Effect of Different Water Sources on Pond Water Quality, Growth, and Production Performance of Whiteleg Shrimp (*Litopenaeus vannamei*) in Deeba Triangle, Egypt: A Comparative Field Study

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1. Abstract

Shrimp aquaculture, particularly of *Litopenaeus vannamei*, is a vital component of global food systems and is rapidly expanding in regions like Egypt's Deeba Triangle, where variable water sources affect farm productivity. This study assessed the impact of two distinct water sources—Lake Manzala and the Mediterranean Sea—on shrimp performance and pond water quality. A comparative longitudinal field study was conducted during the 2024 production season at a private farm using standardized semi-intensive practices. Six earthen ponds were selected and grouped by water source: Group 1 (Lake Manzala, S1) and Group 2 (Mediterranean Sea, S2), each with three ponds. Farm topography, operational procedures, and management practices were evaluated via a structured checklist, routine water quality monitoring, and biweekly shrimp sampling. Results showed S2 water had higher salinity, nitrite, and total iron, while S1 had greater total hardness. Among pond groups, only total hardness differed significantly. Shrimp in Group 2 reached target weight faster, exhibited higher weekly growth rates, and survived better. These findings highlight that source water significantly influences pond water characteristics and shrimp productivity. The consistency in pond preparation and farm operations strengthens the reliability of the results, confirming water source as the primary factor affecting performance. *L. vannamei* cultured in the Mediterranean Sea outperformed those in Lake Manzala, emphasizing the importance of selecting suitable water sources. Water quality improvement and locally adapted management strategies should be prioritized for sustainable aquaculture in Egypt, especially where water source modification is constrained.

Key words: Lake Manzala; *Litopenaeus vannamei*; Production performance; Shrimp management; Shrimp Operational Procedures; Survivability.

2. Introduction

Blue foods, derived from aquaculture and capture fisheries, play a vital role in global food security, nutrition, and livelihoods. Among these, shrimp aquaculture primarily in tropical and subtropical regions represents a significant sector contributing to economic development and dietary protein supply [1,2].

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The top shrimp-producing countries globally include China, Indonesia, Vietnam, India, Ecuador, and Thailand. Shrimp aquaculture is predominantly based on penaeid species, particularly *Litopenaeus vannamei* [3]**.** In 2022, *L. vannamei* emerged as the most widely produced aquatic animal species worldwide, with an estimated 6.8 million tonnes of production primarily derived from aquaculture. This species is favored for its adaptability to various temperatures and salinities, disease resistance, and rapid growth under intensive farming conditions, including high stocking densities [4]**.**

Shrimp farming in Egypt has experienced considerable fluctuations since its inception in the early 1980s, marked by the establishment the country's first shrimp farm near Alexandria [5]. Among Egypt's key aquaculture zones is the Deeba Triangle, a strategically located region bordered by the Mediterranean Sea to the north, Lake Manzala to the south, and the Damietta Estuary to the west [6,7]. This unique geographical positioning enables the Deeba Triangle to access three distinct water sources marine and brackish namely, the Mediterranean Sea, Lake Manzala, and the Damietta Estuary, which collectively support the area's intensive aquaculture activities [8].

Several studies have investigated the environmental factors that influencing the sustainability of coastal aquaculture, particularly shrimp and fish farming in the Deeba Triangle. Findings indicate significant spatial and temporal variability in water quality, driven by mixed water sources, including brackish inflows and agricultural runoff [6-12]. Water in the region is primarily derived from interconnected irrigation and drainage canals, making it susceptible to nutrient-rich effluents and fluctuating salinity. The Deeba Triangle's semi-arid Mediterranean climate—with hot, dry summers and mild, wetted winters—results in low and irregular rainfall, requiring reliance on managed water inputs. Favorable ambient temperatures and high solar exposure support prolonged shrimp culture seasons. The surrounding landscape integrates agriculture, aquaculture, and irrigation infrastructure, contributing to environmental stressors such as limited water exchange and salinity instability [13,14]. These interconnected climatic, hydrological, and anthropogenic factors collectively shape the water quality dynamics in the Deeba Triangle, underscoring the importance of continuous monitoring and adaptive farm management.

Despite the well-documented variability in water quality across sources, comprehensive studies directly linking these differences to shrimp production outcomes remain scarce. To address this gap, the present study investigated the effects of two distinct water sources Lake Manzala and the Mediterranean Sea on pond water quality, growth parameters, and overall production performance of Whiteleg shrimp (*Litopenaeus vannamei*) in the Deeba Triangle region of Egypt.

3. Materials and Methods

3.1. Study Design, Location, and Duration

A comparative longitudinal field study assessed the effects of two different water sources on shrimp performance and water quality across a production cycle. The study was conducted during the 2024 production season at a private shrimp farm in the Deeba Triangle, Port Said, Egypt (31°21'53"N, 32°03'16"E), encompassing approximately 24 acres. The farm comprises eight varying-sized earthen ponds with an average water

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depth of 1.25 – 1.5 m, each equipped with an 8 – horsepower (HP) paddlewheel aerator. Six ponds were selected for the study and divided into two groups based on their primary water source: Group 1 (ponds A, B, and C) received water from Lake Manzala (S1), while Group 2 (ponds D, E, and F) utilized water from the Mediterranean Sea (S2). Management practices (feeding regime, stocking density, and aeration protocols) were consistent across all ponds. Pond characteristics are summarized in table (1).

3.2. Topographical, Operational, and Management Farm Assessment

A topographical assessment of the farm and its water source was conducted using a structured questionnaire (Table 2) covering the farm's location, topography, and farm operational and management practices. The questionnaire addressed aspects such as the aquaculture system, stocking density, water source, feeding type, aeration, biomedications, routine water quality assessment, production monitoring, and regular shrimp sampling. It also included farm construction and infrastructure details, such as the number, type, and area of ponds, water depth, electricity supply, aerator types and numbers, and pond layout. Pond preparation procedures were also assessed, including pond bottom drying, tilling, liming, disinfection, and fertilization practices. Production performance parameters were recorded, including the source and type of shrimp seeds (post-larvae, PLs), initial body mass, transportation, acclimation, stocking procedures, stocking density, feeding regime, and sampling routine. Finally, routine water quality monitoring and harvesting practices were evaluated, covering harvesting method and time.

3.3. Pond Preparation and Management

Before stocking, ponds were disinfected with Virocid® (0.5%) following the manufacturer's recommendations. A commercial soil conditioner (Pond Restore, Proquatic®, Elanco) was applied to improve the pond bottom quality. The ponds were stocked with 12-day-old postlarvae (PL12) of *Litopenaeus vannamei (L. vannamei)* supplied by a private shrimp hatchery in Damietta governorate. The shrimp were fed twice daily with a commercial tilapia pelleted feed containing 30% crude protein (Grand Aqua, Cairo, Egypt. No water exchange was performed during the first five weeks. Aeration was maintained throughout the entire production cycle.

3.4. Growth and Production Assessment

Growth and production performance of *L. vannamei* were evaluated using standard metrics [15]. Weight gain (g/wk) was calculated by subtracting the average initial body weight from the average final body weight and dividing the result by the total number of culture weeks.

$$\text{Weight gain (g/wk)} = \frac{\text{Average final body weight} - \text{Average initial body weight}}{\text{Number of culture weeks}}$$

Weight gain percentage (%) was determined by dividing the difference between the average final and initial body weights by the average initial body weight, then multiplying by 100 to express the result as a percentage.

$$\text{Weight gain (\%)} = \frac{\text{Average final body weight} - \text{Average initial body weight}}{\text{Average initial body weight}} \times 100$$

Additionally, survival percentage (%) was assessed by dividing the final number of shrimps at harvest by the initial number of shrimps stocked and

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multiplying by 100. These indicators provided insight into shrimp growth dynamics and overall production efficiency across the different water source groups.

$$\text{Survival Percentage (\%)} = \frac{\text{Final number of shrimp at harvest}}{\text{Initial number of shrimp at stocking}} \times 100$$

3.5. Water Quality Analysis

Water quality parameters were monitored throughout the production cycle to evaluate the physicochemical conditions of the water sources and ponds under investigation. Collection, transportation, and analysis of pond water and water sources following the standard procedures outlined by Boyd and Tucker [16]. Spot measurements of temperature and pH were taken using a PH-208 pH/mV meter (Lutron Electronic, Taiwan), and salinity was recorded using a YK-31SA salt meter (Lutron Electronic, Taiwan). Temperature, salinity, pH, total ammonia nitrogen (TAN), nitrite-N, phosphorus, total iron, and chlorophyll-a were monitored biweekly. In contrast, total hardness and alkalinity were assessed once monthly. Total ammonia nitrogen (Phenate method) and total iron (Phenanthroline method) were determined calorimetrically using a UNICO 1200 Series spectrophotometer (United Products & Instruments, Inc.), following the standard procedures described by Baird et al. [17]. Nitrite-N, phosphorus, and chlorophyll-a were also measured calorimetrically according to Boyd and Tucker [15]. Total hardness and alkalinity were quantified via titration methods, as described in the same reference. Samples were transported in an icebox and analyzed in the Laboratory of Veterinary Hygiene and Management, Faculty of Veterinary Medicine, Cairo University, Egypt.

3. 6. Statistical Analysis

Shapiro-Wilk and Levene's tests were used to check data normality and equality of variances, respectively. Differences in water quality parameters between the two sources: S1 (Lake Manzala) and S2 (the Mediterranean Sea); and pond groups: Group 1 (n=3) and Group 2 (n=3), were analyzed using a Linear Mixed-Effects Model. Meanwhile, growth and production data between pond groups, Group 1 (n=3) and Group 2 (n=3), were analyzed with a *t*-test. All statistical analyses were performed using SAS® (version 9.4; SAS Institute, Cary, North Carolina, USA). Data were presented as mean ± standard deviation (*SD). P*-values < .05 were considered to indicate significant differences.

4. Results

4.1. Water Quality Analysis for Water Sources (Lake Manzala and The Mediterranean Sea)

Water quality parameters of the two water sources supplying the shrimp farm S1 (Lake Manzala) and S2 (the Mediterranean Sea) are summarized in table (3). Statistical comparisons were conducted, with differences considered significant at $p < 0.05$. S2 exhibited significantly higher salinity levels (44.19 ± 6.02 ppt) than S1 (41.13 ± 3.24 ppt; p = 0.0024). Nitrite-N concentrations were also significantly greater in S2 (0.0030 ± 0.0004 mg/L) than in S1 (0.0017 ± 0.0010 mg/L; p < 0.0001). Moreover, total iron content was significantly elevated in S2 (0.79 ± 0.34 mg/L) compared to S1 (0.29 ± 0.18 mg/L; p < 0.0001). In contrast, S1 showed a significantly higher total hardness concentration (6,646.64 ±

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1,707.99 mg $CaCO_3$/L) relative to S1 (6,061.06 ± 1,861.99 mg $CaCO_3$/L; $p < 0.0001$). No significant differences were observed between the two water sources for water temperature, pH, total ammonia nitrogen, phosphorus, total alkalinity, and chlorophyll-a concentrations ($p > 0.05$).

4.2. Water Quality Analysis for Farm Pond Groups

Water quality parameters were assessed in six shrimp ponds divided into two groups according to their water sources: Group 1 (n=3) received water from Lake Manzala (S1), and Group 2 (n=3) received water from the Mediterranean Sea (S2). The measured parameters are summarized in table (4). Statistical analysis indicated a significant difference ($p < 0.05$) in total hardness between the two groups.

Group 1 exhibited significantly higher total hardness values, with a mean concentration of 8,680.98 ± 596.72 mg $CaCO_3$/L, compared to Group 2, which had a mean of 7,320.65 ± 1,798.89 mg $CaCO_3$/L ($p = 0.0098$). Apart from total hardness, no statistically significant differences were observed between Groups 1 and 2 for other water quality parameters.

4.3. Growth And Production Assessment

Table (5) presents the growth and production indices of Whiteleg shrimp (Litopenaeus vannamei) reared in the two pond groups, Group 1 and Group 2. Statistical significance was considered at $p < 0.05$.

No significant differences were observed between Group 1 and Group 2 in pond area, stocking density, and initial body weight. However, the culture period differed significantly, with Group 2 reaching the target final body weight earlier (145.00 ± 12.77 days) than Group 1 (191.33 ± 9.24 days). Weight gain per week was also significantly higher in Group 2 (0.82 ± 0.11 g/wk) compared to Group 1 (0.56 ± 0.05 g/wk). Furthermore, Group 2 showed a significantly higher survival percentage (43.33 ± 2.52%) than Group 1 (30.00 ± 2.00%). No significant differences were found between the two groups regarding weight gain (%), final body weight, or final biomass per hectare.

5. Discussion

Routine monitoring of physical water quality parameters, combined with an assessment of farm topography, operational protocols, and management practices, alongside biweekly shrimp sampling, constitutes a sound aquaculture approach. This integrated strategy supports adaptive management, enabling timely responses to environmental stressors and biological performance indicators.

The investigated shrimp farm is in the Deeba Triangle, Port Said, Egypt. The Deeba Triangle is a significant marine aquaculture zone in Egypt characterized by flat, low-lying terrain with clay-silt soils of moderate permeability, typical of reclaimed deltaic lands. Such soil properties are advantageous for shrimp farming, offering good water retention while allowing sufficient drainage, and are frequently recommended for earthen pond aquaculture systems [18]. The selection of this region aligns with broader trends in aquaculture development, which often targets coastal or deltaic areas due to their accessibility to water sources and suitability for infrastructure [19]. The farm operates semi-intensive earthen ponds, a production model widely adopted in developing countries to balance productivity and environmental impact [19]. Pond preparation included bottom drying, a critical step in reducing organic matter accumulation and disrupting pathogen cycles, consistent with

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established best practices [21]. However, the absence of tiling, liming, and fertilization could limit improvements in pond sediment quality and reduce natural primary productivity, which may necessitate greater reliance on formulated feeds [22]. Disinfection was achieved using Virocid®, a widely used commercial product with proven efficacy against a broad spectrum of pathogens when applied as recommended by the manufacturer [23]. This measure helps minimize microbial load before stocking, thereby enhancing biosecurity. Post-larvae (PLs) were sourced from a nearby hatchery in Damietta, ensuring short transport times and minimizing stress factors known to influence early-stage survival and performance [24]. Although stocking was conducted directly into grow-out ponds without a nursery phase, PLs were acclimated to pond conditions upon arrival, which mitigates osmotic shock and improves survival chances [25]. Group 2 (Mediterranean Sea, S2) exhibited a slightly higher initial mean weight (0.020 ± 0.000 g) compared to Group 1 (Lake Manzala, S1: 0.010 ± 0.010 g), potentially influencing early growth dynamics under comparable management conditions. Uniformity in stocking density, feeding regime, and aeration across all ponds was maintained to ensure valid comparisons between the two water sources. Commercial tilapia feed (30% crude protein) is commonly observed in Egyptian shrimp aquaculture. However, it should be continuously evaluated for species-specific adequacy [20]. Aeration, achieved using 8-horsepower paddlewheel aerators per pond, is a standard approach in semi-intensive systems and is essential for maintaining dissolved oxygen levels, especially under warm climatic conditions [26].

Our comparative study of the source water quality revealed that the Mediterranean Sea (S2) had higher salinity levels, nitrite, and total iron. In contrast, Lake Manzala (S1) had greater total hardness (Table 2). For ponds' water quality, total hardness was significantly higher in group 1 ponds, which received water from Lake Manzala (Table 3). Water temperatures for sources (S1: 29.78 ± 2.87, S2: 29.66 ± 3.34 ◦C) and ponds (Group 1: 30.22 ± 1.43, Group 2: 30.27 ± 1.52 ◦C) were within the optimum range for *L. vannamei* growth, 25-32 °C [27,28]**.** This finding was also reported by several studies [6,29,30]. *L. Vannamei* is known as an Euryhaline species [31]. However, the optimum salinity range for growth and production is 15-25 ppt [17]. In our study, the lowest salinity observed was (41.13 ± 3.24 ppt) in S1, and the highest was (50.38 ± 3.78 ppt) in Group 1. El-Mezayen et al. [8] reported that the average salinity measured during 2014 to 2015 in the same study area was (20.12 ± 8.57 ppt). This increase in salinity could be attributed to the rising temperature as a prominent climate change impact on the northern coast [6]. Also, it may be due to saltwater intrusion from the Mediterranean Sea due to rising sea levels [28]. Mahmoud et al. [11] confirmed the salinity fluctuation in Lake Manzala in the last decades. In our results, higher ammonia levels (> 0.1 mg/L NH_3-N) likely resulted from afternoon sampling, when increased temperature and pH raise toxic unionized ammonia (NH_3) concentrations due to natural daily fluctuations [18]. S2 (the Mediterranean Sea) showed significantly higher levels of nitrite, but it was within the normal range <0.005 ppm [32]. Furthermore, it showed significantly higher levels of total iron (S1: 0.29 ± 0.18, S2: 0.79 ± 0.34 ppm, $p < .0001$). It seems possible that this result is due to heavy metal pollution of the Mediterranean Sea along the Egyptian coast due to agricultural, industrial,

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domestic wastes, harbor activities, as well as the Nile River's Rosetta and Damietta drainage into the Mediterranean coast [33]. No research had mentioned a reference range for total iron concentrations in the culture water of *L. vannamei*; existing studies focus on iron supplementation through diet rather than iron levels in water [34,35]. Total hardness was higher in S1 (Lake Manzala) and the corresponding ponds (Group 1) (S1: 6,646.64 ± 1,707.99, Group 1: 8,680.98 ± 596.72 mg CaCO3/L). This finding is consistent with [36, 37]. While far above those Colón et al. [38] observed, the total hardness was about 340 mg $CaCO_3$/L in low-salinity cultured shrimp. This difference can be attributed to soil characteristics among different geographical areas. Another possible explanation is that the salinity level may be associated with total hardness. The total hardness of seawater is about 6500 mg/L $CaCO_3$, while freshwater's is up to 400 mg/L $CaCO_3$ [18]. Other measured water quality parameters were within the acceptable level for *L. vannamei* culture.

The comparison of the growth and production performance of *L. vannamei* cultured in these water quality profiles revealed that group 2 ponds (n=3, water source the Mediterranean Sea) had gained target body weight in a shorter culture period, with higher weight gain g/wk and survival percentage (Table 5). The average initial body weight of the seedstock (PL12) used in this study was not statistically different (Group 1: 0.010 ± 0.010, Group 2: 0.020 ± 0.000 g, $p < .0906$). This weight was also reported by Mirzaei et al. [39]. But not consistent with other studies [30,40]. This inconsistency may be due to the quality of the broodstocks and different hatchery management practices [39]. The final body weight was (Group 1: 15.37 ± 2.03, Group 2: 16.93 ± 0.80 g, $p < .2839$). Like the findings of Ghosh et al. [41]. These results contradict Eid et al. [30], who reported a final body weight of 40 g after a 120-day culture period of *L. vannamei* in a Deeba Triangle farm. Spatial water quality variance could explain this difference [8]. The most important finding of this study is the notably low survival percentage observed (Group 1: 30.00 ± 2.00, Group 2: 43.33 ± 2.52 %, $p < .0020$). Our data contrasts with the earlier findings of Eid et al [30], who reported a survival percentage of 70%. Survival rates reported in the literature vary widely. Sadek and Nabawi [42] reported a survival percentage above 90%. It could be explained by the initial cultivation of juvenile *L. vannamei* rather than postlarvae and lower salinity levels than those observed in our study. The postlarval stages of *L. vannamei* exhibit reduced immunity, which leads to high mortality rates [43]. In our study, all recorded hardness levels were above the acceptable level for L. vannamei, which may explain the reduced survival percentage [36,37].

The main strength of our study is its focus on *L. vannamei*, a species increasingly important for aquaculture in the Egyptian Mediterranean coastal zone, providing valuable baseline data on growth and survival. However, limitations include not measuring key water quality parameters like dissolved oxygen, heavy metals, and pollution indicators. Additionally, sampling frequency was restricted. Future research should include a more thorough assessment of water quality, such as hardness, to understand better how these factors influence the reduced survival rates. Exploring nursery rearing and polyculture systems could also offer practical strategies to enhance shrimp production and sustainability [41,44,45].

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6. Conclusions

Consistent pond preparation, feeding, and management confirmed that variations in L. vannamei performance were driven by differences in water quality between Lake Manzala and the Mediterranean Sea. Superior growth in seawater underscores its favorable physicochemical profile for shrimp health and production. Water quality emerges as a critical determinant of aquaculture success; thus, in contexts where seawater access is limited, strategies should focus on enhancing current water sources and applying site-specific management to maximize sustainability and productivity.

Conflict of interest: Nothing to declare
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Table (1): Management and operation data of the investigated pond grouped by their water source

Group	Pond	Water source	Stocking date	Area (ha)	Stocking density (PLs/m2)	Harvesting
1	A	S1	17/5/2024	1.02	12.7	5/12/2024
1	B	S1	3/6/2024	1.16	8.2	6/12/2024
1	C	S1	3/6/2024	0.56	12.5	6/12/2024
2	D	S2	16/5/2024	0.54	18.5	11/10/2024
2	E	S2	16/5/2024	0.66	15.1	19/10/2024
2	F	S2	17/5/2024	1.00	9.5	25/9/2024

Ponds are divided into two groups based on water sources: S1 (Lake Manzala) and S2 (the Mediterranean Sea)

Table 2: General overview and topographical findings of the farm investigated

Overview and topographical data	Result
	1. Farm location and topography
Farm location	Deeba Triangle, Port Said, Egypt (31°21'53"N, 32°03'16"E)
Environmental context	The area features flat, low-lying terrain with clay-silt soils of moderate permeability, typical of reclaimed deltaic lands
Water source	Lake Manzala (S1) for Group 1 (ponds A, B, and C) The Mediterranean Sea (S2) for Group 2 (ponds D, E, and F)
	2. Pond preparation procedure
Pond bottom drying	Performed
Tilling	Not performed
Liming	Not performed
Disinfection	Virocid® following the manufacturer's recommendations
Fertilization	Not performed
	3. Farm stocking, operational, and management practices
Aquaculture system	Semi-intensive earthen ponds
Source of PLs	Private shrimp hatchery in Damietta governorate
Initial body weight (g)	Group 1 had a mean value of 0.010 ± 0.010, whereas Group 2 had 0.020 ± 0.000 (values presented as mean ± SD) Table (5)
Transportation of PLs	Transportation of post-larvae was facilitated by the hatchery's proximity to the farm
Acclimation of PLs	Post-larvae were acclimated to pond water after transport to reduce stress.
Stocking procedure	Post-larvae were stocked directly into grow-out ponds without an intermediate nursery phase
Stocking density	Ponds' stocking density is presented in Table (1)
Feeding	Commercial tilapia pelleted feed containing 30% crude protein (Grand Aqua, Cairo, Egypt
Aeration	8-horsepower (HP) paddlewheel aerator for each pond
Biomedications	Commercial soil conditioner (Pond Restore, Proquatic®, Elanco)
Routine water quality monitoring	Physical water quality parameters (temperature, salinity, pH) were measured routinely
Regular shrimp sampling	A random shrimp sample is taken biweekly for growth monitoring.
	4. Harvesting
Harvesting method	Each pond was harvested separately with a single, complete harvest at the end of its production cycle.
Timing	Ponds' harvesting date is presented in Table (1)

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Table 3: Water quality parameters were measured in the two water sources supplying the shrimp farm under study: S1 (Lake Manzala) and S2 (the Mediterranean Sea)

Parameter	S1 (Lake Manzala)		S2 (the Mediterranean Sea)		Comparison	
	mean ± *SD*	min–max	mean ± *SD*	min–max	z-value	*P*-value
Water temperature (°C)	29.78 ± 2.87	24.00–34.00	29.66 ± 3.34	23.00–34.00	0.64	.5201
Salinity (ppt)	41.13 ± 3.24	35.00–46.00	44.19 ± 6.02	30.00–52.00	3.03	**.0024**
pH	8.58 ± 0.15	8.30–8.80	8.61 ± 0.26	8.00–8.90	0.96	.3356
Total ammonia nitrogen (mg/L)	0.21 ± 0.15	0.06–0.47	0.18 ± 0.18	0.05–0.51	0.26	.7966
Nitrite-N (mg/L)	0.0017 ± 0.0010	0.0006–0.0027	0.0030 ± 0.0004	0.0027–0.0033	5.03	**<.0001**
phosphorus (mg/L)	0.05 ± 0.06	0.01–0.15	0.03 ± 0.02	0.01–0.05	1.03	.3040
Total iron (mg/L)	0.29 ± 0.18	0.04–0.60	0.79 ± 0.34	0.48–1.27	4.08	**<.0001**
Total hardness (mg $CaCO_3$/L)	6,646.64 ± 1,707.99	3,683.68–8,008.00	6,061.06 ± 1,861.99	3,323.32–7,407.40	7.84	**<.0001**
Total alkalinity (mg $CaCO_3$/L)	219.44 ± 44.44	168.00–286.00	182.10 ± 29.62	152.00–214.00	1.38	.1685
Chlorophyll-a (µg/L)	58.91 ± 34.23	35.70–126.14	38.79 ± 16.86	26.18–67.83	1.35	.1762

Data are presented as mean ± standard deviation (*SD*), minimum (min) measurement, and maximum (max) measurement; Bold values indicate a statistically significant difference ($p < .05$)

Table 4: Water quality parameters in six ponds, grouped by water source

Parameter	Group 1 (3 ponds)		Group 2 (3 ponds)		Comparison	
	mean ± *SD*	min–max	mean ± *SD*	min–max	z-value	*P*-value
Water temperature (°C)	30.22 ± 1.43	28.00–33.00	30.27 ± 1.52	27.50–33.00	0.83	.4074
Salinity (ppt)	50.38 ± 3.78	42.00–55.00	47.71 ± 4.35	37.00–54.00	1.44	.1500
pH	8.64 ± 0.16	8.30–8.90	8.66 ± 0.19	8.30–9.00	0.21	.8308
Total ammonia nitrogen (mg/L)	0.21 ± 0.22	0.03–1.12	0.14 ± 0.10	0.02–0.37	1.08	.2807
Nitrite-N (mg/L)	0.0015 ± 0.0013	0.0001–0.0035	0.0194 ± 0.0328	0.0024–0.0686	1.32	.1879
phosphorus (mg/L)	0.06 ± 0.13	0.00–0.59	0.02 ± 0.01	0.01–0.04	0.70	.4815
Total iron (mg/L)	0.31 ± 0.29	0.04–1.18	0.37 ± 0.34	0.07–1.43	0.55	.5819
Total hardness (mg $CaCO_3$/L)	8,680.98 ± 596.72	7,607.60–9,629.62	7,320.65 ± 1,798.89	3,603.60–9,269.26	2.58	**.0098**
Total alkalinity (mg $CaCO_3$/L)	208.00 ± 42.81	148.00–278.00	191.03 ± 31.22	152.00–258.40	1.00	.3160
Chlorophyll-a (µg/L)	40.80 ± 14.22	23.80–64.60	27.14 ± 25.45	0.00–88.06	1.02	.3064

Group 1 – Lake Manzala (S1), Group 2 – Mediterranean Sea (S2).

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Table 5: Growth and production indices (mean ± SD, min–max) of *Litopenaeus vannamei* reared in six ponds with two water sources

Index	Group 1 (3 ponds)		Group 2 (3 ponds)		Comparison	
	mean ± *SD*	min–max	mean ± *SD*	min–max	*t*-test	*P*-value
Pond area (ha)	0.91 ± 0.32	0.56–1.16	0.73 ± 0.24	0.54–1.00	0.79	.4727
Stocking density (PLs/m^2)	11.13 ± 2.56	8.18–12.72	14.37 ± 4.55	9.50–18.52	1.07	.3431
Initial body weight (g)	0.010 ± 0.010	0.010–0.020	0.020 ± 0.000	0.020–0.020	2.22	.0906
Culture period (d)	191.33 ± 9.24	186.00–202.00	145.00 ± 12.77	131.00–156.00	5.09	**.0007**
Weight gain (g/wk)	0.56 ± 0.05	0.50–0.60	0.82 ± 0.11	0.72–0.93	3.84	**.0184**
Weight gain (%)	229,034.15 ± 102,608.77	112,943.48–307,592.31	98,334.78 ± 18,046.78	78,160.87–112,943.48	2.17	.0955
Survival (%)	30.00 ± 2.00	28.00–32.00	43.33 ± 2.52	41.00–46.00	7.18	**.0020**
Final body weight (g)	15.37 ± 2.03	13.33–17.39	16.93 ± 0.80	16.00–17.39	1.24	.2839
Final biomass (kg/ha)	524.46 ± 190.83	327.02–707.90	1,039.8 ± 280.23	760.00–1,320.45	2.63	.0580

Group 1 received water from S1 (Lake Manzala) and Group 2 from S2 (the Mediterranean Sea). Bold values indicate a statistically significant difference ($p < .05$)

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