J. Mar. Biol. Ass. India, **53** (2) : 230 - 236, July - December 2011
doi: 10.6024/jmbai.2011.53.2.01594-12

Salinity tolerance and fishery of mud shrimp *Solenocera crassicornis* (H. Milne Edwards) in the coastal waters of Mumbai

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Abstract

Salinity tolerance of mud shrimp *Solenocera crassicornis* investigated at different salinities ranging from 15‰ to 55‰ showed that shrimps in the salinity range 30‰ - 42‰ survived but those in lower and higher salinities died soon after the transfer. Ionic concentration in the hemolymph and free amino acids in the body muscle in response to different salinity ranges showed hypo-regulation initially but later became hyposmotic to the medium and died eventually when the salinity decreased. The abundance of shrimp showed inverse relationship with rainfall and consequent lowering of salinity in the inshore waters. The study showed that *S. crassicornis* can regulate osmotic and ionic concentrations of body fluids efficiently in the salinity range of 30 - 42‰ but unlike euryhaline penaeid shrimps it is a poor regulator at lower salinities and therefore it migrates offshore during monsoon months.

Keywords: *Solenocera crassicornis*, salinity tolerance, osmotic regulation, fishery abundance, monsoon migration

Introduction

In marine environment, salinity plays crucial role in osmoregulation and seems to have profound impact on the general pattern of distribution of animals. The abundance of penaeid prawns has long been related to distribution of salinity in the sea (Williams, 1955; Gunter *et al*., 1964). The dynamic physico-chemical processes in coastal waters and estuaries in particular, bring about frequent changes in pH and salinity due to which prawns face duel problem of dilution of internal body fluids at low salinity (hyposmosis) and loss of water at higher salinity (hyperosmosis). The salinity tolerance and distribution of prawns depend on ability to regulate ionic concentration in their body fluids which can be determined by comparing the concentration of the hemolymph to that of the ambient sea water over a range of salinities. Besides ionic concentration in the hemolymph, intracellular free amino acids are reported to play an important role in osmotic regulation (Sameshima and Shimamura, 1980) and maintaining the hydrogen ion concentration (Giles and Schoffenils, 1969).

The marine prawn, *Solenocera crassicornis* (H. Milne Edwards) with annual landings of 25,000-30,000 t along the northern coast of Maharashtra and Gujarat, is an important constituent of penaeid prawn fishery (Sukumaran, 1978; Deshmukh, 2007). This prawn has long been believed to emigrate to deeper offshore waters *en mass* during southwest monsoon season owing to lowering of salinity in the coastal inshore and nearshore waters (Kunju, 1967). Therefore, in the present study salinity tolerance and osmoregulatory capability under laboratory conditions of *S. crassicornis* were investigated to relate its fishery in the coastal waters and ascertain the cause of migration during monsoon months.

Material and Methods

The fishery data for *S. crassicornis* was collected from bag nets operated in inshore and nearshore waters from New Ferry Wharf (NFW) and Sassoon Docks landing centres respectively during the year 2000. For offshore fishery data, species-wise shrimp trawler landings maintained by Fishery Resources Assessment Division of CMFRI was used for the same year. The catch, effort, catch rate and percentage of *S. crassicornis* in total penaeid shrimps were collected once a week and estimated monthly, considering the number of fishing days and the boats landed.

For salinity tolerance and osmoregulatory studies, live specimens of *S. crassicornis* were collected from bag net fishing grounds near Mumbai harbour mouth and transported to the laboratory in well aerated containers. The animals were maintained in 100% seawater (35 ± 1‰) at 28° ± 2° C for a week in large glass aquaria of 500 l capacity and fed with clam meat and fresh paste shrimp *Acetes indicus*. The experimental salinities, ranging from 15‰ to 55‰ were adjusted by adding required quantity of tap water and raw common salt collected from the salt pans. Seawater was changed daily, aerated constantly and uneaten food was removed. Healthy prawns in intermoult stage ranging from 41 to 80 mm in total length were selected for the experiment.

For the salinity tolerance experiments, 20 prawns were directly transferred from the stock tank to 100 l capacity aquaria each with seawater salinity from 15‰ to 55‰ at 5‰ interval initially. Later on for more precision, 18‰, 42‰ and 52‰ salinities were also tested. The response and survival of the prawns in the aquaria was monitored for at least 48 hours from the time of transfer. Judging from the results of the 'direct transfer', the prawns were gradually acclimated to 22‰ and 48‰ salinity at the rate of 5‰ every 24 hours. The prawns were held at the desired salinity for 24 hours before they were sacrificed for extraction of hemolymph for electrolytes and free amino acid analysis. Prawns were used for hemolymph extraction only after 3 hours at 22‰ and 48‰ salinities as their survival period was very short. Hemolymph was taken by inserting a micro capillary tube into pericardial cavity between cephalothorax and the first abdominal segment. The hemolymph was centrifuged and 100 µl of clear supernatant was used to determine osmolality and concentrations of Na^+, K^+ and Cl^-. The osmolality was estimated by freezing point osmometer (Osmatte A, model 5002) while Na^+, K^+ and Cl^- concentrations were estimated by flame photometer (Systronics, Model 121) after diluting the hemolymph 500, 200 and 1000 times respectively.

Monthwise rainfall data were collected from Colaba observatory (Indian Meteorological Organization) situated at the southernmost tip of Mumbai island city very close to the sea. The salinity of seawater was recorded monthly by the Fishery Environment Management Division of CMFRI at Apollo Bundar near Gateway of India which is located between NFW in the north and Sassoon Docks in the south by the eastern coast of Mumbai island alongside the harbour.

Results

Survival: Direct transfer of prawns to 15‰, 18‰, 20‰, 52‰ and 55‰ salinities resulted in total mortality of prawns within 5 minutes. In 25‰ salinity, nearly 40% mortality of prawns occurred within 6 hours and 80% mortality within 5 hours. In 45‰ salinity, 50% prawns died after 9 hours and 70% after 28 hours and those at 22‰ and 48‰ salinities showed total mortality after approximately 5 hours after the transfer. The prawns in 30‰, 35‰, 40‰ and 42‰ salinities survived through the experimental period of 48 hours (Table 1).

Osmolality: The osmolality and electrolyte contents of the hemolymph and seawater at 30‰, 35‰, 40‰ and 42‰ salinities in which the prawns survived indefinitely (30-42‰) is given in Table 2. The osmolality of the seawater medium from 30‰ to 42‰ salinity ranged between 642 and 1,480 mOsm/kg and electrolyte contents 365-710 meq/l for Na^+, 5.4-9.4 meq/l for K^+ and 475-1015 meq/l for Cl^-. It was noted that the hemolymph osmolality showed a significant decline ($p<0.001$) as the salinity increased to 45‰ (Fig. 1).

Electrolytes: Na^+: At 30‰ and 35‰ salinity, hemolymph remained slightly hypertonic with respect to Na^+ and declined significantly with further decrease in salinity. The Na^+ concentration in hemolymph showed significant increase ($p<0.01$) at 40‰ salinity but declined significantly with further

Table 1. Survival of *S. crassicornis* after direct transfer to different salinity concentrations

	Survival time in minutes at tested salinities												
Salinity	15‰	18‰	20‰	22‰	25‰	30‰	35‰	40‰	42‰	45‰	48‰	50‰	55‰
% mortality													
10	-	-	-	5	30	IS	IS	IS	IS	120	45	-	-
20	-	-	-	18	120	IS	IS	IS	IS	250	72	-	-
30	-	-	-	60	270	IS	IS	IS	IS	348	90	-	-
40	-	-	-	90	300	IS	IS	IS	IS	450	108	-	-
50	-	-	-	108	480	IS	IS	IS	IS	540	120	-	-
60	-	-	-	120	630	IS	IS	IS	IS	1200	210	-	-
70	-	-	-	180	780	IS	IS	IS	IS	1680	246	-	-
80	-	-	-	240	900	IS	IS	IS	IS	IS	264	-	-
90	-	-	-	270	IS	IS	IS	IS	IS	IS	285	-	-
100	5	5	5	300	IS	IS	IS	IS	IS	IS	300	5	5

IS: Survival until end of the experiment

increase in salinity. The hemolymph remained hypoionic at higher salinities (Fig. 1).

K^+: The hemolymph was slightly hyperionic at 35‰ salinity, but became hypoionic with further decline in salinity. Although concentration of K^+ in hemolymph declined marginally at 30‰ salinity, it reduced significantly ($p<0.001$) further when the salinity was reduced to 22‰. At higher salinities the hypoionic regulation was evident. Although, significant decline ($p<0.001$) at 40‰ was observed, an increase in concentration was noted at 45‰ ($p<0.02$) and 48($p<0.005$).

Cl^-: The hemolymph was hypoionic to all experimental salinities with respect to K^+ but a noteworthy increase ($p<0.001$) with the increase in salinity and a significant decrease ($p<0.001$) was discernible when salinity was decreased (Fig. 1).

***Free amino acids*: ** Total free amino acid content in the abdominal muscles at 35‰ salinity was 446.6 µmole/g wet weight but declined to 49.8 µmole/g at 22‰ with decreasing salinity and with rising salinity of the medium, it increased to 929 µmole/g at 48‰ (Fig. 1).

Fishery: The bag netters operating in inshore waters of Mumbai harbour landed an estimated catch of 3.6 t of *S. crassicornis* at NFW landing centre at the catch rate of 1.76 kg/boat trip in the year 2000 that contributed 14.5% to the total penaeid prawn landings by the gear. The species was landed in most of the months except in July; the abundance of prawns indicated by the catch rates peaked in pre-monsoon months from January to May but the rate was meager in post-monsoon months from September to December. During monsoon from June to August, the catch was negligible and no catch was

Table 2. Osmolality and ionic concentration in seawater and hemolymph of *S. crassicornis* at different salinities

Salinity	Seawater				Hemolymph			
‰	Osmolality mOsm/kg	Na^+ meq/l	Cl^- meq/l	K^+ meq/l	Osmolality mOsm/kg	Na^+ meq/l	Cl^- meq/l	K^+ meq/l
48	1480±4.5	710±1.2	1015±4.3	9.4±0.04	1074±2.3**	465±1.73**	950±5.77***	7.7±0.05***
45	1352±3.1	605±2.5	960±5.7	8.8±0.1	1238±5.77***	505±4.04n.s.	875±6.92***	7.4±0.23***
40	1229±1.6	560±2.3	842±8.4	8.6±0.1	1185±1.73n.s.	540±2.88**	700±10.39*	7±0.11n.s.
35	1156±12.2	510±3.5	727±7.3	8.5±0.04	1156±11.36	512±4.58	625±8.08	8.5±0.05
30	995±8.2	475±4.2	600±3.5	7.6±0.1	1020±7.21**	490±5.29n.s.	545±2.51**	8.1±0.11***
25	847±4.8	420±6.2	560±10.8	6.8±0.1	693±5.56***	400±6.8***	410±14.36***	5.9±0.15***
22	642±6.7	365±2.8	475±7.2	5.4±0.04	459±8.02***	185±3.6***	328±5.68***	4.1±0.05***

*p<0.05, **p<0.01, ***p<0.001, n.s. not significant

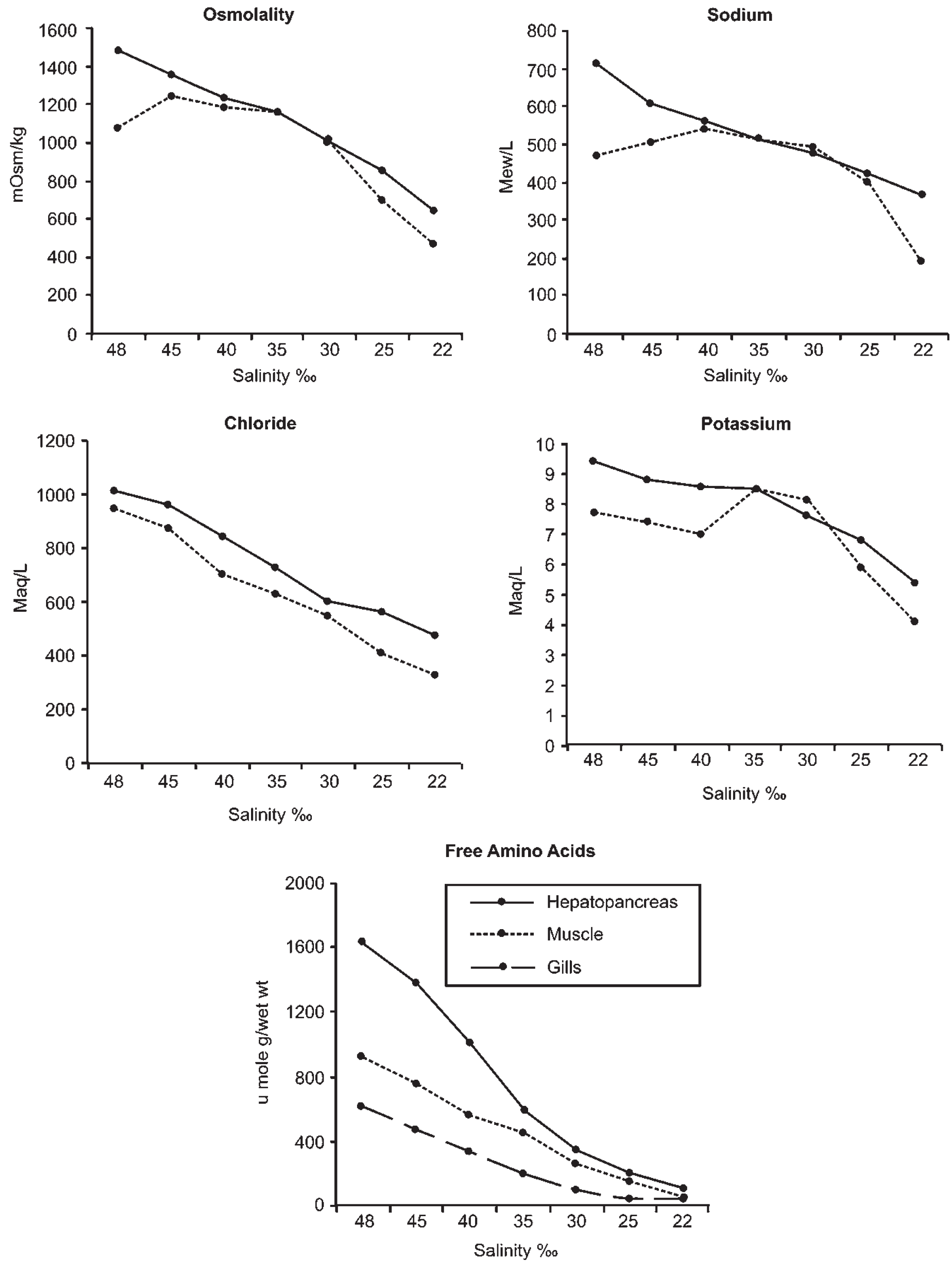

Fig. 1. Osmolality and ionic concentrations in seawater (----) and hemolymph (- - -) and total free amino acids in hepatopancreas and muscles

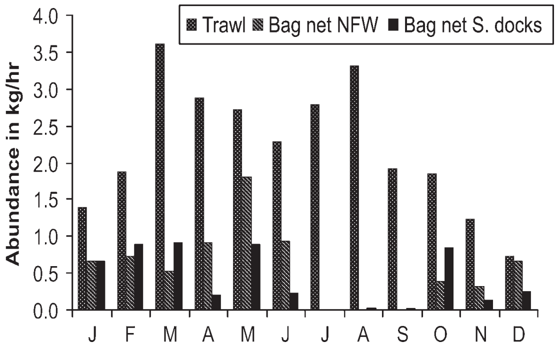

Fig. 2. Monthly catch rates of *S. crassicornis* in trawlers and in 'dol' nets at NFW and S. Docks during 2000

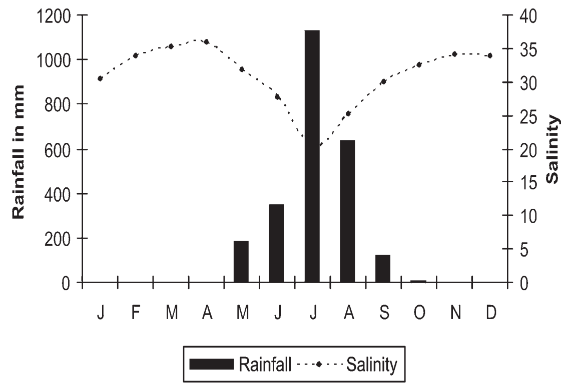

Fig. 3. Monthly rainfall and salinity of seawater in Mumbai

noticed in July which coincided with peak rainfall recorded in Mumbai.

At Sassoon Docks, bag nets are operated in relatively open sea at the mouth of the harbour notice in July which coincided with peak rain fall recorded in Mumbai (Fig. 2). These boats landed an estimated 9.1 t of the species contributing 7.1% to the total penaeid prawn landings at the catch rate of 1.27 kg/ boat trip. The catch rate peaked from January to March and in May and October. The catch as well as the catch rate of *S. crassicornis* was poor in June, August, September, November and December and no catch was recorded in July 2000.

At NFW shrimp trawlers operating from 30 to 90 m depth in the open sea landed 1,866 t *S. crassicornis* contributing 16.2% to the total penaeid prawn catch. The species occurred in the catch throughout the year and the catch rate increased in pre-monsoon from January and peaked in April. In monsoon months also the catch rate was notable though it was less in August (0.70 kg/h) but comparable to that in January (0.73 kg/h).

Rainfall and salinity: The Colaba observatory recorded 2,445 mm of annual rainfall in the year 2000. The month-wise rainfall increased from May (188 mm) and continued till September (122 mm) with peak at 1,130 mm in July.

Monthwise salinity of seawater ranged between 12.8‰ in July and 35.8‰ in February in the year 2000. Throughout the monsoon season, salinity along the inshore and nearshore waters fluctuated, recording 28.6‰ in June, 12.8‰ in July, 25.1‰ in August and 28.6‰ in September but regaining to 35.9‰ in October (Fig. 3).

Discussion

A number of penaeid prawns can withstand a wide range of salinities and they have been shown to be strong osmoregulators, conforming to their euryhaline nature. While *Metapenaeus monoceros* remains hyposmotic to seawater (Panikkar and Viswanath, 1948), *Penaeus aztecus*, *P. duorarum* and *P. setiferus* are reported to be hyposmotic at higher salinities (>40‰) and hyperosmotic at lower salinities (<30‰) (Castille and Lawrence, 1981). However, the present study shows that *S. crassicornis* has unique pattern of osmotic and ionic regulation. While its hemolymph remains hyposmotic to the medium at higher salinities (35‰), it is marginally hyperosmotic at 30‰ and then becomes hyposmotic when the salinity is further reduced, and dies eventually at 22‰. The ionic regulation with Na^+ and K^+ shows almost similar pattern. The prawn seems to be isoionic with respect to Na^+ when salinity is increased but the concentration of Na^+ in hemolymph decreases further as it can not regulate it and dies eventually. The concentration of K^+ shows a sudden drop initially when the salinity is increased but it increases further and remains hypotonic to the medium. Hyporegulation of chloride concentration is evident at all the experimental salinities.

In crustaceans, the role of large free amino acids pool in osmoregulation has been well documented

(Awapara, 1962; Giles and Schoffenils, 1969; Sameshima and Shimumura, 1980). In case of *S. crassicornis* it was seen that there is decrease in the concentration of free amino acids when salinity of the medium is lowered and the concentration is enhanced when salinity is increased. Sameshima and Shimumura (1980) reported that in *Penaeus japonicus* when the salinity of ambient seawater was lowered the shrimp was obliged to decrease its concentration sharply and change the composition of free amino acids. The release of large quantities of free amino acids in hyposmotic medium was regarded as a significant mechanism for reducing intracellular osmolality and an increase in concentration in the hemolymph has been attributed to enhanced synthesis of non- essential amino acids, together with decreased diffusional loss from the nerve fibres in crustaceans (Giles and Schoffenils, 1969). It was further pointed out that nonessential amino acids such as glycine, proline, alanine and arginine were the osmoregulatory factors. In the present case, increase in free amino acids at higher salinities and decrease at lower salinity in the hemolymph indicate their primary function as intracellular osmoregulators in *S. crassicornis*. Besides, they have a role in maintaining the pH that regulates various enzymatic processes concerned with osmoregulation (Huang *et al*., 2001).

The present study shows that *S. crassicornis* can regulate osmotic and ionic concentrations of its body fluids efficiently in the salinity range of 30-42‰ but unlike other euryhaline penaeid prawns it is a poor regulator at lower salinities. Similarly, the adults of brown shrimp *P. aztecus* are better osmoregulators at higher salinities than in the lower ranges (McFarland and Lee, 1963).

Kunju (1967) and Sukumaran (1978) did not notice *S. crassicornis* in bag net catches during June-October and therefore opined that possibly it mi grates *en mass* to offshore waters due to lowering of seawater salinity in monsoon months. It is evident in the present investigation that *S. crassicornis* occurs in offshore catch almost throughout the year where influence of rain and land run off is minimal. This is due to the fact that saline water being heavier remains at the bottom, while freshwater lies at the top in stratified manner in offshore region where the prawns remain buried in the mud. However, in inshore and nearshore waters due to mixing by the tidal forces the influence of rainfall and consequent lowering of salinity is pronounced. As the species is a poor osmoregulator at lower salinities, it disappears from the bag nets in June and totally vanishes in July when salinity of the inshore water drops below 20-25‰. However, the species reappears in the fishery gradually from August onwards when salinity of inshore water rises up and returns to normal by October. Therefore, almost total absence of *S. crassicornis* in bag net catches concurrent with lowering of salinity during monsoon strongly supports the possibility of monsoon migration of the species *en mass* to higher saline offshore waters.

Acknowledgements

The authors are grateful to the Director, Institute of Science, Mumbai for laboratory facilities, the Director, C.M.F.R.I. Cochin, for the fishery environment data and the Regional Meteorological Centre RS/RW Observatory, Vile Parle, Mumbai for providing the rainfall data.

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Received : 03/11/2009
Accepted : 20/09/2011
Published : 15/12/2011