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Valve Closure by Juvenile Scallops as a Protective Mechanism in Response to Elevated Levels of Environmental Copper

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Since about 1800, copper mining in Chile has developed and grown to major proportions, often producing elevated environmental concentrations of this metal in coastal zones near sites of extraction and refining. In some cases dramatic effects on ecosystems have been reported, including destruction of local flora and fauna (Castilla 1983). Massive deaths of marine invertebrates in certain areas have been attributed to pollution from copper-mine waste effluents (Valle 1984), as has been direct damage to human health (Bor-Cheng and Tsu-Chang 1990). Ecologically, motile species may be able to move away from contaminant foci, while sessile species either fail to resist pollutant effects or may posess behavioral or other mechanisms which allow them to resist or avoid pollution for periods of time which may favor their survival. This report describes a behavioral mechanism in the scallop of northern Chile *(Argopecten purpuratus)* by which it may avoid otherwise toxic levels of copper in its surrounding seawater. Juveniles of this species were observed due to their position in the trophic web, limited possibilities of escape,and high commercial value for human consumption in the adult stage.

MATERIALS AND METHODS

Observations on the behavioral effects of environmental copper on juvenile scallops were made in our laboratory at the Coastal Center for Aquaculture and Marine Research of the Universidad Católica del Norte (30%). *Argopecten purpuratus* with mean length of 12.7 ± 0.3 mm and weight of 0.37±0.4 g were obtained from the adjacent La Herradura Bay. These scallops had a tissue concentration of about 8.07 ug/g copper as determined by atomic absorption spectroscopy, a typical value for wild scallops of this region (Cuturrufo *et al.* 1992). Groups of fifteen scallops were each exposed in triplicate to 8 different concentrations of copper ranging from 0.08 to 0.40 mg L^{-1} made up in artificial seawater using analytical grade $CuC1_2$ (Merck Inc.).

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Previous determinations had shown the $LC_{50/48}$ for copper in this species to be 0.116 mg L^{-1} (Cuturrufo *et al.* 1992). Each group of scallops was maintained in 60 L of water in glass containers with continuous aeration, and observed for periods of 24 and 48 h. Over the 48 h period there was no significant change in experimental water which included T°C = 16, pH = 7.8, salinity = 34.4, and O_2 % saturation = 93%. The scallops were fed to repletion with a mixture of cultured microalgae 24 h prior to experimental runs.

Bioassy mortality was evaluated every four hours, and dead individuals, as evidenced by gaping and lack of motion, were removed at each observation period. Statistical evaluation of treatment effects was made by applying Barlett's homocedasticity analysis, ANOVA, and average differences using a Tukey test with a confidence interval of 95% (Sokal and Rohlf 1969).

RESULTS AND DISCUSSION

Soon after initiation of the experiment to 24 hours, individuals exposed to copper concentrations greater than 0.15 mg L^{-1} showed an instantaneous

containers, and retraction of the mantle to within the shell. With copper concentrations at or above 0.20 mg L^{-1} similar behavior was observed, followed by tight closure of the valves. Mortality of specimens in these conditions was constant at about 30% irrespective of ambient copper concentration. Tight valve closure was maintained for 24-30 hours after which the individuals began to open and die if the copper concentration exceeded 0.08 mg L^{-1} (Fig. 1).

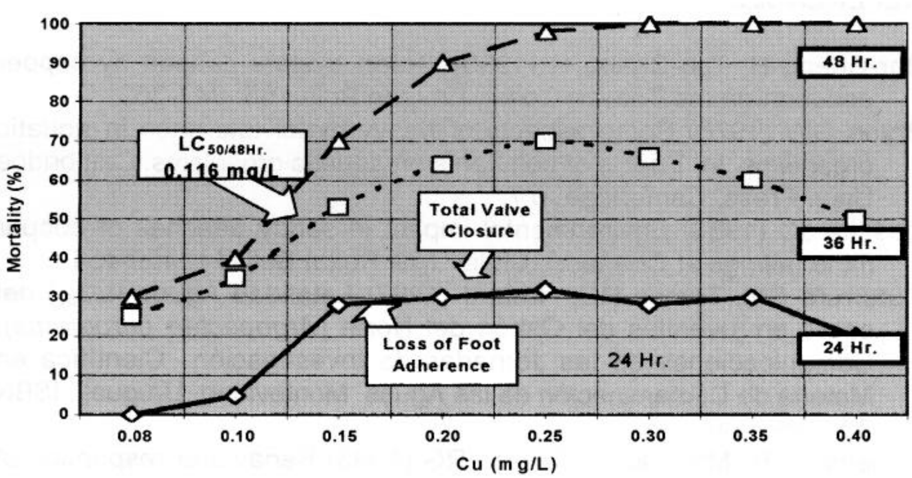

Figure 1. Average mortality at 24, 36 and 48 hours exposure to copper (mg L^{-1}) iin the juvenile scallop *Argopecten purpuratus.*

Tight valve closure as a behavioral response to external copper stress as seen in *A. purpuratus* juveniles has also been described for *Mytilus edulis* (Howell *et al.* 1984) as well as for the gastropod *Polinices sordidus* (Hughes et al. 1987) (which shuts its operculum). Similar responses have been described in copper-contaminated sediment where *Macoma* baltica and *Tellina tenuis* were unable to bury themselves (Stirling 1975; McGreer 1979). The phenomena observed in the scallops for copper also occurs when bivalves are exposed to hydrocarbon pollution (Engelhardt *et al.,* 1983), demonstrating the broad ecological advantage of this behavioral response in Molluscs. The mechanism of valve closure provides the northern scallop with a comparative ecological advantage, providing at least temporary refuge (to 30 h), from a contaminated environment, while waiting for suitable conditions to prevail.

This was obvious when individuals were removed from lethal concentrations of copper prior to reaching a critical point at 20-30 h; when placed in a normal environment they soon assumed normal behavior patterns. Normal concentrations of copper in seawater off the coast of Chile are usually less than 0.05 mg L^{-1} and do not appear to affect behavior of *A. purpuratus,* which is known to accumulate this metal in proportion to its environmental concentration (Boyden 1997). It may be indirectly concluded that this species has chemoreceptors which trigger a threshold response to copper. It is unknown whether final relaxing of the valves is due simply to exhaustion of energy reserves needed to maintain the valves closed, depletion of oxygen or to “leakage” of toxic levels of copper into scallop tissues via the byssal opening which allows minor, but ever present contact with the environment.

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