

OSMOTIC BEHAVIOUR OF SHRIMPS AND PRAWNS  
IN RELATION TO THEIR BIOLOGY AND CULTURE

by

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CONTENTS

	<u>Page</u>
1. INTRODUCTION	529
2. DISTRIBUTION OF PRAWNS	529
3. OSMOTIC BEHAVIOUR OF PRAWNS	530
4. THE RELATION OF OSMOTIC BEHAVIOUR TO CULTURE PRACTICES	533
5. ROLE OF TEMPERATURE AND COMBINED EFFECTS OF TEMPERATURE AND SALINITY	534
6. ROLE OF CALCIUM AND OTHER IONS	536
7. CONCLUSION	536
8. REFERENCES	537

Abstract

The prawns which are useful for cultural purposes belong mostly to the decapod families Penaeidae and Palaemonidae. Most penaeids are marine prawns which migrate to estuaries and brackish water in their young stages but go back to the sea to breed. A small number of them breed in coastal inlets and others are exclusively marine. Species of marine Palaemon are highly adaptable to lower salinities. The habitat of Palaemonetes ranges from sea water to fresh water while Macrobrachium is largely a fresh water genus. Species of Macrobrachium include those which migrate from fresh water to brackish water during the breeding season. The marine penaeids and palaemonids show capacities for hypo-osmotic regulation when in sea water and high powers of hyper-osmotic regulation in brackish and fresh water. They have not developed extreme specialization as fresh-water inhabitants in that their normal blood osmotic values are high as compared with old established fresh-water crustacea and they do not produce hypotonic urine for conserving salts. These features have endowed these prawns with unusual adaptational abilities to live in variable surroundings, although each species has its own optimal range. There is close correlation between euryhalinity and hyper-osmotic adaptation. There is a relationship between osmotic behaviour and temperature, and a combined influence of temperature and salinity is also in evidence. A fuller knowledge of isosmotic levels and critical evaluation of the influence of environmental conditions on osmotic and ionic behaviour would help to rationalize prawn and shrimp cultural practices. The paper discusses the distribution of prawns and shrimps, their value in culture, existing knowledge of their osmotic properties, influence of salinity and temperature on their physiology and related problems.

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COMPORTEMENT OSMOTIQUE DES CREVETTES EN FONCTION  
DE LEUR BIOLOGIE ET DE LEUR ELEVAGE

Résumé

Les crevettes présentant un intérêt pour l'élevage sont essentiellement des Décapodes des familles Penaeidae et Palaemonidae. La plupart des Pénéidés sont des crevettes marines qui émigrent vers les estuaires et les eaux saumâtres durant leurs premiers stades de croissance, mais retournent à la mer pour se reproduire. Un petit nombre se reproduisent dans les criques, tandis que quelques-uns sont strictement marins. Les espèces du genre marin Palaemon sont extrêmement adaptables aux basses salinités. L'habitat des Palaemonetes va de l'eau de mer à l'eau douce, tandis que les Macrobrachium sont essentiellement liés aux eaux douces. Parmi les espèces du genre Macrobrachium, certaines émigrent des eaux douces aux eaux saumâtres à l'époque de la reproduction. Les Penaeidae et les Palaemonidae marins manifestent une aptitude à la régulation hypo-osmotique lorsqu'ils se trouvent en eau de mer et une forte capacité de régulation hyperosmotique en eaux saumâtres et douces. En outre, ils n'ont pas acquis une spécialisation extrême en tant qu'habitants des eaux douces, leurs valeurs osmotiques sanguines normales étant élevées par rapport à celles des crustacés vivant en eaux douces de longue date, et ils ne produisent pas d'urine hypotonique pour conserver les sels. Ces caractéristiques dotent ces crevettes d'extraordinaires capacités d'adaptation à divers milieux, quoique chaque espèce possède sa gamme optimale d'habitats. L'euryhalinité et l'adaptation hyperosmotique sont étroitement liées. Il existe un rapport entre le comportement osmotique et la température, et l'on a constaté aussi une influence combinée de la température et de la salinité. Il serait bon, pour rationaliser l'élevage des crevettes, d'approfondir la connaissance des niveaux iso-osmotiques et de procéder à l'évaluation critique de l'influence des conditions écologiques sur le comportement osmotique et ionique. La communication examine la répartition des crevettes, l'intérêt qu'elles présentent en pisciculture, les connaissances actuelles touchant leurs caractéristiques osmotiques, l'influence de la salinité et de la température sur leur physiologie et les problèmes connexes.

COMPORTAMIENTO OSMOTICO DE LAS GAMBAS Y CAMARONES EN RELACION  
CON SU CULTIVO Y BIOLOGIA

Extracto

Los camarones útiles para su cultivo son principalmente los Decápodos de las familias Penaeidae y Palaemonidae. Casi todos los peneidos son camarones marinos que emigran en sus fases juveniles a los estuarios y aguas salobres, en donde se desarrollan, volviendo después al mar para su reproducción. Un pequeño número de ellos se reproducen en las calas costeras, y otros pocos son exclusivamente marinos. Las especies de Palaemon marino son sumamente adaptables a las bajas salinidades. El habitat de Palaemonetes varía del agua del mar hasta el agua dulce, mientras que Macrobrachium es esencialmente un género de agua dulce. Hay especies de Macrobrachium que emigran de las aguas dulces a las salobres durante la época de reproducción. Los Peneidos y Palaemonidos marinos muestran capacidad de adaptación hipoosmótica cuando viven en aguas marinas así como también una gran capacidad de adaptación hiperosmótica en aguas dulces y salobres. Como habitantes de aguas dulces no han desarrollado una gran especialización porque sus valores sanguíneos osmóticos normales son altos si se comparan con los crustáceos ya establecidos desde hace mucho tiempo en las aguas dulces, y no producen orina hipotónica para conservar las sales. Estas características confieren a estos camarones una insólita facultad de adaptación para la vida en diferentes medios, a pesar de que cada especie tiene su propio habitat óptimo. Hay una estrecha correlación entre la eurihalinidad y la adaptación hiperosmótica. El comportamiento osmótico está relacionado con la temperatura y es también evidente una influencia combinada de esta última y la salinidad. Un conocimiento más profundo de los niveles isosmóticos y la valoración crítica de la influencia de las condiciones del medio ambiente en el comportamiento osmótico e iónico contribuiría a racionalizar las prácticas de cultivo de las gambas y camarones. En el trabajo se estudia su distribución y su valor para el cultivo, los conocimientos actuales de sus propiedades osmóticas, la influencia de la salinidad y de la temperatura en su fisiología y otros problemas análogos.

## 1 INTRODUCTION

A very considerable amount of information on the osmotic behaviour of Crustacea has accumulated in recent years and the mechanisms of osmotic regulation in them have been studied from various points of view. In the relation between osmotic behaviour and cultural practices of shrimps and prawns the principal factors that need examination are the distribution of these crustaceans in waters of varying salinities and the physiological adjustments observed in these animals, in an effort to rationalize our knowledge as to what species can thrive best under what conditions. It is interesting to note that there is a close relationship between their osmotic physiology and their possible cultural use because the latter is invariably based on species which have wide temperature and salinity tolerance.

Prawns and shrimps of commercial importance fall under the sub-order Natantia of the order Crustacea Decapoda and consists of three tribes: Penaeidea, Stenopodidea, and Caridea.

The two families under the first tribe are the Penaeidae and the Sergestidae and the species which are of interest in culture are those belonging to the well-known genera Penaeus, Metapenaeus, Penaeopsis and related forms. The sergestids which are exclusively marine, have not been subjected to large scale culture. The tribe Stenopodidea are also exclusively marine.

Under the tribe Caridea again we have several shrimps and prawns which are of interest from the point of view of culture. These are firstly the Crangonids, particularly Crangon crangon (L.), and a large number of species belonging to the family Palaemonidae, particularly Palaemon, Leander, Palaemonetes and Macrobrachium. There are numerous related forms whose generic status is uncertain.

The family Atyidae are fresh water forms with a wide geographical distribution and mainly consisting of the genus Caridina and related forms. Although small in size they are of fishery interest in many countries, both directly, as in Japan, and indirectly as forage organisms for carnivorous teleosts in the tropics. They are not known from marine or brackish waters. Many other caridean families are marine stenohaline species having feeble powers of adaptation, and often the species have restricted ranges of distribution.

## 2 DISTRIBUTION OF PRAWNS

The vast majority of penaeid species are marine except that during the younger stages they migrate to creeks, backwaters and estuaries of varying salinities. They grow in the low salinity environment rather rapidly. This habit of penaeid prawns entering estuaries and growing there to their adult size, has been the basis of fish cultural and trapping practices in many parts of the world, more particularly in tropical regions like India where it is an established fishery practice (Panikkar, 1937; Gopinath, 1956; Menon, 1955). The question as to whether these prawns which grow in the coastal inlets attain sexual maturity and breed there, has been one of the most difficult problems to solve conclusively; but it seems fairly certain that most of the species do not breed in the brackish waters and that the sexual reproduction and the hatching of the penaeid nauplii from the eggs take place only in the open sea. Important departures to this rule amongst the penaeids are probably to be found in certain species of Metapenaeus (M. monoceros (Fabricius) and M. bennettiae (as M. mastersii)) (Panikkar and Aiyar, 1939; Dakin, 1946). It is apparent that in spite of the essential marine habitat of the adult they are able to survive a very considerable amount of variation in the salinity of the external medium. This ability is shown particularly by the young stages. In fact early postlarvae and juvenile penaeids are a common feature of the Indian brackish-water fauna (Panikkar, 1937; Panikkar and Aiyar, 1937). The possibility of collecting these early penaeid stages and transplanting them for culture has been emphasized (Panikkar, 1952) and the practice is increasingly being adopted in many parts of the world, such as India, Malaysia, the Philippines and Japan.

E/25

The taxonomy and distribution of Palaemonidae of commercial importance has been extensively studied, notably by Kemp (1915) and Holthuis (1952), and the distribution of palaemonids in fresh and brackish water from the physiological angle has been reviewed (Panikkar, 1941: generic names under old nomenclature). The broad features are as follows: The genus Macrobrachium, which incidentally includes the largest commercial prawn known (Macrobrachium rosenbergii (de Man) = Palaemon carcinus), is a largely fresh-water genus although a few species are known to migrate to brackish water during breeding periods (Kemp, 1915; Panikkar, 1937). In India it is a common experience to find the larvae of species of Macrobrachium in brackish water, but only under low salinity conditions; the obvious inference is that the breeders move from fresh water to brackish water in the upper reaches of the estuarine system. The genus Palaemon, which for many years included species of Macrobrachium and Leander and which now includes many species formerly included in Leander, is found in the sea and brackish water. Species of Leander (sensu stricto) are found in marine, brackish water and fresh water environments, the latter condition especially in the tropics. The well-known European marine prawn is Palaemon serratus (Pennant) and the Black Sea prawn is Palaemon elegans (Rathke) (= Leander squilla (La)). Species of Palaemonetes are equally at home in sea water although their typical habitat is brackish water and fresh water. Isolated populations of brackish-water species of Palaemonetes have become established in fresh waters of different parts of the world, while some species of Palaemonetes are found on the sea coast presumably under low salinity conditions (Table I shows distribution of Indian shrimps and prawns).

### 3 OSMOTIC BEHAVIOUR OF PRAWNS

The adaptation of marine animals to brackish and fresh water is closely dependent on the development of osmoregulatory powers. Body fluids of most marine invertebrates generally have the same osmotic pressures as the surrounding sea water, but when they migrate to brackish waters they have to maintain their body fluids at levels higher than that of the dilute medium. The dilution of the body fluids by osmotic inflow is counteracted by active processes. The extent of the higher range to which they could regulate their body fluids is a variable factor amongst species belonging to a group, but the osmotic curve of an individual species is a distinct physiological criterion. The degree of hypertonicity which these animals can maintain is an index of their salinity tolerances. Good hypertonic regulators are able to reach lower salinity ranges and, in rare instances, even fresh waters, as exemplified by Palaemonetes varians (Beach). Animals which do not have this power of regulation are spoken of as marine stenohaline forms and they are unable to enter brackish and fresh waters.

The vast majority of the sergestids, stenopodids and several families of Caridea are marine stenohaline crustaceans. Under this category come the well-known genera Acetes, Processa and Pandalus, which are extremely sensitive to salinity changes and do not easily lend themselves to large scale culture.

Many palaemonids and penaeids, on the other hand, are endowed with high powers of osmoregulation and are able to maintain the concentration of their body fluids well above that of their surroundings. (Fig. 1)

The palaemonid prawns which live in sea water are not merely good regulators when in dilute sea water but they are endowed with the remarkable property of hypo-osmotic regulations when in sea water. They exhibit homiosmotic behaviour which is one of the most advanced mechanisms ever perfected by marine invertebrates. This finding (Panikkar, 1939; 1940a) opened up much further work on hypo-osmotic regulation and has been dealt with in detail (Panikkar, 1941). It has clearly been established that Palaemon serratus is capable of maintaining body fluids at a much lower concentration than the external medium, e.g. at 2.6 to 2.9 percent NaCl in fully marine waters of 3.5 percent NaCl. A much more advanced regulatory power, almost equal to that of the marine teleosts, was found in Palaemonetes varians which has a range of distribution from sea water to almost fresh water. Following the osmotic studies, these prawns have been critically examined for their ionic regulations by Parry (1954) and we have now a much clearer idea of the way in which this regulation is achieved. The point of special

TABLE I

Distribution of Indian Commercial Prawns

Species (cultivated species with asterisk)	Habitat
* <u>Penaeus indicus</u>	Marine; young in brackish water
* <u>Penaeus carinatus</u>	Marine and inshore in young stages
<u>Parapenaeopsis stylifera</u>	Purely marine
<u>Parapenaeopsis sculptilis</u>	Marine and estuarine
* <u>Metapenaeus dobsoni</u>	Marine; young in brackish water
* <u>Metapenaeus monoceros</u>	Inshore and brackish water
* <u>Metapenaeus brevicornis</u>	Marine, brackish water, nearly fresh water
<u>Leander tenuipes</u>	Marine and inshore, spawns in sea
* <u>Leander styliferus</u>	Inshore and estuarine. Breeds in estuaries and sea
<u>Leander fluminicola</u>	Fresh water
* <u>Macrobrachium rosenbergii</u>	Fresh water, breeds in brackish water. Larvae require saline water
<u>Macrobrachium malcolmsonii</u>	Fresh water, breeding migration doubtful
<u>Macrobrachium mirabile</u>	Fresh water, breeds in brackish water
<u>Macrobrachium lamarrei</u>	Fresh water and brackish water
<u>Macrobrachium idae</u>	Fresh water
* <u>Macrobrachium rude</u>	Fresh water
<u>Caridina gracilirostris</u>	Fresh water

5

E/25

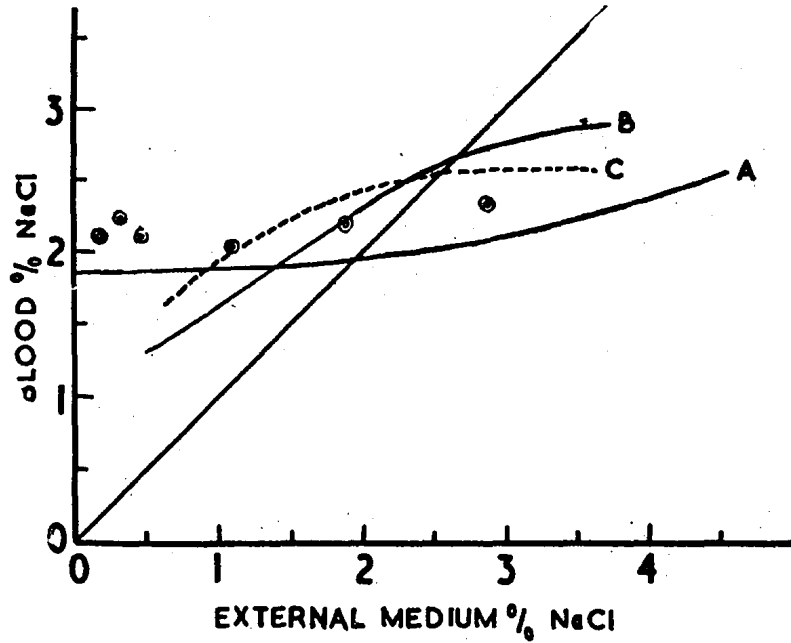


Fig. 1 Osmotic pressure (in % NaCl) of the blood of (A) Palaemonetes varians, (B) Palaemon serratus and (C) Palaemon elegans (dotted line) in different concentrations of the external medium measured under experimental conditions. Straight line indicates where points would fall if external and internal media were isotonic. Circles represent osmotic pressures (mean values only) of Palaemonetes from water of different salinities in its natural habitat. (After Panikkar, 1941).

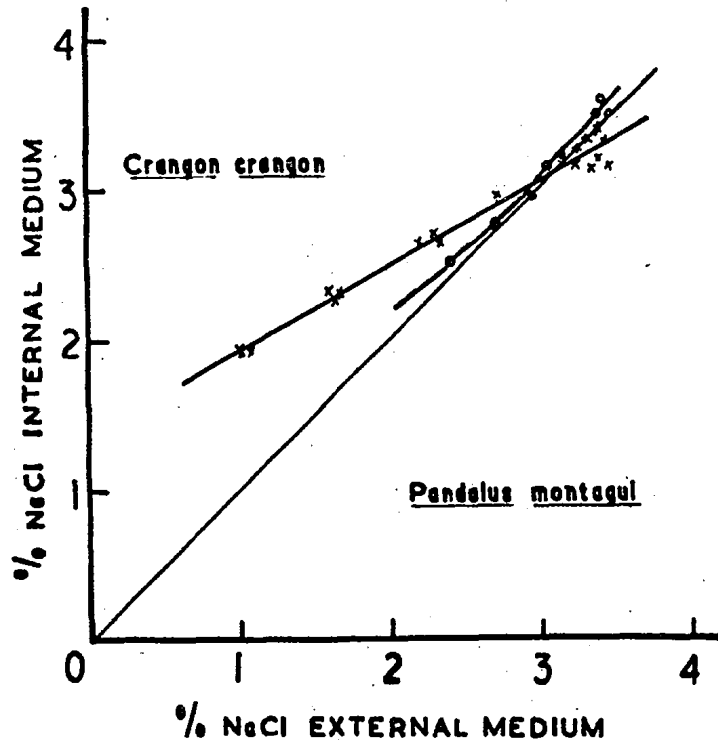


Fig. 2 Osmotic pressure of the blood of Crangon crangon and Pandalus montagui in different concentrations of sea waters under experimental conditions.

x — x — x = Crangon  
 o — o — o = Pandalus

interest that emerges from all these studies is that the urine is isotonic and that the normal osmotic value of these prawns acclimatizing in fresh water is much higher than that of the more specialized fresh water Crustacea exemplified by astacoids (Astacus). It is probably the very high normal osmotic value in these palaemonids and the absence of a fresh water stenohaline adaptation, involving production of large amounts of hypotonic or very dilute urine, which has enabled them to be distributed in sea water, brackish water and fresh water. The structure of the excretory system in these prawns as compared with that of Astacus confirms this view (Panikkar, 1941, as Potamobius).

Taking now the case of penaeids, it is interesting to note that hypo-osmotic regulation has also been established in Metapenaeus monoceros (c.f. Panikkar and Viswanathan, 1948) and in a number of other penaeids in India (Panikkar, 1950) and in P. aztecus Ives and P. duorarum Burkenroad in America (Williams, 1960). From the results on Metapenaeus it is clear that the osmotic regulation is largely achieved through chloride regulation (Panikkar and Viswanathan, 1948). The degree of hypotonicity is less than the values for palaemonids. From the evidence on the distribution of penaeids presented by a large number of authors, particularly Gunter (1964, and many earlier papers) and his school in the United States, and various authors in India, adaptation to lower salinity is highly developed in the younger stages, and, consequently, the young and juvenile prawns are more widely distributed in the estuarine and brackish-water environment than the full grown adults. The apparent conclusion is that osmotic regulation in dilute media is less effective in the full sized individuals and probably particularly in the reproductive phases, which necessitates their migration back to the sea. In the case of fresh-water prawns of the genus Macrobrachium there is a comparable migration over a lower range of salinities, i.e., they have to move to brackish water to maintain their body fluid concentration at a sufficiently high (hypertonic) level.

The well-known European shrimp Crangon crangon is also slightly hypotonic when in sea water, but the degree of hypotonicity is very much less than in the Palaemonidae and Penaeidae investigated and the range of tolerance in brackish water is also correspondingly less. The study of Broekema (1941) has brought interesting evidence on the distribution of Crangon in the inlets of the Netherlands.

Pandalus montagui, the North Sea marine prawn, is nearly isotonic in sea water and is a poor regulator in reduced salinities, showing an almost isosmotic curve. Comparative data on Crangon and Pandalus from the author's observations, previously unpublished, are given in Fig. 2.

#### 4 THE RELATION OF OSMOTIC BEHAVIOUR TO CULTURAL PRACTICES

The process of osmotic regulation of marine and estuarine prawns, as is now understood, has clearly shown the need for certain features of the environment for the successful penetration of these organisms into waters of lower salinity. The work of Krogh (1938, 1939) and other investigators has established that active absorption of ions, particularly chlorides, forms an essential feature of the adaptational process and that it is the active transport of ions through the membranes separating the internal and external media which enables many aquatic animals to maintain steep osmotic gradients. This is particularly to be noted in fresh water and brackish water. Other factors at play are the reduction in the permeability of the body walls and the ability of the renal organs to pump out the excess water with the minimum loss of salt.

It is apparent that the penaeid and palaemonid prawns growing under low salinity or fresh-water conditions are able to survive only if there is sufficient chloride in the surroundings to enable the blood concentration to be maintained at a high level. It is important to note that for species like Palaemonetes the mechanism is effective even in very low salinities. Survival becomes possible for these animals even under artificial conditions, provided that the availability of the chloride ions is assured. The active process is functional even when the ions are present only in exceedingly minute quantities, a process which some authors have called "anion-atmung".



E/25

In those species of Macrobrachium which migrate from fresh to brackish water in the breeding season, the most important limiting factor is again the concentration of chloride ions in the medium. It is uncertain at present whether this applies to the ovigerous females, the newly hatched larvae or both. Ovigerous females of Palaemon serratus have higher osmotic values than non-ovigerous specimens (Panikkar, 1941); this suggests that they may need higher salinities in their surroundings, and the same may apply to species like M. rosenbergii. It is not clear from the available evidence whether there is any impairment of regulatory mechanism in ovigerous females. The findings of Rajyalakshmi (1960) and Ling and Merican (1961) tend to show that later development and larval stages require saline water.

The large number of coastal and estuarine prawns distributed in many parts of the world have differences in their osmotic adaptation, particularly as regards their points of isotonicity (Table II). In the perfection of cultural practices, knowledge of the isotonic conditions for these prawns will be of very considerable value, because it is reasonable to expect that the osmotic work required is minimal where the external and internal media are at equilibrium. Under such conditions the oxygen requirements of the organisms will also be low and, correspondingly, also the natural mortality due to low oxygen tension. It is reasonable to assume that under isosmotic conditions the largest number of organisms could be cultured in a given volume of water. In this connection the results obtained by Lofts (1956) on the respiratory rate of the prawn Palaemonetes varians are of great interest. It was found from a series of measurements of the oxygen consumption of this prawn in different salinities that the lowest rate occurred under isotonic saline conditions. A point of further interest is the fact that the isotonic point is variable even within the same species if different populations are involved. Lofts found that in the populations of P. varians from saline areas the isotonic point and minimum respiratory rate was at 26 ppm NaCl, whereas in another population which had become isolated in fresh water the minimum respiratory rate was at 6 ppm NaCl, which obviously was at a condition of hypertonicity.

The homoiosmotic Indian prawn Metapenaeus monoceros from the brackish-water habitat has a minimal rate of respiration in 50 percent sea water, with increase in higher and lower salinities. On the other hand the same species from the marine habitat showed the minimal rate in sea water (Rao, 1958).

## 5 ROLE OF TEMPERATURE AND COMBINED EFFECTS OF TEMPERATURE AND SALINITY

Most of the prawns and shrimps useful for culture are not merely euryhaline, as discussed before, but also eurythermal. The indications are that cultural practices are easier at temperatures above 15°C. The possible influence of temperature on osmoregulation and its bearing on problems of crustacean distribution have been pointed out (Panikkar, 1940b). In the Decapoda Natantia the distribution patterns indicate that temperate marine species tend to become inhabitants of brackish and fresh water under tropical conditions. There are many instances of marine species of colder latitudes being represented by brackish-water and fresh-water species in the tropics. This peculiarity of distribution has been noticed by many workers, but the suggestion made that the influence of temperature on the osmotic behaviour may provide a probable answer is one worthy of more vigorous pursuit (Verwey, 1957). The exact mechanism of this is not clear, although lower osmotic values have been encountered in individuals acclimatized to high temperatures.

In the European shrimp Crangon crangon, Broekema (1941) found that adults seek higher salinities in cold weather and lower salinities in warm weather, and the young in summer tolerate lower salinities than the adults. This animal is similar to the European prawn Palaemon serratus, being a hypo-osmotic regulator in sea water and a good hyper-osmotic regulator in brackish water. Under constant salinities, there was an increase in the blood osmotic pressure with a fall in temperature. The same type of seasonal cycle in osmotic behaviour of palaemonid prawns was found on the British coast by Panikkar (1940b) who interpreted it in the light of the known distribution of

TABLE II  
Isotonic levels of Marine and Estuarine Shrimps and Prawns

Species	Isosmotic Point (expressed as % NaCl):Approximate	Author
<u>Pandalus montagui</u>	3.50	Panikkar (this paper)
<u>Crangon crangon</u>	2.15 - 2.3 3.1	Broekema (1941) Panikkar (this paper)
<u>Palaemon serratus</u>	2.5	Panikkar (1940a)
<u>Palaemon elegans</u>	2.4	Panikkar (1941)
<u>Palaemonetes varians</u>	2.0	Panikkar (1939)
<u>Penaeus aztecus</u>	2.51	Williams (1960)
<u>Penaeus duorarum</u>	2.75	Williams (1960)
<u>Metapenaeus monoceros</u>	2.63	Panikkar and Viswanathan (1948); Panikkar (unpubli- shed)

E/25

Crustacea. Discussing these results from the evolutionary point of view Huxley (1942) considers the temperature-salinity distribution relationship of Crustacea as one of "pre-adaptation".

Recent work of Williams (1960) has again confirmed this trend with reference to the penaeids on the North Carolina coast of America. Both Penaeus aztecus and P. duorarum inhabit a wide range of salinities and are hypotonic in sea water. He has brought out the interesting point that regulatory ability of both juveniles and adults is impaired at low temperatures (8.7 - 8.8°C) and the blood tends to become isotonic. The survival of these prawns was better in higher salinities at low temperatures.

There are many questions which could be asked. Is the tendency for the blood to become isotonic at low temperatures due to lack of efficiency in the osmoregulatory mechanism or increased ability to establish equilibrium? Recent work of Schlieper (1964) has yielded information on the possible effects of other ionic factors, such as potassium in tissue adaptation. These are certainly fields in which much further work is required, and it is important to emphasize that apart from the individual effects of temperature or salinity there is a need to take into account their combined effects. The problems of temperature-salinity relationship and the different roles of genetic and non-genetic adaptation have been extensively reviewed by Kinne (1963; 1964).

## 6 ROLE OF CALCIUM AND OTHER IONS

Moulting behaviour is an essential feature of arthropod growth. The crustacean exoskeleton has a high calcium component, and it has been shown by many workers that there is a close relationship between calcium metabolism, growth, moulting and osmotic pressure (Robertson, 1937; Panikkar, 1941). From the point of view of cultural practices the availability of sufficient calcium in the surroundings has to be taken into consideration. Owing to the importance of calcium in regulating the permeability of membranes, the osmo-regulatory mechanism breaks down in calcium-deficient surroundings. Quick growth and moulting of the younger stages become impossible in external media where the calcium supply is inadequate. Unpublished observations of the author show that in living aquatic Crustacea it is impossible to achieve a calcium-free state owing to the residual calcium in the body walls, but osmotic efficiency is reduced in both hyper-osmotic and hypo-osmotic gradients when Palaemon serratus is kept in calcium-free sea water. As the calcium content of the crustacean moult is high, lack of calcium in the surroundings may affect the frequency of moulting and play a major part in the growth process.

## 7 CONCLUSION

Highly developed osmoregulatory powers in marine prawns and shrimps belonging to the families Penaeidae and Palaemonidae have enabled them to withstand considerable changes in the external medium and to move freely from sea water to brackish water or even to fresh water. In the general biology of several species these movements are obligatory and for some fresh-water palaemonids migration to brackish waters is necessary. In the selection of species for culture, commercially valuable prawns and shrimps with the widest range of adaptation should be chosen, because they are most likely to tolerate the conditions imposed upon them. There is a fairly good correlation between the cultural practices now developed and the physiology of the crustacea concerned, but further application of physiological knowledge would lead to the selection of environments to obtain higher yield and lower natural mortality. It cannot be said that the existing knowledge of the subject is comprehensive enough for immediate application and much further work is needed in not only collecting the basic information on osmotic behaviour but also assessing the combined influence of factors like temperature and salinity on osmotic and ionic regulation.

8 REFERENCES

- Broekema, M.M.M., Seasonal movements and the osmotic behaviour of the shrimp, Crangon  
1942 crangon L. Archs néerl.Zool., 6:1-100
- Dakin, W.J., Life history of a species of Metapenaeus in Australian coastal lakes.  
1946 Nature, Lond., 158(4003):99
- Gopinath, K., Prawn culture in the rice fields of Travancore-Cochin, India. Indo-  
1956 Pacif.Fish.Coun., 6(3):419-24
- Gunter, G., J.Y. Christmas and R. Killebrew, Some relations of salinity to population  
1964 distributions of mobile estuarine organisms, with special reference to  
penaeid shrimp. Ecology, 45(1): 181-5
- Holthuis, L.B., A general revision of the Palaemonida of the Americas. Los Angeles,  
1952 Allan Hancock Foundation. 728 p.
- Huxley, J., Evolution: the modern synthesis. London, G. Allen & Unwin.  
1942
- Ibrahim, K.H., Observations on the fishery and biology of the freshwater prawn Macro-  
1962 brachium malcolmsoni M.Ed. of River Godavari. Indian J.Fish., 9:433-67
- Kemp, S., Fauna of the Chilka lake: Crustacea Decapoda. Mem.Indian Mus., 5(3):199-  
1915 325
- Kinne, O., The effects of temperature and salinity on marine and brackish-water  
1963 animals. I. Temperature. Oceanogr.mar.Biol., 1:301-40
- \_\_\_\_\_, The effects of temperature and salinity on marine and brackish-water  
1964 animals. II. Salinity. Oceanogr.mar.Biol., 2:281-339
- Krogh, A., Active absorption of ions in some freshwater animals. Z.vergl.Physiol.,  
1938 25:235-50
- \_\_\_\_\_, Osmotic regulation in aquatic animals. Cambridge, Cambridge University  
1939 Press, 242 p.
- Ling, S.W. and A.B.O. Merican, Notes on the life and habits of the adults and larval  
1961 stages of Macrobrachium rosenbergii (de Man). Proc.Indo-Pacif.Fish.Coun.,  
9(2):55-60
- Lockwood, A.P.M., The osmoregulation of Crustacea. Biol.Rev., 37:257-305  
1962
- Lofts, B., The effect of salinity changes on the respiration rate of the prawn  
1956 Palaemonetes varians (Leach). J.exp.Biol., 33:730-6
- Menon, M.K., On the paddy field prawn fishery of Travancore-Cochin and an experiment  
1955 in prawn culture. Proc.Indo-Pacif.Fish.Coun., 5(2):131-5
- Panikkar, N.K., The prawn industry of the Malabar coast. J.Bombay nat.Hist.Soc.,  
1937 39(2):343-53
- \_\_\_\_\_, Osmotic behaviour of Palaemonetes varians (Leach). Nature, Lond.,  
1939 144:866

E/25

- Panikkar, N.K., Osmotic properties of the common prawn. Nature, Lond., 145:108  
1940a
- \_\_\_\_\_, Influence of temperature on osmotic behaviour of some crustacea and its  
1940b bearing on problems of animal distribution. Nature, Lond., 146:366
- \_\_\_\_\_, Osmoregulation in some palaemonid prawns. J.mar.biol.Ass.U.K., 25:  
1941 317-59
- \_\_\_\_\_, Physiological aspects of adaptation to estuarine conditions. Proc.  
1950 Indo-Pacif.Fish.Coun., 2
- \_\_\_\_\_, Possibilities of further expansion of fish and prawn cultural practices  
1952 in India. Curr.Sci., 21:29-33
- Panikkar, N.K. and R.G. Aiyar, The brackishwater fauna of Madras. Proc.Indian Acad.  
1937 Sci., 5(6):245-60
- \_\_\_\_\_, Observations on breeding in brackishwater animals of Madras. Proc.  
1939 Indian Acad.Sci.(B), 9(6):343-64
- Panikkar, N.K. and M.K. Menon, Prawn fisheries of India. Proc.Indo-Pacif.Fish.Coun.,  
1956 6(3):328-44
- Panikkar, N.K. and R. Viswanathan, Active regulation of chloride in Metapenaeus  
1948 monoceros Fabricius. Nature, Lond., 161-137
- Parry, G., Ionic regulation in the palaemonid prawn Palaemon (=Leander) serratus.  
1954 J.exp.Biol., 31:601-13
- Pearse, A.S. and G. Gunter, Salinity. Mem.geol.Soc.Am., 67(1):129-57  
1957
- Potts, W.T.W. and G. Parry, Osmotic and ionic regulation in animals. London, Pergamon  
1964 Press, 423 p.
- Rajyalakshmi, T., Observation on the embryonic and larval development of some estua-  
1960 rine palaemonid prawns. Proc.nat.Inst.Sci.India(B), 26:395-408
- Rao, K.P., Oxygen consumption as a function of size and salinity in Metapenaeus mono-  
1958 ceros Fab. from marine and brackish water environments. J.exp.Biol.,  
35:307-13
- Robertson, J.D., Some features of the calcium metabolism of the shore crab Carcinus  
1937 maenas. Proc.R.Soc.(B), 124:182-82
- \_\_\_\_\_, Ionic regulation in the crab Carcinus maenas (L) in relation to the  
1957 moult cycle. Comp.Biochem.Physiol., 1:183-212
- Schlieper, C., Ionale und Osmotische Regulation bei astuarleben Jierew. Kieler.  
1964 Meeresforsch., 20:169-78
- Verwey, J., A plea for the study of temperature influence on osmotic regulation.  
1957 Annls Biol.,Paris, 33:129-49
- Williams, A.B., Influence of temperature on osmotic regulation in two species of  
estuarine shrimps (Penaeus). Biol.Bull.mar.biol.Lab., Woods Hole, (119):  
560-71

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