Distribution of DDTR in a Uniformly-treated Stream

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DIMOND et al. (1971) noted large variation in residue loads of DDT (DDTR) in several streams receiving the same spray treatment. For example, in Table 2 they showed a range of DDTR of 0.072 to 1.958 ppm in bottom muds of 5 streams receiving 1 aerial application of DDT at 1 lb/acre 5 years previously. One factor that appeared to correlate with variable residue was size of the watershed upstream from the sampling location, with larger streams having greater residue.

In the present study, we investigated further the relationship of stream size to residue retention. Variability in chemical and physical characteristics between streams was eliminated by making all observations in one stream. Residues were determined at 19 points spaced between the origin of the stream and its mouth. If larger streams in fact carry a heavier residue load, residues should increase progressively downstream in a single stream.

Methods

We selected Webster Brook, located in T12R7 and Nashville Plt. in northern Maine, as the experimental stream. This 9,870 acre watershed was uniformly sprayed with 1 lb/acre of DDT in 1960 and in 1963 for the control of the spruce budworm, Choristoneura fumiferana. A map and details of all treatments were presented earlier (SHERBURNE and DIMOND 1969).

The Webster Bk watershed is uninhabited and completely forested with primarily spruce-fir type and some northern hardwoods on the uplands. The area has been frequently logged and is bisected in several places with logging roads, now impassable. One heavily-travelled, improved gravel road crosses the stream approximately 7 miles from its source. The mouth of the stream is about 10 miles from its source and enters the Little Machias River.

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The gradient of Webster Bk is relatively even. It is a quick water stream, but with a natural deadwater surrounded by a swamp at its midpoint. Beaver activity has been common and flow is frequently interrupted by ponding.

Brook trout, Salvelinus fontinalis, and a crayfish, Cambarus bartoni, were collected in August 1971 as indicators of DDTR levels. Trout were captured by angling and crayfish by hand searching under rocks and debris. Mud samples were taken from the same collection points in October, 1972. One quart of mud composed of several subsamples was obtained at each site. Mud was obtained from pools and eddies where ther was evidence of settlement of organic matter. Trout and muds were available at all 19 collection points; crayfish could no be collected at 4 sites, the uppermost collection point, whic was too cool for persistence of the species and at 3 flowage areas too deep for hand collecting.

Numbers of trout collected at each point ranged from 3 to 13 with most collections containing 10-12. Length and weight were measured on each fish, and each was aged through examination of annuli on scales. Three age classes were present, 1+, 2+, and 3+; fish of the same age were analysed together.

Crayfish collections comprised 5-15 animals. These were also measured, sexed, and each collection divided into 2-5 pools based on size (carapace length) and on sex.

Animals were wrapped in aluminum foil and stored at $-18^{o}C$ until analysis. Muds were collected in glass bottles, air dried at room temperature and stored at $5^{o}C$.

Extraction of residues, clean-up, gas chromatographic analysis, and laboratory controls have all been described previously (DIMOND et al. 1971). Residues of other pesticides and of PCB's have not been a problem in samples from the study area. It is well removed from industrial activity and had no history of pesticide application other than DDT at the time of sample collection.

Because organic matter in soils is a principal site of bonding of DDT (PORTER and BEARD 1968, YULE 1970), the organic content of the muds was determined, using the Walkley Black method (ALLISON 1965). Residues in muds were calculate on the basis of organic matter weight and total sample weight

Results

The data suggest a constant residue concentration throughout the drainage (Table 1). Trout varied between 0.4 and 0.9 ppm of DDTR with no particular trends apparent in terms of location along the stream. Differences were not noted in the 3 age classes collected. Mean residue was 0.63' 0.621, and 0.689 ppm for the ages 1+ - 3+ respectively, and the age classes are combined in Table 1. The value for trout at point 1 is the highest residue detected and probably reflects a real difference. The stream at this headwater site was noticeably colder than in the remainder of the stream and the trout smaller. Age class 1+ averaged 9.7 cm in length at this point but ranged from 11.0-14.2 at sites 2-19. Figures for age classes 2+ and 3+ were 12.2 cm with a range of 13.8-17.7 and 14.1 cm with a range of 17.8-21.8. The higher residue in small, slow-growing fish and the lack of differences in residue level between age classes of trout both conflict with data presented for other salmonid fishes (ANDERSON and FENDERSON 1970, YOUNGS *et al*. 1972). We did not have data on fat content of the samples, an important correlate of residue level (ANDERSON and FENDERSON 1970).

Residue levels in crayfish were 10-25% of those in trout. There was much variation in concentration between individuals or groups of individuals from the same collection points; however, these differences did not correspond to size or sex. Therefore, only the means for the total collections

TABLE 1

DDTR in trout, crayfish, and muds at 19 points along Webster Bk, Maine. DDTR concentrations in muds are expressed on the basis of total sample weight (A) and on the basis of organic matter in the sample (B).

Collection point	Watershed acreage	Trout	Crayfish	Muds A	Muds B
1	1,100	0.881	no data	0.107	2.37
2	2,550	0.462	0.145	0.051	1.54
3	2,910	0.535	0.196	0.546	5.20
4	3,580	0.616	0.088	0.120	1.35
5	3,750	0.708	0.151	0.252	3.72
6	1,800[1]	0.506	0.054	0.150	1.85
7	5,600	0.566	0.101	0.287	5.48
8	6,000	0.706	0.121	0.198	1.29
9	6,330	0.480	no data	1.313	17.94
10	6,730	0.414	0.100	0.113	1.47
11	6,840	0.605	0.108	0.390	3.58
12	7,340	0.743	0.150	0.127	1.18
13	7,510	0.790	0.156	0.117	2.64
14	8,440	0.547	0.106	0.108	2.64
15	8,570	0.659	0.111	0.633	2.59
16	9,260	0.518	0.045	0.107	1.32
17	9,640	0.577	0.052	0.096	1.77
18	9,790	0.431	no data	0.160	3.54
19	9,870	0.607	no data	0.031	1.58

[1]Collection point 6 was located within the largest tributary of Webster Bk. rather than in the main stream.

are presented. We noted no trends in residue that deviate from an impression of uniformity along the stream.

The proportions of isomers of DDT in the 2 organisms were quite different. The total residue was 60-80% DDE in trout with the remainder about equally divided between DDT and DDD. In crayfish, DDE comprised about 60%, DDT about 40% with traces of DDD in only a few specimens. There were no differences in the proportions of isomers that suggested any trends involved with position in the watershed.

Mud residues were extremely variable when expressed on the basis of total sample weight (Table 1). A regression analysis of organic matter content of each sample with residue level was significant (Figure 1) and recalculation of residue on the basis of the organic matter content of the samples reduced much of the variability (Table 1).

The highest residue values, 17.9, 5.4, and 5.2, were in the upper half of the stream but with more toward the central area of the stream than the headwater. The sample with the highest value was from the large deadwater area mentioned earlier, and the other high values were from that portion of the stream where most of the beaver ponding was concentrated. Collection points 2, 3, 5, 6, 7, 9, 11, and 18 were classified as flowage at the time of collection whereas the remaining points were fast-water sections of the stream. If a comparison is made between mud residues (based on organic content) of flowages and fast-water points, we find that all the higher values (>3 ppm) were from the flowage collections. Analysis of variance showed a significant difference ($F=4.92$, $p<0.05$) in residue levels between these 2 habitats. This may result from a greater proportion of fine-particle soils in the muds of ponded areas compared to areas of quick flow. Clays and other fine soils are reported to retain more DDT than coarse soils (EDWARDS 1964, ROUTH 1972). The variability in the DDT content of the muds is due to varying content of organic matter and probably also of fine mineral soils. There is nothing to indicate that size of the upstream watershed is a factor directly affecting residue levels.

DDD predominated in the mud samples, comprising 35-60% of the total residue. DDT and DDE were about 30% and 25% respectively. This high degree of degradation of DDT in aquatic soils was noted previously (YULE and TOMLIN 1971). The proportions of the different isomers did not vary with position in the watershed.

Discussion

The results of this study refute the suggestion of DIMOND *et al*. (1971) that residues in similarly treated streams will be larger in larger streams. We do show, however, that ponded areas (flowages) contain greater residues

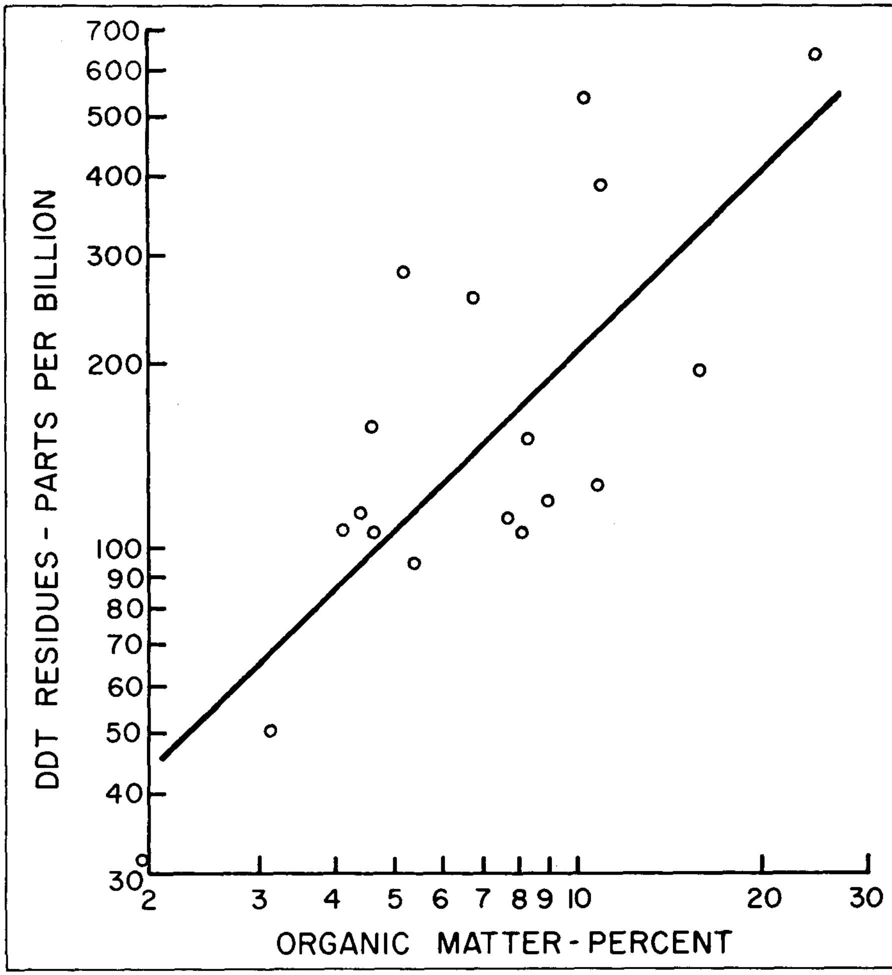

Figure 1. Relationship of percent organic matter in mud samples from Webster Bk to DDT residue.
$\log Y = 1.367 + 0.976 \log X$
$r=0.77$, $t=4.78$, d.f.$=16$

in muds than fast-water areas, and this agrees with ROUTH's (1972) study of the Salinas River, California. The results of DIMOND et al. (1971) probably do not reflect a direct relationship of watershed size to magnitude of residue in muds, but rather, the tendency of some larger streams or larger areas of a stream to contain more areas of slow current, producing greater settling of suspended particles. Re-examination of the nature of the streams sampled by DIMOND et al. (1971) suggests this was the case.

Trout did not show any differences in residue accordin to whether caught in a flowage or in fast-water. This may re flect the mobility of trout, moving between flowages and shallows in feeding. It also reflects the feeding of trout on drifting aquatic invertebrates (WATERS 1969) originating from a variety of upstream habitats.

Crayfish were nearly all collected from fast-water areas. Even where a collection point was a flowage, we tende to obtain them in nearby shallow stretches where there was suitable rocky stratum for cover. We can not discriminate between flowage and fast-water with this group.

YULE and TOMLIN (1971) studied DDTR in muds of the Mirimichi River system in New Brunswick, Canada. The site is ecologically similar to Webster Bk except the Mirimichi is a much larger stream. YULE and TOMLIN suggested a dilution effect from headwater to estuary in DDTR in muds at 15 spaced collections along the S. W. Branch. This conflicts with the Webster Bk data.

The conflict can be resolved as follows, however. The map presented of the Mirimichi indicates that the lower 15-20% of the sampled section of the S. W. Branch was never sprayed, and this portion of the watershed would contribute little residue. In addition, there is no indication that the upstream, sprayed portions of the watershed were sprayed uniformly. Both of these conditions differ from those of Webste Bk, which can be considered more controlled experimentally.

YULE and TOMLIN characterized these mud samples as sandy bottom or muddy bottom, and no allowances were made for this difference in the analysis or computation of residues. With one exception in each category, the 7 mud bottom samples are all 2-10 times higher in residue than the 8 sandy bottom samples, 6 of which represent the lowest 6 samples taken in the River. The main effect in their data probably derives from the fact that all the samples in the lower third of the river were sandy bottom, and therefore low in residue, while the majority of samples in the upper two-thirds were muddy bottom.

No generalization can be made whether DDTR are greater in larger watersheds (DIMOND et al. 1971) or decrease in the lower, larger portions of a watershed (YULE and TOMLIN 1971). It depends on the nature of the stream. Where ponding is more prevalent in the central or upper sections, as in Webster Bk and presumably in the S. W. Mirimichi and the Salinas River (ROUTH 1972), greater mud residues will be found. Where the lower stretches of a stream become sluggish, as in Blackwater River (DIMOND et al. 1971), greater settling of organic matter and fine inorganic particles will produce greater residue.

In an "ideal" stream of completely even speed and gradient, residue levels should be uniform throughout, assuming uniform treatment of the entire watershed with DDT.

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