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SHORT COMMUNICATION

GROWTH AND SURVIVAL OF THE WHITE LEG SHRIMP *(LITOPENAEUS VANNAMEI)* REARED INTENSIVELY IN THE BRACKISH WATER OF THE ISRAELI NEGEV DESERT

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Key words: brackish geothermal water, growth, high density, *Litopenaeus vannamei*

Juvenile shrimp, *Litopenaeus vannamei* (initial weight 0.019±0.009 g), were reared at densities of 2000/m³ and 5000/m³ in brackish (2.5-3.0 ppt) geothermal (~40°C at the source) water from beneath the Israeli Negev desert in a recirculating system for 72 days. The shrimp grew significantly faster ($p<0.01$) at the lower density than at the higher density. The weekly mean weight and specific growth rate in the low density were 0.57 g and 8.68 and, in the high density, 0.404 g and 8.02. The feed conversion ratio was 2.01 in the lower density and 2.36 in the higher. The survival rate was 87% and 63.5% in the low and high densities, respectively. Data obtained in this study, particularly at the low density, are comparable to favorable published results for *L. vannamei* in marine waters. The present study is the first experimental attempt to evaluate the potential of mass culture of high quality, healthy *L. vannamei* in the brackish, geothermal water of Israel's Negev desert. This water, which is free of pollutants and marine pathogens, has been found to be highly suitable for the culture of a number of species of fish and aquatic organisms.

Introduction

Global production of farmed shrimp totals over 2.5 million tons annually (approximately $6 billion, FAO, 1999). Worldwide, shrimp are farmed in sea water despite marine viral epidemics which spread quickly causing catastrophic losses (Browdy, 1996). Israel's Negev desert contains large quantities of underground brackish geothermal water (2.5-3 ppt, ~ 40°C at source) which is suitable for fish culture (Appelbaum, 1995) and is used to rear several marine and freshwater species. Shrimp farming in such water, which is not

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connected to the sea and therefore eliminates the risk of marine viral diseases, would obviously be highly advantageous. Unfortunately, salinities below 18 ppt were unsuitable for rearing the indigenous Israeli shrimp, *Penaeus semisulcatus* (Harpaz and Karplus, 1991). However, the white leg shrimp, *L. vannamei*, is widely cultured in Central and South America (Wen-Young Tseng, 1988) and tolerates salinities of 2-45 ppt (Parker et al., 1974; Samocha et al., 1998). Several authors have reported good growth and survival of *L. vannamei* in brackish water of 1.7-2.3 ppt (Bray et al., 1994, 1999; Emberson et al., 1999; Moya et al., 1999; Samocha et al., 1999). Bray et al. (2000) even succeeded in spawning *L. vannamei* after rearing in a salinity of 2.2 ppt.

The present study is the first experimental attempt to evaluate the culture of *L. vannamei* in the brackish, geothermal water of the Israeli Negev desert which has been used for fish farming in recent years. Consideration was also given to high stocking densities of juvenile shrimps for more economical use of the water.

Materials and Methods

System design and management. The experiment was carried out in two indoor recirculation systems with brackish water (2.5-3.0 ppt, 40°C at source, Ashalim well; Table 1). Each system consisted of a 1400 l polyethylene holding tank (200 x 103 x 65 cm) in which two 140 l polyethylene shrimp rearing containers (70 x 50 x 40 cm) floated. Water in each system was filtered through a 700 l polyethylene settling tank to collect organic waste and a 700 l biological filter (with volcanic gravel). The bottoms and walls of the floating rearing containers were replaced with 1 mm mosquito mesh to assure maximum water exchange between the holding tank and the rearing containers. Water from the biological filter entered each rearing container at 3 l/min and each holding tank at 8 l /min. Half of the system's water volume was renewed every second day. Temperature in the rearing containers was maintained at 30±1°C and the oxygen level was >4 ppm; both were checked twice daily. Total ammonia nitrite and pH were tested every second day.

Procedure. Shrimp (PL_9) from the USA (Molkai Sea Farms International, Hawaii) were reared in sea water (30 ppt) for one week and fed *Artemia* nauplii. Thereafter, for 15 days, they were gradually acclimated to the brackish water and fed a dry shrimp feed (Zeigler Bros, USA; crude protein 50%, crude fat 15%, crude fiber 2%). At 31 days, the metamorphosed juveniles (mean weight 0.019±0.009g) were randomly stocked into the floating rearing containers in duplicate groups at two densities, 2000/m^3 and 5000/m^3. The juveniles were manually fed a dry shrimp feed at two-hour intervals, eight times a day. The daily feeding rate was 50% of the shrimp body weight on days 1-19 of the experiment, 30% on days 20-32 and 5% on days 33-72. The holding tanks were cleaned every day by siphoning. Mortality was recorded daily and growth was determined at two-week intervals by individually weighing thirty specimens from each rearing container. The specific growth rate (SGR) and feed conversion ratio (FCR) were calculated as follows: SGR = $100(LnWt_f - LnWt_i)\backslash(T_f - T_i)$, where Wt_f and Wt_i are the final and initial individual mean weights and T_f and T_i are the day of measurement and the first day; FCR = amount of food given/$(B_f - B_i)$ where B_f and B_i are the final and intial shrimp biomass and the difference between them represents net production. Growth results were compared using one-way analysis of variance (ANOVA) at a 0.01 probability level. Statistical analysis was carried out with Sateview statistical software.

Results

Water quality at the two densities was similar but ammonia was higher in the higher density (Table 2). No diseases or other detrimental effects were observed in the shrimp. The growth rate at 2000/m^3 was significantly ($p<0.01$) higher than at 5000/m^3 (Fig.1). Mortality, mostly due to cannibalism, began on day 30 in the higher density group and on day 45 in the lower density group (Fig. 2). The final weight, weekly growth rate, SGR and survival rate were higher at the lower

Table 1. Composition of the brackish geothermal water used in this experiment, compared to that of normal sea water.

Compound	*Brackish water*[1] *(ppm or mg/l)*	*Normal sea water*[2] *(ppm or mg/l)*
NH_4^+	0.04	0.02-0.04
N^+	560	NA
K^+	16	380-399
Ca^{++}	187	400-412
Mg^{++}	81	1272-1294
Mn	0.015	0.01
Cu	0.025	0.04-0.01
Zn	0.04	NA
Cr	0.976	<0.05-0.01
NO_2^-	<0.01	0.1-0.25
HCO_3	284	142
So_4	404	2648-2712
Po_4	<0.02	NA
H_2SiO	16	NA
pb	0.04	0.005-0.1
As	<0.03	NA
Cd	0.006	0.01
Hg	<0.0003	<0.0025
Cl^-	1017	18,978-19,344
H_2S	<0.1	<0.01
Temperature (°C)	41.3	26-33
pH (in field)	6.9	7.4-8.2
Turbidity (NTU)	6.5	NA
Alkalinity M as $CaCo^3$	250,000	NA
NO_3	1.00	NA
Salinity	2.542 ppt	32 ppt

NA = Not available

1 Analysis made by The Israel Water Company (Mekorot Water Co. Ltd., Southern District, Lab No. 19500, Ashalim well)

2 *Encyclopedia of Aquaculture* (edited by Robert R. Stickney), 2000. pp. 856-858.

Table 2. Mean values (n = 50) of water parameters during the 72-day rearing experiment with juvenile *Litopenaeus vannamei*.

Parameter	*Shrimp density*	
	2000/m³	*5000/m³*
Temperature (°C)	29.3±0.18	29.8±0.23
DO_2 (mg/l)	5.1±0.13	4.9±0.31
pH	8.0±0.03	7.8±0.17
NO_2^- (ppm)	0.05±0.091	0.07±0.08
NH_4^+- N (ppm)	0.08±0.007	0.16±0.06

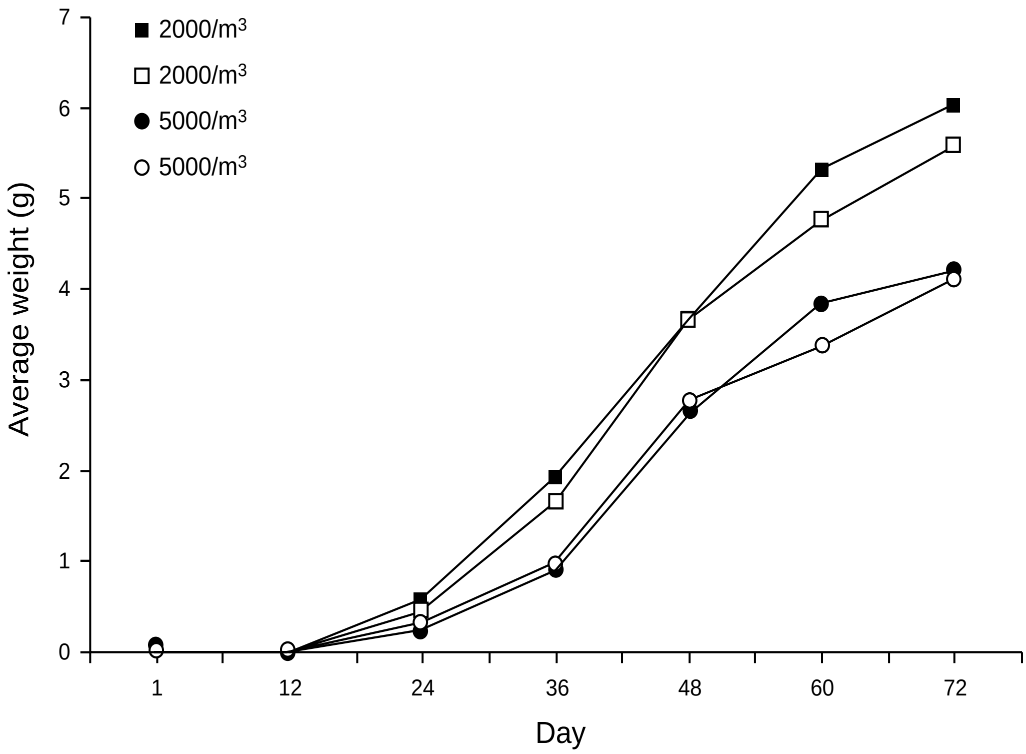

Fig. 1. Growth of juvenile *Litopenaeus vannamei* reared indoors in brackish water at different densities (two replicates).

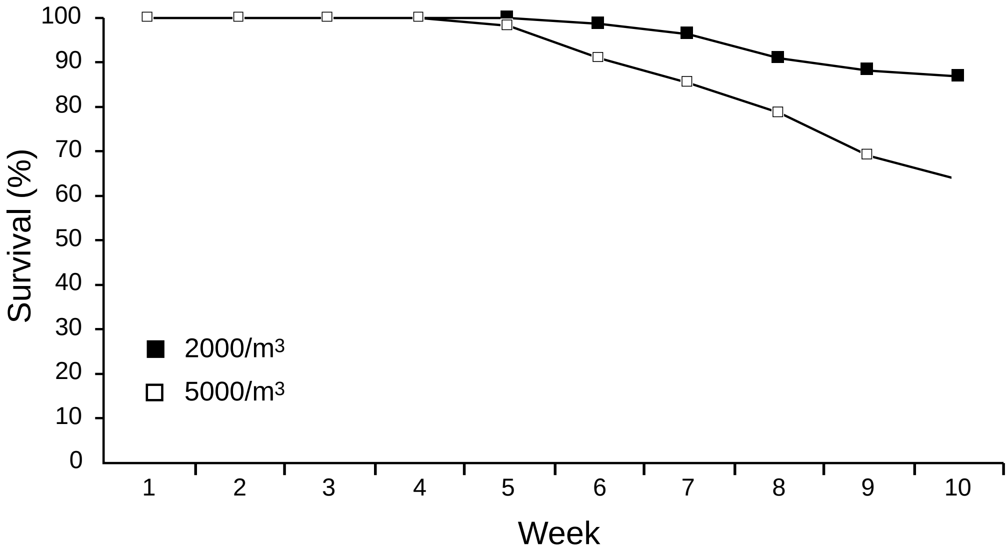

Fig. 2. Survival of juvenile *Litopenaeus vannamei* reared in brackish water at different densities.

density (Table 3). The FCR was better at the lower density except during days 33-47 when it was 2.1 in the lower density and 1.8 in the higher.

Discussion

This study shows that stocking density affects growth and survival of *L. vannamei*. Several authors have reported on growth and survival of *L. vannamei* in different salinities and densities (Table 4). In spite of differences in the rearing methods described in the publications, the results of the present study are comparable to favorable published data (in marine and brackish water). Later observations (unpublished) made at a new shrimp farm (Kibbutz Mashaabe Sade) in the Ramat HaNegev district revealed that *L. vannamei* juveniles of 0.5-10.0 g could, when stocked at high density (>100/m^2), grow approximately 20 g within five months at a survival rate of over 70% in the local geothermal, brackish water of 2.5-3 ppt. Bray et al. (1994) found that a population of *L. vannamei* juveniles infected by IHHNV (Infectious Hypodermal and Hematopoietic Necrosis Virus) grew at a slower rate when reared in a high salinity (49 ppt) than in lower salinities (5-15 or 25 ppt). Our findings, as well as the results of others, that *L. vannamei* can grow well at a very low salinity should stimulate further study of the optimal salinity level for *L. vannamei* and the possibly higher resistance of *L. vannamei* to IHHNV at a lower salinity.

The present study is the first report on experimental culturing of *L. vannamei* in the brackish geothermal water of the Negev Desert in Israel. The Negev and Arava deserts, which are rich in underground brackish geothermal water, have unique potential for culturing *L. vannamei* because: (a) *L. vannamei* well tolerate the salinity of 2-5 ppt; (b) the constant heat of the water (~40°C at the source) allows the required rearing water temperature to be maintained; (c) this water is not connected to the sea, eliminating the risk of marine viral diseases and (d) the pollutant-free brackish water guarantees product quality. High quality, healthy shrimp exported fresh to Europe at premium prices has attractive potential.

Table 3. Average growth, specific growth rate (SGR), survival and feed conversion ratio (FCR) of juvenile *Litopenaeus vannamei* reared indoors in brackish water for 72 days.

Density (*individuals/m³*)	*Initial weight* (*g*)	*Final weight* (*g*)	*Gained weight* (*g*)	*Growth/week* (*g*)	*SGR* (*g*)	*Survival* (*%*)	*FCR* (*%*)
2000	0.019± 0.009	5.88± 0.82[a]	5.86±1.02[a]	0.57± 0.72[a]	8.68	87.0	2.01
5000	0.019± 0.009	4.17± 0.48[b]	4.15± 0.82[b]	0.404±0.244[b]	8.02	63.5	2.36

Conclusions

Based on the growth performance in this study, the culture of *L. vannamei* juveniles in tanks with brackish geothermal water at the stocking density of 2000/m³ seems commercially promising. This conclusion, however, applies to juveniles and should not be applied to subadult or adult shrimp before testing. Shrimp culture at low density stimulates faster growth and higher survival yet, in arid conditions, culture in high stocking densities merits serious consideration.

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Table 4. Growth and survival rates of *Litopenaeus vannamei* at different salinities and stocking densities.

Stocking density	*Shrimp size (g)*	*Average growth/week (g)*	*Survival (%)*	*Salinity (ppt)*	*Final biomass (kg/m^3)*	*Reference*
6000/m^3	-	0.71	70	-	-	Sturmer and Lawrence, 1988
100/m^3	-	0.5-0.3	-	-	-	Wyban et al., 1988
75/m^3	-	1.4	67	-	-	
223/m^3	1.19	78	-	-	-	Robertson et al., 1992
299/m^3	-	0.94	83	-	-	
970/m^3	-	-	82	-	-	Reid and Arnold, 1992
2132/m^3	-	-	48	-	-	
27.5/m^3	-	1.67-1.7	98.75-100	2-8[a]	-	Samocha et al., 1993
1.3/m^2	Broodstock	2.7	-	2.3[b]	-	Bray et al., 1999
35-110/m^2	0.1-0.4	1.0	-	1.6-2.0[c]	-	Emberson et al., 1999
73/m^2	-	1.47	69	2.0[d]	-	Samocha et al., 1999
91/m^2	-	1.49	72	2.0[d]	-	
105/m^2	-	1.47	59	2.0[d]	-	
337/m^2	-	1.12	86	2.0[d]	-	
408/m^2	(0.003-0.001)	-	93	-	0.12	Moya et al., 1999
23,852/m^2	-	-	92	-	2.2	

- = Not available
[a] Artificial sea water prepared by mixing local well water with salt
[b] Ground water
[c] Low saline geothermal well water
[d] Ground saline water

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