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Comparative Analysis of pH and Dissolved Oxygen Relationships With Pacific White Shrimp (*Litopenaeus vannamei*) Growth in Aquaculture Ponds at Diponegoro University, Jepara, Central Java

Mutiara Laili Maulida Firdaus¹, Eny Heriyati^{2*}, Renita Della Puspita Sari¹, Angelia Putri Sefiyandani¹

¹Department of Marine Science, Faculty of Fisheries and Marine Science, Diponegoro University, Jl Prof. Sudharto, Tembalang, Semarang, Indonesia.

²Marine Science and Aquaculture Study Programs at Jl. Soekarno Hatta No. 02, East Kutai, East Kalimantan, Indonesia

Abstract



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Corresponding Author email:
*taufiqspj_1999@yahoo.com

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The Pacific white shrimp (*Litopenaeus vannamei*) is an important aquaculture commodity whose growth is closely associated with culture-environment conditions. This study comparatively analyzed three independent datasets from shrimp culture studies conducted at the aquaculture facilities of Diponegoro University, Jepara, Central Java. The datasets differed in culture duration, pond units, measurement schedules, and culture conditions and were therefore maintained as separate analytical units. Water-quality variables included pH and dissolved oxygen (DO), while shrimp growth was represented by Average Body Weight (ABW) and Average Daily Gain (ADG). The reported relationships were evaluated using Spearman rank correlation coefficients from each source study. DO showed a significant negative association with ABW in all three datasets, with correlation coefficients of -0.324 , -0.779 , and -0.425 , respectively. In contrast, pH-ABW relationships varied among datasets, ranging from weak positive and non-significant to significant negative and positive associations. Relationships between DO and ADG were less consistent, with only the first dataset showing a significant association. These findings indicate that the relationships between pH, DO, and shrimp growth varied according to culture context, temporal observation, and pond conditions. Therefore, water-quality correlations should be interpreted as study-specific associations rather than evidence of direct causation. Integrated and repeated monitoring of water quality and shrimp growth is recommended for more appropriate interpretation of culture-system dynamics.

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1. Introduction

Pacific white shrimp (*Litopenaeus vannamei*) is widely cultured because of its economic value, relatively rapid growth, and capacity to adapt to a range of cultural conditions. Water quality parameters significantly influence of whiteleg shrimp cultivation, such as acidity (pH) and dissolved oxygen (DO). pH is the degree of acidity or alkalinity of a liquid, indicating the concentration of hydrogen ions (H⁺). Adequate DO availability can support the life of various aquatic organisms, such as shrimp (Telaumbanua, 2025). High and low pH and DO can affect Average Body Weight (ABW) and Average Daily Growth (ADG). Therefore, regular monitoring and management of pH and DO are necessary to maintain optimal pond environmental conditions (Hertika *et al.*, 2025).

Among the various water-quality parameters routinely monitored in shrimp ponds, dissolved oxygen (DO) and pH are particularly important because they are associated with shrimp physiological processes and growth. DO is required for respiration and aerobic metabolism, while increasing shrimp biomass and organic-matter decomposition can increase oxygen demand and consequently reduce DO concentrations. pH is also an important parameter because changes in pH can affect shrimp physiological processes and growth performance. Previous studies have demonstrated the relationship between water-quality parameters and the growth of *Litopenaeus vannamei*. Pramudia *et al.* (2022) reported that water-quality dynamics, including pH and DO, were associated with vaname shrimp growth in the Millennial Shrimp Farming system. Jelinda *et al.* (2024) found that

different pH conditions resulted in differences in shrimp growth, with the highest growth observed at pH 8. Meanwhile, Shilman *et al.* (2025) reported that DO concentrations decreased to approximately 2.0 mg/L during several culture periods, while shrimp growth continued to increase throughout the observation period.

These findings indicate that pH and DO are dynamic water-quality parameters that may be associated with shrimp growth. However, the relationships between these parameters and growth may vary depending on pond conditions and environmental fluctuations. Albab *et al.* (2025) reported that DO had the strongest association with shrimp weight among the water-quality parameters examined in a traditional shrimp pond in Semarang. Therefore, further investigation is needed to examine the relationships between pH, DO, and *L. vannamei* growth under the specific pond conditions at the Marine Science Techno Park, Universitas Diponegoro, Teluk Awur, Jepara.

Although pH and DO are commonly monitored in shrimp aquaculture, their statistical relationships with shrimp growth may differ among culture units and observation periods. The three source studies were conducted in different pond units and under different observation periods at the Universitas Diponegoro aquaculture area in Jepara. These differences provide an opportunity to compare whether similar water-quality variables show consistent relationships with shrimp growth across different culture contexts. This study aims to conduct a comparative synthesis of three independent studies of *L. vannamei* culture in Jepara by comparing their culture design, pH and DO conditions, growth indicators, and Spearman correlation results. More specifically, the study compares (1) the observation period and culture units, (2) the reported pH and DO ranges and their temporal patterns, (3) ABW and ADG patterns, and (4) the correlations of pH and DO with ABW and ADG. The comparison is intended to produce a broader interpretation while preserving the original results of each thesis.

2. Material and methods

2.1 Material

The materials used in this comparative study consisted of secondary data obtained from three previous studies on Pacific white shrimp (*Litopenaeus vannamei*) cultivation at Universitas Diponegoro, Jepara, Central Java.

The data included water-quality parameters, namely pH and dissolved oxygen (DO), and shrimp growth parameters, particularly Average Body Weight (ABW). Each dataset was obtained from the respective original study and compiled for comparative analysis. The data sources, observation periods, sampling frequencies, measurement methods, and cultivation conditions were identified to establish the provenance and comparability of the datasets. Differences in data collection procedures and experimental conditions were considered when interpreting the results.

The data included water quality parameters, namely pH and dissolved oxygen (DO), as well as growth parameters, namely Average Body Weight (ABW) and Average Daily Weight Gain (ADG), obtained from different pond units and cultivation periods. Water parameter data was collected twice a day during observations every five days. Correlation tests were conducted with the obtained data, including pH and DO with ABW and ADG. The datasets were compared based on the reported Spearman correlation results without being pooled into a new statistical dataset.

2.2 Methods

2.2.1 Source studies and comparative design

This article employed a comparative synthesis approach using secondary data obtained from three independent thesis studies on *Litopenaeus vannamei* culture conducted at Universitas Diponegoro, Jepara, Central Java. The present study did not conduct additional field sampling or generate a new experimental dataset. Instead, the reported water-quality and growth results from each source study were reviewed and compared while preserving the original study-specific analytical units. Study 1 covered ponds 1A, 1B, 2A, and 2B over a 40-day culture period. Study 2 covered ponds 3A, 3B, and 3C over a 60-day culture period. Study 3 covered ponds 1C, 1D, and 2C, with observations represented across the day 5–40 culture period and with differences in pond size among units. All three studies evaluated pH and DO as water-quality variables and ABW and ADG as growth indicators. However, measurement schedules, culture conditions, and observation structures differed among the studies. Because the datasets were generated under different experimental conditions and sampling structures, they were not statistically pooled. The comparison was therefore conducted at the study level using the correlation coefficients reported in each source study.

Table 1. Comparative design of the three source studies.

Study	Period	Culture units	Main focus
Study 1	40 days	1A, 1B, 2A, 2B	DO and pH in relation to ABW and ADG
Study 2	60 days	3A, 3B, 3C	pH and DO in relation to ABW and ADG
Study 3	40 days	1C, 1D, 2C	pH and DO in ponds of different sizes

2.2.2 Water-quality and growth measurements

The three studies monitored pH and DO using pH meters and DO meters, using a random method, twice a day, in the morning and afternoon, for 40 and 60 days of observation. Then, shrimp growth was measured using ABW and ADG. In Study 1, water quality was observed twice daily throughout the 40-day period. In Study 2, water-quality measurements were taken in situ twice daily, in the morning and afternoon, and growth was observed at five-day intervals during the 60-day culture period. Study 3 collected pH, DO, ABW, and ADG observations from three ponds of different sizes during the culture period represented in the source

graphs. ABW generally represents the mean body weight of shrimp at a given sampling point, whereas ADG represents the average increase in body weight per unit of time. Because the source studies used different observation schedules and starting conditions, the absolute ABW and ADG values were interpreted within their respective studies rather than ranked as directly comparable production performance.

2.2.3 Statistical analysis

The original study used Spearman's rank correlation to evaluate the relationship between water quality variables and growth indicators. Correlation coefficients (r^2) were categorized as weak (<0.5), moderate (0.5), and strong (>0.5).

The reported significance level was used to distinguish statistically significant relationships from insignificant ones ($p < 0.05$). For the comparative synthesis, the four relationships of interest were pH–ABW, DO–ABW, pH–ADG, and DO–ADG. A pooled correlation analysis was not performed because the three datasets differed in sampling design, culture duration, pond units, and observation structure. Therefore, each reported coefficient was treated as a study-specific result. This approach prevented differences in data structure from being hidden by aggregate statistics and maintained the analytical meaning of the original studies.

2.2.4 Comparative interpretation

The comparison was organized into four steps: first, differences in study design were identified; second, pH and DO ranges and temporal patterns were compared; third, ABW and ADG patterns were summarized; and fourth, the direction, magnitude, and significance of each Spearman coefficient were compared. Interpretation was then extended to the possible influence of pond size, biomass, biological activity, aeration, feeding, and observation timing, but these factors were not statistically controlled across all three datasets.

3. Result

3.1 Comparison of study design

The three studies shared a common analytical theme but differed in duration and culture-unit configuration. Study 1 involved four ponds over 40 days, Study 2 involved three

ponds over 60 days, and Study 3 involved three ponds of different sizes over a culture period represented from day 5 to day 40. These differences are important because the same water-quality value can occur under different biomass levels, feed inputs, aeration conditions, and stages of culture.

Measurement frequency also differed. Study 1 used twice-daily water-quality observations for 40 days, while Study 2 combined twice-daily in situ measurements with growth observations every five days. Study 3 used twice-daily water-quality observations for 40 days with growth observations every five days. Therefore, the comparative coefficients should be understood as relationships generated within different temporal resolutions rather than as replicated measurements from a single standardized experiment.

3.2 Comparison of pH and DO conditions

The comparison of the three studies revealed differences in the reported pH and dissolved oxygen (DO) conditions. Study 1 recorded a pH range of 8.27–8.40 and DO concentrations of 3.52–3.76 mg L⁻¹, whereas Study 2 reported a pH range of 8.17–8.22 and DO concentrations of 4.04–4.34 mg L⁻¹. Study 3 showed a wider pH range of 7.86–8.93, while DO concentrations decreased until day 35 and subsequently increased by day 40. These findings indicate differences in the reported water-quality conditions and highlight the importance of considering temporal variation when evaluating pH and DO in shrimp ponds.

Table 2. Comparison of Reported pH and DO Conditions Across Three Studies.

Study	pH	DO	General interpretation
Study 1	8.27–8.40	3.52–3.76 mg L ⁻¹	pH was relatively stable, while DO remained below the 4 mg L ⁻¹ reference threshold.
Study 2	8.17–8.22	4.04–4.34 mg L ⁻¹	Both pH and DO were within relatively narrow ranges, with DO above the 4 mg L ⁻¹ reference threshold.
Study 3	7.86–8.93	Decreased until day 35 and increased by day 40	pH showed a wider range, while DO exhibited temporal variation during the culture period.

Using 4 mg L⁻¹ as a reference threshold, DO concentrations in Study 1 were below the threshold, whereas those in Study 2 were above it. However, these comparisons should be interpreted cautiously because the studies may differ in sampling frequency, culture duration, measurement procedures, and environmental conditions. Furthermore, the observed differences in pH and DO cannot independently establish their effects on shrimp growth without corresponding quantitative growth data and statistical analysis.

3.3 Comparison of growth performance

Study 1 reported a clear increase in ABW, reaching 14.609 g in pond 2B at day 40 (DOC 40), while the highest reported ADG was 1.031 g day⁻¹ in the same pond at DOC 15. Study 2 reported the highest ABW and ADG in unit 3C, with values of 0.0869 g and 0.0035 g day⁻¹, respectively, and the lowest performance was reported in 3A. Study 3 reported a clear increase in ABW, reaching 14.94 g in pond 2C at DOC 40, while the highest reported ADG was 1.00 g in the pond 2C at DOC 15 and pond 1C at DOC 20.

Table 3. Reported growth indicators across the three source studies.

Study	Highest reported ABW	Highest reported ADG	Observed pattern
Study 1	14.609 g (2B; DOC 40)	1.031 g day ⁻¹ (2B; DOC 15)	ABW increased; ADG fluctuated
Study 2	0.0869 g (3C)	0.0035 g day ⁻¹ (3C)	3C highest; 3A lowest
Study 3	14.94 G (2C; DOC 40)	1.00 (2C; DOC 15 & 1C; DOC 20)	ABW increased; ADG fluctuated

The absolute values should not be interpreted as a direct ranking of the three culture systems. The studies differed in initial shrimp size, culture duration, sampling structure, and pond unit. The most defensible cross-study observation is therefore the shape of the growth response: ABW generally increased with culture time, whereas ADG was more dynamic and could rise or decline between observation periods. This distinction is important because a cumulative measure and a rate measure respond differently to

short-term changes in feeding, molting, physiological condition, and sampling interval.

3.4 Comparison of Correlations Between Water Quality and Growth

The Spearman correlation analysis revealed different patterns of association between water-quality parameters and shrimp growth across the three studies. In Study 1, DO was negatively correlated with ABW ($r_2 = -0.324$, $p < 0.05$) and ADG ($r_2 = -0.640$, $p < 0.05$), whereas

the correlations between pH and both growth parameters were not statistically significant. In Study 2, pH and DO were negatively correlated with ABW ($r^2 = -0.541$ and -0.779 , respectively; $p < 0.05$), while their correlations with ADG were not statistically significant. In Study 3, pH showed

positive correlations with ABW ($r^2 = 0.591$, $p < 0.05$) and ADG ($r^2 = 0.503$, $p < 0.05$), whereas DO was negatively correlated with ABW ($r^2 = -0.425$, $p < 0.05$) but was not significantly correlated with ADG.

Table 4. Spearman's Rank Correlation Coefficients Between Water-Quality Parameters and Shrimp Growth

Study	pH-ABW	DO-ABW	pH-ADG	DO-ADG
Study 1	0.164 (NS)	-0.324 (NS)	0.190 (NS)	-0.640 (S)
Study 2	-0.541 (S)	-0.779 (S)	-0.141 (S)	-0.248 (S)
Study 3	0.591 (S)	-0.425 (S)	0.503 (S)	-0.350 (NS)

Note : Values represent Spearman's rank correlation coefficients (r^2 ABW = Average Body Weight, ADG = Average Daily Growth, S = Statistically significant ($p < 0.05$); NS = Not statistically significant ($p > 0.05$))

The differences in correlation coefficients indicate that the direction and strength of the observed associations varied among studies. However, these coefficients should be interpreted descriptively because the datasets may differ in sample size, observation period, culture conditions, and measurement procedures. The coefficients do not establish that the relationships differ statistically between studies unless a formal comparison is conducted.

The negative correlations between DO and growth in some datasets indicate that higher DO values tended to coincide with lower ABW or ADG values during the observations. These associations do not necessarily indicate that increased DO reduces shrimp growth. Other factors, including feeding conditions, molting, physiological status, and changes in biomass, may contribute to the observed patterns, but these mechanisms cannot be confirmed without corresponding measurements and further analysis. Similarly, differences between ABW and ADG correlations should not be interpreted as statistically different responses without a direct comparison test.

3.5 Temporal Patterns and Ponds-Size Effect

4. Discussion

The comparative results reveal both consistency and divergence among the correlation patterns. The consistent component refers specifically to the direction of the DO-ABW association, which was negative in all three datasets. This consistency in direction does not imply statistical equivalence in the magnitude or strength of the correlations across studies. In contrast, the pH-ABW relationship differed in direction and significance among the datasets, ranging from weak positive and non-significant in Study 1 to significant negative in Study 2 and significant positive in Study 3. These differences indicate that the observed relationships between water-quality variables and shrimp growth may depend on the environmental and methodological context in which the measurements were obtained.

The magnitude of the DO-ABW correlation also varied among studies, with coefficients of -0.324 in Study 1, -0.779 in Study 2, and -0.425 in Study 3. These values are presented descriptively because no formal statistical test of differences between correlation coefficients was performed. Therefore, the coefficient of -0.779 in Study 2 can be described as numerically larger in absolute magnitude than those of Studies 1 and 3, but it should not be interpreted as demonstrating a statistically stronger relationship between studies. Within each dataset, the coefficient represents the strength of the monotonic association between DO and ABW.

ABW and ADG represent different aspects of shrimp growth. ABW describes the average body weight of shrimp at a given observation period and can be calculated as the total shrimp biomass divided by the number of shrimp

The third study showed temporal variations in dissolved oxygen (DO), while pH remained relatively stable within the range of 7.8–9.0. DO concentrations decreased until approximately day 35 and subsequently increased by day 40. Pond 2C also exhibited greater DO fluctuations during part of the culture period. These observations indicate that pH and DO followed different patterns of variation over time.

Although these temporal patterns were observed, their relationships with shrimp growth cannot be established without further statistical analysis. Similarly, the differences in DO fluctuations between ponds should be interpreted as descriptive findings rather than evidence of a pond-size effect. Potential explanations involving pond size, water movement, and oxygen distribution remain hypothetical unless supported by measurements or additional analyses. Therefore, further investigation is needed to determine whether temporal changes in water quality and differences in pond characteristics are associated with shrimp growth performance.

sampled. In contrast, ADG represents the rate of weight gain over a specific period and can be calculated as the difference between final and initial body weight divided by the observation period. Therefore, ABW reflects cumulative growth, whereas ADG reflects the rate of growth between observation periods. The differences observed between ABW and ADG correlations should be interpreted descriptively because the datasets differed in sample size, observation period, and data structure. A statistically significant correlation does not necessarily indicate a stronger biological relationship than a non-significant correlation, particularly when sample sizes and measurement intervals differ among studies. Therefore, differences in statistical significance between ABW and ADG correlations should not be interpreted as evidence of statistically different relationships without a direct comparative statistical test.

Across the studies, ABW generally increased over the culture period, whereas ADG showed greater variation between observation periods. This pattern is consistent with the different mathematical properties of the two growth measures: ABW represents accumulated body weight, while ADG describes changes in weight over a shorter interval. Variations in feeding, molting, physiological condition, and sampling intervals may be partly associated with fluctuations in ADG; however, these factors were not directly measured in the present comparison and therefore cannot be established as the causes of the observed variation.

The observed correlations between water-quality parameters and growth should therefore be interpreted as statistical associations rather than evidence of direct biological effects. Differences in the pH-ABW, DO-ABW,

pH–ADG, and DO–ADG correlations may be partly explained by differences in temporal resolution, culture conditions, and the characteristics of the datasets used in each study. Further studies using standardized sampling intervals, adequate sample sizes, and measurements of relevant environmental and biological variables are needed to clarify these relationships. The pH results require cautious interpretation because the three studies did not show the same direction of association. A positive coefficient in one system and a negative coefficient in another does not necessarily indicate contradictory biological responses. The observed differences may reflect variation in pH range, temporal variability, sampling structure, culture conditions, and other environmental factors among the studies. Because the datasets were generated under different study designs and sampling conditions, the present analysis cannot determine whether the differences in pH–growth relationships reflect biological responses or methodological and statistical differences, including restricted pH ranges and differences in sampling structure. Within the present evidence, pH should therefore be regarded as a water-quality indicator associated with the culture environment rather than a stand-alone predictor of growth. The correlation coefficients describe associations within the respective datasets and should not be interpreted as evidence of a direct causal effect of pH on shrimp growth. Differences in the range and distribution of pH values may also influence the magnitude and direction of correlation coefficients. Previous studies provide relevant context for interpreting pH in shrimp culture. Supriatna *et al.* (2020) examined pH as part of broader water-quality conditions, whereas Jelinda *et al.* (2024) investigated different pH treatments in *Litopenaeus vannamei* culture. These studies support the relevance of pH as a component of the shrimp culture environment, but their experimental conditions and objectives differ from those of the present comparative analysis. Therefore, these references provide contextual support rather than direct evidence explaining the differences in correlation coefficients observed among the three datasets.

Aisyah *et al.* (2023) examined plankton abundance and water quality in relation to *vannamei* growth performance in intensive culture, while Fahrurrozi *et al.* (2023) focused on water-quality dynamics in intensive *L. vannamei* ponds. Pramudia *et al.* (2022) addressed shrimp growth and survival under different water-quality conditions, while Shilman *et al.* (2025) evaluated pond water quality in relation to *vannamei* growth condition. These studies provide broader context for the relevance of water-quality conditions in shrimp culture. With respect to pH, Jelinda *et al.* (2024) specifically investigated different pH conditions in *L. vannamei* culture, whereas Supriatna *et al.* (2020) examined pH as part of broader water-quality conditions. These studies provide contextual support for considering pH as an important component of the culture environment. However, their experimental conditions, study designs, and objectives differ from those of the present comparative analysis. Therefore, they should not be considered direct explanations for the differences in correlation coefficients observed among the three datasets. The present comparison contributes a cross-study perspective by examining the relationships between pH, DO, and shrimp growth across three datasets from Jepara. The comparison also indicates a methodological consideration for future research. When studies use different starting sizes, observation intervals, pond dimensions, and environmental conditions, direct comparison of absolute growth values and correlation coefficients may be difficult.

Standardizing the sampling design would make it easier to determine whether an observed correlation reflects a biological response, a temporal co-trend, or a characteristic of the culture system.

From a management perspective, the findings support the use of repeated monitoring of DO and pH to describe temporal changes in water quality during shrimp culture. Recording these parameters at regular intervals may help farmers and researchers identify changes that occur concurrently with variations in biomass, feeding practices, aeration, or other culture events. However, because the present study did not experimentally evaluate management interventions, these observations should be interpreted as a monitoring consideration rather than evidence that trend-based monitoring directly improves culture outcomes.

An integrated monitoring strategy could combine water-quality measurements with records of relevant culture-management events, such as feeding and aeration, when these variables are systematically recorded. Where possible, consistent observation schedules should be maintained across ponds to improve temporal comparability and reduce heterogeneity in the dataset. Monitoring should consider not only whether an individual measurement falls within an acceptable range, but also whether a parameter is increasing, decreasing, or fluctuating over time.

DO monitoring may be particularly relevant during periods of increasing biomass and during periods when oxygen conditions fluctuate over the daily cycle. Aeration, water circulation, organic-matter control, and feed management are relevant components of maintaining a stable culture environment; however, their specific effects were not experimentally evaluated in the present comparison. Similarly, pH monitoring remains relevant because its observed relationship with growth differed among the culture systems. Therefore, pH and DO are more appropriately considered as components of integrated water-quality monitoring rather than as isolated determinants of shrimp growth.

Future studies could evaluate whether standardized monitoring schedules improve the detection and interpretation of changes in water quality and shrimp growth. Collecting water-quality measurements together with detailed records of feeding, aeration, stocking density, biomass, and other relevant culture conditions would provide a stronger basis for distinguishing persistent relationships from short-term co-variation. The principal limitation of this study is the retrospective and comparative nature of the analysis. The three datasets were obtained from separate studies and were generated under different experimental and sampling conditions. Therefore, differences in initial shrimp size, pond characteristics, stocking density, feeding, aeration, and other environmental conditions may contribute to the observed variation among datasets.

5. Conclusions

The comparative analysis of three independent *Litopenaeus vannamei* culture datasets showed that the relationships between pH, DO, and shrimp growth varied according to culture context and observation structure. DO exhibited a consistent negative association with ABW across the three datasets, whereas its relationship with ADG was less consistent. In contrast, pH showed different directions and levels of significance across the three studies, indicating that its relationship with shrimp growth was context-dependent. These findings demonstrate that correlation coefficients should be interpreted together with culture duration, pond

characteristics, biomass development, aeration, feeding, and observation timing. The observed correlations represent statistical associations and do not establish causal relationships between water-quality variables and shrimp growth. Future studies should use standardized sampling designs and simultaneously monitor water quality, shrimp growth, biomass, and relevant culture-management variables to improve the interpretation of these relationships.

Ethics approval

No permits were required for marine biota sampling because this article uses data derived from existing aquaculture studies and does not report additional experimental sampling.

Data availability statement

The data analyzed in this comparative article are derived from three independent thesis datasets listed in the references (Firdaus, 2026; Sari, 2026; Sefiyandani, 2026). These datasets were not merged into a single new statistical dataset; the study-specific correlation coefficients and the reported values for growth and water quality were retained.

Author contributions

M.L.M.F.: Conceptualization, methodology, formal analysis, data synthesis, visualization planning, and writing – original draft. R.D.P.S.: Data curation, investigation, source-data interpretation, and writing – review & editing. A.P.S. and E.H.: Data curation, investigation, source-data interpretation, and writing – review & editing. All authors contributed to validation of the comparative interpretation and approved the manuscript.

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Declaration of competing Interest

None

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