Trace Metal Levels in Beach Dipterans and Amphipods

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The study of major elements in plant and animal tissue dates back to antiquity, and by the middle of the eighteenth century, a true trace element, lead, had been detected in animals (VINOGRADOV, 1953). Recent advances in organic chemistry and analytical techniques have enabled estimation of trace elements in diverse organisms (VINOGRADOV, 1953; GOLDBERG, 1966). As late as 1953, however, none of the 750,000 known species of insects had been tested for trace element composition, and only 100 of the 15,500 species of crustaceans had been analyzed (VINOGRADOV, 1953). Although more recent studies have begun to fill the vacuum in this area (eg. SPECTOR, 1956; WARNICK and BELL, 1969), no work to date has focused on metal levels in sandy beach arthropods.

Over a seven-week period, trace element levels were determined in a marine and a terrestrial arthropod inhabiting the beach. Of special interest were the questions: How do a primarily marine and a primarily terrestrial arthropod compare in metal levels? How do metal concentrations vary with geographical location, time, and age? Beach hoppers - amphipods of the genus Orchestoidea - and marine flies were selected for comparison because they are known to exploit the same food source, the beach wrack. A base line with which future analyses could be compared in a temporal study of pollution was set, and reasonable ranges of daily fluctuation for each metal were established.

MATERIALS AND METHODS

Beach hoppers were collected from four points on the Monterey Peninsula, California (Fig. 1): Orchestoidea corniculata from two pocket beaches adjoining Hopkins Marine Station (B,C); O. californiana from Del Monte beach directly inshore from the Monterey sewage outfall (A), and from the southern end of Carmel beach (D). Hoppers were found by digging in the sand with a shovel or by lifting segments of wrack. In the former case, the sand was combed by hand, and no hoppers which had been contacted by the metal shovel were taken. Flies of the species Coelopa vanduzeei and Fucellia rufitibia were caught at the same sites. A butterfly net was used to trap the flies as they swarmed above the wrack. In addition, larvae of the coelopid fly were collected from Carmel and lady bug beetles (genus Hippodamia) from Del Monte beach. These were taken by hand directly from the wrack and underlying sand. Sterile flasks were used in all cases to transport animals from

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collection sites to the laboratory.

Beach hoppers were retained in collection flasks for 24 hours, after which they were frozen, washed in distilled water to remove sand and parasitic mites, and dried at 60°C for one day. The same procedure was followed for fly larvae and lady bugs. Fly specimens were killed immediately with ethyl acetate in a clean killing jar. They were then sorted by species, washed, and dried. Triplicate samples were collected when possible.

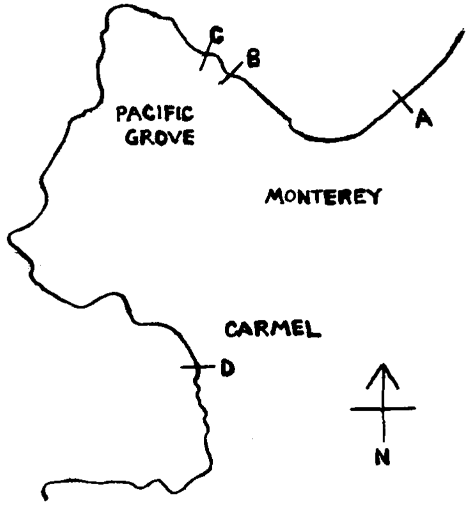

Figure 1: Collection sites on the Monterey Peninsula.

Dried samples were ground to a fine powder. Ten ml of 90 % nitric acid were added to each gram or half-gram sample, after which the latter was allowed to reflux until clear. The solutions were then simmered down to 5 ml, cooled, and treated with hydrogen peroxide until visible oxidation ceased. One ml of hydrochloric acid was added, and the samples were diluted to 25ml with distilled water. A blank containing the reagents and water was prepared as a control in each digestion.

Analysis for silver, cadmium, copper, iron, manganese, nickel, lead, and zinc was carried out on a Perkin-Elmer atomic absorption spectrophotometer model 303. Laboratory standards were run with each test series to calibrate the absorption scale. As there was no correction for background noise, values up to 2% absorption were discarded due to possible inaccuracy. A sample of ethyl acetate was analyzed as a control for fly specimens. It proved to have no trace metals of detectable amounts.

RESULTS AND DISCUSSION

Zinc, Iron, Copper and Cadmium: Beach flies showed consistently higher levels of Zn. Fe, Cu and Cd than did amphipods (Fig. 2). For Zn and Fe, this relationship is anticipated by former research on insects and crustacea (BOWEN, 1966). Copper is important as an arthropod respiratory pigment, and BOWEN (1966) states that flies and amphipods contain an equal amount of this metal, 50 ppm. My results fall short of this figure except at site B, directly below the Monterey Boat Works, where copper may enter the bay from boat paint intended to leak the element to discourage fouling by marine organisms. Zinc, iron, and copper

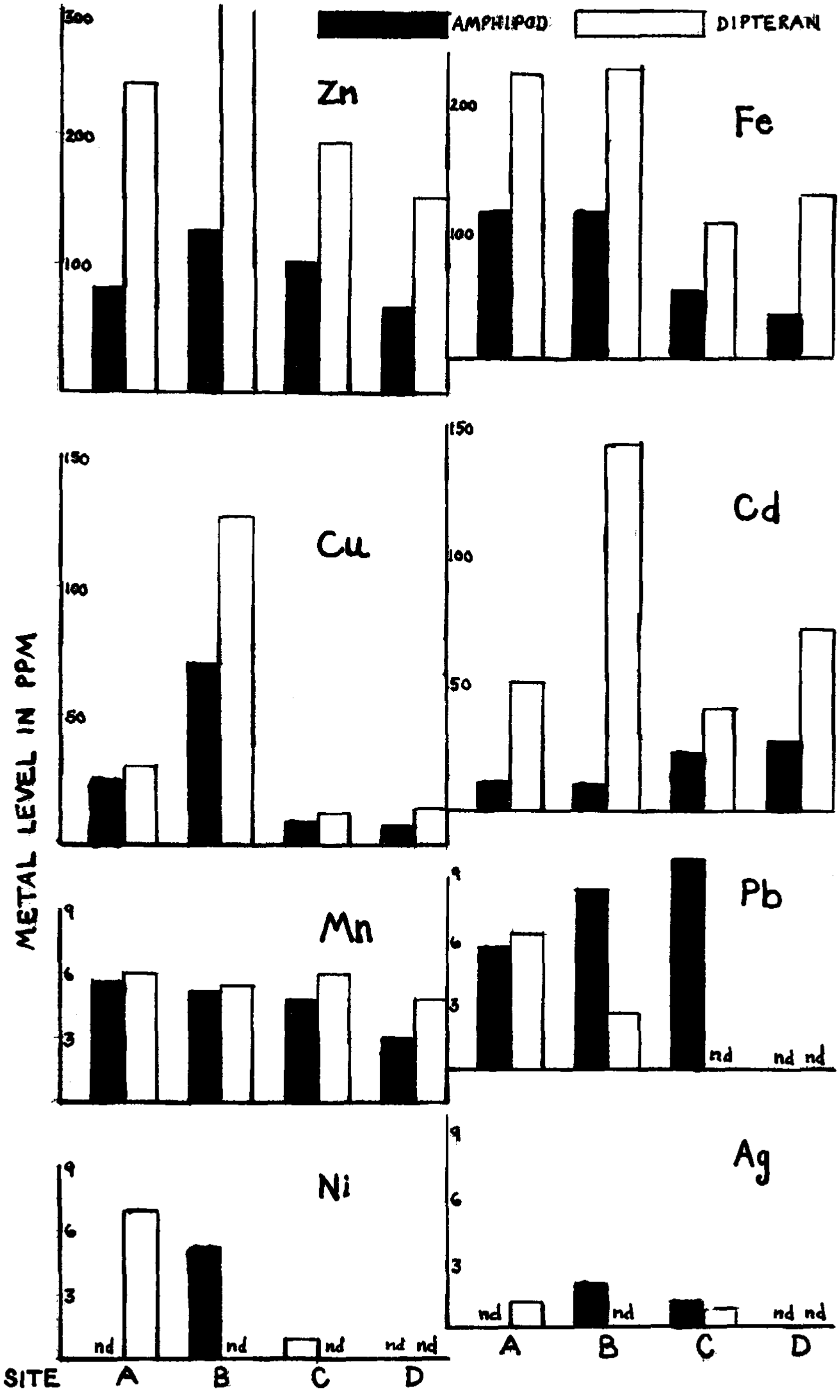

Figure 2: Metal levels in ppm dry weight for dipterans and amphipods at four locations; "nd" indicates that metal was not detectable.

are all essential to living organisms as constituents of metalloenzymes and proteins.

Cadmium levels reported by BOWEN (1966) indicate too little of the metal for detection in insects and only 0.15 ppm in crustacea. WARNICK and BELL (1969) found that cadmium was acutely toxic to fresh water insects in concentrations of 0.016 to 0.064 ppm. In light of these figures, the beach arthropods showed very high (up to 149.7 ppm) levels of this metal, suggesting a local source of contamination. The herbivorous terrestrial lady bugs contained no detectable cadmium. This indicates that the metal's imput may be largely marine despite its low (0.05 microgram/liter) level in "normal" sea water (RILEY and CHESTER, 1971). Proteins containing cadmium have been found in several animals VINOGRADOV, 1953; KAGI and VALLEE, 1961), but the metal is considered toxic due to its ability to replace zinc in enzymes. The effects of high cadmium levels on beach arthropods are not known.

Manganese: Manganese was low in all beach arthropods tested (less than 10 ppm). High levels of this metal are moderately toxic, but the element is essential in trace amounts for activation enzymes as a protein constituent.

Lead, Nickel and Silver: Lead, nickel, and silver occurred in truly trace amounts in hoppers and flies. The recorded levels are subject to inaccuracy because of background noise. Despite this limitation, the hoppers' lead level is significantly higher than that expected from BOWEN'S (1966) data. As yet, no biological function is known for lead. It is a cumulative poison in animals and it may inhibit protein and gene synthesis, cellular oxidations, and other essential functions (UNDERWOOD, 1971).

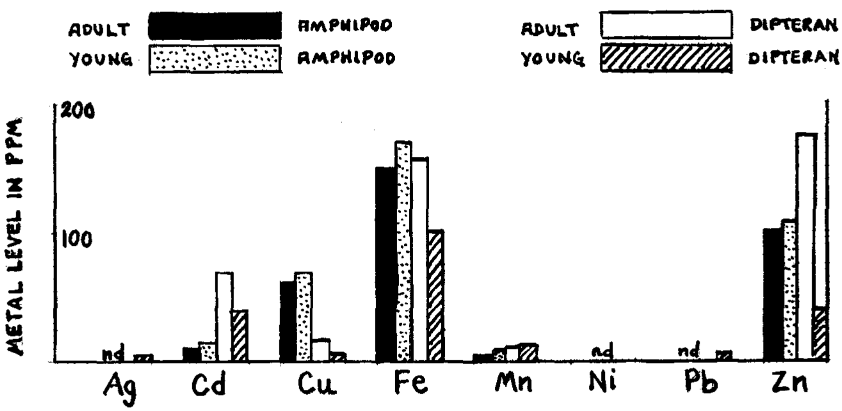

Figure 3: Comparison of metal levels in juveniles and adults by ppm dry weight. Dipterans from site D; Hoppers from site B.

Metal Concentration and Age: A comparison of larval and adult coelopid flies and of old (body length without antenna 2 - 3 cm) and young (body length less than 0.5 cm)beach hoppers is shown in Figure 3. Lower metal levels in the larvae for all elements present except Mn may be due to their shorter lives, different diets, or juvenile set of enzymes and hormones. (They are physically limited to decaying wrack in which they are scavengers, while the adults range over the entire beach). Adult and juvenile hoppers were very similar in trace metal levels, perhaps because the two groups share a habitat and food source.

Interspecific Variation: Variation in metal level due to species difference was studied for the beach flies *Coelopa vanduzeei* and *Fucellia rufitibia* collected from the same wrack beds. Over the Monterey Peninsula, no significant difference in elementary composition was noted. A comparison between the two beach hopper species was not possible because the animals did not occur sympatrically in any of the collection sites.

Temporal Variation: Variation in trace element levels on any one beach over time would be expected due to chance importation of the metal itself, metal-rich foods, run-off, etc. The result of a day-to-day study on pocket beach B with the hopper *O. corniculata* are summarized in Figure 4.

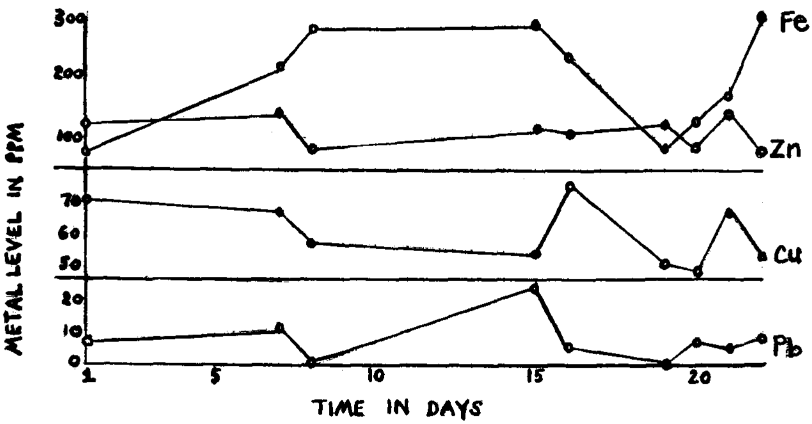

Figure 4: Variation in metal concentration (ppm dry wt.) with time. Continuous slope between points does not imply knowledge of intermediate levels.

Iron was found to fluctuate dramatically over the time period tested (variation up to 200 ppm). This may have resulted from leaching of the beach's scrap iron at high tides, changes in the animals' food source, or dust contamination. Copper, lead, and zinc fluctuated moderately over time, while cadmium, manganese, silver and nickel (not illustrated) showed stable levels. Each metal varied independently. The range of fluctuation of Fe,Zn, Cu and Pb is certainly significant enough to justify studies over time rather than single day sampling for these metals on a particular beach. The results throw doubt on data from single collections, especially in pollution studies.

Higher trace element levels in flies than in beach hoppers may have several causes. Although both prefer the same food - the giant kelp Macrocystis pyrifera - secondary foods differ, the hoppers apparently having a broader diet (from carrion to chewable trash and cardboard according to BOWERS, 1964). It is probable that adult flies eat the bacteria off the wrack rather than the seaweed itself. In addition, UNDERWOOD (1971) reminds us that knowing the concentration of a metal is not meaningful unless its interactions with other elements is also understood. The insect's absorption of metals through its intestine and tracheole walls may exceed that of the amphipod. Metabolic pathways could be sufficiently different in the two animals to cause consistent variation in metal levels.

It is of interest that the beach "visitors" - the flies - showed higher levels of all major metals than the stationary amphipods. This suggests that contamination of a possibly marine origin has more impact on the terrestrial ecosystem via the beach interface than was previously suspected. Metal analysis of other terrestrial animals that find food on the beach would be an important follow-up to this study. No fewer than seven species of birds have been observed to eat fly larvae from the wrack. In addition, an attempt to track down the source of cadmium pollution in Monterey Bay and to determine the metal's physiological effects on local dipterans and amphipods should be made.

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