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# CONTROL OF *CULICOIDES MELLEUS* (COQ.) (DIPTERA: HELEIDAE) WITH GRANULAR INSECTICIDES AND THE EFFECT ON OTHER FAUNA

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During the years 1958 and 1959 we conducted a series of studies aimed at establishing an economically feasible method of controlling *Culicoides melleus* (Coq.), one of the most common blood sucking gnats found on Cape Cod. These studies resulted in recognition of the principal breeding areas in intertidal sand (Wall and Doane, 1960), effective control in small plots with a variety of chemicals (Wall, 1960), and general information on its life span and habits.

The early work also indicated that chlorinated hydrocarbons might kill or injure shellfish located in or adjacent to *C. melleus* breeding areas, and that considerable chemical residue might be left on or in the shellfish following insecticide application. Consideration was also given to the possibility that this residue would render these organisms objectionable for human consumption.

The tests described in the present paper were planned to determine: (1) the effect of granular chlorinated hydrocarbons on *C. melleus* in clam breeding areas; (2) the quantity of insecticidal residue on and in the clams; and (3) the effect of a large scale helicopter application of granular material on *C. melleus* and other fauna.

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## EXPERIMENT I

METHOD AND MATERIALS. In the summer of 1960, upon approval of the local shellfish warden, a site bordering on a commercial clam bed in the Town of Chatham was selected for treatment. This site was in a protected bay having a high and relatively uniform *C. melleus* larval population. Six plots, each 25 yards in length and 8 yards in width were laid out in the test area. BHC, DDT, and dieldrin, formulated on 30/40 mesh attaclay at a concentration of 1.0 percent with urea were distributed by hand on the test plots at about low tide. Each plot received a single dosage of one insecticide. Sampling procedure was the same as that employed by Jamnback and Wall (1958). The check area was adjacent to the treated areas. Larval samples were taken immediately before treatment, and 3, 7, and 14 days after treatment. The results of these tests are summarized in Table 1.

Table 1 shows that DDT at a dosage of 0.5 pound per acre, and dieldrin at dosages of 0.4 and 0.2 pound per acre reduced *C. melleus* larval populations more than 95 percent three days after application, and 100 percent 14 days after application. DDT at a dosage of 1.0 pound per acre also gave 100 percent

TABLE 1.—Results of field tests with granular insecticides against *Culicoides melleus* larvae in small intertidal sand plots.

| Insecticide | Dosage (technical) lbs./acre | No. days after treatment | Average number of larvae | | Percent reduction* |
|---|---|---|---|---|---|
| | | | treated plot | check plot | |
| DDT | 0.5 | (before tr.) | 41.3 (3)** | 50 (3) | ..... |
| | | 3 | 1.7 (3) | 50 (2) | 95.6 |
| | | 7 | 0.6 (3) | 41 (2) | 98.2 |
| | | 14 | 0.0 (3) | 50 (1) | 100.0 |
| | 1.0 | (before tr.) | 29.3 (3) | 50 (3) | ..... |
| | | 3 | 6.3 (3) | 50 (2) | 78.5 |
| | | 7 | 1.0 (3) | 41 (2) | 95.9 |
| | | 14 | 0.0 (3) | 50 (1) | 100.0 |
| BHC | 0.1 (gamma isomer) | (before tr.) | 49.3 (3) | 50 (3) | ..... |
| | | 3 | 19.3 (3) | 50 (2) | 60.9 |
| | | 7 | 4.3 (3) | 41 (2) | 89.4 |
| | | 14 | 16.6 (3) | 50 (1) | 66.3 |
| | 0.2 (gamma isomer) | (before tr.) | 44.0 (3) | 50 (3) | ..... |
| | | 3 | 0.3 (3) | 50 (2) | 99.3 |
| | | 7 | 0.3 (3) | 41 (2) | 99.2 |
| | | 14 | 0.3 (3) | 50 (1) | 99.3 |
| Dieldrin | 0.2 | (before tr.) | 50.0 (3) | 50 (3) | ..... |
| | | 3 | 0.3 (3) | 50 (2) | 99.4 |
| | | 7 | 0.0 (3) | 41 (2) | 100.0 |
| | | 14 | 0.0 (3) | 50 (1) | 100.0 |
| | 0.4 | (before tr.) | 24.3 (3) | 50 (3) | ..... |
| | | 3 | 0.7 (3) | 50 (2) | 97.1 |
| | | 7 | 0.0 (3) | 41 (2) | 100.0 |
| | | 14 | 0.0 (3) | 50 (1) | 100.0 |

* Adjusted using Abbott's formula.
** The number of samples is given in parentheses.

larval control 14 days after treatment. Three days after application, the lower dosage of DDT resulted in more effective control of the larvae than the higher dosage. It is possible, however, that inadequate sampling caused this apparent discrepancy.

BHC applied at the rate of 0.2 pound of gamma isomer per acre gave excellent control of the larvae, although complete reduction was not obtained the 14th day after treatment. BHC applied at 0.1 pound of gamma isomer per acre provided good control, but was the least effective of the insecticide dosages used. We feel, however, that the limited control resulting from the use of this dosage of BHC was primarily due to the poor distribution of the granules at one end of the plot during application. The majority of the live larvae found in the samples taken following treatment were from this relatively untreated end.

Small and submicroscopic crustaceans, arachnids, oligochaetes, nematodes, turbellarians, and a few dipterous larvae were recorded in the sand taken from the treated plots on the third day following treatment. As was to be expected, the plots which received the larger dosages of insecticide had the smaller number of living organisms. At the end of two weeks, small and submicroscopic crustaceans, arachnids, oligochaetes, collembolans, and pelecypods were present and active in the treated plots. There also appeared to be an increase in the numbers of these invertebrates present at this time, indicating the possibility of repopulation from the surrounding areas or by the offspring of the surviving organisms.

Eight days following treatment, clams

of varying size were dug from the plots treated with the lower dosage of each insecticide. Approximately ten soft shell clams, *Mya arenaria* Linn., were taken from each plot, and two razor clams, *Ensis directus* Conrad, were also found in the dieldrin plot. None were dead and none appeared to have suffered any ill effects from the insecticides.

## EXPERIMENT II

In order to obtain more specific information on the amounts of chlorinated hydrocarbons actually on or in clams from the treated areas, a second series of tests was conducted in the vicinity of the original test area during this same summer.

METHODS AND MATERIALS Three plots each containing a large number of well-developed *Mya arenaria* were treated with 0.4 pound of dieldrin, 0.2 pound of gamma isomer of BHC, and 1.0 pound of DDT per acre respectively, in granular form. The dosages were higher than those previously determined as effective in controlling *C. melleus* larvae.

The day following treatment, four quarts of living *M. arenaria* were dug from each of the treated plots and from a nearby untreated area. Although the check area was very close to the treated plots, its location was such that it was virtually impossible for any of the insecticide to be carried into it through tidal action.

Two kilograms of clams, unwashed, were ground up with the shell intact in order to ascertain if any of the insecticides were present on the surface, as well as in the body of the clams. The presence of insecticide in and on the clams was determined by calculating the organic chlorine content of the ground-up clams. The values obtained were corrected for the organic chlorine content found on and in the clams from the untreated area.[2] The results of the analysis are shown in Table 2.

[2] The grinding, analysis, and calculations were carried out by the Skinner and Sherman Company, Incorporated, Newton, Massachusetts.

TABLE 2.—Results of chemical analysis for organic chlorine content of *Mya arenaria* taken from small intertidal sand plots treated with granular insecticides.

| Insecticide | Dosage (technical) lbs./acre | Organic chlorine content (ppm) |
|---|---|---|
| Control | ... | 0.02 |
| DDT | 1.0 | 0.14* |
| Lindane | 0.2 | 0.14* |
| Dieldrin | 0.4 | 0.18* |

* Corrected for the organic chlorine content found in the control plot.

RESULTS AND DISCUSSION. Although Table 2 shows that some chemical residue was present on and in the clams from the treated areas, the amounts were relatively small, and were below the tolerances established by the Food and Drug Administration for these same insecticides on most fruits and vegetables. Because of the tidal action, it is possible that had we waited a few more days before digging and analyzing the clams, even less residue would have been present.

We did not attempt to establish the effect of the insecticides on clam larvae, since no facilities were available to cultivate these organisms. However, the work of others, such as Loosanoff (1947), Davis (1961), and Haskins and Haines (1962), has indicated that concentrations of dieldrin and lindane of 1.0 p.p.m. or less would cause only minor mortality to developing larvae of *Crassostrea virginica* Gmelin and *Venus mercenaria* Linn.

## EXPERIMENT III

METHODS AND MATERIALS. In order to determine the value of aerial application of a granular insecticide against *C. melleus* larvae, dieldrin was used as the test material. It was formulated on 30/40 mesh attaclay at a concentration of 2.0 percent with urea.

Seacoast Shores in the Town of Falmouth was selected as the test area. It is a heavily populated peninsula with a sandy shoreline. This peninsula and the immediately adjacent shoreline measure

approximately three and one quarter miles in length. This area had been surveyed during the past few years and was known to be heavily infested with *C. melleus* as determined through sand samples, light trap counts, biting counts, and complaints from local residents.

The west side of Seacoast Shores and adjacent intertidal areas were treated by helicopter on May 27, 1961 at the rate of 0.3 pound of dieldrin per acre. The wind velocity averaged 5 to 10 miles per hour during the period of application. Due to an increase in the wind velocity during this initial treatment, the application on the east side of the peninsula and adjacent potential breeding area was delayed until June 3, 1961, when the wind velocity was 2 to 4 miles per hour. Our observations indicated that fairly good distribution of the granules was obtained.

Approximately two miles of shoreline surrounding Seacoast Shores and its adjacent shoreline were also treated with granular dieldrin, because our past light trap surveys, made throughout Cape Cod over a period of four summers, had shown that adults of *C. melleus* migrated or were carried by wind distances of a mile or more from their breeding sites.

Since the numbers of larvae vary somewhat from area to area, we took the sand samples from the same sites before and after treatment, with one exception. The results are shown in Table 3.

RESULTS AND DISCUSSION. The results of this test were excellent, even though much of the area had seaweed, eel grass, and other vegetation covering part of the intertidal sand where some of the *Culicoides* were breeding. The majority of the larvae found after treatment were in areas where the shoreline turned abruptly. These are points where the distribution of granules is often relatively poor, due to the sudden changes in direction made by the helicopter. In fairly straight stretches of sand where the distribution of granules was more uniform, very few live larvae were found after treatment.

The samples collected 28 days after treatment were taken from ten sites in the treated area not previously sampled, and the results are in close agreement with the others. By the 50th day following treatment, very small, apparently newly hatched larvae were found in the samples. These larvae were not included in the larval counts made on this day.

Light trap counts taken during the summers of 1960 and 1961 confirmed the results obtained from the sand samples. Over a period of ten weeks during the summer of 1960, a total of 1393 *C. melleus* adults were taken from a light trap located in the test area, and 1045 from one in an untreated area. During a similar period in the summer of 1961, a total of 25 adults were taken in the test area, and 710 in the untreated area. Using Abbott's formula to correct these figures, the approximate reduction in the light trap count obtained from the treated area was 97 percent.

TABLE 3.—Effectiveness against *Culicoides melleus* larvae of granular dieldrin applied to intertidal sand at the rate of 0.3 pound per acre.

| Average number of days after treatment | Average number of larvae | | Percent reduction * |
|---|---|---|---|
| | treated area | check area | |
| (before treatment) | 32.3 (14)** | 50 (2) | .... |
| 15 | 4.9 (14) | 50 (2) | 84.8 |
| 22 | 1.7 (12) | 50 (2) | 94.8 |
| 28 | 3.0 (10) | 50 (2) | 90.7 |
| 50 | 4.0 (12) | 44 (2) | 85.9 |
| 78 | 7.7 (11) | 40 (2) | 75.2 |

* Adjusted using Abbott's formula.

** The number of samples is given in parentheses.

Observations on the presence or absence of other fauna in the treated area were made during the larval counts. The following organisms were found alive and active in the treated areas before, and approximately two weeks following treatment: small and submicroscopic crustaceans, oligochaetes, collembolans, and nematodes. Although no quantitative study was made, at least some of the above mentioned organisms were alive and active in most of the sites sampled during the entire period of observation. No dead fish, birds, crabs or other large organisms were noted in the treated area before or after treatment.

In May of 1962, Seacoast Shores and adjacent shoreline were retreated with 0.3 pound per acre of dieldrin applied in granular form by helicopter. The surrounding shorelines were not treated. A total of 53 sand samples from a variety of locations along the shore were examined for *C. melleus* larvae during the summer months. Counts averaged 1.3 larvae per sample as compared to an average count of 4.3 larvae per sample from a total of 59 samples taken during the summer of 1961.

Over a period of ten weeks during the summer of 1962, a total of 366 *C. melleus* adults were collected in the light trap at Seacoast Shores and 725 from the trap in the check area. Although the check area count was comparable to that obtained in 1961, the test area count was considerably higher, and does not substantiate the larval reduction in the sand samples. It is possible, however, that this increase in adults was due to their dispersion from untreated breeding areas surrounding Seacoast Shores.

Approximately one month after treatment, the first sand samples were taken and the following organisms were found alive: collembolans, oligochaetes, polychaetes, nematodes, and crustaceans. A few newly hatched *C. melleus* larvae were noted in the sand samples on the 62nd day after treatment.

The results of the two large scale dieldrin granule applications indicate that this material applied to intertidal sand at the rate of 0.3 pound per acre in the spring, will effectively control *C. melleus* larvae breeding therein. However, the repopulation of the intertidal sand by the larvae within a period of two months indicates that the tides may limit the residual action of dieldrin.

SUMMARY. DDT, BHC, and dieldrin granules applied to small intertidal sand plots at the rate of 0.5 and 1.0 pound per acre, 0.2 pound of gamma isomer per acre, and 0.2 and 0.4 pound per acre respectively, resulted in control of *C. melleus* larvae ranging from 78.5 to 100 percent. BHC applied at the rate of 0.1 pound of gamma isomer per acre was less effective. Some of the small and submicroscopic organisms inhabiting the treated plots apparently were killed by the insecticides, but indications of repopulation were noted two weeks after treatment. Eight days after treatment *Mya arenaria* and *Ensis directus* taken from the test areas treated with the lower dosage of each insecticide, were alive and showed no ill effects.

Three small intertidal plots containing *Mya arenaria* were treated with 0.4 pound of dieldrin, 0.2 pound of gamma isomer of BHC, and 1.0 pound of DDT on granules per acre respectively. Unwashed, unshelled clams taken from these plots and an adjacent untreated area the day after treatment, were analyzed for the presence of organic chlorine. Small amounts of residue were found on or in the clams from the treated plots.

In May and June of 1961 approximately three and one quarter miles of intertidal sand at Seacoast Shores, and the adjacent shoreline were treated with granular dieldrin at the rate of 0.3 pound per acre. Approximately two miles of surrounding shoreline were also treated. Excellent control of *C. melleus* larvae was obtained and these results were confirmed by light trap counts. Living small and submicroscopic organisms were found in the intertidal sand approximately two weeks after treatment.

Seacoast Shores and the adjacent shore-

line were retreated with the same dosage of dieldrin granules by helicopter in May of 1962. The surrounding shoreline was not treated. Sand samples taken from the treated area after treatment averaged 1.3 *C. melleus* larvae per sample as compared to 4.3 larvae per sample taken in 1961. Light trap counts obtained from the treated area in 1962 had increased considerably over those taken in 1961. Approximately one month after treatment, small and submicroscopic living invertebrates were found in the treated sand, while approximately two months after treatment, newly hatched *C. melleus* larvae were found.

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# DDT AND DIELDRIN RESISTANCE IN *ANOPHELES QUADRIMACULATUS* FROM HARTWELL AND CLARK HILL RESERVOIRS, GEORGIA

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Resistance to DDT was demonstrated in *Anopheles quadrimaculatus* collected from Clark Hill Reservoir near Augusta, Georgia, in 1959 (Mathis *et al.*, 1960). After this detection, DDT as an aerial larvicide treatment (0.08 to 0.20 pound DDT per acre) on selected areas was replaced by a malathion-lethane application (0.1 lb. of malathion/acre). Such treatment during the 1960–1962 period was effective in controlling *A. quadrimaculatus*.

At Hartwell, a reservoir located approximately 25 miles north of Clark Hill Reservoir on the same river, the first DDT larvicidal treatments were made in 1961. Based on adult counts in designated stations, satisfactory control was obtained with these treatments both in 1961 and 1962. However, in August 1962, susceptibility tests of adults collected at Hartwell Reservoir indicated resistance to DDT and to dieldrin.

All susceptibility tests were made with the World Health Organization procedures (1960). Data are presented for (1) field-collected females from both reservoirs; (2) colonized strains from each reservoir; and (3) a colonized strain from

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