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Behavioural Responses of Some Marine Bivalves to Heightened Seawater Copper Concentrations

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In the past, safe levels of toxic pollutants have been largely equated with biologically lethal LC_{50} (96-hour) concentrations, despite the fact that behavioural disabilities have been shown to occur at concentrations well below these levels (WEIR and HINE 1970, ANDERSON 1971, COOKE 1971).

The ability to detect and avoid potentially lethal concentrations of pollutants has been recorded in several freshwater species: fish (SPRAGUE 1964, 1968; HANSEN 1969, HANSEN et al. 1972, SUMMERFELT and LEWIS 1967); crustaceans (HANSEN et al. 1973, BARTHALAMUS 1977), and molluscs (HARRY and ALDRICH 1963, MACINNES and THURBERG 1973). However until recently no such behaviour had been observed on marine forms.

The study reported here constitutes a summary of preliminary investigations of the behavioural responses of several marine mollusc species to copper as a pollutant, and stems from the observation (DAVENPORT 1977) that the common mussel *Mytilus edulis* (L.) is capable of detecting and avoiding potentially lethal concentrations of copper delivered intermittently. The initial behavioural reaction of *M. edulis* occurs at copper concentrations of 0.02 ppm (DAVENPORT and MANLEY, in press), representing 0.2 ILL (FRY 1947, SPRAGUE et al. 1965), the ILL taken to be 0.1 ppm copper (DAVENPORT and MANLEY, in press).

MATERIALS AND METHODS

Specimens of *Modiolus modiolus*, 6-9 cms in length, were collected off Langness Point, Isle of Man; *Chlamys opercularis* 4-6 cms in length were collected near Point Lynas, Anglesey. *Crassostrea gigas* were supplied by the M.A.F.F. Laboratories, Conwy. *Anadara senilis* (the "Blood Clam") and *Modiolus demissus* were collected in Ghana and New England, U.S.A., respectively and flown to Britain. Animals were experimented upon in seawater at 12-15°C, with the exception of the tropical *Anadara* which required 25°C.

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The experimental design and procedure have been described in detail elsewhere (DAVENPORT and MANLEY, in press). Essentially the method relies upon the delivery to the experimental organisms of an increasing concentration of pollutant, in this case copper, by introducing a constant flow of pollutant into a relatively large experimental vessel supplied with a constant through flow of sea water; the contents of the vessel are thoroughly mixed by a magnetic stirrer. The mixing characteristics of such a system produce a roughly sinusoidal pattern of concentration change. The concentration of copper in the experimental chamber was continuously monitored by use of an Orion M94-27 specific ion electrode, which measures free ionic copper in solution. However, all results have been expressed, after prior calibration, as total added copper in solution. The threshold concentration of detection of the bivalve species studied was taken to be the concentration at which the normal pattern of valve movements was interrupted. This interruption was usually characterised by a sharp adduction of the shell valves. The gape of the shell valves was measured by cementing one valve to the base of the experimental chamber and connecting the other by a nylon thread to a silicon chip strain gauge. The gauge was connected, via a Wheatstone Bridge circuit to one channel of a Smiths Servoscribe chart recorder on which the amplified valve movements were displayed. The second channel of the recorder was used for synchronous recording of the copper concentration measurements derived from the specific ion electrode.

RESULTS

Sample traces of shell valve movements and changing copper concentrations for each species are shown in Figs. 1-5. A similar record showing the reactions of *Mytilus edulis* (DAVENPORT and MANLEY, in press) is shown for comparison in Fig. 6.

As for *M. edulis*, *C. gigas*, *M. demissus*, *A. senilis* and *M. modiolus* all show an initial shell valve adduction (A) followed by testing behaviour (T), the latter normally characterised by a gradual decrease in valve gape associated, sometimes, with intermittent partings of the valves. Eventually total closure of the shell valves occurs (C). After closure the valves may gape occasionally for a short time, possibly to allow further testing of the medium. If the animal is immersed in a toxic medium for a long period these tests become more frequent as the need to relieve respiratory stress outweighs the necessity to isolate the living body tissues from the pollutant.

The reactions of *A. senilis* and *M. modiolus* are rather more variable than the other species and this may account for

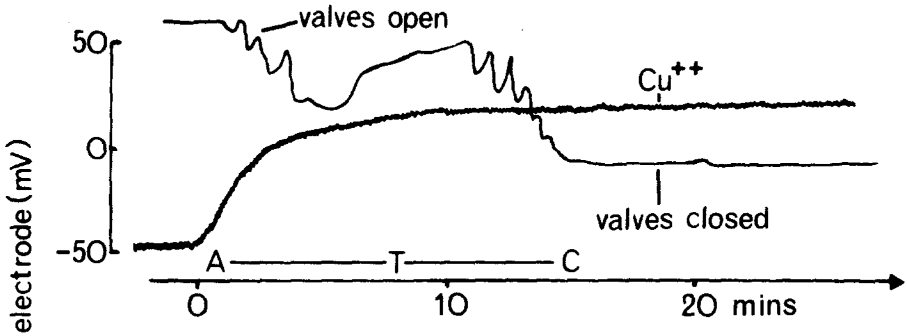

Fig.1 A.senilis

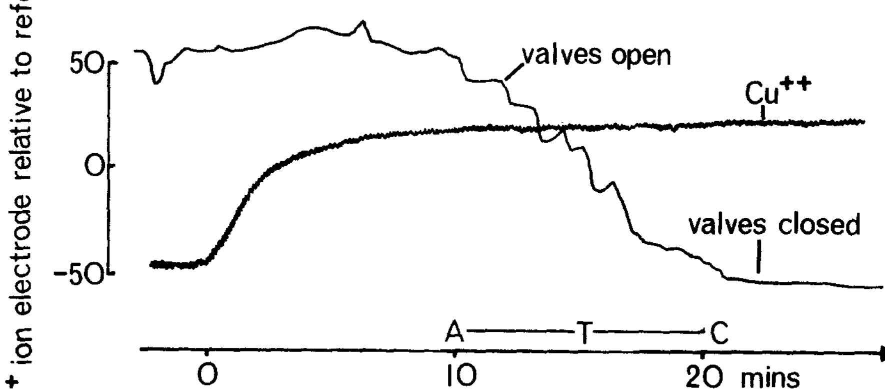

Fig.2 C.gigas

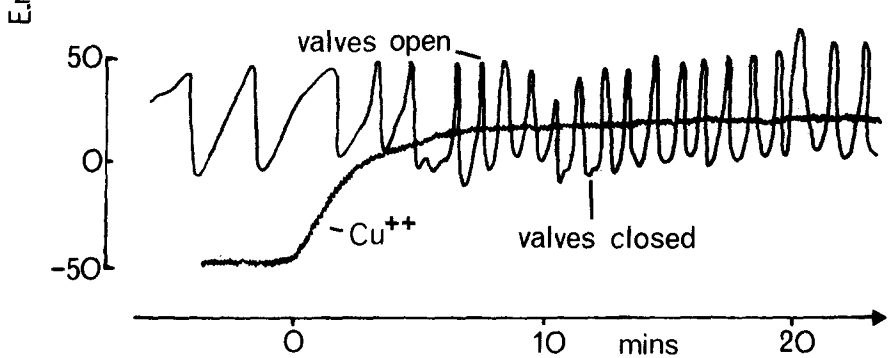

Fig.3 C.opercularis

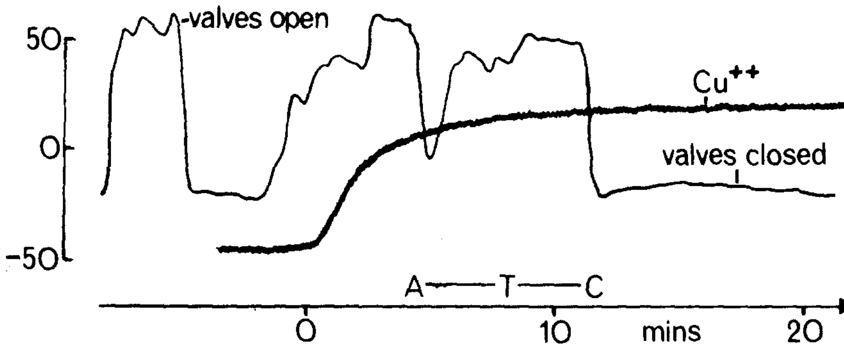

Fig. 4 M. modiolus.

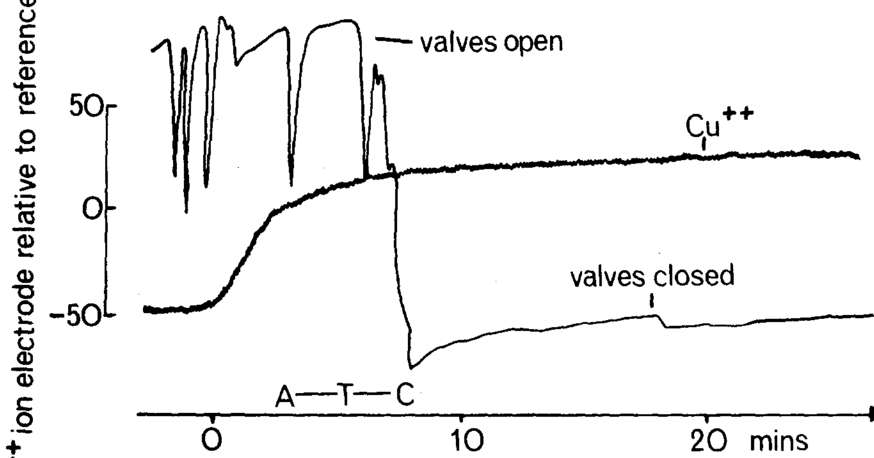

Fig. 5 M. demissus

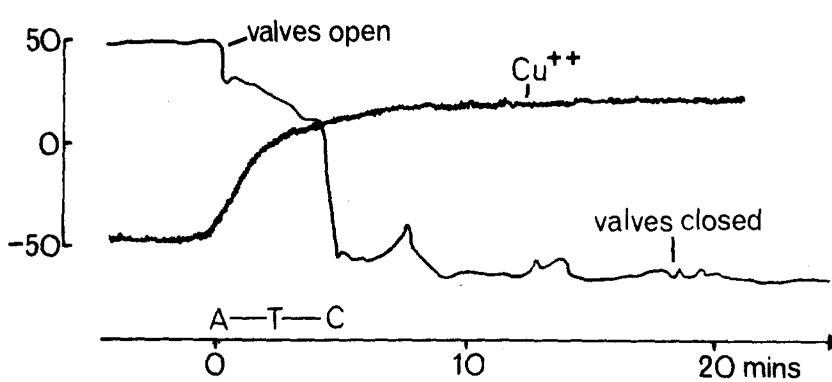

Fig. 6 M. edulis.

the larger confidence intervals for the concentration at which initial interruption of the normal valve movements occurs, the threshold of detection (T_D) (DAVENPORT and MANLEY, in press), for these two species. T_D concentrations for all species are summarised in Table 1.

TABLE 1

Concentrations of total copper in seawater at which normal behaviour is interrupted, T_D, (in ppm total added copper) with 95% confidence intervals, where available.

Modiolus modiolus	.141 ± .108
Mytilus edulis	.021 ± .01
Crassostrea gigas	.085 ± .025
Anadara senilis	.120 ± .123
Modiolus demissus	approx. .05

The only species not sharing this general behavioural pattern was C. opercularis. For this animal the only discernible response to the increasing copper concentration lies in an increase in the frequency of shell valve movement. Since C. opercularis is the only mobile species tested this response may reflect an attempt to initiate swimming. However, because the animals were fixed in position, it is not clear whether the valve movements are strong enough to be equivalent to swimming or whether they simply represent attempts to expel copper laden sea water. Further experiments to establish whether C. opercularis can swim away from and thus avoid polluted water will be necessary to clarify this point.

DISCUSSION

Given a background concentration of copper locally of .003 ppm (MORRIS 1974), the detection threshold concentrations of copper for M. edulis represents less than one order of magnitude increase in copper concentration; C. gigas and M. demissus, a thirty fold increase; M. modiolus and A. senilis represent less than a fifty fold increase.

The results raise several points of interest. Firstly the sequence of behaviour observed in most of these species, where a low concentration initiates a valve adduction response, followed by testing behaviour and valve closure at a higher concentration is very similar to that observed in two species of freshwater gastropod. The freshwater snail Taphius glabratus exhibits "distress" at .05 ppm copper and retracts into its shell at .1 ppm copper (HARRY and ALDRICH 1963), and the mud snail Nassarius obsoletus which shows "distress" at .1 ppm and retracts at 4 ppm copper (MACINNES and THURBERG 1973).

Whether or not the detection and avoidance of copper is relevant in the range of likely environmental levels encountered by each species is questionable. Concentrations of total copper of the magnitude required to result in total valve closure are not normally encountered in the marine environment where precipitation of copper complexes tends to keep the concentrations in solution very low. Also it is not certain that total sea water copper content is the factor detected by the bivalves; one or more of the many individual inorganic and organic complexes that copper assumes in sea water may be responsible for initiating the response. Where the responses may be of particular relevance is in conventional toxicity tests where concentrations below the levels inducing valve closure may have effects earlier than higher concentrations which induce valve closure and avoidance of the toxic medium. This possibility has already been shown for M. edulis (DAVENPORT 1977) where concentrations of 0.5 ppm and 0.25 ppm copper delivered intermittently (6 hours presence, 6 hours absence) to mussels were not lethal, as they were when delivered on a continuous basis.

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