International Research Journal of Environment Sciences ISSN 2319–1414
Vol. 3(10), 38-42, October (2014) Int. Res. J. Environment Sci.

Effect of Acute Salinity Stress on Oxygen Consumption and Survival of the Fiddler Crab, *Uca (Celuca) Lactea Annulipes* (Milne- Edwards, 1837) in Different Seasons

Mangale Vilas Y.[1] and Kulkarni Balasaheb G.[2]
[1] Mahatma Phule Arts, Science and Commerce College, Panvel, MS, INDIA
[2] The Institute of Science, 15, Madam Cama Road, Mumbai, MS, INDIA

Available online at: www.isca.in, www.isca.me
Received 23th July 2014, revised 26th August 2014, accepted 4th October 2014

Abstract

The present research was undertaken to study the effect of a sudden change in the salinity of the medium on the oxygen consumption and survival of fiddler crab Uca (Celuca) lacteal annulipes from mangrove area of Vashi. Since fiddler crabs are exclusively found in coastal and estuarine habitats in upper intertidal zone, they are subjected to significant fluctuations in salinity during monsoon due to seasonal river input, fresh water runoff and rainfall. The oxygen consumption increased and tolerance levels decreased in dilute seawater. Uca annulipes is a euryhaline where salinity tolerance is found to be season dependent. In monsoon the crabs could tolerate lower salinity of 4.86‰ and survived four days in fresh water. This shows a sort of adaptation to lower salinity during monsoon season. In pre and post monsoon all crabs subjected to fresh water died within a day. In winter they are more susceptible to lower salinity as compared to other seasons.

Keywords: Fiddler crab, salinity fluctuations, tolerance, intertidal zone.

Introduction

Marine animals occupying the intertidal zone are frequently subject to variations in the ambient salinity. Although, salinities are quite constant in the oceans at about 35‰, in coastal and estuarine regions salinity varies from fresh water to full oceanic salinity. Moreover, depending on the geological location salinity varies seasonally due to variation in seasonal river input, fresh water runoff and rainfall. Since fiddler crabs exclusively found in upper intertidal zone, they are subjected to wide fluctuations in salinity, especially at lower salinities. More extreme changes may be temporarily restricted but can ultimately result in the death of organism. The coastal and intertidal organisms adjust to salinity variation in their surrounding by restoring the physiological and biochemical mechanisms present in them.

Plenty of research has been carried out to study the effect of salinity fluctuation on the oxygen consumption and physiology of fiddler crabs. Emmerson observed seasonal differences of oxygen consumption in *U. urvillei*[1]. Miller has studied distribution of the fiddler crabs in relation to salinity[2,3]. Osmotic and ionic regulation in *U. rapax* subjected to dilute and hypersaline seawater is studied by Zanders. Thurman have studied osmoregulation in six species of fiddler crabs from different locations differing markedly in salinity[4]. Koch and Gillen have studied acute physiological and behavioral responses to dilute seawater in *U. pugilator*[5].

Present study was carried out with the objective of understanding the metabolic responses of fiddler crab, *Uca annulipes* in response to abrupt salinity changes in the medium. Metabolic response, measured as oxygen consumption of *Uca annulipes* over time, was studied when the fiddler crabs were exposed to acute change in salinity of the medium. *U. annulipes,* found abundantly on the shore in and around Mumbai, was selected to find out the effect of change in salinity of the medium on the oxygen consumption and the species' tolerance to seawater dilution in different seasons.

Material and Methods

During low tide *Uca annulipes* were collected at Vashi shore, New Mumbai ($19^0$13'00"N $73^0$6'30"E). The acclimatized fiddlers, which did not show any mortality, were used for measurement of oxygen uptake after exposing them to different salinity viz. 0.32 ‰, 4.86 ‰, 9.61 ‰, 16.02 ‰, 22.43 ‰, and 32.04 ‰. Seawater dilutions were prepared by adding distilled water to local seawater of salinity 32.04 ‰.

Experimental setup consisted of covered glass tanks each with fifteen fiddler crabs and equal volume (4 liters) of seawater of different experimental salinity. The water was aerated continuously and changed every 24 hours to prevent the build-up of toxic wastes. Experiments were carried out in duplicate. The crabs were checked for survival every 60 minutes for the first 12 hours and then at 24 hour intervals for 30 days. Measurement of initial oxygen consumption as well as after the exposure period of four days and again after one month was carried out. The acute response of oxygen consumption to salinity change was measured in all the experimental salinities. The experiment was repeated in three season viz. pre monsoon, monsoon and post monsoon.

For measuring oxygen uptake, initial oxygen content of sea water of different salinities was estimated by Winkler's method[6]. Wide mouthed amber coloured bottles each with a capacity of one liter were filled with seawater of different salinities and then four weighed fiddler crabs were placed in each bottle. The bottles were made airtight by rubber corks and then sealed carefully with molten wax. These bottles were kept undisturbed at room temperature for 1 hour. After one hour, the water from these bottles was siphoned out carefully into BOD bottles of capacity 300 ml each and the oxygen content was estimated by Winkler's method [6].

The rate of oxygen consumption of fiddler crab was determined by taking the difference between initial oxygen content and final oxygen content obtained after the exposure of the crab for one hour. Results were expressed as oxygen consumed per gm. of body weight per hour.

Results and Discussion

Effect of salinity variation on survival: It is found that tolerance of the *Uca annulipes* to salinity variation is season dependent. When the crabs were exposed to lower salinities like 9.61‰ and 16.02‰ in monsoon season, mortality was not recorded. During monsoon, the crabs were found to survive in water with salinity 0.32‰ for more than 4 days. However, in pre and post monsoon 100% mortality of the crabs was noted after their exposure to water with salinity 0.32‰ during four days.

Seasonal variation of oxygen consumption: A variation in respiratory rate is evident in *Uca annulipes* as shown in table No.1. The data therein shows that in post monsoon lowest rate of oxygen consumption i.e. 0.124 ± 0.02 ml/gm/hr was noted and crabs were found inactive mostly in early morning. A highest rate of 0.176 ± 0.01 ml/gm/hr was noted in monsoon. In pre monsoon oxygen consumption was 0.171 ± 0.01 ml/gm/hr.

Table–1
Seasonal variation in oxygen consumption of *Uca annulipes* Values are mean (± SD) of 3 determinations. Values in parenthesis indicate range

Season	Oxygen Consumption ml/gm/hr
Pre monsoon	0.19 ± 0.01 (0.18 – 0.21)
Monsoon	0.16 ± 0.01 (0.15 – 0.17)
Post monsoon	0.14 ± 0.02 (0.12 – 0.16)

Effect of salinity variation on oxygen consumption in different seasons: The data presented in table nos. 2 to 4 and figure no. 1 shows that lower salinity affects oxygen consumption remarkably in *Uca annulipes* in all the three seasons. When the crabs were exposed to lower salinity of 4.86‰, a significant increase in oxygen consumption was noted after 4 days of exposure in all the three seasons. However, in pre and post monsoon season, a remarkable elevation in oxygen consumption was noted after 4 hours of exposure. The crabs would not tolerate lower salinity water (0.32‰) beyond 4 hours and 100 % mortality of the crab was noted in pre and post monsoon season. In monsoon season it was found that crabs survived in the salinity of 0.32‰ for four days.

Table – 2
Effect of salinity variation on oxygen consumption of *Uca annulipes* in pre monsoon Values are mean (± SD) of 3 determinations. Values in parenthesis indicate range

Sea Water (Salinity)	Exposure period	Oxygen consumption (ml/gm/hr)
0.32‰	Initial	0.187± 0.002 (0.185 – 0.189)
	4 Hours	0.248 ± 0.002 (0.248 – 0.250)
	30 Days	------------------
4.86‰	Initial	0.180 ± 0.002 (0.178 – 0.181)
	4 Days	0.241± 0.002 (0.239 – 0.242)
	30 Days	0.184 ± 0.004 (0.179 – 0.187)
9.612‰	Initial	0.175 ± 0.001(0.174 – 0.176)
	4 Days	0.231 ± 0.002 (0.230 – 0.233)
	30 Days	0.179± 0.002 (0.177 – 0.181)
16.02‰	Initial	0.174 ± 0.002 (0.172 – 0.176)
	4 Days	0.186 ± 0.003 (0.183 – 0.189)
	30 Days	0.176 ± 0.001(0.175 – 0.177)
22.43‰	Initial	0.171 ± 0.002 (0.169 – 0.173)
	4 Days	0.168 ± 0.005 (0.163 – 0.172)
	30 Days	0.172 ± 0.002 (0.171 – 0.174)
32.04‰	Initial	0.172 ± 0.006 (0.165 – 0.177)
	4 Days	0.176 ± 0.002 (0.174 – 0.177)
	30 Days	0.171 ± 0.002 (0.169 – 0.172)

Table–3
Effect of salinity variation on oxygen consumption of *Uca annulipes* in monsoon. Values are mean (± SD) of 3 determinations. Values in parenthesis indicate range

Sea Water (Salinity)	Exposure period	Oxygen consumption (ml/gm/hr)
0.32‰	Initial	0.186 ± 0.001 (0.185 – 0.187)
	4 Days	0.204 ± 0.002 (0.202 – 0.205)
	30 Days	----------------------
4.86‰	Initial	0.177 ± 0.001 (0.176 – 0.177)
	4 Days	0.187 ± 0.003 (0.185 – 0.190)
	30 Days	0.186 ± 0.003 (0.183 – 0.188)
9.612‰	Initial	0.176 ± 0.000 (0.176 – 0.176)
	4 Days	0.182 ± 0.002 (0.181 – 0.184)
	30 Days	0.177 ± 0.002 (0.175 – 0.179)
16.02‰	Initial	0.172 ± 0.001 (0.171 – 0.173)
	4 Days	0.178 ± 0.003 (0.175 – 0.180)
	30 Days	0.176 ± 0.001 (0.175 – 0.177)
22.43‰	Initial	0.170 ± 0.001 (0.179 – 0.170)
	4Days	0.171 ± 0.002 (0.169 – 0.172)
	30 Days	0.173 ± 0.002 (0.171 – 0.174)
32.04‰	Initial	0.174 ± 0.002 (0.173 – 0.176)
	4 Days	0.175 ± 0.002 (0.173 – 0.176)
	30 Days	0.174 ± 0.002 (0.173 – 0.176)

Table–4
Effect of salinity variation on oxygen consumption of *Uca annulipes* in post monsoon, Values are mean (± SD) of 3 determinations. Values in parenthesis indicate range

Sea water (Salinity)	Exposure period	Oxygen consumption (ml/gm/hr)
0.32‰	Initial	0.178 ± 0.001 (0.178 – 0.179)
	4 Hours	0.224 ± 0.001 (0.223 – 0.225)
	30 Days	----------------
4.86‰	Initial	0.166 ± 0.001 (0.165 – 0.167)
	4 Days	0.202 ± 0.003 (0.198 – 0.204)
	30 Days	------------
9.612‰	Initial	0.145 ± 0.001 (0.144 – 0.146)
	4 Days	0.192 ± 0.002 (0.190 – 0.193)
	30 Days	0.147 ± 0.002 (0.146 – 0.149)
16.02‰	Initial	0.128 ± 0.001 (0.127 – 0.128)
	4 Days	0.171 ± 0.002 (0.169 – 0.173)
	30 Days	0.136 ± 0.003 (0.133 – 0.139)
22.43‰	Initial	0.122 ± 0.002 (0.121 – 0.124)
	4 Days	0.127 ± 0.002 (0.125 – 0.129)
	30 Days	0.131 ± 0.003 (0.129 – 0.134)
32.04‰	Initial	0.122 ± 0.002 (0.120 – 0.124)
	4 Days	0.119 ± 0.002 (0.117 – 0.121)
	30 Days	0.124 ± 0.002 (0.122 – 0.125)

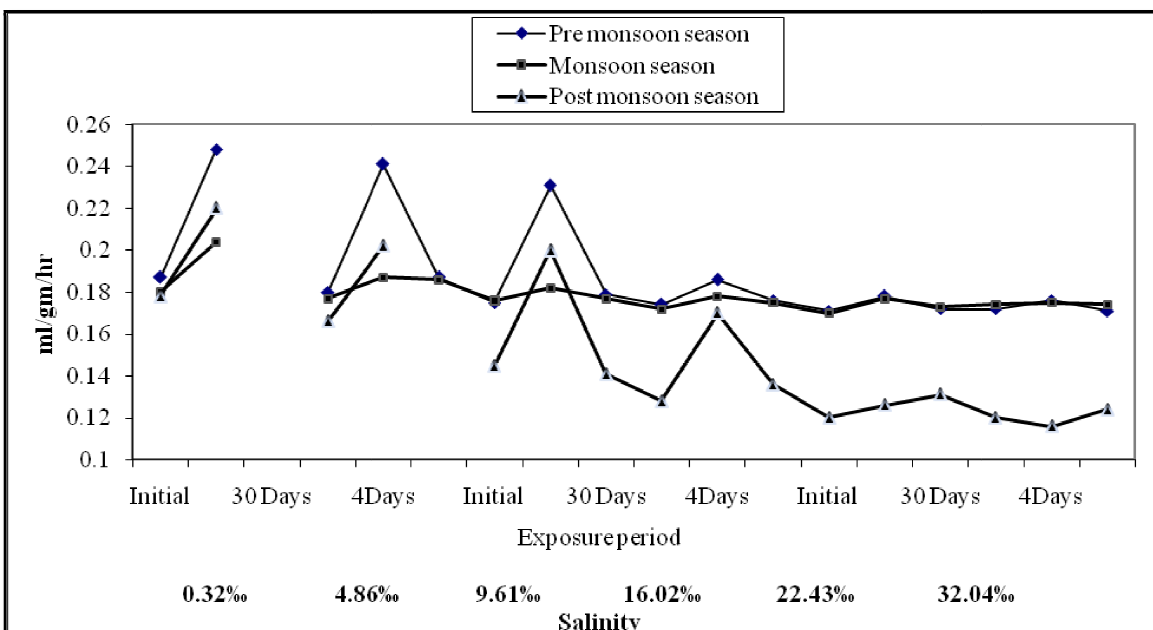

Figure-1
Effect of salinity variation on oxygen consumption (ml/gm/hr) in *Uca annulipes* in various seasons

When crabs were exposed to salinity of 4.86‰, 9.61‰ and 16.02‰, increase in oxygen consumption was noted after 4 days of exposure in all the three seasons. Maximum elevation of 65.57 % was noted in the crabs after exposure to salinity of 4.86‰ in post monsoon. The crabs could not tolerate salinity of 4.86‰ in post monsoon beyond 4 days of exposure. In sea water with lower salinities, the oxygen consumption was found to be elevated during 4 days of exposure. However, it was found to be decreased again after 30 days of exposure. In sea water with salinity 9.61‰ and 16.02‰, oxygen consumption after 30 days of exposure was found to be normalized showing slight elevation as compared to the initial oxygen consumption in respective saline water.

Water with salinity 22.43‰ shows a significant increase in oxygen consumption in post monsoon season. However, in pre monsoon a variation in oxygen consumption after 4 and 30 days found to be insignificant. Similar trend of oxygen consumption was noted in salinity of 22.43‰ in monsoon. At normal salinity of 32.04 ‰ in all three season, oxygen consumption showed slight variation with respect to initial values. Figure 1 shows the effect of salinity variation in different seasons on oxygen consumption of fiddler crabs. The oxygen consumption was found to be increased during four days of exposure to low salinity. But the consumption decreased to initial level after thirty days. This shows an adaptation in changed salinity after prolonged exposure.

The observed differences in survival of *U. annulipes* at various salinities in different seasons can be attributed to the acclimatization of the crabs to a particular salinity regime in particular season. Further, distribution of *U. annulipes* at upper zone of intertidal region is also responsible for their survival at lower salinities during different seasons. It was observed that the area inhabited by *U. annulipes* gets flooded with freshwater during monsoon which results in decrease of salinity in the surroundings of the crabs. Presence of low saline water in the surroundings of the crab leads to acclimatization of the crabs to lower salinity. Therefore, it was noted that during monsoon period crabs could tolerate salinity of 0.32‰ for the period of four days under laboratory conditions. However, during pre and post monsoon the crabs could not survive beyond twenty four hours at salinity of 0.32‰. Further, low survival rate in winter at salinity of 4.86‰ can be attributed to the effect of low salinity and low temperature in the surroundings of the crab. Miller has studied distribution of the fiddler crabs in relation to salinity[2]. Some investigators have studied the effect of salinity on the metabolic rate of crustaceans [7-11].

Salinity is one of the main environmental factors disturbing the metabolism of intertidal organisms[12]. Organisms living in an environment with fluctuating salinity levels have to cope with substantial ionic and osmotic stress, either through active osmoregulation or by osmoconforming[9]. Oxygen consumption rates can be used to evaluate the amount of energy an organism is using to maintain a stable concentration of the internal fluids[13].

The results reported here show increase in the oxygen consumption of *U. annulipes* when exposed to dilute seawater, a response seen commonly in previous studies. Rao has suggested that the rate of oxygen consumption of many species of crustaceans depends on the salinity of the medium to which the animals are naturally adapted[9]. He showed that the oxygen consumption rate increased with increased differences in osmotic concentration between the blood of the prawn and the external medium. Many investigators have shown that the respiratory rate increases as salinity decreases[14-17]. Several theories have been formulated to explain this increase in respiratory rate in low salinities. In low salinities, however, there would be a tendency for carbon dioxide to accumulate, thus increasing respiratory rate. Lange proposed that the increased solubility at lower salinity, coupled with oxygen-dependent respiration, is responsible for enhanced oxygen consumption at lower salinity [13]. The most commonly proposed theory is that the increased metabolic rate is caused by increased osmotic work [15,18,19].

In present investigation it was recorded that low saline acclimated *U. annulipes* showed lower respiratory rates in midrange salinities (16‰ and 22‰) and higher respiratory rates in low (0.5‰, 5‰ and 10‰) salinities. Such characteristic responses to salinity have been reported for various crustaceans[9-21]. It has been shown that in euryhaline crustaceans, maintenance of a hyper osmotic extracellular fluid in low salinities requires the expenditure of energy[22]. Hyperosmoregulation in low salinities relies on the ability to absorb ions against a concentration gradient, which involves expenditure of energy. Other predominant energy consuming phenomena operating in low saline media are reported to be an increase in oxidative deamination of free amino acids [21].

Conclusion

Uca annulipes shows seasonal dependent salinity tolerance. In monsoon the crabs could tolerate lower salinity of 4.86‰ and survived four days in fresh water. This shows a sort of adaptation to lower salinity during monsoon season. In pre and post monsoon all crabs subjected to fresh water died within a day. In winter they are more susceptible to lower salinity as compared to other seasons.

In the present study, the increase in oxygen consumption in *U. annulipes* with the decrease in salinity can be taken as a stress response to adjust to the subnormal and abnormal medium to compensate for the energy needed for osmoregulation.

References

1. Emmerson W.D., The effect of temperature and season on the aerial oxygen consumption of *Uca urvillei*, *J. Therm. Biol.*, **5(1)**, 41-46 **(1990)**

2. Miller K. G. and Maurter D., Distribution of the fiddler crabs, *Uca pugnax* and *Uca minax*, in relation to salinity

in Delaware rivers, *Chesapeake sci.,* **14(3)**, 219-221 **(1973)**

3. Zanders I. P. and Rojas W.E., Osmotic and ionic regulation in the fiddler crab Uca rapax acclimated to dilute and hypersaline seawater, *Mar. Biol.,* **125(2)**, 315-320, **(1996)**

4. Thurman C., Osmoregulation by six species of fiddler crabs (Uca) from the Mississippi delta area in the northern Gulf of Mexico, *J. Exp. Mar. Biol. Ecol.,* **291(2)**, 233-253, **(2003)**

5. Koch A. S. and Gillen C. M., Acute physiological and behavioral responses to dilute seawater in *Uca pugilator*. Conference Society for Integrative & Comparative Biology, 2005 Annual Meeting, San Diego, CA (USA), 4-8 Jan **(2005)**

6. Barnes H., Apparatus and methods of oceanography, part I. (Allen, G and Unwin Ltd; London), 341 **(1959)**

7. Chen, J.C. and Chia P.G., Oxygen uptake and nitrogen excretion of juvenile *Scylla serrata* at different temperature and salinity levels, *J. of Crustacean Biol.,* **16**, 442-467 **(1996)**

8. Lei C.H., Hsieh L.Y. and C.K. Chen., Effect of salinity on the oxygen consumption and ammonia nitrogen excretion of young juveniles of the glass shrimp *Penaeus monodon*, *Bull. Institute of Zoology*, **28**, 245-256 **(1989)**

9. Rao K.P., Oxygen consumption as a function of size and salinity in *Metapenaeus monoceros* from marine and brackishwater environments, *Ind. J. Exp. Biol*., **35**, 307-313 **(1958)**

10. Rosas C., Ocampo L., Gaxiola G., Sunchez A. and Soto L. R., Effect of salinity on survival, growth and oxygen consumption of post larvae of *Litopenaeus setiferus*, *J. Crusta. Biol.,* **19**. 244-251**(1999)**

11. Stern S., Barut A. and Cohen D., The effect of salinity and ion composition on oxygen consumption and nitrogen excretion of *Macrobrachium rosenbergii, Comparative Biochemistry and Physiology,* **79A**, 271-274 **(1984)**

12. Findley A. M., Belisle B. W. and Stickle W. B., Effect of salinity fluctuations on respiration rate of oyster drill *Thais haemastoma* and the blue crab *Callinectes sapidus*, *Mar. Biol.,* **49**, 59-67 **(1978)**

13. Lange, R. Staaland H. and Mostad A., The effect of salinity and temperature on solubility of oxygen and respiratory rate in oxygen-dependent marine invertebrates, *J. Exp. Mar. Biol. Ecol*., **9**, 217-229 **(1972)**

14. Dimock R. V. and Groves K. H., Interaction of temperature and salinity on oxygen consumption of the estuarine crab *Panopeus herbstii*, *Mar. Biol*., **33**, 301-308 **(1975)**

15. Flemister L.J. and Flemister S.C., Chloride ion regulation and oxygen consumption in the crab *Ocypoda albicans*, *Biol. Bull. Woods Hole*, **101**, 259-273 **(1951)**

16. King E. N., The oxygen consumption of intact crabs and excised gills as a function of decreased salinity, *Comp. Biochem. Physiol*, **15**, 93-102 **(1965)**

17. Shumway S.E. and Jones M.B., Influence of salinity on the respiration of an estuarine mud crab, *Helice crassa*, *Comp. Biochem. Physiol*., **70**, 551-553 **(1981)**

18. Hagerman L., The oxygen consumption of *Crangon vulgaris* in relation to salinity, *Ophelia,* **7**, 283-292 **(1970)**

19. Schlieper C., Physiology of brackish water, *Biol. of brackish water,* Pp, 211-350 **(1971**)

20. Chen J.C. and Nan F.H., Changes in oxygen consumption and ammonia-N excretion by *Penaeus chinensis* at different temperature and salinity levels, *J. of Crust. Biol.,* **13**, 706-712 **(1993)**

21. McNamara. J.C. and Moreira G.S., Oxygen consumption and acute salinity exposure in the freshwater shrimp *Macrobrachium olfersii, J. Exp. Mar. Biol. Ecol.,* **113**, 221-230 **(1987)**

22. Gilles R., Intracellular organic osmotic effectors. Mechanisms of Osmoregulation in Animals, New York. *R. Gilles. ed.,* 111-153 **(1979)**