



Effects of Ecological Factors on the Growth Performance and Abundance of Oriental River Prawn *Macrobrachium nipponense* (De Haan, 1849) (Decapoda: Palaemonidae) in the Anzali Lagoon, Iran

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Abstract: The effects of environmental factors (water temperature, pH, dissolved oxygen, chlorophyll, salinity, water depth, transparency and electrical conductivity) on growth performance (weight, total length and carapace length) and abundance (number of prawns caught) of *Macrobrachium nipponense* in the Anzali Lagoon were studied from January to December 2015. There was seasonal variation in the growth performance of *M. nipponense* ($P < 0.05$). This shrimp species was more abundant in June – October than in the other months. The growth of *M. nipponense* was positively correlated with water temperature, chlorophyll and electrical conductivity ($P < 0.5$). The results showed that the Anzali Lagoon was a suitable place for the breeding of *M. nipponense*.

Key word: *Macrobrachium nipponense*, ecological factors, biological factors, Anzali Lagoon.

Introduction

The Anzali Lagoon is located on the southern coast of the Caspian Sea and has four basins: Western, Eastern, Central and South-West. These four sections are distinguished by having different physical, chemical, ecological and geographical parameters (KHANIPOUR et al. 2020). The Anzali Lagoon location between land and sea ecosystems and between freshwater and brackish ecosystems forms a special ecotone embracing a unique blend of plant and animal communities.

The oriental river prawn *Macrobrachium nipponense* (De Haan, 1849) is natively distributed in east Asia, while in Iran, Uzbekistan and Iraq is an introduced species (NEW et al. 2010). This species was reported in the Anzali Lagoon in 2006 (DE GRAVE & GHANE 2006). It is omnivorous. Spawning takes place in spring and summer (WAKEFIELD 2015). The

temperature has an important influence on reproduction for *M. nipponense*. Morphologically, there are differences between males and females, with mature males being larger than females (BACHELER 2013).

In the present study, traps were evaluated for catching *M. nipponense* in the Anzali Lagoon. The aim of the study was to determine the effect of ecological factors on the weight, length, carapace length and the numbers of *M. nipponense* over a period of one year in the Anzali Lagoon, Iran.

Materials and Methods

Specimen sampling

Three localities were used, i.e. Site 1 (GPS coordinates: 37° 27' 9446.43" N – 49° 22' 9944.18" E), Site 2 (37° 25' 026.42" N – 49° 27' 307.12" E) and Site 3 (37° 25' 2998.45" N – 49° 24' 6902.1" E)

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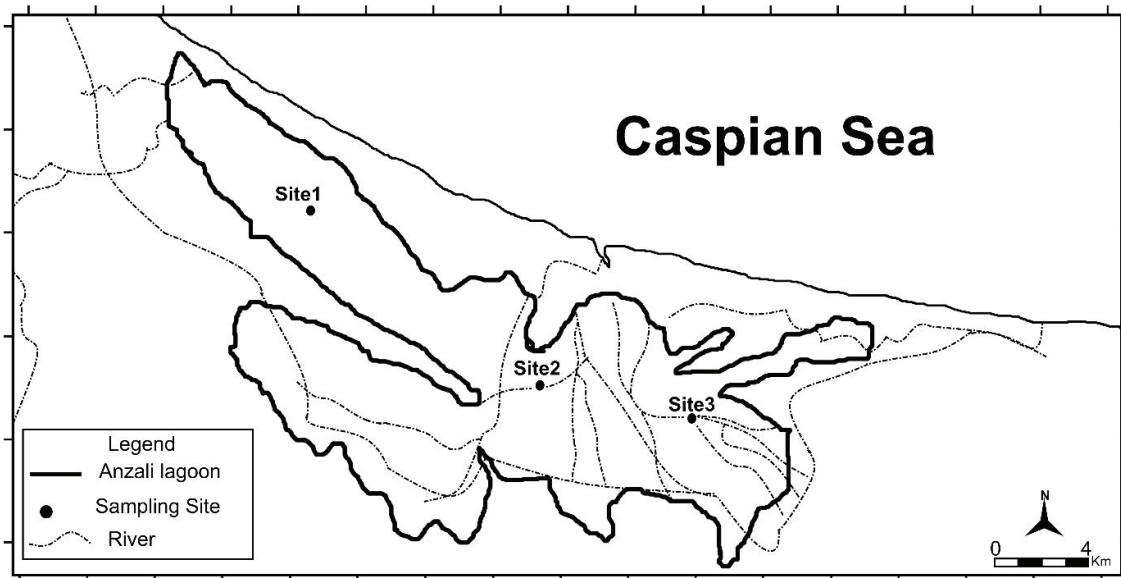


Fig. 1. Sampling area for *Macrobrachium nipponense* in the Anzali Lagoon, Iran.

(Fig. 1). Twenty-seven traps were randomly selected for the three sites. All the traps were used simultaneously for the sampling of prawns in this study. The traps were checked every 24 hours and the samples were collected five times per month for 12 months in 2015. All traps were scent baited with bread. Collected samples were removed and placed in iceboxes and transferred to the laboratory for further analyses. Total weight was measured on a digital scale with 0.1 g accuracy. Carapace length (the distance from the base of the rostrum to the first body segment) and total length (the distance from the tip of the rostrum to the end of telson) were measured for each sample with a Vernier calliper to the nearest 0.1 mm. Samples were extracted each month, then were measured and preserved separately.

Environment factors

The water pH, temperature ($^{\circ}\text{C}$), dissolved oxygen, DO (mg/L) and electrical conductivity (EC, $\mu\text{S}/\text{cm}$), chlorophyll, transparency and salinity were measured in situ, using the calibrated multi-parameter meter (Multiprobe, Hach HQ40d). Transparency was measured by Secchi disc. The water samples were collected at the bottom level of the waters using Nalgene bottles (1000 mL). Water samples were stored in the refrigerator at 4°C until analysis.

Statistical methods

Data were tested for normal distribution using the Shapiro-Wilk test for normality before applying the parametric tests. To detect the effects of months on physical and chemical variables, the General Linear Model (GLM) under ANOVA was applied (CHAP-

MAN et al. 2004). The Tukey method was used to establish the significant variables in the outputs pairwise comparison (KWOK et al. 2007).

Principal component analysis (PCA) was performed utilizing a two-way table of physical and chemical parameters (BASATNIA et al. 2015) and months. During this analysis, Principal Components (PCs) with eigenvalues greater than one were retained as those explaining the highest total water quality variability. Biplots for the first two components were constructed out of the resulting scores and loadings to provide an overall view of the multivariable relations within months (MURIITHI & YU 2015, JABBAR & GROTE 2019).

Canonical correspondence analysis (CCA) was used to analyse growth performance for prawns across the environmental gradients measured. These multivariate ordination analyses were carried out with XLSTAT2020 software.

Correlations between ecological factors and growth performance of prawns were tested by parametric Spearman correlation coefficient. Analyses were performed with R v. 2.9.0 (www.Rproject.org).

Results

Monthly status of physical and chemical variables and water quality

The mean values of physical and chemical variables and their statistical differences were evaluated on monthly basis (Table 1). The temperature values were highest in July and lowest in January ($P < 0.05$). There was a significant difference in temperature between samples collected in different seasons

Table 1. Characteristics of selected water physical and chemical variables (mean \pm standard error) and their seasonal differences in the Anzali Lagoon. Physical and chemical factors: DO = dissolved oxygen, pH = potential of hydrogen, EC = electrical conductivity, T ($^{\circ}$ C) = Temperature, Tu = transparency, Ch = chlorophyll.

Months	T ($^{\circ}$ C)	DO (ppm)	pH	EC (μ S/cm)	Salinity (ppt)	Depth (cm)	Tu (cm)	Ch (μ g/l)
January	9.4 \pm 0.5 ^a	6.9 \pm 0.3 ^a	7.9 \pm 0.3 ^{ab}	565 \pm 48 ^a	0.2 \pm 0.08 ^a	92 \pm 9 ^a	56 \pm 5 ^a	41 \pm 4 ^a
February	10.2 \pm 0.4 ^a	6.7 \pm 0.4 ^a	8.2 \pm 0.1 ^b	712 \pm 95 ^a	0.3 \pm 0.07 ^a	87 \pm 10 ^a	46 \pm 2 ^a	43 \pm 3 ^a
March	11.3 \pm 0.3 ^a	6.8 \pm 0.3 ^a	8.2 \pm 0.2 ^b	450 \pm 48 ^a	0.1 \pm 0.06 ^a	96 \pm 8 ^a	51 \pm 5 ^a	42 \pm 1 ^a
April	16.2 \pm 0.5 ^b	4.9 \pm 0.4 ^b	8.1 \pm 0.1 ^b	530 \pm 46 ^a	0.4 \pm 0.01 ^{ba}	88 \pm 7 ^a	53 \pm 5 ^a	51 \pm 6 ^{ab}
May	25.9 \pm 0.5 ^c	4.8 \pm 0.5 ^b	8.3 \pm 0.2 ^b	1130 \pm 123 ^b	0.5 \pm 0.2 ^b	72 \pm 4 ^a	40 \pm 3 ^b	58 \pm 2 ^b
June	26.8 \pm 0.9 ^c	4.6 \pm 0.4 ^b	8.4 \pm 0.3 ^b	2993 \pm 849 ^c	1.5 \pm 0.4 ^{bc}	91 \pm 9 ^a	39 \pm 4 ^b	78 \pm 6 ^c
July	29.2 \pm 0.2 ^c	4.1 \pm 0.3 ^c	8.5 \pm 0.1 ^{cb}	3310 \pm 712 ^c	2.5 \pm 0.3 ^c	95 \pm 12 ^a	36 \pm 2 ^b	68 \pm 3 ^c
August	28.2 \pm 0.2 ^c	3.9 \pm 0.2 ^c	8.6 \pm 0.3 ^c	4776 \pm 895 ^c	3.7 \pm 0.5 ^c	84 \pm 12 ^a	35 \pm 4 ^b	163 \pm 5 ^d
September	27.5 \pm 0.3 ^c	4.2 \pm 0.1 ^c	8.7 \pm 0.2 ^c	3890 \pm 726 ^c	3.6 \pm 0.3 ^c	66 \pm 10 ^a	37 \pm 6 ^b	70 \pm 2 ^c
October	17.1 \pm 0.4 ^b	4.5 \pm 0.4 ^b	7.8 \pm 0.1 ^a	1316 \pm 358 ^b	0.6 \pm 0.08 ^b	89 \pm 7 ^a	49 \pm 2 ^a	45 \pm 1 ^a
November	14.9 \pm 0.2 ^b	4.6 \pm 0.3 ^b	8.1 \pm 0.1 ^b	995 \pm 160 ^b	0.5 \pm 0.06 ^b	112 \pm 12 ^a	72 \pm 8 ^c	48 \pm 3 ^a
December	10.8 \pm 0.2 ^a	5.8 \pm 0.2 ^{bd}	8.0 \pm 0.2 ^b	675 \pm 75 ^a	0.3 \pm 0.03 ^a	114 \pm 14 ^a	69 \pm 6 ^c	40 \pm 4 ^a

Table 2. Biological data of examined specimens *Macrobrachium nipponense* (mean \pm standard error) and their seasonal differences in the Anzali Lagoon.

Months	Weight (g)	Number	Length (mm)	Carapace length (mm)
January	7 \pm 0.02	21	34.15 \pm 1.3 ^a	9.22 \pm 0.5 ^a
February	30 \pm 3	21	35.93 \pm 1.2 ^a	9.63 \pm 0.6 ^a
March	10 \pm 0.1	7	38.91 \pm 1.3 ^a	9.81 \pm 0.4 ^a
April	30 \pm 2.8	14	46.16 \pm 0.9 ^b	12.11 \pm 0.3 ^b
May	136 \pm 32	50	58.87 \pm 1.5 ^b	14.63 \pm 0.6 ^b
June	323 \pm 58	70	59.26 \pm 1.8 ^b	14.97 \pm 0.2 ^{bc}
July	300 \pm 42	90	64.12 \pm 2.1 ^c	16.72 \pm 0.3 ^c
August	374 \pm 63	200	65.68 \pm 2.3 ^c	17.62 \pm 0.1 ^c
September	200 \pm 36	120	60.12 \pm 1.8 ^c	15.21 \pm 0.2 ^c
October	170 \pm 33	110	52.28 \pm 1.2 ^b	14.07 \pm 0.6 ^b
November	85 \pm 23	35	46.41 \pm 1.3 ^b	10.23 \pm 0.4 ^a
December	30 \pm 3.2	18	41.52 \pm 1.6 ^b	10.01 \pm 0.3 ^a

($P < 0.05$). However, there was no significant difference in spring and summer (Table 1). DO values were highest in January and lowest in August; there was a significant difference in seasons ($P < 0.05$). However, there was no significant difference in spring and autumn ($P > 0.05$) (Table 1). The Anzali Lagoon's depth was different during the year because of the sediment load of the rivers but the difference was not significant ($P > 0.05$).

The values of pH, EC, chlorophyll and salinity were significantly higher ($P < 0.05$) during summer. The transparency values were highest in November and lowest in August ($P < 0.05$). Because of the rain, transparency values were higher during the wet than the dry season ($P < 0.05$).

Length-frequency distribution

The mean weight, total length and carapace length of prawns were 145.25 \pm 38.16 g, 50.28 \pm 1.52 mm and 12.85 \pm 0.37 mm, respectively. There was a significant difference in total length between samples collected in a different season ($P < 0.05$). However, there was no significant difference in April, May, June, October and November (Table 2). Analysis of variance of body weight showed significant differences in different seasons ($P < 0.05$). However, there was no significant difference in spring and autumn ($P > 0.05$) (Table 2). Analysis of variance of carapace length showed significant differences in different seasons ($P < 0.05$). However, there was no

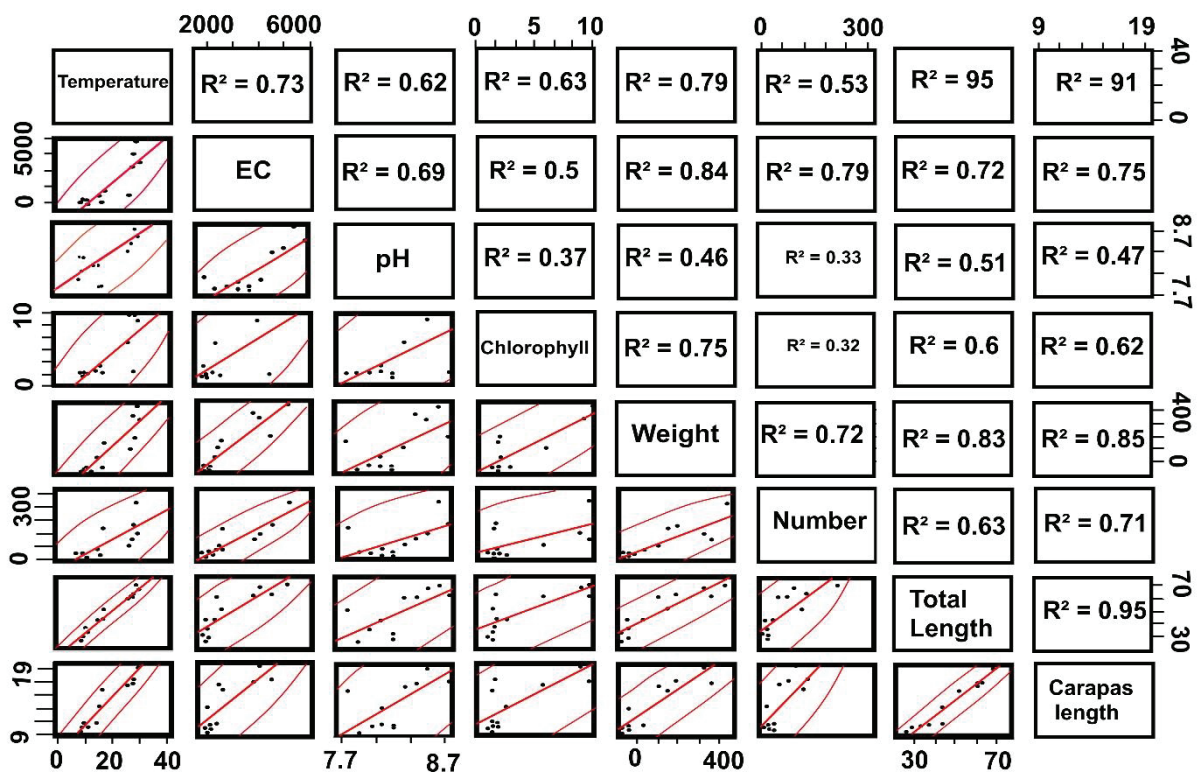


Fig. 2. Scatterplot matrix of the different physical and chemical factors and biological parameters for *Macrobrachium nipponense* in the Anzali Lagoon.

significant difference between autumn and winter ($P > 0.05$) (Table 2).

Correlations between indices

The correlations (Fig. 2) between growth parameters with physical and chemical variables were significant and strong. The highest positive correlations were found between total length and temperature ($R^2 = 95$, $P < 0.05$). The total length had a positive correlation with pH, EC and chlorophyll ($P < 0.05$). The result for carapace length was the same as the total length. The result showed a positive correlation between weight and pH, EC, temperature and chlorophyll ($P < 0.05$). The results showed that chlorophyll increases (positive correlation) during the summer due to the temperature increasing and subsequently causes an increase in the weight and the individual number of prawns. There was no significant correlation between the number of prawns, chlorophyll and pH ($P > 0.05$). The number of prawns showed a significant positive correlation with temperature and EC ($P < 0.05$).

PCA and CCA analysis

The PCA carried out using physical and chemical parameters set a well-defined distinction during the sampling period. The PCA results indicate that our set of variables explained 81.9 % of the variability

with the first two axes (Fig. 3). The first principal component (F1) explained 66.85 % of the total variance and was positively correlated to water temperature, EC, salinity and pH negatively correlated with transparency. The F2 was positively correlated to depth and negatively correlated with DO, while F2 explains 14.24 % of the variance (Fig. 3). The results showed a clear temporal separation (spring and summer in Purple Circle and autumn and winter in Black Circle). Spring and summer were more affected by pH, EC, salinity and temperature because the level of Caspian Sea comes up, which is a direct influence on the Anzali Lagoon.

The CCA results indicate that our set of variables explained 99.87 % of the variability with the first two axes (Fig. 4). The first principal component (F1) explained 82.86 % of the total variance and was positively correlated to water temperature and EC, negatively correlated with DO. The F2 was positively correlated to salinity and negatively correlated with pH, chlorophyll, depth and transparency. At the same time, F2 explains 17.01 % of the variance (Fig. 4). The CCA showed that the season was located in a separate area. They showed a clear preference for temperature (Fig. 4). The weight was mostly affected by chlorophyll and water temperature.

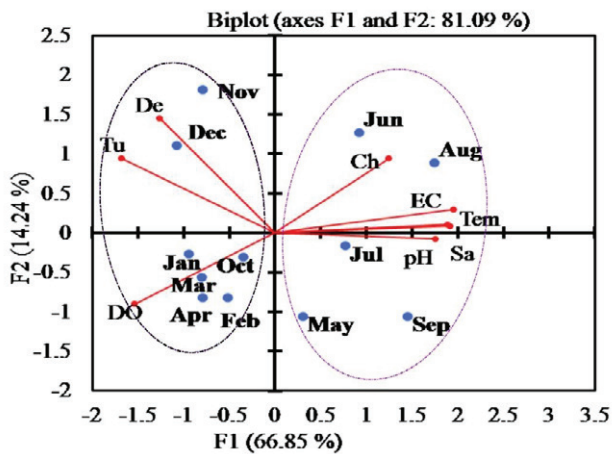


Fig. 3. Diagram of the principal components analysis results based on environmental variables (Red vectors). Sampled month are abbreviated by the first three letters: Nov. (November, etc.). Physical and chemical factors: Tem = temperature, pH, DO = dissolved oxygen, Sa = salinity, De= Depth, Tu = transparency, Ch = Chlorophyll, EC = Electrical Conductivity. Biological parameter: W = weight, N = number, L = total length, CL = carapace length.

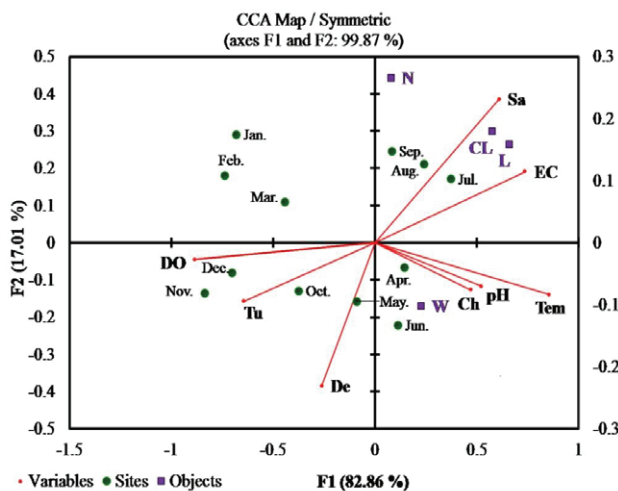


Fig. 4. Canonical correspondence analysis of *Macrobrachium nipponense* in the Anzali Lagoon. The environmental variables are indicated with arrows. Months are marked with circle symbols. Biology parameters are marked with square symbols.

Discussion

The temperature influenced the reproduction and growth pattern. *Macrobrachium* spp. are considered tropical species requiring water temperatures of 26 to 31°C (SANDIFER & SMITH 1985) for proper growth, with 29 to 31°C as an optimal condition. However, TIDWELL et al. (1994) reported rapid growth rates for prawns raised at a mean water

temperature of 25°C. In this study, the best month for growing patterns base on temperature was May to September (25.9-27.5). Prawns can survive winter under natural conditions, but they do not grow during December to early March due to the low temperature (NEW et al. 2010). The temperature had a direct effect on the growth pattern. As shown in the results, the relationship between temperature and weight, number of prawns, total length and carapace length was significant and strongly positive. In addition to affecting prawn growth patterns, temperature also affects its feeding, mating and spawning rates. MIRZAJANI et al. (2020) showed during the warm season (spring and summer), *M. nipponense* grows more due to the abundance of food; therefore, during this time, the total length and carapace length growth more. LAJAJOO et al. (2019) showed 99 % of *M. nipponense* had empty stomachs during the winter. They have indicated omnivorous feeding as a significant reason for being successful, high tolerance and adaptation of *M. nipponense* in the Anzali Lagoon. Due to the abundance of food, suitable temperature and spawning, the number of *M. nipponense* was higher in hot seasons (spring and summer).

Freshwater prawns can reproduce continuously or periodically, depending on their geographical distribution. In some regions (e.g., Malaysia), reproduction is possible throughout the year, but in others, particularly monsoon regions, it is seasonal (LING 1969). In the Anzali Lagoon, reproduction occurs in spring and summer when males with a hard shell and females with a soft one mate together (WAKEFIELD 2015). NEW et al. (2010) noted the breeding season for *M. nipponense* was from May to July. The principal spawning periods were mid-April to mid-July (water temperature at 20.5°C –31°C). In this study, the number of prawns was low from April to July due to spawning at this time.

WONG & MCANDREW (1990) showed that a population of *M. nipponense* in Hong Kong with optimal salinity for larval survival of 10 ppt had a high realized heritability for larval freshwater tolerance. WANG & QIANHONG (1999) reported that *M. nipponense* could reproduce in natural (inland) waters. SALMAN et al. (2006) noted the ubiquitous ability of *M. nipponense* to adapt to salinity changes. KWON & UNO (1969) reported that larval development duration was 18 to 20 days at a salinity of 8.3 to 9.3 ppt at 23 to 26.5°C. In another study, WANG et al. (2004) investigated the effects of salinity on growth and osmotic adjustments in *M. nipponense*. They reported the maximum weight gain was obtained at a salinity of 14 ppt. In the Anzali

Lagoon, the mean salinity was 1.18 ppt. The Anzali Lagoon is located between freshwater (because of the rivers) and brackish ecosystems (because of the Caspian Sea). The salinity of the Anzali Lagoon is affected by rivers and the Caspian Sea. In some months, some parts of the lagoon's salinity become equal to the Caspian Sea salinity (12-14 ppt), which occurs in summer and has the highest salinity. According to the results, the best time for growing larva was August and September (in some parts of the Anzali Lagoon).

Larvae and adults are omnivorous, mainly eating zooplankton, but they can feed on small organic material particles (LING 1969). This study showed a significant correlation between weight with temperature and chlorophyll (the best time was from May to October). Similar results showed feeding rate is influenced by water temperature; the quantity is reduced at temperatures below 15°C (winter time) (NEW et al. 2010). A study of the specific growth rate of juvenile *M. nipponense* at different temperatures, ranging from 16 to 32°C, showed that the optimal temperature for growth was 25°C (WANG et al. 2006). ZHANG et al. (2020) showed that the diet of medium and large prawns was proportionally higher in particulate organic matter and zooplankton compared to small prawns.

Macrobrachium nipponense, having a maximum size of 86 mm of males and 75 mm of females (HOLTHUIS 1980), is one of the few members of the genus *Macrobrachium* that has a temperate distribution (WONG & MCANDREW 1994). Its freshwater and brackish water habitats were mentioned by HOLTHUIS (1980). In the Anzali Lagoon, this species' maximum total length was 97 mm for the male and 92 mm for the female during the summer. This indicates that the Anzali Lagoon's prawn has a good feeding situation due to proper ecological parameters, which creates a suitable environment for them.

The results showed pH was 7.8-8.7. Similar results were presented by MORAES-RIODES et al. (2006), has reported that the minimum and maximum values of pH variables in *M. amazonicum* rearing ponds were 7.3-8.1. NEW et al. (2010) reported water quality for *M. nipponense* larvae measured during the test period (September–December 2002) was found conducive for larval growth; water temperature ranged from 29 to 33°C, DO 4.3 to 5.1 mg/L and pH 8.4 to 8.5. In the Anzali Lagoon, DO was 3.9-6.9. From July to September, DO was low.

According to the resulting transparency, for the Anzali Lagoon was 35-72 cm. NEW et al. (2010)

showed for transparency, the best range in Secchi disk visibility was from 25 to 40 cm in ponds. Conditions in natural places are different from human-made places, but generally, May to September was the best transparency for *M. nipponense*.

KEPPELER & VALENTI (2006) reported 138.5 µg/l as the total chlorophyll on pond water in Brazil for *M. amazonicum*. The total chlorophyll in the Anzali Lagoon was 163 µg/l during August, which the optimum was found from June to September. Chlorophyll had a significant positive correlation compared with weight, total length and carapace length. However, the result indicated the highest weight for the prawns from June to September.

The range for depth in the Anzali Lagoon was 72-114 cm. NEW et al. (2010) presented similar results and noted the best water depth (100-150 cm) for *M. nipponense*. Because in this depth, the births cannot hunt the prawn and, therefore, the food and DO is enough for prawn. The result showed that autumn and winter were more affected by depth, transparency and DO because they are the rainy season for the Anzali Lagoon.

In conclusion, all physical and chemical factors affected *M. nipponense*. The Anzali Lagoon had a good ecological condition for growing, breeding and prawning of *M. nipponense*. All physical and chemical factors in the Anzali Lagoon were suitable and in the range for *M. nipponense*. With good management and taking care of the Anzali Lagoon ecosystem, they can have a good harvest of *M. nipponense* in the Anzali Lagoon. Besides, this prawn creates jobs and income for local fishers.

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