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THE EFFECTS OF FLUCTUATING SALINITIES ON FOUR SPECIES OF ASTEROID ECHINODERMS

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Abstract—1. Measurements were made of osmotic, Na^+, K^+, Mg^{2+}, Ca^{2+} and SO_4^{2-} concentrations of the coelomic fluid and of the tissue water content of *A. rubens*, *S. papposus*, *H. sanguinolenta* and *A. irregularis* during exposure to both gradual (sinusoidal) and abrupt (square-wave) salinity fluctuations.

2. In both gradual and abrupt salinity regimes the coelomic fluid ionic and osmotic concentrations of all four species followed those of the external medium.

3. Tissue water content showed an inverse response to salinity change.

4. There was no evidence of ionic or osmotic regulation in any of the species studied.

INTRODUCTION

The echinoderms are usually considered to be an exclusively marine, stenohaline phylum tolerating very little change in the salinity of their environment; however, many authors have recorded examples of echinoderms entering areas of dilute seawater (for review see Binyon, 1966). Echinoderms have no known excretory organ and possess little or no power of osmotic regulation of their extracellular fluids. Ellington & Lawrence (1974) have shown that the estuarine asteroid *Luidia clathrata* regulates the volume of the coelomic fluid and the intracellular osmotic concentrations. Volume regulation has also been shown to exist in the sea urchin, *Strongylocentratus droebrachiensis* (Lange, 1964).

The ionic composition of echinoderms is well documented. With the exception of slight potassium accumulation in the watervascular system and calcium accumulation in the perivisceral fluid, echinoderms are poor ionic regulators (Binyon, 1966). Most previous work has been concerned with long term effects on echinoderms exposed to seawater of constantly lowered salinity. The exception is the work of Stickle & Ahokas (1974) who investigated the effect of tidal salinity fluctuations on three species of echinoderms and found that the perivisceral fluid osmotic shifts were due predominantly to ion flux. This study deals with the effect of fluctuating salinity on osmotic, ionic and volume regulation in four species of starfish exposed to fluctuating salinities.

MATERIALS AND METHODS

Specimens of *Asterias rubens*, *Solaster papposus*, *Henricia sanguinolenta* and *Astropecten irregularis* were collected locally from the Anglesey coast. All animals were kept at 12°C in aquaria supplied with running seawater from the Menai Strait (salinity approximately 32‰) and were used in experiments as soon as possible after capture, but always within 1 week.

Steady state experiments were carried out in which 10 specimens of each species were exposed to 100, 90, 80 and 70% seawater for 1 week.

The apparatus used to produce fluctuating salinity regimes has been described by Davenport *et al.* (1975) and used in the study of bivalve molluscs by Shumway (1977*a*, *b*). All species were subjected to both gradual (sinusoidal) and abrupt (square wave) salinity changes (see Figs. 1 and 2). Maximum seawater concentration was 100% (salinity approximately 32‰); minimum seawater concentration was 50% (salinity approximately 16‰) since it was found in preliminary experiments that exposure to lower salinities was fatal to all four species. All experiments were carried out at 12°C.

A total of 108 individuals of each species were examined. Animals were removed from the experimental chambers every 3 hr, blotted dry and weighed. The perivisceral fluid was collected by cutting off the tips of one or more arms and the fluid allowed to drain into a beaker (Binyon, 1962). pH measurements were taken immediately using a Radiometer PHM 3 digital pH meter. The osmolality was then measured using a Halbmikro Osmometer accurate to ± 1 mOsm. Three determinations were made upon each sample and the mean value calculated. Samples were then centrifuged for 2 min at 8000 *g* to remove debris and frozen for subsequent determinations of sodium, potassium, magnesium, calcium and sulphate ions. The drained bodies were then frozen, freeze-dried and reweighed to give the tissue water content.

Sodium, potassium, calcium and magnesium concentrations were determined using a Pye Unicam atomic absorption spectrophotometer. Lanthanum oxide at a final concentration of 0.02% was added to samples for the determination of calcium and magnesium to prevent interference by other cations (Stickney, 1971). Sulphate was determined turbidometrically according to a scaled-down version of the American Public Health Association Method (1967).

RESULTS

Table 1 shows the Na^+, K^+, Ca^{2+}, Mg^{2+} and SO_4^{2-} ion and osmotic concentrations and the pH values for Menai Strait seawater and the coelomic fluid of *A. rubens*, *S. papposus*, *H. sanguinolenta* and *A. irregularis*. Values for tissue water content are also given for the four species. In all species, the osmolality, Na^+, K^+ and Mg^{2+} values are slightly higher

Table 1. Na^+, K^+, Ca^{2+}, Mg^{2+} and SO_4^{2-} ion and osmotic concentrations and the pH values for Menai Strait seawater and the coelomic fluid of *A. rubens*, *S. papposus*, *H. sanguinolenta* and *A. irregularis* and tissue water content for the four species

	mOsm	Na^+	K^+	Ca^{2+}	Mg^{2+}	SO_4^{2-}	pH	% Tissue water
Menai Strait s.w.	965 ± 5	465 ± 7	9.8 ± 0.6	10.0 ± 0.4	52.1 ± 1.0	28.1 ± 1.0	7.90 ± 0.03	
Asterias rubens	1068 ± 11	479 ± 6	10.0 ± 0.7	10.0 ± 0.4	53.1 ± 1.3	26.1 ± 0.8	7.26 ± 0.01	79.91 ± 1.1
Solaster papposus	1088 ± 9	476 ± 8	9.9 ± 0.5	10.0 ± 0.3	53.9 ± 1.0	26.8 ± 0.8	6.99 ± 0.02	78.14 ± 1.3
Henricia sanguinolenta	1109 ± 11	489 ± 11	10.1 ± 0.4	9.8 ± 0.6	54.0 ± 1.1	27.3 ± 0.9	6.89 ± 0.03	74.59 ± 1.9
Astropecten irregularis	1078 ± 8	481 ± 11	10.0 ± 0.5	9.9 ± 0.5	52.8 ± 1.0	27.9 ± 1.1	6.90 ± 0.03	71.86 ± 1.7

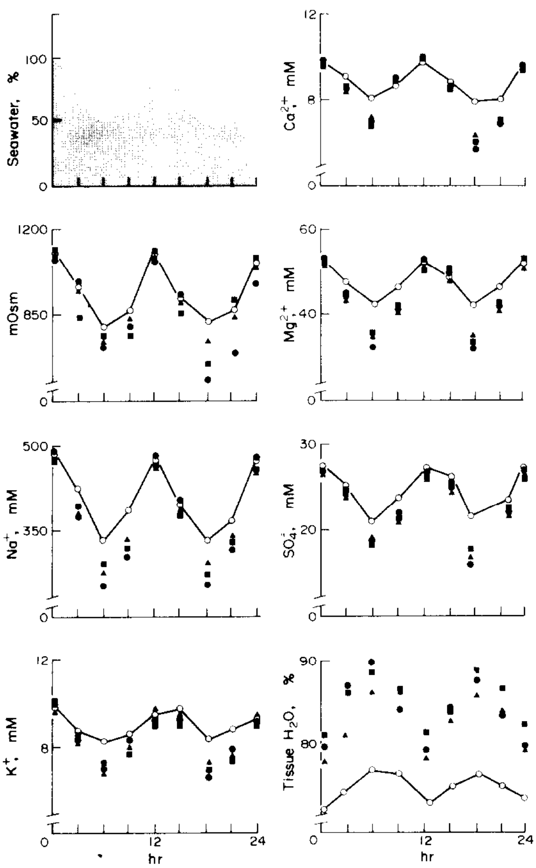

Fig. 1. Changes in coelomic fluid osmolality, Na^+, K^+, Mg^{2+}, Ca^{2+}, SO_4^{2-} concentrations and in the tissue water content of *Asterias rubens* (●), *Solaster papposus* (■), *Henricia sanguinolenta* (▲) and *Astropecten irregularis* (○) exposed to a 50% seawater minimum sinusoidal salinity regime. Each point is a mean of 5 animals. Error bars representing 95% confidence limits are smaller than the actual points.

in the coelomic fluid than in the surrounding seawater. Ca^{2+} levels in the coelomic fluid were the same as that of the surrounding seawater, but SO_4^{2-} levels were lower than those of the external medium. The pH of the coelomic fluid was consistently lower than that of the Menai Strait seawater and remained constant during exposure to fluctuating salinities in all four species (results not shown).

Figures 1 and 2 show the changes in coelomic fluid osmolality, ionic concentration and tissue water content of *A. rubens*, *S. papposus*, *H. sanguinolenta* and *A. irregularis* during exposure to 50% seawater minimum gradual and abrupt salinity fluctuations. In both regimes, the smallest changes in total osmolality and ion concentration were in *A. irregularis* (shown by the continuous line) and the greatest changes occurred in *A. rubens* (shown by solid circles). The osmotic and ionic concentrations of the coelomic fluid of all four species followed the changes in the external medium, whereas the tissue water content showed an inverse response to the salinity change.

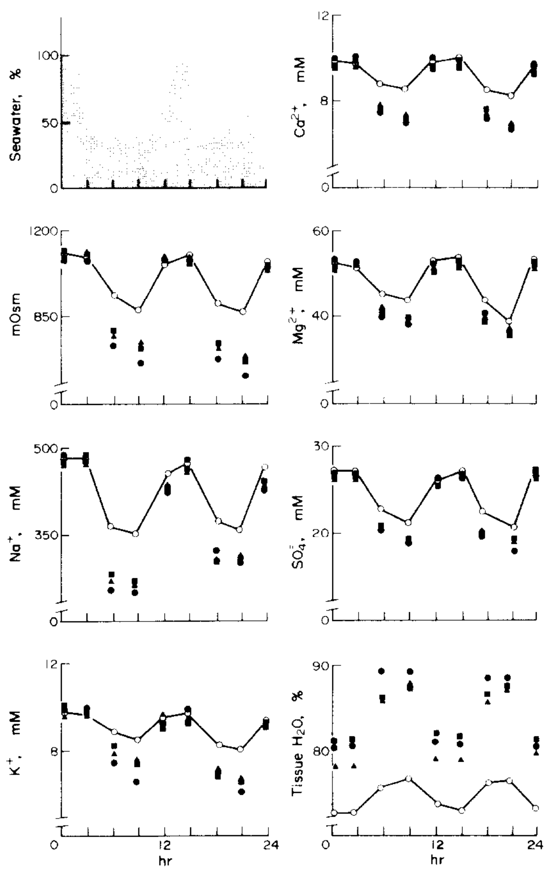

Fig. 2. Changes in coelomic fluid osmolality, Na^+, K^+, Mg^{2+}, Ca^{2+}, SO_4^{2-} concentrations and in the tissue water content of *Asterias rubens* (●), *Solaster papposus* (■), *Henricia sanguinolenta* (▲) and *Astropecten irregularis* (○) exposed to a 50% seawater minimum square-wave salinity regime. Each point is a mean of 5 animals. Error bars representing 95% confidence limits are smaller than the actual points.

DISCUSSION

There was no evidence of ionic or osmotic regulation in any if the species studied. The concentration of Na^+, Ca^{2+}, K^+, Mg^{2+} and SO_4^{2-} ions in the coelomic fluid of the four species followed the changes in the external medium. The difference in the amplitude of change between the species is most likely due to differences in body wall dampening by the individual species, dampening being greatest in *A. irregularis.*

In all four species, there was a rise in tissue water concentration during periods of decreasing salinity and similarly, a decrease in tissue water concentration during periods of increasing salinity. The greatest change in tissue water concentration was in *A. rubens* (79.9–91.1%) and the least change was in *A. irregularis* (71.86–77.4%). These differences are most likely a reflection on the nature of the exoskeleton, as was the case in ionic and osmotic changes of the coelomic fluid. *A. rubens* possesses a relatively soft, pliable exoskeleton while that of *A. irregularis* is very thick and rigid.

Stickle & Ahokas (1974) exposed 3 species of echinoderms to gradual salinity fluctuations reaching a minimum salinity of 10‰ and found that percentage body water values did not change. They attributed this lack of change to their method of seawater dilution. Since seawater dilution in this study was also done gradually (and only to approximately 16‰) and tissue water concentration changed by as much as 11% it seems likely that some other factor caused the animals in their study to maintain constant tissue water levels.

Steady state experiments showed that the lower lethal limit (LLL) for all four species was 80% seawater (salinity approximately 26‰). All animals exposed to lower salinities died after 2 days. This limit is in agreement with those of *Asterias rubens* (Binyon, 1961), *Hemipholis elongata, Amphiodia limbata* (Ferguson, 1948) and *Strongylocentratus purpuratus* (Giese & Farmanfarnaian, 1963).

Figures 1 and 2 show that the LLL for all four species could be lowered if the animals were exposed to gradual salinity fluctuations rather than constantly lowered salinities. All four species were found to tolerate salinities fluctuating between 100 and 50% seawater for 2 weeks. These results are not in agreement with the results of Loosanoff (1945) who found that tolerance values for *A. forbesi* were independent of the rate of salinity change. Although the animals appeared healthy and were capable of righting themselves, it is possible that 2 weeks is not sufficient time to determine the animals' permanent tolerance limit. It has been shown (Shumway, 1977*a*) that the LLL of some stenohaline bivalve molluscs could also be lowered if the animals were exposed to fluctuating rather than constantly lowered salinity changes.

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