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# Seasonal variation in the ionic and protein content of haemolymph from seven deep-sea decapod genera from the Northeast Atlantic Ocean

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**Abstract**

Deep-sea decapod crustaceans belonging to seven genera (*Plesiopenaeus*, *Nephropsis*, *Glyphocrangon*, *Neolithodes*, *Polycheles*, *Parapagurus* and *Munidopsis*) were sampled from depths of 800–4300 m in the Porcupine Seabight and Abyssal Plain areas of the Northeast Atlantic Ocean, on cruises in summer (August) 2001 and spring (March) 2002. Haemolymph samples were obtained immediately from all captured intermoult individuals and frozen for ionic (magnesium, calcium and copper) and protein analysis. There were significant seasonal differences in magnesium, copper and protein content of the haemolymph of the seven decapod genera analysed with a large decline in all three parameters in spring 2002. Calcium concentration in the haemolymph was much more closely regulated by the decapods, but three genera (*Nephropsis*, *Glyphocrangon* and *Parapagurus*) did show significant decreases in calcium content in spring 2002 compared with summer 2001. It would appear that limited food availability in spring 2002 (before the annual fallout of organic matter from the surface waters) could have caused a stress response as seen in the variations in ionic and protein content. Previous work on shallow water decapods has shown that decreased magnesium content equates to increased activity for foraging, and observations from video evidence strongly suggests a similar link in deep-sea decapods. Decreased copper and protein contents are further indicators of nutritional stress because the haemocyanin is used as an emergency energy source during times of starvation. The present study is believed to be the first to report the occurrence of seasonal fluctuations in the physiological response of any deep-sea animal group and raises further questions on the influence of seasonality on the physiology of deep-sea animals.


*Keywords:* North Atlantic; Mesobenthic zone; Bathybenthic zone; Abyssobenthic zone; Ionic physiology; Decapod crustaceans

## 1. Introduction

In contrast to the wealth of information on the physiological adaptations of shallow water decapod

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crustaceans, much less is known about the physiology of deep-sea decapods. In the past two decades, however, there has been considerable interest in the physiology of decapods associated with hydrothermal vents. These studies have examined aspects of the respiratory physiology of these species (e.g. Arp and Childress, 1981, 1985; Mickel and Childress, 1982a, b; Lallier and Truchot, 1997; Sanders et al., 1988; Chausson et al., 2001, 2004) and the adaptations that they show to the high temperatures (Ravaux et al., 2003) and to the high sulphide and metal concentrations in the vicinity of the vents (Vetter et al., 1987; Geret et al., 2002).

Pelagic crustaceans appear to have been the subject of even fewer studies but some information on their respiratory adaptations is available (Childress, 1971, 1975, 1977; Sanders and Childress, 1990; Torres et al., 1994). These studies have shown that their metabolic rate decreases with depth of occurrence. Childress (1975) and Childress et al. (1990) suggested that this relationship was the result of changes in water temperature with depth, which had a direct effect on the animals' metabolic rate. The recent study by Torres et al. (1994) demonstrated a similar reduction in metabolic rate of Antarctic micronektonic crustaceans but these authors were of the opinion that, for these species, the relationship was independent of temperature since there was little change in temperature throughout the depth range at which they occurred. The consensus view appears to be, however, that the metabolic rate of a number of taxa including fish and crustaceans decreases with increasing depth (Smith and Hessler, 1974; Somero et al., 1983; Childress, 1995). In these groups, this reduction in metabolic rate is greater than would be predicted on the basis of $Q_{10}$ relationships alone. Interestingly, many gelatinous animals such as medusae, chaetognaths and some polychaete worms do not show a significant reduction in metabolic rate with depth (Robison, 2004).

There is still considerable debate over the causes of the observed reduction in metabolic rate with increasing depth. Smith and Hessler (1974) and Somero et al. (1983) have suggested that the decline in food availability with depth is the principal cause but other factors such as increased pressure or a reduction in oxygen availability have also been implicated although the evidence to support this is not convincing (Robison, 2004). Childress (1995) suggested that a reduction in down-welling light might be a major factor influencing the reduction in metabolic rate with depth. As light intensity decreases, active predation becomes less effective and many animals adopt a 'sit and wait' strategy because of the reduction in reaction range and hence chase duration. Many species, therefore, show a reduced locomotory capacity that may be accompanied by a reduction in metabolic rate.

There is also evidence that deep-sea species may experience seasonal changes in the food availability, which may lead to them experiencing periods of starvation at certain times of the year and which in turn may affect their metabolic rate. Studies of shallow-water decapod crustaceans have shown that, in many species, the haemocyanin concentration decreased markedly as a result of malnutrition or starvation because the haemocyanin was used as an energy reserve (Uglow, 1969; Djangmah, 1970; Cuzon and Ceccaldi, 1973; Hagerman, 1983; Baden et al., 1990). This reduction in the concentration of haemocyanin in the haemolymph will affect activity levels since the supply of oxygen to the tissues is likely to be reduced.

Studies of other aspects of the physiology of deep-sea crustaceans are rare. For example, almost nothing is known about the ionic regulation of deep-water pelagic crustaceans although Childress and Nygaard (1974) studied the ionic composition of some mid-water species and its effect on their buoyancy. Again, this paucity of information is in contrast to the numerous studies of the osmotic and ionic regulation of shallow water species (see Robertson, 1960; Mantel and Farmer, 1983 for reviews of the early literature).

An invitation to join two research cruises on the R.R.S. *Discovery* provided an opportunity to collect specimens of a number of genera of deep-sea decapods from the Porcupine Seabight and Abyssal Plain areas of the North Atlantic Ocean. The aim of this opportunistic study was to examine possible seasonal differences in the ionic content and protein concentration of the