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Effects of DDT on the Density and Diversity of Tardigrades

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SYNOPSIS. Twenty lichen-bearing tree bark samples were collected from DDT sprayed American elm trees (*Ulmus americana* L.) in central Iowa. Twenty comparable samples were collected from an adjacent nontreated habitat. A tardigrade density of 4 individuals collected from the treated habitat was found to differ significantly ($P < .01$) from a density of 97 individuals collected from the non-treated area. Margalef's diversity index ($D = S-1/\ln N$) determinations were found to be 0.00 and 0.44 for the treated and non-treated habitats, respectively. Tardigrade species organization within the nontreated habitat did not differ significantly from that as predicted by MacArthur's broken-stick model, suggesting that tardigrade species occupy contiguous, non-overlapping niches within a lichen-bearing tree bark ecosystem. It is suggested that measurements depicting micropfauna-lichen-tree bark relationships might serve as useful criteria in evaluating pesticide stress effects on total forest ecosystems.

INDEX DESCRIPTORS: Tardigrades, Density, Diversity, Effects of DDT.

The ecological effects of DDT when used in the control of Dutch elm disease have been studied by several investigators (Benton, 1951; Blagbrough, 1952; Barker, 1958; Hunt, 1960; and others). Several studies have also been concerned with the effects of DDT on natural invertebrate populations (Davis, 1952; Menhinick, 1962; Odum, Woodwell, and Wurster, 1969; and others). Many of these findings have been summarized in review articles by Ripper (1956) and Moore (1967). However, no studies have been concerned with the effects of DDT on natural populations of tardigrades. This investigation was designed to measure and evaluate the effects of DDT on the density, diversity, and species organization of tardigrades collected from sprayed American elm trees (*Ulmus americana* L.) in central Iowa.

MATERIALS AND METHODS

Twenty lichen-bearing tree bark samples, 25 cm^2 each, were collected from DDT sprayed American elm trees in Polk County, Iowa. Twenty comparable samples were collected from an adjacent nontreated habitat. All samples contained lichens belonging to the genera *Physcia*. All samples were collected on 29 September 1967, approximately one meter above ground level on the east side of randomly selected trees. The twenty treated samples were collected from separate trees that had been aerially sprayed with DDT on 5 November 1966 at the rate of 0.5 lb. per acre (Mr. Harold E. Smith, Executive Administrator, Public Works Division, City of Des Moines, Iowa, personal communication).

Tardigrades were removed from the samples by a water flooding technique as described by Kimmel and Meglitsch (1969). Specimens from each sample were fixed mounted in Hoyer's medium and identified as to species.

The $D = S\text{-}1/\ln N$ index of Margalef (1957) and the broken-stick model of MacArthur (1957) were computed as indications of tardigrade species diversity and group organization, respectively.

RESULTS

Only one species (*Milnesium tardigradum* Doyere), represented by four individuals, was collected from the DDT sprayed area, whereas three species (*Milnesium tardigradum* Doyere, *Macrobiotus islandicus* Richters, and *Macrobiotus areolatus* Murray), represented by a total of 97 individuals, were found to inhabit samples collected from the nontreated habitat. The three species in the nontreated area were represented as follows: *M. tardigradum,* 53 individuals; *M. islandicus,* 35 individuals; and *M. areolatus,* 9 individuals. A highly significant difference ($P < .01$) was found between the densities of the two areas when tested with a Mann-Whitney U test.

Margalef's diversity index ($D = S\text{-}1/\ln N$), where S equals the total number of species and N equals the total number of individuals, was computed and found to be 0.00 and 0.44 for the treated and nontreated samples, respectively (Margalef, 1957).

Tardigrade species organization within the nontreated samples did not differ significantly ($X^2 = 3.34$, 2 df) from that as predicted by MacArthur's broken-stick model for contiguous, non-overlapping niches (MacArthur, 1957). This model generates the expected abundance of species according to their rank in rarity and is based upon the observed total number of species and individuals. It may be summarized as follows:

r^{th} rarest species =

$$\frac{S}{N} \sum_{i=1}^{r} \frac{1}{S-i+1}$$

where S equals total number of species, N equals total number of individuals, and i equals rank in rarity of species.

DISCUSSION

The present study was conducted in an attempt to measure and evaluate the effects of a pesticide stress (DDT) on the density, diversity and species organization of tardigrades located within a lichen-bearing tree bark ecosystem. One might, perhaps, view the trunk of an American elm tree as a multichanneled system composed of numerous potential water pathways; these channels being water fed during rainy periods by an overhead deliquescent type of branching tributaries. Further, lichens adhering to this trunk system often tend to serve as "sponges" for the rapid uptake of water due to a system of air-filled spaces which appear between the

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cortical hyphae during dry conditions (Stocker, 1927). Also, lichens have been shown to adsorb and retain numerous organic compounds (Smith, 1960). Thus, an intensive analysis of this lichen-bearing tree bark ecosystem, with its associated microfauna, should provide an excellent site in which to monitor the effects of a pesticide following its application to a forest community. Such was the rationale behind the present study.

Tardigrade density was significantly reduced in samples collected from the sprayed area. Of greater importance, perhaps, was an indication of a reduction in species diversity in the treated area. Once again, as has been found by other investigators (Elton, 1958; Menhinick, 1962; Barrett, 1968; and others), a pesticide stress tends to reduce the diversity of a system, thereby making it more susceptible to additional external perturbations (Odum, 1969).

Of ecological interest was the organization of tardigrade species within the nontreated habitat. Species organization within this relatively simple system appeared to fit MacArthur's broken-stick model for contiguous, non-overlapping niches (MacArthur, 1957). Should further studies confirm this species arrangement, then such a criterion would serve as a useful tool in evaluating the effects of an environmental stress (e.g., pesticides, fire, radiation, etc.) on the structure of an intact, functional forest ecosystem.

The functional parameters of a lichen-bearing tree bark ecosystem (i.e., energy flow or mineral recycling) have not been investigated. We suggest that this relatively simple and accessible system should lend itself well to such future investigations.

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