Bull. Environm. Contam. Toxicol. 21, 11-16 (1979)

Increased Spontaneous Locomotor Activity in the Fiddler Crab, *Uca pugilator*, After Exposure to a Sublethal Concentration of DDT

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The pesticide DDT has been used in such large quantities that vast amounts of it have accumulated in the environment. Although the use of DDT has now been reduced, because it is such a persistent substance its effects on fauna will continue to be evident for years. ODUM et al. (1969), studying marshes that had been sprayed regularly for more than 15 years with DDT for mosquito control, found an average of about 50 ppm of this pesticide in organic detritus. Fiddler crabs, being consumers of plant detritus, do accumulate DDT residues (ODUM et al. 1969). Odum and his colleagues also observed that male fiddler crabs, Uca pugnax, which were fed DDT-containing detritus (10 ppm), not only experienced a threefold increase in the concentration of DDT residues in the muscle of their large cheliped but also developed poor locomotor coordination. The crabs would move a few centimeters, lose coordination, and roll over once or twice before regaining their equilibrium.

The activity patterns of fiddler crabs are adaptively related to both the 24 hr day and the tidal events in the area where they are living. Spontaneous locomotor activity patterns of fiddler crabs, recorded continuously for at least one week showed both circadian and circatidal periodicity (BENNETT et al. 1957, BARNWELL 1966). Uca pugilator, the species used in the present study, exhibited conspicuous nocturnal activity and a tendency for its circadian component of activity to become even more conspicuous under constant illumination (BARNWELL 1966). The objects of the present experiments were to determine (a) the effect of DDT on the level of spontaneous locomotor activity of the fiddler crab, Uca pugilator, throughout a 24 hr day and (b) whether DDT alters the circadian pattern of this activity.

MATERIALS AND METHODS

Adult specimens of the fiddler crab, Uca pugilator, from the area of Panacea, FL, were used in these experiments. The stock supply of crabs was kept in aquaria containing artificial sea water (Instant Ocean, Aquarium Systems) and was exposed to 12 hr of illumination (312.8 lux) each day. The lights were turned on at 08 hr.

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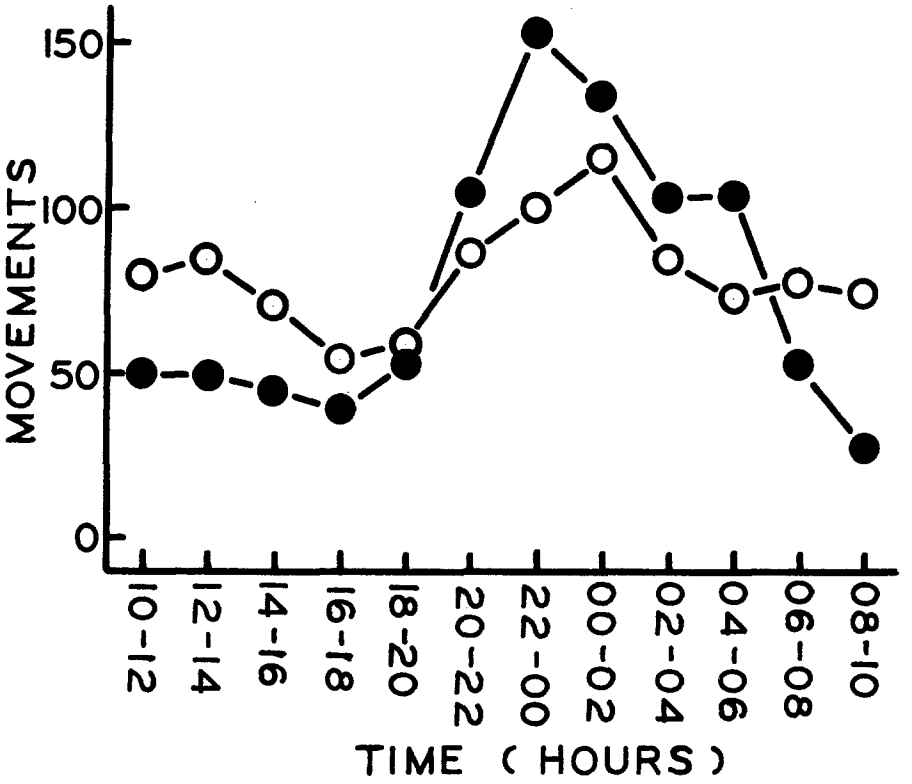

Figure 1. Relationships between the mean number of movements of 10 male fiddler crabs and time of day. Closed circles, crabs in sea water; open circles, the same crabs as depicted by the closed circles after they had been in acetone-sea water 3 days.

The spontaneous locomotor activity of a fiddler crab was recorded under constant illumination, 430.9 lux, at 24°C by use of the method of FINGERMAN et al. (1958) which is a modification of that devised by KALMUS (1938). A thread was tied around the cephalothorax of a crab between the second and third walking legs on each side. The string was then tied to a light aluminum lever which recorded, on carbonized paper fastened to the drum of a 24 hr kymograph, every movement of the crab. The drum rotated at the rate of 2.0 cm/hr. The activity chambers were round bowls, 14.5 cm wide, that had fine gravel on the bottom to provide traction. There was only a single crab per bowl. The appropriate solution, as described below, was added to each bowl to a depth of about 15 mm.

Recording of locomotor activity began at 10 hr. Twenty-four hr later the records were removed and sprayed with a trans-

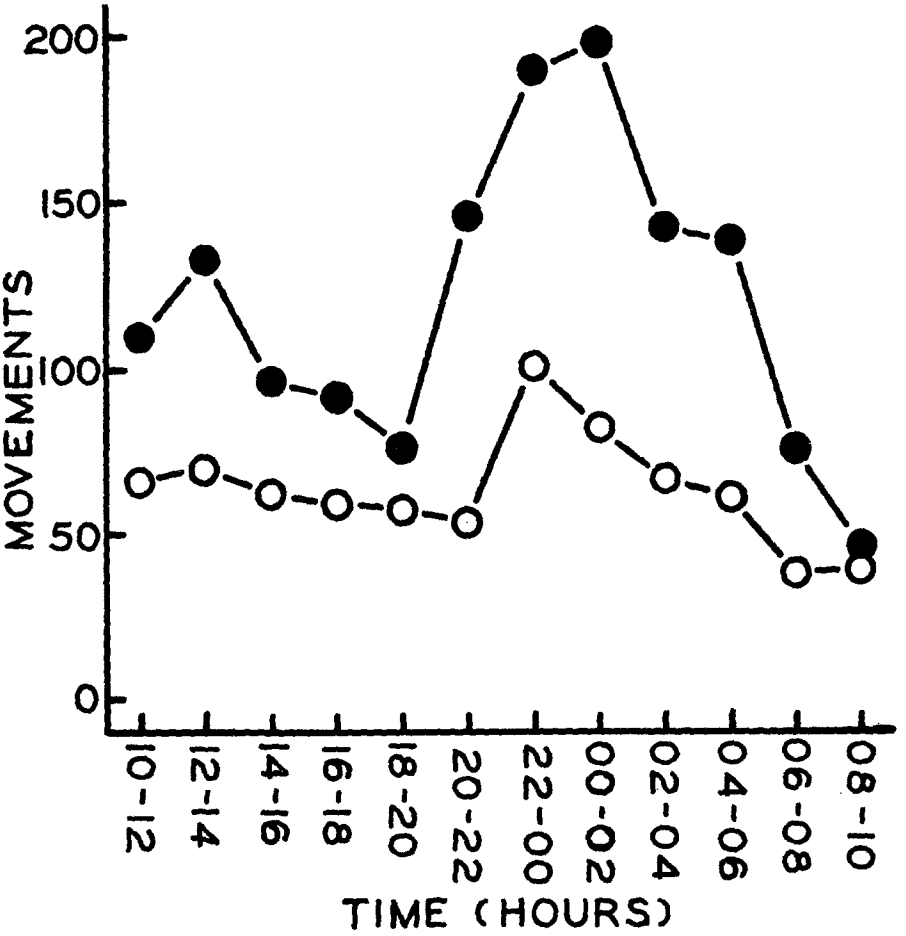

Figure 2. Relationships between the mean number of movements of 10 male fiddler crabs and time of day. Closed circles, crabs in sea water; open circles, the same crabs as depicted by the closed circles after they had been in DDT-sea water for 3 days.

parent fixative. Two-hr intervals were then marked off on the records and the number of movements in each interval was counted.

The DDT was obtained from Analabs. It was dissolved first in acetone, 0.08 mg/ml. For use with the crabs this stock solution was diluted 1:1000 with sea water giving a final DDT concentration of 0.08 ppm in sea water containing 0.1% acetone. Control crabs were exposed to sea water containing acetone alone (0.1%). When crabs were being exposed to these solutions, the old solution was discarded and replaced with fresh each day.

EXPERIMENTS AND RESULTS

A preliminary experiment was performed wherein female crabs were kept in the DDT solution for 3 days and their movements were recorded on the fourth day. Control crabs were exposed to the acetone-sea water for the same period of time. It was found that the 22 DDT-exposed females average 41% more movements per day than did the 18 control crabs. Apparently, the DDT had caused these crabs to become hyperactive.

It was then decided to perform the experiment in a somewhat altered fashion to rule out the chance that inherent differences in total activity among the crabs, and not the DDT, were solely responsible for the difference seen in the preliminary experiment. The second experiment, for which only male crabs were available, was performed in the following fashion. A crab was taken from the stock group and its activity pattern was determined over a period of 24 hr as described above, while in sea water alone. At the end of the 24 hr the crab was placed into a container in which was either the DDT-sea water or the acetone-sea water. The container was then exposed to the same LD 12:12 as were the stock crabs for 3 days. On the fourth day their activity was again recorded for 24 hr with the crabs still in the DDT or acetone solutions. In this way each crab served as its own control, so to speak, thereby eliminating the possibility that the hyperactivity seen in the preliminary experiment was due to chance selection of hyperactive crabs. When the activity pattern of a crab was recorded the second time, the crab was attached to the same lever as it was the first time in order to eliminate the possibility that any difference in the level of activity might be due to the lever system. In deciding which crabs to put into DDT-sea water and which into the acetone-sea water after they had been on the recorder for the first time, an attempt was made to pair off the crabs by visual scanning of the records so that crabs of equal activity went into each solution. A total of 10 experimental and 10 control crabs were run. The averaged results for the 40 successful runs (20 crabs each run twice) are presented in Figure 1 (acetone-sea water) and 2 (DDT-sea water). Inspection of both figures reveals that the crabs were most active from 22-02 hr regardless of whether they had been in DDT-sea water or acetone-sea water. The crabs that were exposed to the acetone-sea water were more active between 20 and 06 hr but less active between 06 and 20 hr than they were initially. The total number of movements made by each group over the 24 hr period averaged 950 for the crabs taken from the stock tank and 909 after they had been exposed to the acetone-sea water for 3 days, a decrease of 4.3%. In contrast, the DDT-exposed crabs exhibited an average of 1440 movements per 24 hr after their 3 day exposure to DDT whereas at the outset they produced an average of only 757 movements. This represents an increase in their activity of 91%. The DDT-exposed crabs, like the acetone-exposed crabs, were most active between 22 and 02 hr.

As stated above, an effort was made to pair the crabs that

were to be exposed to the acetone with those of the crabs that were to be exposed to the DDT so that they had approximately equal activities before being put into the DDT-sea water or the acetone-sea water. However, this was not completely successful. The crabs that were put into the acetone-sea water turned out to have actually a mean total activity of 950 movements per 24 hr (Fig. 1) whereas those placed into the DDT-sea water produced a mean of 757 movements per 24 hr (Fig. 2). Much of the difficulty in pairing the crabs resided in looking at the records that had not yet been counted and trying to get a close match coupled with the occasional inability to use the data from an initial record because the crab died during the 3 day period before the crabs were run again on the recorders. However, the fact that the locomotor hyperactivity of the DDT-exposed crabs was not due to the lower initial level of activity of these crabs than of those exposed to the acetone-sea water alone was immediately evident when we examined the activity records of the 5 least active crabs that were exposed to the acetone-sea water. These 5 crabs had an average initial activity level of 702 movements per 24 hr, quite comparable but lower than the mean 757 movements per 24 hr of the DDT-exposed crabs prior to their being put into the DDT-containing sea water. After the 3-day exposure to the acetone-sea water, these 5 crabs had a mean activity of only 746 movements per 24 hr, an increase of only 6.3% compared to the 91% increase of the DDT-exposed crabs. It is quite clear, therefore, that DDT did indeed produce an increase in the spontaneous locomotor activity of these fiddler crabs. The circadian nature of their activity appears not to have been affected by the DDT.

DISCUSSION

The observation made herein that DDT produced an increased level of spontaneous locomotor activity in the fiddler crab is in conformity with other studies done with this insecticide on arthropods. WELSH and GORDON (1947) using nerves from a cheliped of the crayfish, Orconectes virilis, and from a walking leg of the crab, Cancer irroratus, found that a brief electric shock applied to a DDT-treated nerve gave rise to a train of impulses instead of only a single impulse. LALONDE and BROWN (1954) using DDT-exposed crural nerves of the American cockroach, Periplaneta americana, confirmed Welsh and Gordon's earlier observation. WEIS and MANTEL (1976) using the fiddler crabs, Uca pugilator (the species used in the present experiments) and Uca pugnax, reported that DDT accelerated limb regeneration and the rate of molting in these crabs. The locomotor hyperactivity induced in the crabs by the DDT (Fig. 2) most likely stemmed from its action on the nervous system, inducing repetitive discharges of nerve impulses.

The observation (Figs. 1 and 2) that the crabs were more active between 22 and 02 hr than at other times of the 24 hr day confirms with a different population of Uca pugilator the data of BARNWELL (1966) who studied the locomotor activity patterns of

fiddler crabs from the area of Woods Hole, MA. He reported that the 24 hr component of the activity pattern of Uca pugilator is such that this crab is more active between sunset and sunrise.

The crabs used in the present experiments were not fed from the time they were first selected from the stock tank. Presumably, most of the DDT passed into them through the thin covering of their gills.

Fiddler crabs inhabiting the intertidal zone are exposed to both the 24 hr day-night and the cycle of the tides. The locomotor activity patterns of these crabs must be precisely adapted to the light-dark and tidal cycles of their habitat if the crabs are to survive. Should fiddler crabs in nature become exposed to a concentration of this insecticide large enough to produce the hyperactivity seen in Figure 2 the delicate balance that has evolved between the crabs and their environment would no longer exist. The crabs might become active at times when it would be to their advantage to remain quiescent in their burrows, almost certainly affecting their survival.

REFERENCES

BARNWELL, F. H.: Biol. Bull. 130, 1 (1966).

BENNETT, M. F., J. SHRINER, and R. A. BROWN: Biol. Bull. 112, 267 (1957).

FINGERMAN, M., A. D. LAGO, and M. E. LOWE: Am. Midl. Nat. 59, 67 (1958).

KALMUS, H.: Z. Vergl. Physiol. 25, 798 (1938).

LALONDE, D. I. V. and A. W. A. BROWN: Can. J. Zool. 32, 74 (1954).

ODUM, W. E., G. M. WOODWELL, and C. F. WURSTER: Science 164, 576 (1969).

WEIS, J. S. and L. H. MANTEL: Estuarine Coastal Mar. Sci. 4, 461 (1976).

WELSH, J. H. and H. T. GORDON: J. Cell. Comp. Physiol. 30, 147 (1947).