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Effect of different salinities on survival and growth of prawn, *Palaemon elegans* (Palaemonidae)

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The LS_{50}^{96h} of prawn, Palaemon elegans*, was determined at various salinities (0–45 ppt) with the Caspian Sea salt proportion. In addition, growth indices, survival and moulting at salinities 8, 13 and 18 ppt were also studied during four weeks. All the experiments were carried out in the laboratory (24 ± 1°C). The results showed that more than 50% of the prawns survived at 1 to 30 ppt salinity range, while above and below this range, less than 50% survived within 24 hours. No significant differences (*P > 0.05) in growth parameters such as carapace length (CL) increase, specific growth rate (SGR) and also in survival and moulting rates were observed in prawns reared in salinities 8, 13 and 18 ppt. Mean intermoult period in each salinity was 8.12 ± 3.07, 8.61 ± 2.96 and 8.92 ± 3.47 days, respectively. Salinity 8–18 ppt was found to be the optimum range for* P. elegans *in the studied length range (CL, 6–9 mm).*

Keywords: Caspian Sea, growth, *Palaemon elegans*, salinity, survival

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INTRODUCTION

Two species of prawn, *Palaemon elegans* and *P. adspersus* were accidentally released from the Mediterranean Sea to the Caspian Sea in 1930–1934 (Grigorovich *et al.*, 2003). They could adapt themselves to the new environment so well that they would already have become an important food item for the majority of fish species in the Caspian Sea (Birshtein *et al.*, 1968). *Palaemon elegans* is a euryhaline species that can tolerate a large range of salinity (Berglund, 1982) and, therefore, enjoys a wide range of distribution beside the Caspian Sea, including the Mediterranean, Black, Baltic, Azov, and Aral Seas and also the eastern Atlantic coasts (Birshtein *et al.*, 1968; Grabowski, 2006). The maximum size of this species reportedly reaches 65 mm in Western Europe (Barnes, 1994), 58 mm in the Black Sea (Bascinar *et al.*, 2002), and 43.4 mm in Anzali port of the Caspian Sea (Abdolmalaki *et al.*, 2003). *Palaemon elegans* mainly inhabits the rocky substrates in the Caspian Sea (Birshtein *et al.*, 1968).

Various studies have been conducted on this species, among which are the effect of light periods (Dalley, 1980) and feeding regime (Hartnoll & Salama, 1992; Salama & Hartnoll, 1992) on the growth and survival; feeding and digestion in the larval stages (Kumlu & Jones, 1995); the effect of temperature on osmotic and ionic regulation (Ramirez de Isla Hernandez & Taylor, 1985); reproductive biology (Bascinar *et al.*, 2002); population dynamics and biological characteristics (Abdolmalaki *et al.*, 2003). But no separate study on the salinity effect on *P. elegans* has been conducted.

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In this study, however, the tolerance, growth and survival of *P. elegans* in various Caspian salt concentrations have been assessed that can be also used as a basis for future works on this species as live food in aquaculture (Firat *et al.*, 2005; Metin *et al.*, 2006).

MATERIALS AND METHODS

Prawn samples, collected with a hand net (1 mm mesh size) from 0.5–1 m depth of a rocky shore in Noor coast, Mazandaran province (Figure 1) during summer and winter 2005. After transferring to the laboratory, samples of 6–9 mm carapace length range (from eye stalk to the posterior carapace edge) with the average weight of 0.296 g were separated and maintained in a 500 l plastic tank filled with the Caspian Sea water (≈12.5 ppt salinity) for one week before the onset of the experiment. The samples designated to be tested under 1 and 5 ppt salinities were, however, transferred to the respective salinities two hours after the catch. The tank was covered with a small-meshed net to prevent prawns jumping out. They were fed, except the last day, under continuous aeration, light regime (12D:12L) and fixed temperature of 24 ± 1°C with the alga gathered from their natural surroundings. One-third of water in the tank was exchanged once every three days.

Experiments—conducted in two stages—were carried out in aquaria of 44 × 15 × 15 cm, which were divided into 4 equal parts by nylon net of 1 mm mesh, for putting one prawn in each part (Kirkpatrick & Jones, 1985; Campbell & Jones, 1989b). The prawns were directly transferred from the mother tank (≈12.5 ppt salinity) to the designated experimental salinities in aquaria.

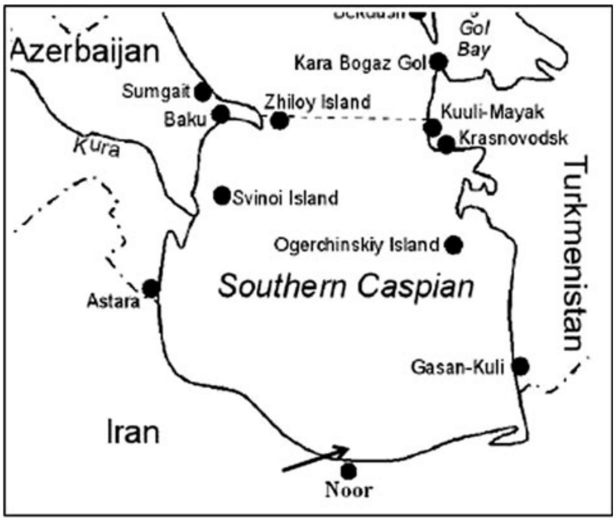

Fig. 1. Map of the sampling area.

In the first stage, the lethal salinities at 96 hours (LS_{50}^{96h}) (Taylor & Seneviratna, 2005; Tsoi *et al.*, 2005; Janas & Spicer, 2008) were determined, using various concentrations of 0, 1, 5, 13, 30, 35 and 45 ppt made with the Caspian Sea salt in the laboratory. The experiment was conducted in two replicates (Campbell & Jones, 1989a, b) with 4 individuals in each replication. No feeding was done in this stage (Kirkpatrick & Jones, 1985; Campbell & Jones, 1989a); continuous aeration, light regime (12D:12L) and temperature of $24 \pm 1^{\circ}$C were maintained throughout this stage (Kirkpatrick & Jones, 1985; Hartnoll & Salama, 1992; Paghe *et al.*, 2003). The designated salinities were fixed using aerated tapwater and the Caspian Sea salt added to the seawater which had been filtered. Salinity was checked by ATAGO, S/Mill-E handheld refractometer/salinometer.

In the second stage, based on the highest survival rate in various experimental salinities in the first stage, salinities 8, 13 and 18 ppt were selected. The prawns were transferred to the designated experimental salinities in aquaria and reared for 28 days.

Feeding was done daily with equal ration of dry pellet food (SFT2 produced by Chineh Co.) for all treatments at the start of the light period and uneaten food of the last day was siphoned off before providing fresh food (Salama & Hartnoll, 1992). As much as 75% of water in each aquarium was exchanged once every three days. This stage of the experiments was conducted in three replications. All other experimental circumstances were similar to the first stage. Growth indices (carapace length increase and specific growth rate (SGR)), moulting (moulting rate, moulting number and intermoult period) and survival (Diaz *et al.*, 2003; Sang & Fotedar, 2004; Bacon *et al.*, 2005; Romano & Zeng, 2006; Ticina *et al.*, 2006), were estimated according to the following relations:

$$\mathrm{SGR}(\%\mathrm{d}^{-1}) = \frac{Lnl_2 - Lnl_1}{t_2 - t_1} \times 100$$

Molting Rate = number of moults/initial number of individuals

$$\text{Survival Rate} = \frac{n_2}{n_1} \times 100$$

l_1 = Initial length at time t_1, n_1 = Initial number at time t_1
l_2 = Final length at time t_2, n_2 = Final number at time t_2

Moulting of each prawn was surveyed 3 times a day and after each moulting, skins were removed and related data were recorded. The first intermoult period (which was followed by the first observed moulting) and the moulting that was followed by mortality were not considered in the estimation of the average intermoult period (Romano & Zeng, 2006).

Statistical analysis

Data analysis was done using SPSS 12. Complete random block was arranged in this set of experiments. Normality of the data was examined by Shapiro–Wilk test. The difference among different measured factors was studied by one-way ANOVA, if data were normal; otherwise, they were studied by Kruskal–Wallis. Differences were considered significant when $^*P < 0.05$.

RESULTS

The result of the lethal salinities in 96 hours (LS_{50}^{96h}) showed that the prawn's survival was above 50% in the salinity range of 1–3 ppt and below 50% in the salinities of 0 (fresh water), 35 and 45 ppt, after 24 hours. In salinities of 5 and 13 ppt, the survival was 100%, while 100% mortality was observed in 0 and 45 ppt, after 96 hours (Figure 2).

No significant differences were observed ($^*P > 0.05$) in the growth indices (carapace length increase and SGR), moulting (moulting rate, moulting number and intermoult period), and survival rate of prawns reared under 8, 13 and 18 ppt salinity treatments (Table 1).

Observation of the prawn's survival during the 4 weeks rearing period showed that in 18 ppt salinity, mortality was seen after 21 days, but mortality in 8 and 13 ppt salinities occurred from the beginning of the rearing period. Higher mortality rate was found to be associated with moulting under the designated salinities (Table 2). The average intermoult periods in 8, 13, and 18 ppt salinities were 8.12 ± 3.07, 8.61 ± 2.96 and 8.92 ± 3.47 days, respectively, which varied from 2 to 18 days.

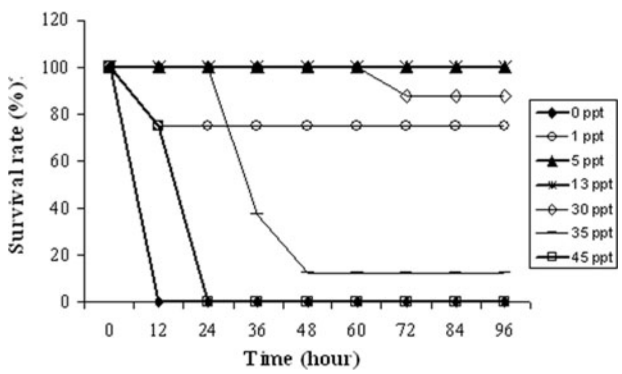

Fig. 2. Survival of *Palaemon elegans* after sudden exposure to a range of salinities with the salt proportion of the Caspian Sea in 96 hours (LS_{50}^{96h}).

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Table 1. Initial mean carapace length (mm), carapace length increase, specific growth rate (SGR), moulting rate, moulting number, mean intermoult period and survival rate of *Palaemon elegans* reared in different salinities for 28 days.

Salinity	8 ppt	13 ppt	18 ppt
Initial mean carapace length (mm)	6.71 ± 0.94^a	7.54 ± 1.34^a	7.62 ± 0.91^a
Growth rate (mm d^{-1})	0.07 ± 0.02^a	0.054 ± 0.02^a	0.059 ± 0.01^a
Carapace length increase (mm)	1.97 ± 0.73^a	1.52 ± 0.57^a	1.66 ± 0.35^a
SGR (% d^{-1})	0.96 ± 0.25^a	0.71 ± 0.31^a	0.71 ± 0.15^a
Moulting rate	2.91 ± 0.52^a	2.72 ± 0.81^a	2.25 ± 0.43^a
Moulting number	3.10 ± 0.87^a	2.63 ± 1.02^a	2.25 ± 1.14^a
Mean intermoult period (day)	8.12 ± 3.07^a	8.61 ± 2.96^a	8.92 ± 3.47^a
Survival rate (%)	66.66 ± 28.86^a	66.66 ± 38.18^a	75.00 ± 0.00^a

Similar letters show no significant difference between means in each row.

Table 2. Survival rate of *Palaemon elegans*, number of mortality and death associated with moulting at different salinities for 28 days.

Survival rate (%)	Salinity		
	8 ppt	13 ppt	18 ppt
0 days	100	100	100
7 days	91.66	91.66	100
14 days	83.33	91.66	100
21 days	75	75	100
28 days	66.66	66.66	75
Death associated with moulting (after 28 days)	4/12	2/12	3/12
Total mortality (after 28 days)	4/12	4/12	3/12

DISCUSSION

Salinity is one of the most important abiotic factors affecting the growth, survival, breeding and distribution of aquatic organisms in various ecosystems (Kumlu *et al.*, 2000; Anger, 2003). The prawn, *P. elegans* (Palaemonidae), has adapted itself to a wide range of salinities in different water bodies (Birshtein *et al.*, 1968; Grabowski, 2006). In the present study, the salinity tolerance (LS_{50}^{96h}) of this prawn was found to lie in the 1–30 ppt range, while a range of 5–45 ppt had been reported earlier (Ramirez de Isla He Hernandez & Taylor, 1985). It should be, however, noted that the prawn's survival at 0 ppt in both studies lasted only for a few hours; a 75% survival was observed at 1 ppt in our study, but no test had been conducted at this salinity level in the latter study. Janas & Spicer (2008) reported a 100% survival of small prawn specimens at 1 ppt in 90 hours, which could be attributed to lower degree of stress as the result of introducing the samples to the designated salinity within 24–72 hours after the catch, while the samples in our work were transferred to the designated salinity 2 hours after the catch. This species has also been reported in 2 ppt salinity of the Vistula Delta (Baltic Sea), but it was unable to survive in fresh water (Janas *et al.*, 2004).

Body size of *P. elegans* is reported to affect the tolerance of *P. elegans* to the salinity change, particularly at reduced salinity (Janas & Spicer, 2008), which could be attributed to higher osmoregulatory capability of the smaller individuals. In our experiment only small individuals (6–9 mm carapace length) were tested, since larger ones reportedly tended to migrate to deeper waters during winter (Janas & Spicer, 2008). If we had used larger individuals, the result would have been different and probably similar to that of Janas & Spicer (2008) where 100% mortality of larger individuals at 1 ppt within 90 hours has been reported.

The highest tolerance for *P. elegans* in the Caspian salinity of the current work was recorded at 30 ppt and 20°C. Ramirez de Isla Hernandez & Taylor (1985), who had observed the 45 ppt as the highest threshold of tolerance for *P. elegans* at 10°C, stated that salinity tolerance decreased with increase in temperature. Besides, the difference in salt composition of the Caspian Sea with open seawaters should not be overlooked.

Janas & Spicer (2008) have reported a 100% survival for *P. elegans* at 35 ppt (local salinity) whereas 12.5% survival rate was recorded at the same salinity (almost 3 times that of salinity of the Caspian Sea) in our experiment. This difference could, probably, be attributed to 75 years of acclimatization of this species (McLusky *et al.*, 1982) to the Caspian Sea.

In the salinity tolerance (LS_{50}^{96h}), survival rates were obtained 87.5% and 12.5% for 30 ppt and 35 ppt, respectively. The reduced survival at 35 ppt can be attributed to reduced osmoregulation capability (Ramirez de Isla Hernandez & Taylor, 1985) as well as being higher than tolerance threshold for *P. elegans*.

Finally, different salt composition and low salinity of the Caspian Sea from that of the open sea as well as different reactions of the same species within different populations can also affect the tolerance to salinity.

In this study, no significant differences were observed ($*P > 0.05$) in the growth indices, moulting, and survival rate of the prawn reared for 4 weeks under 8, 13 and 18 ppt salinity treatments (Table 1). This indicates the suitability of the tested salinity range for this species in the studied length range. However, the observation on mortality trend during the 4-week rearing period indicated the occurrence of mortality in 8 ppt salinity from the beginning of the rearing period (Table 2). This could imply that *P. elegans* was more susceptible to low salinities which corresponds with that of Nugegoda & Rainbow (1989) on the same species. It could somehow be attributed to prawn's excess loss of salt in dilute environment (Mantel & Farmer, 1983). Despite hyper–hypo osmoregulative capability of *P. elegans* (Ramirez de Isla Hernandez & Taylor, 1985), production of iso-osmotic urea to the blood (Mantel & Farmer, 1983) in less saline environments impels it to lose lots of salt along with water.

In the present study, after 21 days, 25% mortality (3/12) was observed at 8 ppt salinity, while a 42% mortality (5/12) under similar salinity and duration has been reported in another study (Nugegoda & Rainbow, 1989). Taylor *et al.* (1985) demonstrated that calcium concentration in the haemolymph of *P. elegans* sharply decreased in salinities below 10 ppt. Considering the importance of calcium ion in crustacean exoskeleton (Ingle, 1997) and as an extra-cellular ion as well as its relatively higher proportion in the Caspian Sea (Alizadeh, 2004), we can assume the capability of *P. elegans* to endure the Caspian salinities below 10 ppt increases.

Moulting increased, however not significantly, with decrease in salinity (Table 1), reaching the highest rate at 8 ppt, which corresponds with other studies on *P. elegans*

(Nugegoda & Rainbow, 1989) and *Upogebia africana* (Paula *et al.*, 2001). Also, the little growth at 8 ppt salinity (Table 1) can only be attributed to water absorption as the result of increased moulting and high water penetration in this species at low salinity (Campbell & Jones, 1990).

In the observation of mortality and moulting in 8–18 ppt salinities, higher mortality rate was associated with moulting (Table 2), which corresponds with that of Nugegoda & Rainbow (1989) on the same species and on *Portunus pelagicus*, which could be attributed to what is known as 'moult death syndrome' (Romano & Zeng, 2006).

CONCLUSIONS

Based on the results of this study and considering the suitable reproductive characteristics of *P. elegans* in the Caspian Sea, including the relatively long reproductive period from May to September (Abdolmalaki *et al.*, 2003), multiple spawning during each reproduction period (Kudelina, 1950), short larval stages (Bascinar *et al.*, 2002) and tolerance to abiotic factors (Berglund & Bengtsson, 2004), rearing this prawn on the southern coast of the Caspian Sea (≈12.5 ppt) as live food should be considered for future studies.

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