbedaan padat tebar berbeda nyata (P<0,05) terhadap keragaman ukuran panjang dan bobot, sedangkan pengaruh padat tebar tidak berbeda nyata (P>0,05) terhadap faktor kondisi. Secara keseluruhan, kepadatan 25 ekor/L memberikan hasil terbaik dalam sistem UFBs-RAS. Maka dari itu, padat tebar ini direkomendasikan sebagai kepadatan optimal dalam fase pemeliharaan benih ikan lele pada sistem UFBs-RAS. Temuan ini menunjukkan bahwa penerapan UFBs-RAS dapat menjadi solusi strategis bagi industri akuakultur untuk meningkatkan efisiensi budidaya benih ikan lele pada padat tebar tinggi dengan tetap mempertahankan kualitas air dan performa pertumbuhan yang optimal, sehingga mendukung produktivitas dan keberlanjutan sistem budidaya intensif.

Kata kunci: akuakultur super intensif, ikan lele, kualitas air, padat tebar, UFBs-RAS

INTRODUCTION

Catfish (*Clairas gariepinus*) is one of the most important aquaculture products in Indonesia, with a total production of 1.01 million tons in 2020. This figure accounts for 15% of the national aquaculture production, placing catfish as the second largest aquaculture commodity in Indonesia after Nile tilapia (KKP 2020). Therefore, it is necessary to increase the production of the catfish fry to ensure the availability of high-quality stock (Sundari and Priyanto 2017), which is essential to support the success and sustainability of the aquaculture industry (Barasa and Ouma 2024).

One of the strategies to enhance catfish fry productivity is by optimizing stocking density, which allows for more intensive production (Silva *et al.* 2020). Stocking density exerts a significant influence on growth performance variables while also reducing aquaculture production costs (Li *et al.* 2021). However, high stocking densities may lead to spatial limitations and potentially cause deterioration in water quality, resulting in stress (Aidos *et al.* 2020), growth impairment (Jewel *et al.* 2023), reduced feed efficiency (Espinoza-Ramos *et al.* 2022), and increased disease susceptibility (Diao *et al.* 2023). Thus, it is crucial to develop a catfish fry rearing system capable of addressing the challenges associated with high stocking densities.

Recirculating aquaculture system (RAS) represents a modern intensive aquaculture approach that can sustain high stocking densities. This system is considered the aquaculture model of the future, as it maximizes production output and profitability while maintaining environmental quality in line with the requirements of sustainable development (Ahmed *et al.* 2019; Xiao *et al.* 2019). In addition, RAS ensures the production of high-quality, safe, and healthy fry (Xiao *et al.* 2019). The integration of ultrafine bubbles (UFBs) technology into RAS further enhances its performance. According to Subhan *et al.* (2021), UFBs-RAS provides several advantages, including increasing dissolved oxygen levels, supplying oxygen in the form of reserve oxygen potential (ROP), generating reactive oxygen species (ROS), reducing ammonia concentrations, and stimulating nitrifying bacteria.

Previous studies have demonstrated the potential of RAS to improve catfish fry growth performance. For instance, Indriastuti *et al.* (2022) reported that rearing catfish fry at a density of 4 fish/L in RAS yielded better production performance compared to an aeration system, with SR 91.03±0.90%, SGR 7.71±0.19%, and feed efficiency 88.45±2.03%. However, further increases in stocking density have been shown to reduce production performance significantly. Baßmann *et al.* (2023) observed that catfish cultured under semi-intensive systems (low density) achieved better growth performance than those raised in intensive or super-intensive systems. Similarly, the application of a microbubble generator in RAS demonstrated improved growth performance in catfish fry reared at 1 fish/2 L compared to conventional aeration and non-aeration systems, with SR 85%, SGR 3.74%, and FCR 1.85 (Setyono *et al.* 2023). Despite these efforts, the application of UFBs in RAS specifically for catfish fry rearing under high stocking densities remains insufficiently explored in scientific literature. This study aimed to evaluate the effects of high stocking densities on survival rate, condition factor, and size variation of catfish fry reared in UFBs-RAS.

METHODS

Time and location

This study was conducted at the Center of Excellence for Science and Technology in Higher Education (PUI-PT) Nano Powder Functional, Universitas Padjadjaran, from October to November 2023. The research activities included equipment and material preparation, rearing, and data analysis.

UFBs-RAS installation setup

The UFBs-RAS system used in this study for catfish fry consisted of three main units: an ultrafine bubble tank (20 L capacity), 16 cylindrical tanks (20 L capacity each), and one water reservoir tank (80 L capacity), designed to accommodate fry and water treatment. The inflow to each rearing tank was maintained at 0.5 L/min with a constant water volume of 15 L per tank. Water exiting the tanks was directed through PVC pipes into a filtration unit. The filter was equipped with Japmat, filter cotton, bioballs, and zeolite. Additionally, 3 thermostats (150 W capacity) were installed in the filter unit and set at 26°C to maintain uniform water temperature across all rearing tanks.

Fry preparation

The catfish fry used in this experiment measured 3–4 cm in length and were obtained from a catfish farmer group in Cileunyi, West Java Province. The experiment employed a Completely Randomized Design (CRD) with 4 stocking density treatments and 3 replications: A (10 fish individuals/L), B (15 fish individuals/L), C (20 fish individuals/L), and D (25 fish individuals/L). Stocking density levels were adapted from Baßmann *et al.* (2023), who reared catfish fry in RAS at different densities: 8 fish individuals/L (semi-intensive), 17 fish individuals/L (intensive), and 33 fish individuals/L (super-intensive), resulting in a specific growth rate ranging between 2.9 and 3.0%.

Feed preparation

Commercial feed (0.5–0.7 mm pellet size) was used, containing a minimum of 39% crude protein, 5% crude fat, 4% crude fiber, a maximum of 11% ash, and a maximum of 10% moisture. The feed was suitable for fry until they reached 5–7 cm in size over a one-month rearing period. The feeding rate was determined based on feeding intake and gastric emptying rate. UFBs' treatments were fed at 7% of biomass weight. Feeding was carried out three times daily at 08:00, 14:00, and 20:00.

Water quality monitoring

Water quality was monitored weekly, including dissolved oxygen (DO) and temperature. DO was measured using a DO meter (Luton DO-5511), temperature using a thermometer, and nitrate/nitrite using a freshwater test kit (API Freshwater Test Kit).

Survival rate, size variation, and condition factor

The survival rate of fish fry was calculated as the ratio between the number of fry at the end of the experiment and the initial stocking number (Goddard 1996):

$$SR(\%) = \left(\frac{Nt-n}{Nt-0}\right) \times 100$$

where:
SR = Survival rate (%)
Nt–n = Number of fry surviving at the end of the experiment
Nt–0 = Initial number of stocked fry

Size variation was calculated using the coefficient of variation (CV) following Warwick *et al.* (1995):

$$CV(\%) = \frac{SD}{X} \times 100$$

where:
CV = Size variation (%)
SD = Standard deviation
X = Mean size

The condition factor was determined using Fulton's Formula (1911):

$$K = 100 \times \left(\frac{W}{L^3}\right)$$

where:
K = Condition factor
W = Body weight (g)
L = Body length (cm)

Data analysis

Data were analyzed using OriginLab 2019 software with one-way ANOVA followed by Tukey's post hoc test at a 95% confidence level. Results were presented in graphs and tables, while water quality parameters were analyzed descriptively and exploratively.

RESULTS AND DISCUSSION

Water quality

Water quality parameters are critical environmental factors influencing production performance. The observed water quality parameters during the study included dissolved oxygen (DO: 8.98–12.1 mg/L), temperature (26°C), pH (7–7.6), ammonia (NH_3-N) (0.002–0.01 mg/L), nitrite (NO_2- aeration system 0.25–2 mg/L; UFBs-RAS 0.5–2 mg/L), and nitrate NO_3- (aeration system 5–10 mg/L; UFBs-RAS 0–10 mg/L) (Table 1).

The elevated DO levels observed in UFBs-RAS were attributed to the ability of UFBs to create oxygen-rich conditions through nano-sized bubbles. Subhan *et al.* (2021) reported that the UFBs system increases dissolved oxygen concentrations due to the prolonged stability of nano-bubbles in the water column. DO levels in UFBs-RAS during this study were within the optimal range for fish growth, as Kelana *et al.* (2021) suggested a minimum DO requirement of 3 mg/L for catfish culture. According to Kusumawati *et al.* (2018), aquatic organisms require sufficient oxygen for swimming, growth, and reproduction. Furthermore, Rosariawari *et al.* (2016) and Tanjung *et al.* (2019) emphasized that higher DO concentrations stimulate fish growth by enhancing metabolic activity.

Water temperature was consistently maintained at 26°C across treatments due to the installation of thermostats, ensuring optimal thermal conditions for catfish fry growth. This temperature falls within the SNI 6484.4-2014 standard (25°C–30°C) for catfish fry rearing. Suboptimal temperatures below this range reduce feeding activity and growth (Kesuma *et al.* 2019). Temperature directly affects metabolism, feeding rate, swimming activity, and neural responses (Stickney 2000; Burggren *et al.* 2019). Kordi and Ghufron (2000) further stated that abrupt temperature shifts of 5°C can induce stress, leading to decreased appetite.

Ammonia levels in UFBs-RAS remained below the permissible limit set by SNI 6484.4-2014 (≤ 0.1 mg/L) and Kelana *et al.* (2021) (<0.01 mg/L). Conversely, stagnant aeration water without filtration showed higher ammonia concentrations (0.077–0.17 mg/L), likely due to the accumulation of metabolic waste (Li *et al.* 2020). Elevated ammonia is toxic to fish, impairing osmoregulation, increasing blood pH and tissue oxygen consumption, and reducing oxygen transport in the blood, which can ultimately cause mortality (Sherif 2016). The consistently lower ammonia in UFBs-RAS was due to oxygen interactions within the system as well as the role of nitrifying bacteria acting as biofilters (Subhan *et al.* 2021).

Survival rate

Survival rates of catfish fry ranged between 94.0±1.21% and 98.1±0.591%. Analysis of variance revealed no significant differences (P>0.05) among stocking density treatments. The highest survival rate (98.07%) was recorded in treatment E (Figure 1), supported by consistently high DO (>80%) throughout the rearing period in UFBs-RAS. Elevated DO reduces stress, indicated by lower glucose levels, red blood cell counts, and hepatic lactate (Li *et al.* 2020). Low ammonia concentrations (≤0.1 mg/L) also contributed to higher survival by minimizing gill damage. Bernardi *et al.* (2018) stated that ammonia levels above 0.02–0.5 mg/L cause gill damage and mortality. These findings confirm that UFBs-RAS effectively support maximum survival even under very high stocking densities.

Condition factor

The condition factor, which describes the length-weight relationship as an indicator of growth performance, health, and welfare, showed no significant differences (P>0.05) among treatments. The recorded ranged from 0.70±0.01 and 0.73±0.03 (Figure 2).

An ideal condition factor approaches or equals one (Olufeagba *et al.* 2016), indicating adequate feeding and suitable rearing conditions (Ujjania *et al.* 2013). Perry *et al.* (1996) noted that low condition factors often reflect poor environmental conditions or nutritional deficiencies. Stress due to low oxygen availability can also compromise health and immunity (Schäfer *et al.* 2021). Stress responses in fish lead to increase leukocyte counts (Barcellos *et al.* 2011), triggered by sympathetic nervous system activity and catecholamine release (Nardocci *et al.* 2014). According to Niklasson *et al.* (2011), prolonged stress suppresses immune function, increasing disease susceptibility.

In this study, condition factors were consistently <1 across treatments, despite optimal water quality. This could be attributed to social hierarchy among fry, where subordinate individuals experienced reduced feed access and higher social stress, diverting energy allocation from growth to stress response (Martins *et al.* 2012). Carbonara *et al.* (2019) observed that social hierarchies in *Dicentrarchus labrax* induced significant physiological differences, including cortisol levels, muscle activity, and immune responses. Similarly, Roy *et al.* (2021) highlighted that stocking density remains a key factor influencing fish welfare, even under good water quality.

Size variation

Length variation ranged from 10.1±1.04 to 13.08±1.89%, while weight variation ranged from 19.97±2.69 to 25.70±2.76% (Figure 3). Analysis of variance indicated that stocking density significantly affected both length and weight variation (P<0.05).

Both parameters exhibited a similar trend, with higher stocking densities leading to greater variability. The highest variation occurred at 25 fry/L, with length variation 13.08±1.89% and weight variation 25.70±2.76%. These values remain acceptable, as variations below 30% are generally market-acceptable for fry distribution. Notably, the weight variation observed was lower than that reported in other high-density studies, such as catfish at 30% (Almazán-Rueda *et al.* 2004), hybrid sunfish (*Lepomis cynellus x Lepomis macrochirus*) at 40.2% (Wang *et al.* 1998), Chinese sturgeon (*Acipenser sinensis*) at 31.7% (Qian *et al.* 2002), and European eel (*Anguilla anguilla*) at 28.99–53.88.

Table 1. Average water quality parameters during catfish fry rearing in stagnant aeration and UFBs-RAS system.

Water Quality Parameters	Rearing System		References
	Stagnant Aeration System	UFBs-RAS	
DO (mg/L)	4.2–5.6	6.8–12.3	>4 (Kelana *et al.* 2021)
Temperature (°C)	26	26	25–30 (Kelana *et al.* 2021)
pH	7–7.6	7–7.6	6.5–8.5 (Kesuma *et al.* 2019)
NH_3-N (mg/L)	0.077–0.170	0.002–0.010	<0.01 (Kelana *et al.* 2021)
NO_2-N (mg/L)	1–2	0–2	<1 (Kusumawati *et al.* 2018)
NO_3-N (mg/L)	5–10	0–10	<20 (Adharani *et al.* 2016)

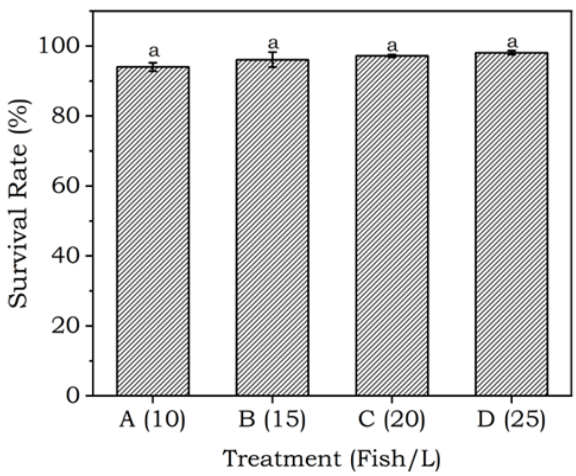


Figure 1. Survival rate of catfish fry reared at different stocking densities in the UFBs-RAS system.

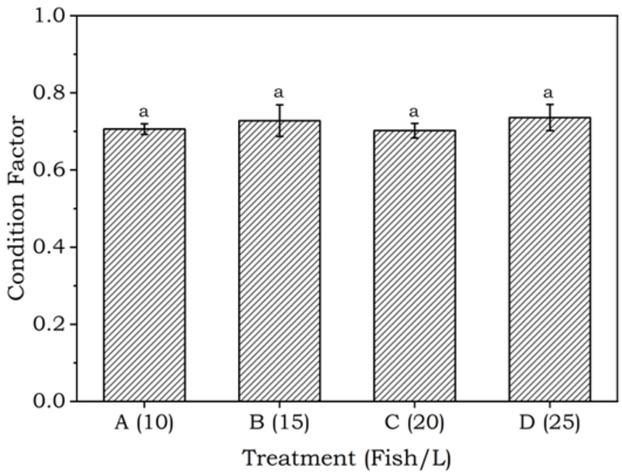
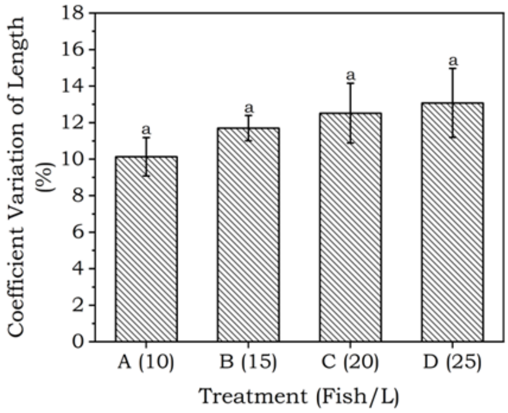
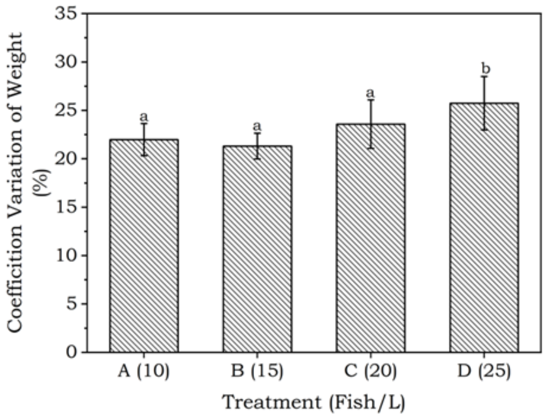


Figure 2. Condition factor of catfish fry reared at different stocking densities in the UFBs-RAS system.



(a)



(b)

Figure 3. (a) Length variation and (b) weight variation of catfish fry reared at different stocking densities in the UFBs-RAS system.

Factors influencing size variation include fry quality (Marciano *et al*. 2018), feed intake (Qian *et al*. 2002), culture duration (Wang *et al*. 1998), behavioral traits of the species, and stocking densities (Tibile *et al*. 2016). Barbosa *et al*. (2006) further emphasized that heterogeneity in growth is often due to competition for feed, which becomes more pronounced as density increases.

Based on these findings, UFBs-RAS demonstrates potential as a promising solution to improve size uniformity during the early nursery phase of catfish fry rearing. Enhanced uniformity is expected to increase product quality and market value.

CONCLUSION

The present study demonstrated that stocking density significantly influenced the size variation of catfish fry reared in the UFBs-RAS system, while survival rate and condition factor were not significantly affected. Among the treatments, a density of 25 fish individuals/L provided the best outcomes, with a survival rate of 98.1%, length variation of 13.08±1.89%, weight variation of 25.70±2.76%, and a condition factor of 0.73±0.03. These results indicate that the UFBs-RAS system can serve as a strategic approach to maintain optimal water quality and improve the efficiency of intensive catfish fry rearing under high stocking densities.

ACKNOWLEDGEMENTS

The authors would like to express their gratitude to the Rector of Universitas Padjadjaran for the research grant provided and to the Head of the PUI-PT Nano Powder Functional for granting permission to use the laboratory facilities to conduct this research.

REFERENCES

Adharani N, Soewardi K, Syakti AD, Hariyadi S. 2016. Manajemen Kualitas Air dengan Teknologi Bioflok: Studi Kasus Pemeliharaan Ikan Lele (*Clarias* sp.). *Jurnal Ilmu Pertanian Indonesia*. 21(1): 35–40. DOI: https://doi.org/10.18343/jipi.21.1.35.

Ahmed N, Thompson S, Glaser M. 2019. Global Aquaculture Productivity, Environmental Sustainability, and Climate Change Adaptability. *Environmental Management*. 63(2): 159–172. DOI: https://doi.org/10.1007/s00267-018-1117-3.

Aidos L, Cafiso A, Serra V, Vasconi M, Bertotto D, Bazzochhi C, Radaelli G, Di Giancamillo A. 2020. How Different Stocking Densities Affect Growth and Stress Status of *Acipenser baerii* Early Stage Larvae. *Animals*. 10(8): 1–15. DOI: https://doi.org/10.3390/ani10081289.

Almazán-Rueda P, Schrama JW, Verreth JAJ. 2004. Behavioural Responses Under Different Feeding Methods and Light Regimes of the African Catfish (*Clarias gariepinus*) Juveniles. *Aquaculture*. 231(1–4): 347–359. DOI: https//doi.org/10.1016/j.aquaculture.2003.11.016.

Badan Standardisasi Nasional. 2014. SNI 6484.4-2014. Ikan Lele Dumbo (*Clarias* sp). Jakarta

Barasa JE, Ouma DF. 2024. Towards Sustainability in Seed Supply for African Catfish, *Clarias gariepinus* (Burchell 1822) Culture in Kenya: Lessons from Asian Catfishes Industry. *Aquaculture Research*. 2024(1): 1–21. DOI: https://doi.org/10.1155/2025/1341858.

Barbosa JM, Brugiolo SSS, Carolsfeld J, Leitao SS. 2006. Heterogeneous Growth in Fingerlings of the Nile Tilapia *Oreochromis niloticus*: Effects of Density and Initial Size Variability. *Brazilian Journal of Biology*. 66(2a): 537–541. DOI: https://doi.org/10.1590/S1519-69842006000300020.

Barcellos LJG, Volpato GL, Barreto RE, Cordebella I, Ferreira D. 2011. Chemical Communication of Handling Stress in Fish. *Physiology & Behaviour*. 103(3–4): 372–375. DOI: https://doi.org/10.1016/j.physbeh.2011.03.009.

Baßmann B, Hahn L, Rebl A, Wenzel LC, Hildebrand MC, Verleih M, Palm HW. 2023. Effects of Stocking Density, Size, and External Stress on Growth and Welfare of African Catfish (*Clarias gariepinus* Burchell, 1822) in a Commercial RAS. *Fishes*. 8(2): 74. DOI: https://doi.org/10.3390/fishes8020074.

Bernardi F, Zadinelo IV, Alves HJ, Meurer F, Dos Santos LD. 2018. Chitins and Chitosans for the Removal of Total Ammonia of Aquaculture Effluents. *Aquaculture*. 483: 203–212. DOI: https://doi.org/10.1016/j.aquaculture.2017.10.027.

Burggren WW, Arriaga-Bernal JC, Mendez-Arzate PM, Mendez-Sanchez JF. 2019. Metabolic Physiology of the Mayan Cichlid Fish (*Mayaheros uropthalmus*): Re-examination of Classification as an Oxyconformer. *Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology*. 237: 110538. DOI: https://doi.org/10.1016/j.cbpa.2019.110538.

Carbonara P, Dioguardi M, Cammarata M, Zupa W, Vazzana M, Spedicato MT. 2019. Basic Knowledge of Social Hierarchies and Physiological Profile of Reared Sea Bass *Dicentarchus labrax* (L.). *PLoS ONE*. 14(1): 1–16. DOI: https//doi.org/10.1371/journal.pone.0208688.

Diao W, Jia R, Hou Y, Dong Y, Li B, Zhu J. 2023. Effects of Stocking Density on the Growth Performance, Physiological Parameters, Antioxidant Status, and Lipid Metabolism of *Pelteobagrus fulvidraco* in the Integrated Rice-Fish Farming System. *Animals*. 13(11): 1721. DOI: https://doi.org/10.3390/ani13111721.

Espinoza-Ramos LA, Quispe-Mayta JM, Chili-Layme V, Nande M. 2022. Effect of Stocking Density on Growth, Feed Efficiency, and Survival in Peruvian Grunt *Anisotremus scapularis* (Tschudi 1846): From Fingerlings to Juvenile. *Aquaculture Journal*. 2(1): 13–22. DOI: https://doi.org/10.3390/aquacj2010002.

Fulton TW. 1911. *The Sovereignty of the Sea*. Edinburgh and London (GB): William Blackwood and Sons.S

Goddard S. 1996. *Feed Management in Intensive Aquaculture*. New York (US): Chapman and Hall.

Indriastuti CE, Ratnawati B, Budiharto IW. 2022. Survival and Growth Performance the Catfish *Clarias gariepinus* in High Density Nurseries Using Recirculating Aquaculture System (RAS). *E3S Web of Conferences*. 348: 1–9. DOI: https://doi.org/10.1051/E3sconf/202234800013.

Jewel MAS, Ara J, Haque MA, Hossain MA, Noor NM, Das SK. 2023. Effect of Stocking Density on the Growth, Body Composition, and Blood Parameters of Cage-reared Gangetic Mytus Catfish (*Mystus cavasius*). *Aquaculture Reports*. 28: 101428. DOI: https://doi.org/10.1016/j.aqrep.2022.101428.

Kelana PP, Subhan U, Suryadi IBB, Haris RBK. 2021. Studi Kesesuaian Kualitas Air untuk Budidaya Ikan Lele Dumbo (*Clarias gariepinus*) di Kampung Lauk Kabupaten Bandung. *Aurelia Journal: Authentic Research* *of Global Fisheries Applications Journal*. 2(4): 159–164. DOI: http://dx.doi.org/10.15578/aj.v2i2.9887.

Kesuma BW, Budiyanto B, Brata B. 2019. Efektifitas Pemberian Probiotik dalam Pakan terhadap Kualitas Air dan Laju Pertumbuhan pada Pemeliharaan Lele Sangkuriang (*Clarias gariepinus*) Sistem Terpal. *Naturalis: Jurnal Penelitian Pengelolaan Sumber Daya Alam dan Lingkungan*. 8(2): 21–27. DOI: https://doi.org/10.31186/Naturalis.8.2.9206.

[KKP] Kementerian Kelautan dan Perikanan Republik Indonesia. 2020. Produksi Perikanan Budidaya Menurut Komoditas Utama Tahun 2020. https://portaldata.kkp.go.id/portals/data-statistik/prod-ikan/tbl-statis/d/53. [10 Januari 2025].

Kordi K, Ghufron MH. 2000. *Budidaya Ikan Nila*. Semarang (ID): Dahara Prize.

Kusumawati AA, Suprapto D, Haeruddin H. 2018. Pengaruh Ekoenzim terhadap Kualitas Air dalam Pembesaran Ikan Lele (*Clarias gariapinus*). *Management of Aquatic Resources Journal* (*MAQUARES*). 7(4): 307–314. DOI: https://doi.org/10.14710.Marj.V7i4.22564.

Li J, Huang K, Huang L, Hua Y, Yu K, Liu T. 2020. Effects of Dissolved Oxygen on the Growth Performance, Haematological Parameters, Antioxidant Responses, and Apoptosis of Juvenile GIFT (*Oreochromis niloticus*). *Aquaculture Research*. 51(8): 3079–3090. DOI: https://doi.org/10.1111/Are.14684.

Li L, Shen Y, Yang W, Xu X, Li J. 2021. Effect of Different Stocking Densities on Fish Growth Performance: A Meta-Analysis. *Aquaculture*. 544: 737152. DOI: https://doi.org/10.1016/j.aquaculture.2021.737152.

Marciano A, Tropea C, Greco LSL. 2018. Effect of Multiple Spawning on Female Reproductive Output and Offspring Quality in a Freshwater Caridean Shrimp with Direct Development. *Invertebrate Biology*. 137(1): 66–77. DOI: https://doi.org/10.1111/ivb.12206.

Martins CIM, Galhardo L, Noble C, Damsgård B, Spedicato MT, Zupa W, Beauchaud M, Kulczykowska E, Massabuau J, Carter T, *et al*. 2012. Behavioural Indicators of Welfare in Farmed Fish. *Fish Physiology and Biochemistry*. 38: 17–41 DOI: https://doi.org/10.1007/s10695-011-9518-8.

Nardocci G, Navarro C, Cortés PP, Imarai M, Montoya M, Valenzuela B, Jara P, Acuna-Castillo C, Fernandez R. 2014. Neuroendocrine Mechanisms for Immune System Regulation During Stress in Fish. *Fish & Shellfish Immunology*. 40(2): 531–538. DOI: https://doi.org/10.1016/j.fsi.2014.08.001.

Niklasson L, Sundh H, Fridell F, Taranger GL, Sundell K. 2011. Disturbance of the Intestinal Mucosal Immune System of Farmed Atlantic Salmon (*Salmo salar*), in Response to Long-Term Hypoxic Conditions. *Fish & Shellfish Immunology*. 31(6): 1072–1080. DOI: https://doi.org/10.1016/j.fsi.2011.09.011.

Olufeagba SO, Okomoda VT, Shuibu G. 2016. Embryogenesis and Early Growth of Pure Strains and Hybrids of Sharptooth Catfish *Clarias gariepinus* and Sampa *Heterobranchus longifilis*. *North American Journal of Aquaculture*. 78(4): 346–355. DOI: https://doi.org/10.1080/15222055.2016.1194926.

Perry RI, Hargreaves NB, Waddell BJ, Mackas DL. 1996. Spatial Variations in Feeding and Condition of Juvenile Pink and Chum Salmon off Vancouver Island, British Columbia. *Fisheries Oceanography*. 5(2): 73–88. DOI: https://doi.org/10.1111/j.1365-2419.1996.tb00107.x.

Qian X, Cui Y, Xie S, Lei W, Zhu X, Xiong B, Yang Y. 2002. Individual Variations in Growth, Food Intake and Activity in Juvenile Chinese Sturgeon *Acipenser sinensis* Gray. *Journal of Applied Ichthyology*. 18(4–6): 695–698. DOI: https://doi.org/10.1046/j.1439-0426.2002.00400.x.

Rosariawari F, Wahjudijanto I, Rachmanto TA. 2016. Peningkatakn Effektifitas Aerasi dengan Menggunakan *Micro Bubble Generator* (MBG). *Envirotek: Jurnal Ilmiah Teknik Lingkungan*. 8(2): 88–97.

Roy J, Terrier F, Marchand M, Herman A, Heraud C, Surget A, Lanuque A, Sandres F, Marandel L. 2021. Effects of Low Stocking Densities on Zootechnical Parameters and Physiological Responses of Rainbow

Trout (*Oncorhynchus mykiss*) Juveniles. *Biology*. 10(10): 1040. DOI: https://doi.org/10.3390/biology10101040.

Schäfer N, Matoušek J, Rebl A, Stejskal V, Brunner RM, Goldammer T, Verleih M, Korytář T. 2021. Effects of Chronic Hypoxia on the Immune Status of Pikeperch (*Sander lucioperca* Linnaeus 1758). *Biology*. 10(7): 649. DOI: https://doi.org/10.3390/biology10070649.

Setyono BDH, Baihaqi LW, Marzuki M, Atmawinata LM, Fitria S, Affandi RI. 2023. Microbubble Technology to Improve Growth of Catfish (*Clarias* sp). *Jurnal Penelitian Pendidikan IPA*. 9(9): 7373–7382. DOI: https//doi.org/Jppipa.V9i9.3433.

Sherif AH, Soliman HA, Heba, Elgharib H. 2014. Negative Impacts of Un-ionized Ammonia (NH_3) on Health Status of Cultured *Oreochromis niloticus*. *Abbasa International Journal of Aquatic*. 6(2): 319–347.

Silva VA, Trushenski J, Schwarz MH, Cavalli RO. 2020. Effects of Rearing Density on Growth, Physiological Responses and Flesh Quality in Juvenile Cobia (*Rachycentron canadum*). *Journal of the World Aquaculture Society*. 51(6): 1301–1312. DOI: https://doi.org/10.1111/jwas.12721.

Stickney RR. 2000. *Encyclopedia of Aquaculture*. Texas (US): A Wiley-Interscience Publication.

Subhan U, Iskandar, Zahidah, Joni IM. 2021. Detection of Reserve Oxygen Potential in the Present of Fine Bubbles and Its Ammonia Removal for Aquaculture Effluent. *Materials Science Forum*. 1044: 103–111. DOI: https://doi.org/10.4028/www.scientific.net/MSF.1044.103.

Sundari RS, Priyanto YA. 2017. Efisiensi Penggunaan Faktor-Faktor Produksi pada Teknologi Pendederan Ikan Lele (*Clarias* sp.) Sangkuriang. *Jurnal Teknologi Perikanan dan Kelautan*. 7(2): 199–206. DOI: https://doi.org/10.24319/jtpk.7.199-206.

Tanjung RRM, Zidni I, Iskandar, Junianto. 2019. Effect of Difference Filter Media on Recirculating Aquaculture System (RAS) on Tilapia (*Oreochromis niloticus*) Production Performance. *World Scientific News*. 118(13): 194–208.

Tibile RM, Sawant PB, Chadha NK, Lakra WS, Prakash C, Swain S, Bhagawati K. 2016. Effect of Stocking Density on Growth, Size Variation, Condition Index and Survival of Discuss, *Symphysodon aequifasciatus* Pellegrin, 1904. *Turkish Journal of Fisheries and Aquatic Sciences*. 16(2): 455–462. DOI: https://doi.org/10.4194/1303-2712-v16_2_25.

Ujjania N, Sharma LL, Balai VK. 2013. Length-Weight Relationship and Condition Factor of Indian Major Carp (*Labeo rohita* Ham, 1822) from Southern Rajasthan, India. *Applied Biological Research*. 15(2): 1–5.

Wang N, Hayward RS, Noltie DB. 1998. Variation in Food Consumption, Growth, and Growth Efficiency Among Juvenile Hybrid Sunfish Held Individually. *Aquaculture*. 167(1-2): 43–53. DOI: https://doi.org/10.1016/S0044-8486(98)00299-3.

Warwick EJ, Astuti JM, Hardjosubroto W. 1995. *Pemuliaan Ternak*. Yogyakarta (ID): Gadjah Mada University Press.

Xiao R, Wei Y, An D, Li D, Ta X, Wu Y, Ren Q. 2019. A Review on the Research Status and Development Trend of Equipment in Water Treatment Processes of Recirculating Aquaculture Systems. *Reviews in Aquaculture*. 11(3): 863–895. DOI: https://doi.org/10.1111/raq.12270.