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THE EFFECTS OF FLUCTUATING SALINITY ON RESPIRATION IN GASTROPOD MOLLUSCS

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Abstract—1. Oxygen consumption was monitored in 11 species of gastropod molluscs during exposure to a simulated tidal salinity fluctuation.

2. Withdrawal into the shell was seen to be the primary response to decreased salinities and oxygen consumption ceased entirely after withdrawal.

3. In all species studied the respiratory rate was constant prior to withdrawal.

4. An experimentally determined distribution pattern is compared with existing field data for the same species.

INTRODUCTION

Gastropod molluscs are amongst the most abundant species characteristic of the intertidal zone and are commonly found over a wide range of salinities. There have been a number of ecological studies concerned with gastropod distribution and salinity (see Fretter & Graham, 1962) but as Arnold (1972) pointed out ecological studies on their own do not always reveal whether the capacity to tolerate a wide salinity range is due to periods of inactivity during adverse conditions or the ability to retain activity within a wide salinity range. Often, too, the species' potential for salinity tolerance is not established.

In the present study eleven species of gastropod molluscs representing a wide range of habitats were exposed to simulated tidal salinity fluctuations in the laboratory. This has two advantages in that the animals' activity may be observed throughout the experiments and by subjecting all species (regardless of natural distribution) to the same salinity regimes any potentials for a greater salinity tolerance than normally experienced in the species' natural habitat would be detected.

MATERIALS AND METHODS

Specimens of *Littorina littorea* (L.), *Nucella lapillus* (L.), *Monodonta lineata* (daCosta), *Gibbula cineraria*, *L. littoralis* and *Patella vulgata* (L.) were collected locally from the Anglesey coast. *Ocenebra erinacea* (L.), *Crepidula fornicata* (L.), *Turritella communis* Risso and *Nassarius reticulatus* (L) were supplied by The Laboratory, Plymouth and *Calliostoma zizyphinum* (L.) were collected at Oban (Scotland). All animals were maintained at 10°C in aquaria supplied with running seawater from the Menai Strait (salinity approximately 33.5‰ = 100% s.w.) for at least one week prior to use in experiments. *C. fornicata* were left in stacks of 3–4 animals and the tissue removed from the bottom shell of the stack. *P. vulgata* were placed on small perspex sheets. All experiments were carried out at 10°C.

The apparatus used to produce fluctuating salinities has been described by Davenport *et al.* (1975). The gastropods were exposed to a gradual (sinusoidal) salinity profile fluctuating between 100 and 30% seawater (see Fig. 1). The method used to monitor oxygen consumption during changing salinties has been described previously (Shumway, 1978a, b). Up to 10 animals were placed in the experimental chamber at least 12 hr prior to the start of the experiments. Specimens of *C. fornicata* were placed in the chamber stacked and *P. vulgata* were placed in the chamber still attached to the perspex sheets. The experiments were repeated three times for each species. At the conclusion of the experiments the animals were removed from the shells, where appropriate the operculae were removed and the tissue freeze-dried. Results are expressed as ml O_2 consumed g^{-1} dry weight^{-1}.

RESULTS

The results are given in Figs 1, 2 and Table 1. "Active" in this study is taken to mean that the animal is not withdrawn in its shell or in the case of the limpets clamped down to the substratum and activity has been measured in terms of oxygen consumption. It was found that as long as the animals remained exposed to the external medium their respiratory rates were constant. The apparent decrease in respiratory rate with decreasing salinity in some of the species (i.e. *C. zizyphinum*, *N. reticulatus*, *N. lapillus*, *L. littorea*, *C. fornicata* and *L littoralis*) is due solely to the number of animals retreating into their shells at a given time. Consequently, the calculated percent time active for any given species includes these points of apparent decreased oxygen consumption.

Of the eleven species studied *O. erinacea* proved to be the least tolerant of seawater dilution retreating into their shells when the external medium had reached a concentration of 77% seawater. The next least tolerant species were *T. communis*, *M. lineata* and *C. cineraria* all of which became inactive in 65% seawater. *P. vulgata* maintained a normal respiratory rate until the external seawater reached approximately 54%. The remainder of the species studied showed similar tolerances, remaining active down to a concentration of approximately 50% seawater.

During periods of zero oxygen consumption (0% activity) all animals were seen to be withdrawn into

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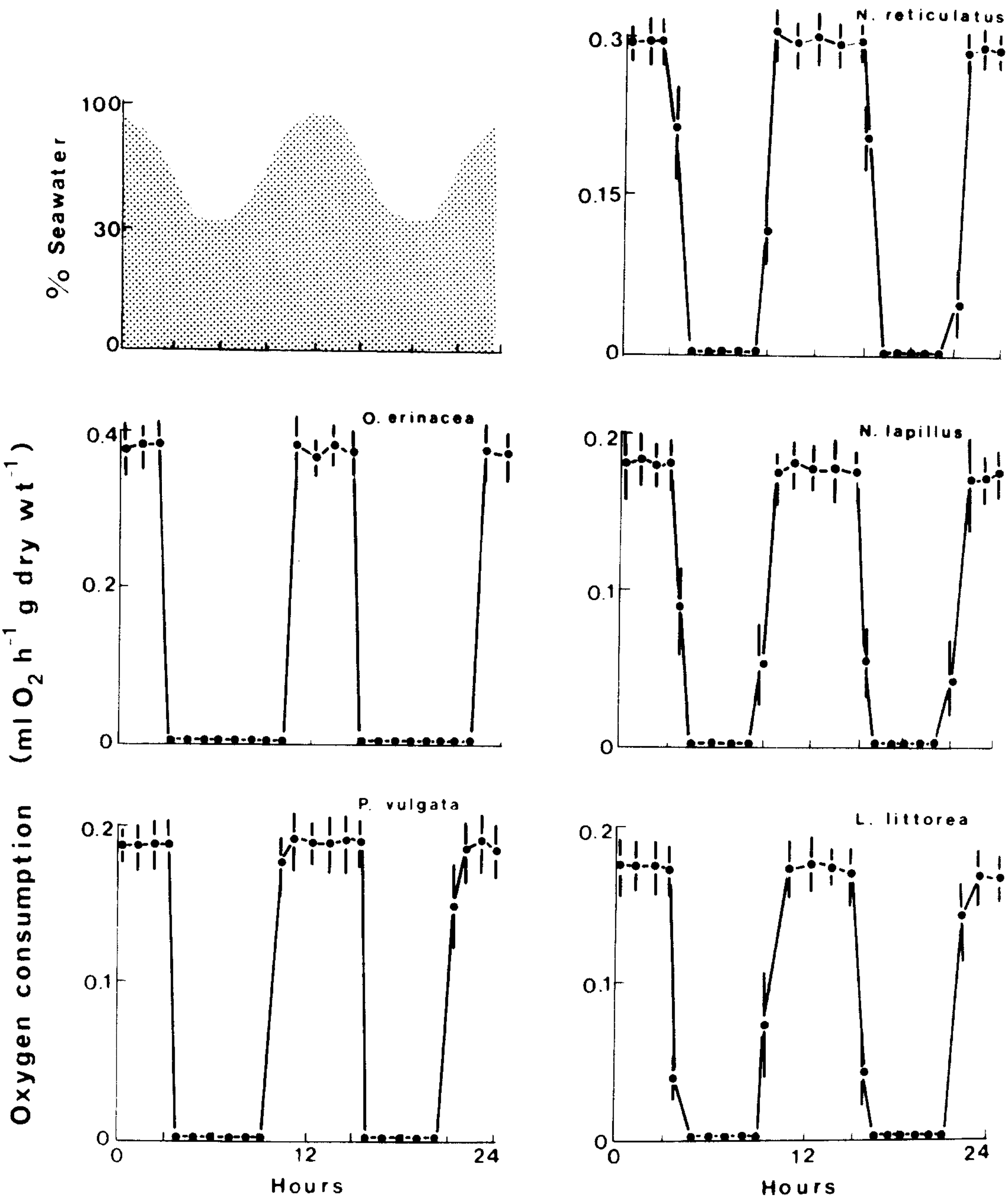

Fig. 1. Changes in oxygen consumption of 5 species of gastropod molluscs during exposure to fluctuating salinities. Error bars represent 95% confidence limits.

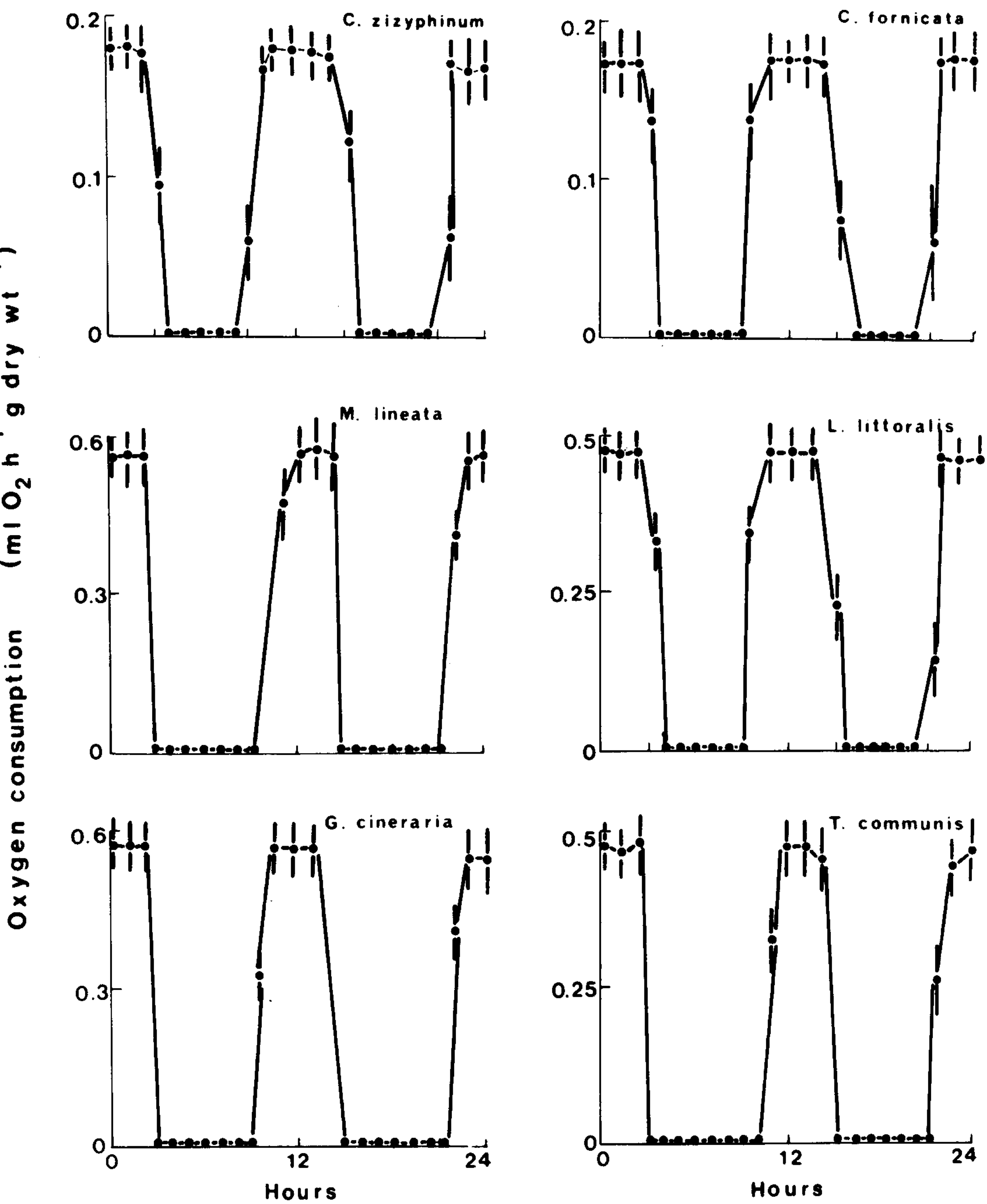

Fig. 2. Changes in oxygen consumption of 6 species of gastropod molluscs during exposure to fluctuating salinities. Error bars represent 95% confidence limits.

Table 1. Salinity at which all animals of each species had isolated themselves from the external environment and the duration of activity (monitored as oxygen consumption) when exposed to a 30% seawater minimum sinusoidal salinity regime

Species	S.W. concentration at 'closure'	% Time active
O. erinacea	77% (25.8‰)	39.1
T. communis	65% (21.8‰)	41.0
M. lineata	65%	43.2
G. cineraria	65%	44.2
P. vulgata	54% (18.1‰)	47.8
C. zizyphinum	51% (17.1‰)	53.6
L. littoralis	51%	54.7
C. fornicata	50% (16.8‰)	59.4
L. littorea	49% (16.4‰)	61.9
N. reticulatus	50%	63.8
N. lapillus	50%	65.2

Table 2. Distribution of gastropod molluscs in the Severn Estuary in order of ascending penetration from Boyden *et al.* (1978): Salinity ranges are from Bassindale (1943)

Species	Minimum salinity winter neaps	Maximum salinity summer springs
N. reticulatus	30‰	33‰
O. erinacea	28‰	29‰
C. zizyphinum	28‰	29‰
M. lineata	28‰	29‰
C. cineraria	28‰	29‰
L. littorea	20‰	28‰
N. lapillus	20‰	28‰
P. vulgata	13‰	27‰
L. littoralis	13‰	27‰

the shells or in the case of *P. vulgata* and *C. fornicata* tightly clamped down to the substratum.

DISCUSSION

There is a trend for gastropod molluscs to increase in euryhalinity with increased height above low tide level (Fretter & Graham, 1962; Remane, 1958; Avens & Sleigh, 1965; Arnold, 1972) and several field studies have been undertaken which include distribution patterns of British gastropods (Fretter & Graham, 1962; Arnold, 1972; Boyden *et al.*, 1978).

All but two of the species studied here (*C. fornicata* and *T. communis*) occur in the Severn Estuary (Boyden *et al.*, 1978). Table 2 shows the salinity tolerances of nine species of gastropods in the estuary as determined from their geographical distribution and it can be seen that the experimentally determined salinity tolerances shown in Table 1 are in close agreement with the field data. There are exceptions, however. The first is *P. vulgata* which was found to occur very high in the estuary sometimes experiencing salinities as low as 40% seawater (approx. 13‰S). In the present study *P. vulgata* was found to clamp down to the substratum when the external medium reached a concentration of approximately 65% seawater (approximately 22‰S). This apparent discrepancy is explained by the work of Arnold (1957) who showed that high water limpets have greater tolerance to lowered salinities than do low shore animals. The limpets used in this study were collected from mid to low shore and would therefore not be expected to be as tolerant of lowered salinity as the high estuary animals recorded in the survey of Boyden *et al.* (1978).

Another obvious difference between the experimentally determined distribution pattern and that of the Severn is the position of *N. reticulatus*. In the Severn this species is found low on the shore and is not normally exposed to salinities below 30‰; however, in this study it was found to tolerate salinities as low as 50% seawater (approximately 17‰S). *N. reticulatus* is known to occur in brackish waters (Fretter and Graham, 1962) which may explain its tolerance of low salinities as demonstrated in this study. It is also possible that factors other than salinity are affecting its distribution in the Severn estuary as is the case in *L. littoralis*. There is a minor difference between the experimentally determined distribution pattern and that of Boyden *et al.* in the position of *L. littoralis* on the shore. This species is found in salinities as low as 13‰ (approx. 40% seawater) in the Severn but in the present study it was found to become inactive in 51% seawater (approx. 17‰S). This species is usually associated with the fronds of *Fucus* and *Ascophyllum* and Fretter & Graham (1962) state that it is the presence of algae which dictates the upper limit of the species. This algae is abundant in the upper reaches of the estuary (Boyden, pers. comm.) thus at least partially explaining the high penetration of *L. littoralis* in the estuary.

Turritella communis is a sub-littoral gastropod not found intertidally (Fretter & Graham, 1962). This species, however, showed considerable tolerance of lowered salinity in the present study and Avens & Sleigh (1965) found *T. communis* to be as euryhaline as most littoral snails. It is probable, as pointed out by Avens and Sleigh, that it is this specie's intolerance of exposure rather than intolerance of salinity changes that limits the species to a sublittoral habitat.

The slipper limpet, *C. fornicata*, although absent from the Severn, is commonly found in other estuarine areas (Chipperfield, 1951; Walne, 1956) and it is therefore not surprising that this species was found to be one of the most tolerant of seawater dilution in the present study.

Although all of the species studied showed some tolerance of lowered salinity none remained active below approximately 50% seawater. The animals were found to retreat into their shells, or in the case of the limpets to clamp down on the substratum during periods of decreasing salinity and remained isolated from the external environment until the salinity increased. Although there are other factors involved, the importance of the shell as a temporary shelter from adverse environmental conditions must not be overlooked when studying the salinity tolerances of gastropod molluscs.

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REFERENCES

ARNOLD D. C. (1957) The response of the limpet, *Patella vulgata* L., to waters of different salinities. *J. mar. biol. Ass. U.K.* **36**, 121–128.

ARNOLD D. C. (1972) Salinity tolerances of some common prosobranchs. *J. mar. biol. Ass. U.K.* **52**, 475–486.

AVENS A. C. & SLEIGH M. A. (1965) Osmotic balance in gastropod molluscs—I Some marine and littoral gastropods. *Comp. Biochem. Physiol.* **16**, 121–141.

BASSINDALE R. (1943) Studies on the biology of the Bristol Channel XI. The physical environment and intertidal fauna of the southern shores of the Bristol Channel and Severn Estuary. *J. Ecol.* **31**, 1–29.

BOYDEN C. R., CROTHERS J. H., LITTLE C. & METTAM C. (1977) The intertidal invertebrate fauna of the Severn estuary. *Fld Stud.* **4**, 477–554.

CHIPPERFIELD P. N. J. (1951) The breeding of *Crepidula fornicata* L. in the river Blackwater, Essex. *J. mar. biol. Ass. U.K.* **30**, 49–71.

DAVENPORT J., GRUFFYDD Ll.D. & BEAUMONT A. R. (1975) An apparatus to supply water of fluctuating salinity and its use in a study of the salinity tolerances of larvae of the scallop *Pecten maximus* (L.). *J. mar. biol. Ass. U.K.* **55**, 391–409.

FRETTER V. & GRAHAM A. (1962) *British Prosobranch Molluscs.* Bartholomew, London.

REMANE A. (1971) Ecology of brackish water. In *Biology of Brackish Water* (By REMANE A. and SCHLEIPER C. E.) pp. 1–210. Schweizebart'sch Verlagsbuchhandlung (Nagele u. Obermiller), Stuttgart.

SHUMWAY S. (1978a) Respiration, pumping activity and heart rate in *Ciona intestinalis* L. exposed to fluctuating salinities. *Mar. Biol.* **48**, 235–242.

SHUMWAY S. (1978b) Activity and respiration in the anemone, *Metridium senile* (L) exposed to salinity fluctuations. *J. exp. mar. biol. ecol.* **33**, 85–92.

WALNE P. R. (1956) The biology and distribution of the slipper limpet *Crepidula fornicata* in Essex rivers. Fish. Invest. Ministry of Agricult. Fish and Food, Series 2, **20**(6) 1–50.