INGESTION OF DEEP-SEA MINING DISCHARGE BY FIVE SPECIES OF TROPICAL COPEPODS

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Abstract. Five species of tropical copepods were exposed to samples of mining discharge and the fecal pellets produced were collected for chemical comparisons with mining discharge and with fecal pellets produced when the same species were held in ambient sea water. Chemical compositions were compared by means of Energy Dispersive Analysis of X-rays (EDAX). Chemical composition of fecal pellets and mining discharge indicates uptake of mining discharge in *Undinula vulgaris*, *Euchaeta rimana*, and *Labidocera acutifrons*, possible uptake in *Undinula darwinii* and no apparent uptake in *Oncaea venusta*. The total difference between the elemental ratios, standardized to Ca, observed for mining discharge and fecal pellets are 22.9 and 6.8 in *Undinula vulgaris*, 23.9 and 13.6 in *Euchaeta rimana*, 23.3 and 2.9 in *Labidocera acutifrons*, 19.8 and 13.7 in *Undinula darwinii*, and 18.2 and 4.0 in *Oncaea venusta* for fecal pellets produced by copepods held in ambient sea water and for fecal pellets produced when exposed to a sample of mining discharge respectively. The application of EDAX to chemical analysis of fecal pellets is described and discussed.

1. Introduction

Deep-sea mining for Mn nodules results in the creation of an extensive discharge plume consisting of abraded nodule fragments and red clay. Field monitoring of two pilot mining projects estimate plume discharge for a single ship as 550 to 240 g s⁻¹ (dw) at a discharge rate of 95 to 160 l s⁻¹ (Lavelle et al., 1980). Measurements during the same studies indicated that the mining plume was discernible in the upper layer for as long as 37 h. Coulter counter analyses of mining discharge indicate approximately 20% of the particulate discharge to have a volume less than or equal to that of a 4 μm diameter sphere (Hirota, 1980). Particles of this small size, if left to sink passively, would remain in the mixed layer for long periods of time.

Previous studies have shown possible detrimental effects of high inorganic suspended particulate load on marine zooplankton. Rosenthal (1971) found ‘red mud’, a waste product of aluminum production from bauxite, slowed the speed of larval development in herring perhaps due to ingestion of ‘red mud’ particles which blocked food intake. Paffenöhöfer (1972) found *Calanus helgolandicus* took longer to develop and were of smaller size at each stage of development when grown in the presence of ‘red mud’.

Ingestion of particulate material by zooplankton and its subsequent incorporation into fecal pellets constitute an important pathway by which material is removed from the water column (Beasley et al., 1978; Benayoun, 1974; Small and Fowler, 1973). Conover (1971) found incorporation into fecal pellets and subsequent deposition was the major pathway for the removal of 10 to 100 μm diameter oil droplets which would otherwise remain in the water column for longer periods of time. Nival and Nival (1976) have shown that *Acartia clausi* can ingest particles down to 7 μm as an adult.
and down to 3 µm in the CI stage. Paffenhöfer and Strickland (1970) found that *Calanus helgolandicus* did not feed on natural detritus collected from below 100 m depth but in subsequent studies Paffenhöfer (1972) found *Calanus helgolandicus* ingested 'red mud' particles even when phytoplankton were scarce.

This study investigates the possible ingestion of mining discharge by copepods. Mining discharge has a chemical composition that is much different than that of suspended particles found in natural sea water. As a result, copepods ingesting mining discharge should produce fecal pellets which have different chemical compositions from fecal pellets produced when natural foods are ingested.

2. Materials and Methods

Copepods and ambient sea water were collected approximately 4.3 km off-shore of Kaneohe Bay located on the windward coast of Oahu, Hawaii except for *Undinula vulgaris* for which collections were made in Kaneohe Bay. Collections were made with a 183 µm mesh, 0.5 m net towed at approximately 2 kt for 3 to 5 min to minimize collection damage to the copepods. Copepods were allowed to acclimate to laboratory conditions for 2 to 3 h before individuals were removed for experimentation.

Fecal pellets were obtained from approximately 20 copepods of the same species held in 1 l containers with either ambient sea water or a mixture of ambient sea water and mining discharge for 48 h. Attempts were made to use only adult female copepods but occasionally CV's and males were placed in the containers. Mining discharge was obtained from the mining ship and was stored at 0 °C until used. Mining discharge was diluted approximately 1 : 105 in ambient sea water for use in the incubations. Suspended particulate concentrations for experimental and control containers were determined with a Coulter counter at the beginning of the incubation.

Fecal pellets were picked out at the end of the incubations under a dissecting microscope, preserved in 2% glutaraldehyde and prepared for analysis in the following way. Pellets were passed through a hydration series and dehydration series as in Paerl and Shimp (1973) and allowed to dry on a clean glass plate. Pellets were then embedded in Epo-mix Epoxide® (Buehler Ltd.) by dropping the embedding resin on the glass plate. Cross sections of fecal pellets were exposed for Energy Dispersive Analysis of X-rays (EDAX) by sanding. Final sandings were done with 8 µm and 3 µm diameter diamond compound.

Fecal pellets were carbon coated and analyzed with a Cambridge stereo-scan 34–10 scanning electron microscope and EDAX 707B analyzer. Analyses were done with an accelerating voltage of 20 kV and a take-off angle of 45°. EDAX analyses were carried out for 100 s with a count rate of 3000 counts s⁻¹. A total of at least 4 spots measuring 15 by 9 µm were analyzed on at least 2 different pellets from experimental and control treatments for each species.

EDAX counts were background-corrected by assuming mean background to be equal to the mean of the reading on both sides of the counting peak (Statham and Pawley, 1978).