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CADMIUM CONCENTRATION  
OF MESOPELAGIC DECAPODS AND EUPHAUSIIDS  
FROM THE NORTH-EAST ATLANTIC OCEAN:  
POSSIBLE USE AS A DIETARY MARKER  
IN FOOD WEB STUDIES

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ABSTRACT

A range of mesopelagic decapods and euphausiids, collected from the N.E. Atlantic, have been analysed for Cd. The data have been compared with previously reported levels of Cd and  $^{210}\text{Po}$  in similar species from the same area.

Caridean decapods are active carnivores and generally have higher Cd concentrations than the more detritivorous penaeids. Amongst the carids the Cd concentration is highest in shallow migrants and may have resulted from their eating prey which has fed upon Cd-enriched phytoplankton. Euphausiids may be such prey but their Cd concentrations are relatively low and it is suggested that there may be other important links in Cd transfer. Detritivorous penaeids have low Cd concentrations but very high levels of  $^{210}\text{Po}$ . The concentrations of both elements reflect their behaviour in the water column. Cd is removed mainly by surface-living phytoplankton and released into solution at depth, whereas  $^{210}\text{Po}$  is rapidly scavenged by non-living particulates in deeper water.

We suggest that Cd does have potential as a biochemical dietary marker. Future studies of oceanic food webs would benefit from a knowledge of the distributions and concentrations of a range of biochemically 'non-essential' metals.





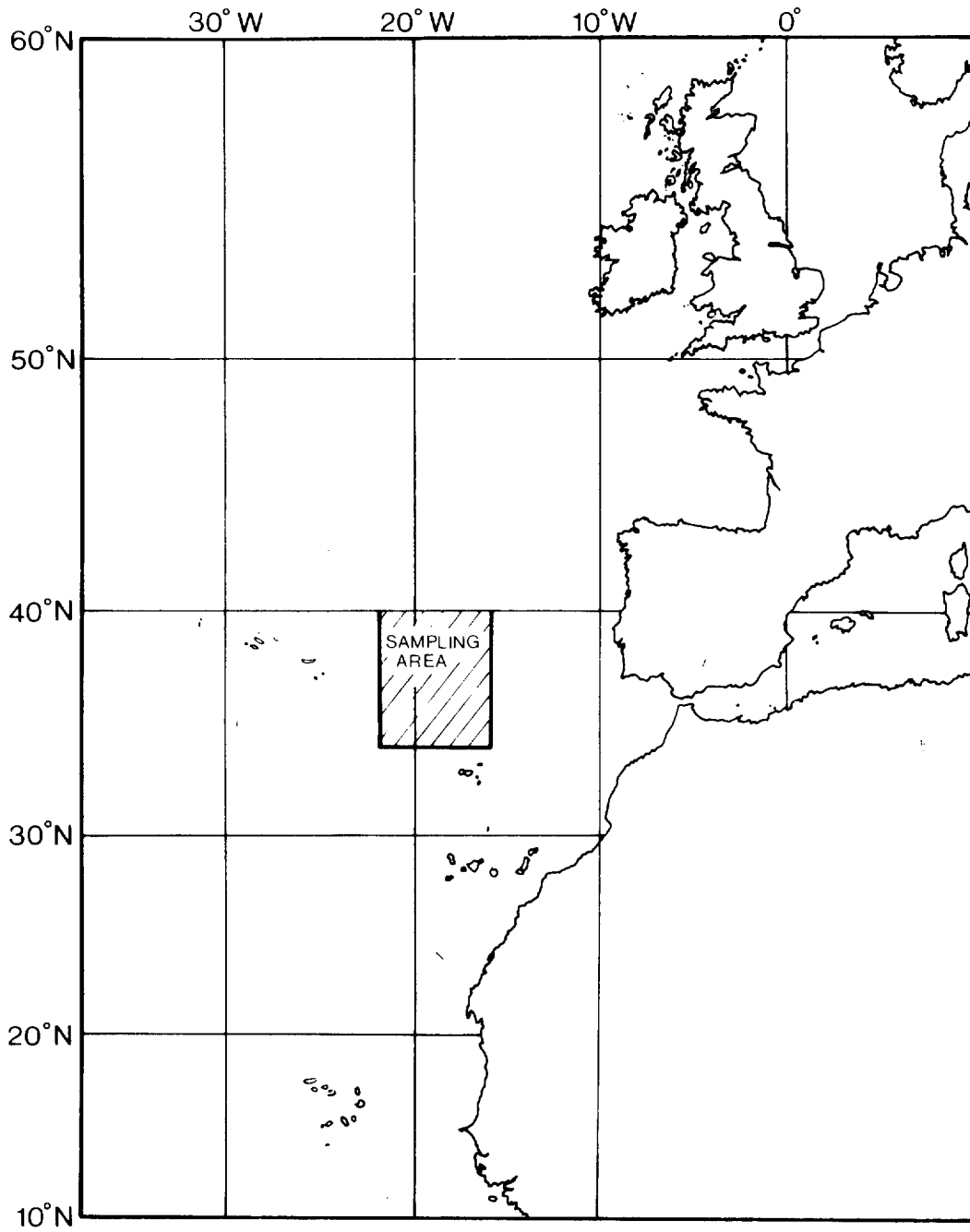
## INTRODUCTION

The study of food webs in the deep oceans has largely relied upon observational analyses of gut contents (e.g. Hopkins and Baird, 1977; Roe, 1984; Roe and Badcock, 1984; Mauchline and Gordon, 1986). Such data provide qualitative information and useful insights into feeding periodicity and dietary preference. These data are much less valuable for quantitative determinations because they usually only provide minimal counts of items which remain recognisable in the gut after ingestion (e.g. exoskeletons, bones and teeth). Less resistant food, such as gelatinous animals, faecal pellets and detritus, cannot be quantified or, in most cases, even identified and their dietary importance could be grossly underestimated.

To try to overcome these problems, chemical tracers, both natural and artificial, have been used to identify structurally unrecognisable prey (e.g. phaeopigments (Nemoto, 1972); antisera (Feller et al., 1985)) and to quantify fluxes through ecosystems (e.g.  $^{14}\text{C}$  (Pearcy and Stuiver, 1983); phaeopigments (Welschmeyer et al., 1984); or through individual animals (Heyraud et al., 1976).

This chemical approach can be expanded by measuring trace metal accumulations in deep-sea organisms. Body concentrations of certain biochemically 'essential' trace metals (e.g. Cu, Fe, Zn) are regulated in marine decapod crustaceans but non-essential metals (e.g. Cd, Pb, Ag, Hg), with no apparent biochemical function are thought to be accumulated without regulation (see Rainbow, 1985). These 'non-essential' trace metals are likely to be useful as biochemical dietary markers. The mesopelagic decapod, Systemellaspis debilis accumulates Cd to a relatively high level (Leatherland et al., 1973; Ridout et al., 1985) and it is thought that the diet is the major source of this Cd. A range of mesopelagic crustaceans have also been shown to accumulate the naturally occurring radionuclide,  $^{210}\text{Po}$  and much of these data have been interpreted in terms of differences in feeding (Cherry and Heyraud, 1981, 1982;).

In this preliminary study we have compared, using our own analyses and literature values, the levels of Cd and  $^{210}\text{Po}$  in a number of species of mesopelagic decapods. These animals are an important link in the transport of material from the surface to bathypelagic communities. We have also determined the Cd concentration of several euphausiid species, some of which are known to be important prey for Systemellaspis debilis (Roe, 1984). Our objective has been to assess the usefulness of the biochemically 'non-essential' metal Cd as a dietary marker in an oceanic food web.



**Fig.1** Sampling area in the north east Atlantic where decapods and euphausiids were collected.

## MATERIALS AND METHODS

### Sampling

Material analysed here was collected in the N.E. Atlantic between 34°N-40°N, 16°W-21°W during July 1985 (Roe, 1985) (Fig. 1). Animals were caught with a rectangular midwater trawl, mesh size 4.5 mm (Baker *et al.*, 1973; Roe and Shale, 1979). Catch data for each species are given in Table 1.

Specimens in good condition, invariably alive, were picked out from the general catch aboard RRS Discovery. They were placed in polythene bags (air excluded) and immediately deep frozen (-20°C) for storage prior to analysis at IOS, Wormley. Plastic implements were used throughout as a precaution against metal contamination and at no time did the animals come into contact with metal objects.

### Sample preparation

Within each species, specimens of similar size were chosen to minimise any variations in Cd concentration due to differences in body size. Each animal was oven-dried at 60°C to constant weight then digested in concentrated nitric acid (Primar\* grade) using a gradual heating programme to 160°C until completely dissolved. Each sample was made to volume using double-distilled water and transferred to plastic bottles for storage.

### Analysis

Cadmium measurement was carried out on diluted samples using flameless atomic absorption spectrophotometry (I.L. 151/655). Matrix interferences were checked using the method of standard additions and corrections for non-specific absorbance were made using a hydrogen continuum source.

The accuracy of the method was checked by the digestion and analysis of a standard reference material of dried lobster hepatopancreas (TORT-1, Canadian Bureau of Standards). Material from the same net-hauls analysed in an independent study at another laboratory showed good agreement with our analyses (Rainbow, unpublished data).

Foregut contents of some species were examined in specimens taken from the same hauls as those used for metal analysis.

TABLE 1 - Catch data and concentrations of Cd and <sup>210</sup>Po in decapods and euphausiids from the NE Atlantic. The mean <sup>210</sup>Po values are from animals caught between 610-1500 m, position 31°N-35°N, 28°W-35°W (Cherry & Heyraud, 1982). The normal depth ranges are the depths where most of the populations occur between 30°N-40°N; 20°W-35°W (IOS database).

Species	Sampling		N*	Normal depth range (m)	Dry weight range (g)	Mean Cd concentration µg g <sup>-1</sup> DW	S.D.	Source	Mean <sup>210</sup> Po concentration pCi g <sup>-1</sup>
	Position	Depth (m)							
<u>DECAPODS</u>									
Caridea:									
<u>Systellaspis debilis</u>	40°N, 16°W	805-675	9	500-700	0.2-0.4	12.35	2.6	This study	21
"	38°N, 25°W	300-210	6	500-700	0.2-0.5	14.7	4.0	Ridout et al., 1985	
"	36°N, 19°W	700-390	18	500-700	0.2-0.5	11.1	3.1	Ridout et al., 1985	
"	38°N, 26°W	225-0	4	500-700	-	13.0	-	Leatherland et al., 1973	
<u>Oplophorus</u> spp.	28°N, 17°W	160-0	2	400-500	-	13.0	-	Leatherland et al., 1973	
<u>Acanthephyra purpurea</u>	35°N, 21°W	300-190	8	700-1000	0.2-0.5	4.9	2.0	This study	14
<u>Acanthephyra eximia</u>	39°N, 28°W	1255-1240	1	1500-2000	-	3.0	-	Leatherland et al., 1973	
Penaeidea:									
<u>Sergestes 'corniculum'</u>	38°N, 19°W	215-120	6	600-800	0.06-0.27	4.0	0.8	This study	25 ( <u>Sergestes henseni</u> )**
<u>Sergia robustus</u>	35°N, 21°W	300-190	8	800-1000	0.03-0.09	2.3	0.4	This study	
<u>Gennadas valens</u>	34°N, 22°W	1300-870	16	700-1000	0.05-0.2	2.3	1.0	This study	117
<u>Benthegennema intermedia</u>	36°N, 20°W	1500-1270	6	900-1500	0.05-0.075	5.3	1.5	This study	84
<u>EUPHAUSTICEA</u>									
<u>Meganyctiphanes norvegica</u>	36°N, 08°W	surface	8	600-700	-	0.25	-	Leatherland et al., 1973	1.9 (euphausiids)
"	39°N, 18°W	600-400	31	600-700	0.03 (mean)	0.26	0.14	This study	
<u>Thysanopoda microphthalmia</u>	38°N, 19°W	215-120	25	600-700	0.01 (mean)	0.69	0.17	This study	
<u>Nematoscelis megalops</u>	39°N, 18°W	810-615	34	600-700	0.015 (mean)	0.75	0.35	This study	
<u>Nematobrachion boopis</u>	39°N, 18°W	810-615	17	300-700	0.015 (mean)	1.02	0.12	This study	

\* N = number analysed

\*\* S. 'corniculum' is a species complex of which S. henseni is a member.

## RESULTS AND DISCUSSION

Cadmium concentrations in the various species are shown in Table 1. The greatest accumulation of Cd clearly occurs in the caridean decapods, especially in Systellaspis debilis. The Cd concentrations found here show good agreement with previously reported levels. Within each species, specimens of similar size were deliberately selected for analysis and there were no significant correlations between size of animal and Cd concentration. Moreover, there was no significant correlation between body size and Cd concentration over the entire size range of all the species analysed here. The gut contents analysed in this study generally agree with previous observations (Mauchline and Fisher, 1969; Hefferman and Hopkins, 1981; Roe, 1984) and they are consequently not detailed here.

Most of the species in Table 1 are active diel migrants and their normal depth ranges in this area of the Atlantic are shown. The Cd and  $^{210}\text{Po}$  data show interesting differences between caridean and penaeid decapods which can be interpreted in the light of their feeding and migratory habits.

Within the carids, the Cd concentration is generally highest in those species which migrate nearest to the surface (e.g. S. debilis, Oplophorus) and lowest in the deeper living species (e.g. Acantheephyra eximia). Cadmium uptake and accumulation in crustaceans can occur via many routes. It seems likely that high Cd concentrations in these decapods originate from dietary components. The lifespan of S. debilis is not known but mesopelagic decapods of similar size and feeding habits live for between 1.5 and 3 years (see Aizawa, 1974; Walters, 1976; Omori & Gluck, 1979). Taking into account the relatively low concentration of Cd in the oceans, it seems likely that direct removal of Cd from sea water would be insufficient to support the body concentration reported. If, as Ridout et al. (1985) concluded, the source of the Cd is in the diet then this suggests that species which migrate to shallower depths gain access to prey which are richer in Cd than those at depth. Cadmium has a nutrient-like distribution in the water column: it is thought to be removed from waters within the photic region by phytoplankton and subsequently released back into solution via oxidative processes (Bruland, 1983). Animals which feed directly upon the phytoplankton may be expected to show some Cd enrichment which could then be passed through the food webs.

Caridean decapods are extremely active carnivores and do not feed directly upon phytoplankton. However, the shallow migrant S. debilis has been shown to feed extensively at night upon euphausiids (Roe, 1984), whereas deeper living decapods encounter fewer of these prey during their diel cycles. The

euphausiids eaten by Systellaspis (M. norvegica, N. megalops, N. boopis; Roe, 1984; present observations) feed upon a mixture of detritus, phytoplankton and small, presumably herbivorous, crustaceans (Mauchline and Fisher, 1969; present observations). Euphausiids may therefore provide a link between phytoplankton and predatory decapods for Cd enrichment and, if this is so, then the differences in Cd levels between the various carids could provide a rough measure of their euphausiid consumption.

The values for Cd in euphausiids are generally low (Table 1), although the highest levels do occur in the two species (N. megalops, N. boopis) which S. debilis eats most extensively (Roe, 1984). If euphausiids are indeed the source of the high Cd levels in Systellaspis then the decapod must eat very large numbers of these or it must accumulate the Cd over a long period. The remains of 26 individual euphausiids have been found in a single S. debilis (Roe, 1984) but there are no data on feeding rates or longevity in these decapods.

Alternatively, or additionally, the major source of Cd in Systellaspis may be from prey which is either unrecognisable or for which the Cd concentrations are unknown. Relatively high Cd levels have also been found in some species of copepods (e.g.  $9.8 \mu\text{g g}^{-1}$  in Labidocera acutifrons; Leatherland et al., 1973), and in some amphipods (e.g. a mean of  $52.6 \mu\text{g g}^{-1}$  in Themisto gaudichaudi; Rainbow, unpublished data). Neither of these species forms part of the normal diet of Systellaspis but copepod remains are common in the guts of caridean decapods. Unfortunately, there are no Cd data at present for any of the copepods so far identified.

Penaeids tend to have lower concentrations of Cd than carids irrespective of their migratory behaviour. This difference may reflect differences in feeding between the two groups. Probably all pelagic decapods eat some detritus, but the amounts of this vary markedly. Carids apparently take very little and are active predators, penaeids such as Sergestes and Sergia combine detritivory and active predation, and penaeids such as Gennadas and Bentheogennema are primarily detritivores (Hefferman and Hopkins, 1981; Roe, 1984; present observations). Detritivory in these decapods may be direct or it may result from their eating animals such as phaeodarian radiolaria which themselves take sinking particulates and dead/dying plankton out of the water column (Kling, 1978; Roe, 1984).

It seems that the higher the proportion of detritus in the diet, the lower the Cd concentration. Conversely,  $^{210}\text{Po}$  concentrations increase with increasing detritivory (Table 1). This interpretation is consistent with the

chemical behaviour of Cd and  $^{210}\text{Po}$  in sea water. The shallow regeneration cycle of Cd, similar to that of phosphate and nitrate, implies that Cd adsorption is associated mainly with living phytoplankton (see Bruland, 1983). The adsorption of Cd on to non-living particulate matter in deeper water is relatively low (see Simpson, 1981).  $^{210}\text{Po}$  also has a somewhat nutrient-like behaviour and is recycled within the surface and sub-surface ocean (Thomson and Turekian, 1976). However, in deeper water it is rapidly removed by particulates (Bacon et al., 1976).

Bentheogennema intermedia appears not to fit this generalised pattern for penaeid Cd concentration. Gut contents suggest a mainly detritivorous diet (Hefferman and Hopkins, 1981; present observations), which is supported by the relatively high  $^{210}\text{Po}$  concentration. However, its Cd concentration is higher than expected. Possibly there are physiological differences between species, allowing some to accumulate Cd more efficiently than others, or perhaps the Cd is present as a marker for some unidentified prey.

## CONCLUSIONS

These data can only provide a basis for speculation on the use of Cd accumulation as a tool in the study of oceanic food webs. However, a number of points have been raised which suggest its potential worth. Comparison of Cd levels within a range of oceanic animals has shown that a dietary intake of Cd may depend upon the type of prey and upon the feeding and migratory behaviour of the individual species. Once dietary sources of Cd have been established for a particular group of animals their relative concentrations should prove useful in quantifying food webs. Comparison of Cd accumulations with those of a metal such as  $^{210}\text{Po}$ , which behaves differently in the water column, may provide independent estimates of flux rates through ecosystems. Such comparisons may also give valuable insights into physiological or biochemical differences between species in their uptake and utilisation of 'non-essential' metals.

For a more complete evaluation of the use of Cd as a biochemical dietary marker a number of food webs must be examined and Cd determinations made in conjunction with a detailed analysis of other accumulated 'non-essential' metals. This work is being undertaken at present as part of a major study. Within the food webs as many trophic levels as possible should be examined and gut contents identified together with metal analyses. Knowledge of biological rates such as growth, feeding, excretion and defaecation are crucial to a full understanding of the accumulation of 'non-essential' trace metals and this must be obtained by laboratory experiments.



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