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Effect of water salinity on growth performance and survival of *Acetes vulgaris* Hansen, 1919 (Crustacea, Decapoda, Sergestidae)

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Abstract

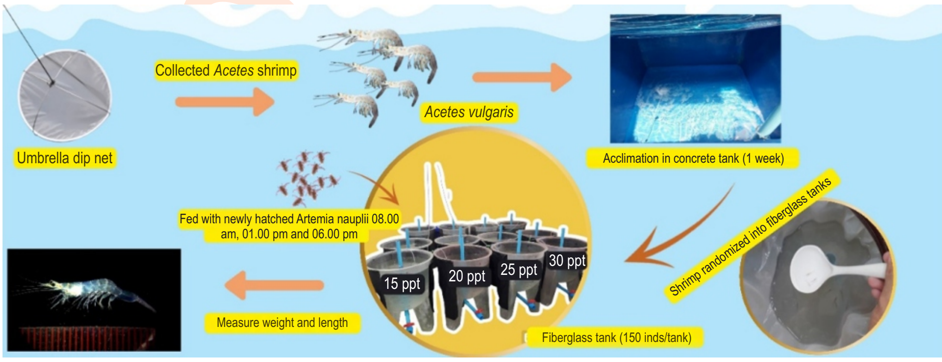
Aim: The sergestid shrimp *Acetes vulgaris* has been a significant fishery species in the estuaries and coastal waters of the Pang-Rad River in Rayong Province, Thailand. In nature, this species can tolerate and thrive across a broad range of salinity levels. The aim of this study was to compare the growth and survival of *A. vulgaris* under various salinity levels to identify the optimal salinity for its cultivation.

Methodology: Four salinity levels: 15, 20, 25 and 30 PSU were investigated in this study. Following one-week acclimi, the shrimp were randomly distributed into one of the twelve 100 m^3 fiberglass tanks, each containing 70 m^3 water. The shrimp were fed newly hatched *Artemia* nauplii thrice a day at 8:00 am, 1:00 pm and 6:00 pm. Twenty individuals shrimp were randomly collected to determine the growth performance immediately before being allocated to the experiment tanks and every two weeks during the experimental period. The experiment lasted for 70 days.

Results: After 70 days of culture, the mean weight of the shrimp increased from 14.17±4.10 to 55.59±15.92, 61.00±20.18, 49.56±17.80 and 58.02±23.47 mg at 15, 20, 25 and 30 PSU salinity levels. The mean length of the shrimp increased from 17.98±1.58 to 27.39±2.50, 28.05±3.50, 25.79±3.50 and 27.25±4.35 mm at 15, 20, 25 and 30 PSU salinity levels. These results suggest that the growth rates of shrimp reared at four tested salinity levels were not significantly different ($p>0.05$). The highest survival rate (77.78%) was noticed at 15 PSU salinity, while the lowest (63.33%) at 25 PSU, however, this difference was in significant ($p>0.05$). The results showed that *A. vulgaris* can tolerate a wide range of salinity levels and adapt well to salinity changes.

Interpretation: The findings of this study indicated that growth and survival of *A. vulgaris* were not compromised at 15 to 30 PSU salinity range. This in sights into the culture of *Acetes* shrimp at different salinities are reported for first time. This study forms a baseline for the further advancement in the aquaculture and conservation of *Acetes* shrimps.

Key words: *Acetes vulgaris*, Growth performance, Sergestid shrimp, Salinity



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Introduction

Sergestid shrimp belongs to genus *Acetes* H. Milne Edwards, 1830 (Crustacea, Decapoda, Sergestidae) are small and nearly transparent (Wong *et al.,* 2015). They swim in large numbers in the water column and their average length varies from 10 to 40 mm (Omori, 1975). *Acetes* shrimp live in tropical and subtropical estuaries and coastal waters (Xiao and Greenwood, 1993; Hanamura, 1999; Amin *et al.,* 2009), and are a vital part of the marine food chain (Xiao and Greenwood, 1992; Oh *et al.,* 2011), linking phytoplankton, zooplankton and higher-level animals in the trophic system (Santos *et al.,* 2015). *Acetes* shrimps provide important fishery resources for some countries (Mantiri *et al.,* 2012) and are used as a food or shrimp paste (Omori, 1978), as live feed for crustacean larvae (Chen and Chen, 1999) and fishes like seahorses in aquaculture (Job, 2002; Teh *et al.,* 2018). Furthermore, *Acetes* fisheries provide livelihoods for coastal communities in several Asian countries, including Thailand (Saengkaew *et al.,* 2023). While this genus has been studied for centuries, most research have focused on their taxonomy, distribution and population (Amin *et al.,* 2009, Amin *et al.,* 2011; Amani *et al.,* 2011; Metillo, 2011).

Studies on the environmental factors affecting *Acetes* aquaculture have been rarely investigated. Salinity is a fundamental environmental factor affecting the survival and growth of organisms living in estuaries, brackish waters and coastal habitats (Levinton, 2001; An *et al.,* 2021). In Thailand, the sergestid shrimp, *Acetes vulgaris*, can be found in estuaries and mangroves (Tangkrock-olan *et al.,* 2019). This species has been specifically found on sandy and muddy bottoms in coastal marine waters and estuaries along the Pang Rad River in Rayong Province (Phudhom *et al.,* 2024). In nature, *A. vulgaris* can survive and grow in different salinity levels. However, the optimal salinity level for culturing. *A. vulgaris* has not been experimentally determined. Salinity is among the most critical abiotic factors affecting the aquatic species growth, metabolism and survival in farming environments (Yong *et al.,* 1989). Changes in salinity affects osmoregulation and also influence other processes in the body, such as increasing the rate of energy use which directly affects the growth. This is especially true for crustaceans, such as shrimp (Lofts, 1956). In view of the above, the objective of this study was to compare the growth and survival of *A. vulgaris* at different salinity levels in order to determine the most suitable level for *A. vulgaris* culture.

Materials and Methods

Animal and acclimation: *A. vulgaris* were collected using an umbrella dip net from the Pang Rad River estuary. in Rayong Province (12°69'69.7''N; 101°78'66.0''E), during August to September 2018. Captured individuals were transported to the laboratory in oxygenated polythene bags and acclimated for one week in a concrete tank filled with seawater having 25 PSU salinity, temperature 2,000 l capacity ranging between 27 to 29°C, under constant aeration. These shrimp were fed newly hatched *Artemia* nauplii thrice a day (8.00 am, 1.00 pm and 6.00 pm). Fecal matter and uneaten feed in the tanks were removed daily by siphoning before feeding.

Experimental salt water: The three treatment salinity levels (15, 20 and 25 PSU) were prepared from 30 PSU stock seawater. The volume of freshwater required to dilute 30 PSU stock seawater to the desired salinity level was calculated as per formula given by Dawson *et al.* (1986). The saltwater used in this experiment was treated with 30 mg l^{-1} chlorine and aerated continuously for 3 - 4 days. The saltwater with different salinities was then pumped into experimental tanks via a filter bag of 5 μm mesh size.

Experimental design: This study was arranged a completely randomized design and conducted in triplicate. After one week of acclimation, the shrimp (with a mean weight of 14.17±4.10 mg and mean length of 17.98±1.58 mm) were randomly assigned to one of twelve 100 m^3 fiberglass tanks containing 70 m^3 water with the experimental salinities (there were three tanks for each salinity level) at a density of 2.14 individuals m^{-3} (150 individuals per tank). Similar to the acclimatization period, the shrimp were fed newly hatched *Artemia* nauplii thrice a day at 8:00 am, 1:00 pm and 6:00 pm. The water in the experimental tanks was aerated continuously to maintain adequate concentration of dissolved oxygen. Fecal matter and uneaten feed was siphoned every day at 7:00 am. Before siphoning, the aeration faucets in the tanks were turned off to let the waste settle at the bottom. Approximately, 20% to 30% of the water in the experimental tanks was changed every week. The experiment lasted for 70 days.

Water quality: Water quality in each experimental tank was controlled before and during the experiment, including temperature, pH, alkalinity and nitrite levels which were monitored weekly. Temperature and salinity were measured using a digital water analysis instrument (Multi-probe, YSI Pro 2010), while pH was determined with a pH meter (Horiba Model: pH-22). Alkalinity was measured based on the potentiometric titration method (APHA, 2023). Nitrite levels were estimated by the method of Strickland and Parsons (1972).

Data collection and calculations: Twenty individual shrimp from each tank were randomly collected to determine the growth-related parameters, immediately before being placed in the experimental tanks and every two weeks throughout the experimental period. During sampling period, each individual was carefully blotted dry and weighed on a 4-digit analytical balance (Sartorius, Ax224). A digital vernier caliper was used to measure the total length, distance from the tip of the rostrum to the end of the telson. At the end of the experimental period, the total number, weight and length of the shrimp in each tank were measured. The weight gain, length gain were calculated using the equations given by Saad *et al.* (2009). The daily weight, length gain, specific growth rate and survival rate by Viet *et al.* (2017).

Statistical analyses: One-way ANOVA was performed on shrimp growth, survival and water quality data, followed by

Tukey's Multiple Range Test to identify significant differences among the treatments (Sadek and Nabawi, 2021). The Statistical Package for the Social Science (IBM Corp., Armonk, NY, USA) was used for the analysis. A p-value<0.05 was considered statistically significant.

Results and Discussion

The water quality parameters monitored in the experiment were within the permissible range (Royal Gazette, 2020). No significant differences were detected in the mean temperature, pH and nitrite levels among the culture tanks during the experimental periods (p>0.05), while alkalinity varied across the salinity levels (p<0.05) (Table 1). All the water quality factors, like temperature, pH, nitrite and alkalinity levels remained within the optimal range throughout the experiment, they did not significantly affect the outcomes of main study. The mean weight of *A. vulgaris* increased over time at all salinity levels (Fig. 1). After 70 days, the mean body weight increased from 14.17±4.10 to 55.59±15.92 (15 PSU), 61.00±20.18 (20 PSU), 49.56±17.80 (25 PSU) and 58.02±23.47 mg (30 PSU). The mean final weight, weight gain, daily weight gain and specific growth rate of *A. vulgaris* did not differ significantly among the salinity treatments (p>0.05) (Table 2). The mean final weight ranged from 49.56±17.80 to 61.00±20.18 mg, and was maximum at 20 PSU and lowest at 25 PSU. Similarly, weight gain (ranging from 35.39±18.26 to 46.83±17.53 mg), daily weight gain (ranging from 0.51±0.26 to 0.67±0.25 mg) and specific growth rate (ranging from 1.69±0.56 to 2.03±0.41 mg) were not statistically different among the treatments (p>0.05). Shrimp raised in the 25 PSU salinity level exhibited lower weight gain, daily weight gain and specific growth rate than those reared at 15, 20 and 30 PSU.

The mean length of *A. vulgaris* increased over the experimental period at all salinity levels (Fig. 2). After 70 days, the mean shrimp length increased from 17.98±1.58 to 27.39±2.50 (15 PSU), 28.05±3.50 (20 PSU), 25.79±3.50 (25 PSU) and 27.25±4.35 mm (30 PSU). The perusal of data (Table 3) indicated that after 70 days of the experiment, *A. vulgaris* had a mean length ranging from 25.79±3.50 to 28.05±3.50 mm, with no significant differences observed among the salinity levels (p>0.05). The mean final length, length gain, daily length gain and specific growth rate of *A. vulgaris* were maximum at 20 PSU and lowest at 25 PSU, although the differences were not statistically significant (p>0.05). Similar findings were observed for mean length gain (ranging from 7.81±3.57 to 10.07±3.34 %), daily length gain (ranging from 0.11±0.06 to 0.14±0.05 mm day^{-1}) and specific growth rate (ranging from 0.50±0.20 to 0.63±0.17 % per day). Shrimp reared in 25 PSU exhibited lower length gain, daily length gain and specific growth rate than those raised in 15, 20 or 30 PSU (p>0.05). The body weight and length of *A. vulgaris* increased over time in all treatments. Although a mild lower weight and length of shrimp raised in 25 PSU was noted than those cultured in other salinity levels, these differences were not statistically significant (p>0.05).

Table 1: Mean water quality parameters analyzed at different salinity treatments during 70 days rearing period of *A. vulgaris*

Parameters	15 PSU	20 PSU	25 PSU	30 PSU
Temp (°C)	28.50±0.83[a] (28.20-29.80)	28.43±0.82[a] (28.10-29.80)	28.33±0.84[a] (28.00-29.10)	28.60±0.84[a] (28.10-29.70)
pH	7.91±0.13[a] (7.77-8.12)	7.91±0.11[a] (7.77-8.04)	7.90±0.14[a] (7.76-8.13)	7.87±0.11[a] (7.74-7.98)
Alkalinity (mg l^{-1} as $CaCo_3$)	60.33±5.77[a] (50.00-70.00)	67.50±5.66[ab] (60.00-78.00)	72.50±8.53[b] (58.00-84.00)	73.33±13.00[b] (58.00-90.00)
Nitrite (mg l^{-1})	0.0319±0.0202[a] (0.0080-0.0700)	0.0339±0.0167[a] (0.0180-0.0610)	0.0261±0.0195[a] (0.0090-0.0630)	0.0315±0.0190[a] (0.0110-0.0650)

Values are expressed as mean of three replicate ±S.D. Different superscripts in the same row indicate a significant difference (p<0.05)

Table 2: Mean final weight, weight gain, daily weight gain and specific growth rate of *A. vulgaris* reared at different salinity levels over 70 days

Growth parameters	Salinity (PSU)			
	15	20	25	30
Initial weight (mg)	14.17±4.10	14.17±4.10	14.17±4.10	14.17±4.10
Final weight (mg)	55.59±15.92[a]	61.00±20.18[a]	49.56±17.80[a]	58.02±23.47[a]
Weight gain (%)	41.42±13.49[a]	46.83±17.53[a]	35.39±18.26[a]	43.85±21.61[a]
Daily weight gain (mg per day)	0.59±0.19[a]	0.67±0.25[a]	0.51±0.26[a]	0.63±0.31[a]
Specific growth rate (%) per day	1.91±0.38[a]	2.03±0.41[a]	1.69±0.56[a]	1.91±0.60[a]

Values are expressed as mean of three replicate ± S.D. Different superscripts in the same row indicate a significant difference (p<0.05)

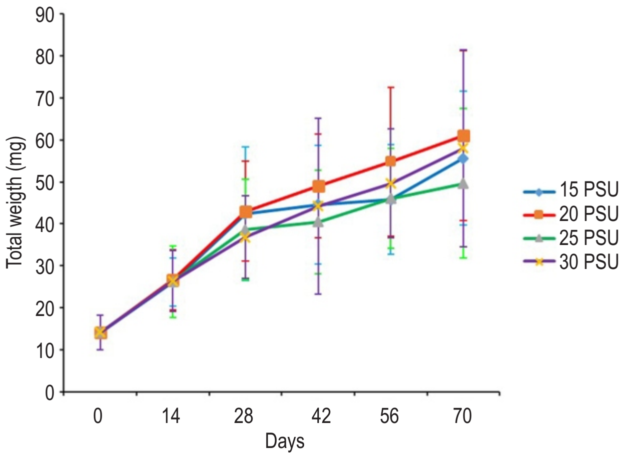

Fig. 1: Mean body weight of *A. vulgaris* across different salinity levels over 70-day experiment period.

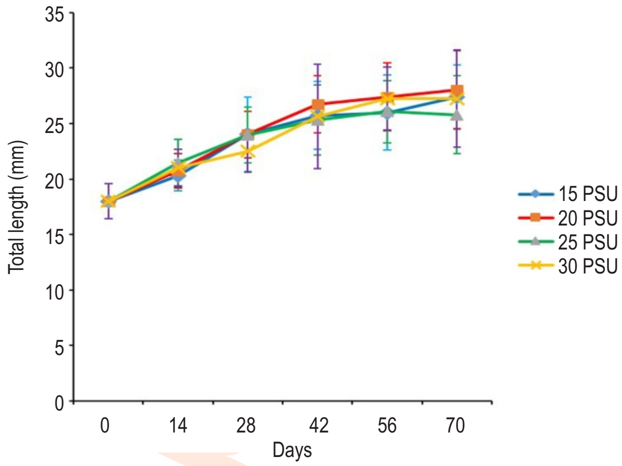

Fig. 2: Mean length of *A. vulgaris* at different salinity levels during the culturing period.

Table 3: Mean final length, length gain, daily length gain and specific growth rate of *A. vulgaris* reared at different salinity levels over 70 days

	Salinity (PSU)			
	15	20	25	30
Initial length (mm)	17.98±1.58	17.98±1.58	17.98±1.58	17.98±1.58
Final length (mm)	27.39±2.50[a]	28.05±3.50[a]	25.79±3.50[a]	27.25±4.35[a]
Length gain (%)	9.41±2.50[a]	10.07±3.34[a]	7.81±3.57[a]	9.27±3.98[a]
Daily length gain (mm per day)	0.13±0.04[a]	0.14±0.05[a]	0.11±0.06[a]	0.13±0.06[a]
Specific growth rate (%) per day	0.56±0.14[a]	0.63±0.17[a]	0.50±0.20[a]	0.57±0.21[a]

Values are expressed as mean of three replicate ± S.D. Different superscripts in the same row indicate significant difference ($p<0.05$)

The final weight ranged between 49.56±17.80 to 61.00±20.18 mg. Additionally, the mean weight gain, daily weight gain and specific growth rate showed no significant differences across the investigated salinity ranges ($p>0.05$). Similarly, the final length of *A. vulgaris* ranged between 25.79±3.50 to 28.05±3.50 mm. The mean length gain, daily length gain and specific growth rate were not significant differences across the salinity treatments ($p>0.05$). The results of this study suggested that *A. vulgaris* can not only tolerate a wide range of salinity levels but also showed satisfactory growth and survival at different salinity ranges. *Acetes* shrimp are commonly found in both brackish and marine environments (Deshmukh, 2002; Pengjamrat and Upanoi, 2005). They can inhabit a wide range of habitats including sandy and muddy beaches, open sea areas and canals connecting to river mouths, all of which have different dominant species (Oh and Jeong, 2003). According to Saengkaew *et al.* (2023), *Acetes* shrimp are abundant and diverse along the coast, living in salinity levels ranging between 2 to 27 PSU. Table 4 shows that *A. vulgaris* had relatively high survival rates across all salinity at the end of 70-day experiment. The highest survival rate was 77.78% (15 PSU) whereas the lowest value was 63.33% (25 PSU), but these differences were not statistically significant ($p>0.05$). Salinity is a critical environmental factor affecting crustaceans in brackish, coastal and marine habitats (Jiang *et al.,* 2000). After 70 days, the survival rates of *A. vulgaris* were relatively high across all the tested salinities. However, the findings of this study differed from those of Chen and Chen (1999) who found that with decreasing salinity, the egg hatching and metamorphosis of *A. intermedius* decreased (Chen and Chen, 2002). The somewhat lower survival may be related to physiological stress. Edwards (1982) emphasized that many aquatic animal species can adjust their ion concentration and osmotic pressure of body fluids in response to salinity changes in their habitats. Osmoregulation governs an organism's adaptive capacity to cope with different salinity levels (Jaffer *et al.,* 2020). When salinity changes exceed an animal's adaptive capacity, osmoregulatory mechanisms are activated to maintain the internal homeostasis. However, these mechanisms are energy intensive and if the salinity stress persists or becomes too extreme, it can lead to physiological overstress, potentially resulting in mortality (Gao *et al.,* 2016). In crustaceans, like *Acetes vulgaris,* prolonged exposure to suboptimal salinity levels

Table 4: Mean survival rates (%) of *A. vulgaris* cultured at different salinity levels over 70 days

Salinity (PSU)	Day 70	Mean survival rate (%) (n=3)
15	116.67±3.21	77.78±2.14[a]
20	114.00±7.00	76.00±4.67[a]
25	95.00±15.00	63.33±10.00[a]
30	105.33±4.51	70.22±3.01[a]

Values are expressed as mean of three replicate ± S.D. Different superscripts in the same row indicate a significant difference ($p<0.05$)

increases metabolic energy demands, thereby diverting energy away from the growth and immune functions (Thabet *et al.,* 2017). At lower salinity levels, the survival rate of *A. vulgaris* may be negatively affected due to elevated energy expenditure required for osmoregulation. This often leads to protein sparing, where proteins are conserved for vital functions instead of being used for growth, while lipid reserves are rapidly depleted to meet the rising energy demand (Silvia *et al.,* 2004). These metabolic shifts can weaken the physiological resilience and ultimately compromise survival, especially when compared to individuals reared under higher, more favorable salinity levels (Luo *et al.,* 2024). Similar trends have been documented in other aquatic species, emphasizing the critical need to define the optimal salinity conditions in aquaculture systems to enhance energy efficiency, growth and survival (Sang and Fotedar, 2004). Growth and survival rates are key elements to successful aquaculture, as they are closely linked to overall yield (Boeuf and Payan, 2001).

In conclusion, this study showed that *A. vulgaris* survival is uncompromised under a wide range of salinity (15 to 30 PSU) and the shrimp also exhibited higher growth in the experimental salinity range. The study on *Acetes* shrimp culture at different salinity levels provides valuable insight for those interested in aquaculture and conservation of *Acetes* shrimp.

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