Plate 1. Mosquitoes resting on army caps (U.S. and Canadian) at Churchill, in June, 1947.

STUDIES OF THE BIOLOGY AND CONTROL OF BITING FLIES IN NORTHERN CANADA*

By **C. R. Twinn**

In many areas in the Canadian arctic and subarctic, biting flies, especially mosquitoes (Plate 1) and black flies, are serious pests and interfere greatly with human comfort and activity during the short summer season.

During the past three years, at the request of the Defence Research Board and in cooperation with that organization and other agencies, the Division of Entomology has been involved in an investigation of the biting fly problem in the North, with the object of obtaining more knowledge of the distribution and biology of the species concerned, and of developing practical measures of control and protection.

In this brief presentation it is not possible to deal adequately with the various projects undertaken, and some are not even mentioned, but it may serve to give some idea of the nature and scope of the investigations. The results of the work have been, or are being, presented in more detail in progress reports and in articles published or to be published in scientific journals.

The biological and control aspects of these investigations were commenced at Fort Churchill, Manitoba, in 1947, and continued during 1948

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as a joint project of the Division of Entomology, on behalf of the Defence Research Board, and the Bureau of Entomology and Plant Quarantine, on behalf of the U.S. Army Committee for Insect and Rodent Control.

The United States group was under the leadership of Wm. C. McDuffie and consisted of 4 entomologists in 1947 and 2 in 1948, plus aircrew of a U.S.A.F. C-47 used in spraying tests in 1948, and U.S. Army personnel who assisted in field repellent studies.

In 1949, the work was continued as a solely Canadian effort, and was expanded to include studies in the vicinity of R.C.A.F. establishments in the North West Air Command: at Fort St. John and Fort Nelson, B.C., and Watson Lake and Whitehorse, Y.T. (with headquarters at Whitehorse); and in the Air Transport Command at Goose Bay, Labr. The Canadian personnel who have taken part in the studies during the three years number as follows*: Division of Entomology (1947) 3, (1948) 5, (1949) 13; Division of Botany (1948) 1, (1949) 4; Defence Research Board (1947) 3, (1948) 6, (1949) 9. Many of these were university students, undergraduate and post-graduate, employed on a seasonal basis.

Several university professors also assisted: A. W. A. Brown, Department of Zoology and Applied Biology, University of Western Ontario, gave direction in aircraft spraying experiments; B. Hocking, Department of Entomology, University of Alberta, gave leadership in black fly larvicide tests and assisted in biological studies; F. P. Ide, Department of Zoology, University of Toronto, directed certain phases of the black fly biological studies. In addition, university personnel doing field work on associated projects under D.R.B. grants numbered 3 in 1948 and 4 in 1949. Furthermore, valuable contributions were made in connection with aerial spraying experiments in 1947 and 1949 by members of the staff of the D.R.B. Suffield Experimental Station, and by air and ground crews of the R.C.A.F. The latter service also provided the materials and equipment used in large-scale control experiments in 1949.

Mosquitoes

Churchill is a region of transition from forest (Plate 2) to tundra, and the ground is permanently frozen a short distance beneath the surface. Here 11 species of *Aedes* were found, representative of forest, prairie, and tundra areas, and of the arctic, subarctic, and temperate zones, and also 2 species of *Culiseta*, which are widespread in northern forests. Preliminary studies on most of these species have already been reported (1).[1] Identification of females of certain of the dark-legged species of *Aedes*, which are the major pests in this region, is difficult if not impossible, and

*Exclusive of those engaged in the Northern Insect Survey, which is a project of the Systematic Entomology Unit coordinated by T. N. Freeman.

[1]See references on page 26.

Plate 2. Subarctic forest south of Churchill. Tracked vehicles such as the snowmobile were required to reach biting-fly breeding areas.

in an attempt to solve this problem large numbers of larvae have been reared individually in the insectary, and the last larval exuviae associated with the adults. The immature stages of all the species recorded at Churchill have been found, except *A. spencerii* (Theo.), a few females of which were taken in 1948, and *Culiseta impatiens* (Wlk.), which appears to be rare.

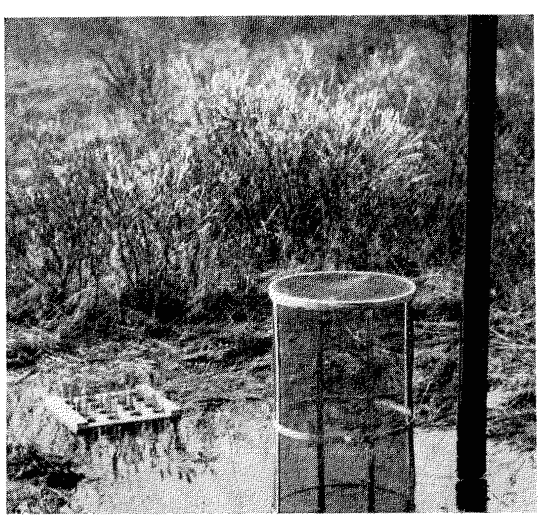

Plate 3. Field study station in a mosquito pool at Churchill, showing cages for individual and mass rearing of mosquitoes.

Field study stations (Plate 3) have been maintained in representative types of breeding areas, and data obtained on species association, succession, abundance, life-histories, and bionomics. Environmental conditions have been recorded such as pH, salinity, colour, temperature, and the macro- and micro-flora of the breeding places. The activities

Plate 4. Lewes River canyon near Whitehorse. Black flies breed in great numbers in the rapids.

of the adults have also been studied at these stations and elsewhere, throughout the mosquito season, including the abundance and succession of species on the wing, and the landing and biting rates as related to temperature, humidity, and light intensity. The studies have also included observations on the mating, feeding, and egg-laying habits of the various species.

At Goose Bay, Labr., in 1949, 15 species of mosquitoes representing 5 genera were identified, and a number of them reared. They included 10 species of *Aedes*, 2 of *Culiseta*, 1 each of *Culex*, *Wyeomyia*, and *Anopheles*. Several of the species are new records for this region. In the North West Air Command region 22 species were reared or collected in 1949, including 17 of *Aedes*, 4 of *Culiseta* and 1 of *Culex*. The data from the biological studies in these areas have not yet been fully evaluated.

Black Flies

The results of studies of black flies at Churchill in 1947 have been published (1). Observations were continued in 1948 and 1949 on species association, and seasonal development, abundance, and activity. The number of species recorded in this region was increased to 16 in 1948, and additional species may have been found in 1949. Several have not yet been described. The major pest species is *Simulium venustum* Say, which occurs in great numbers from late June to September. It has at least two generations in this region, the emergence dates overlapping.

Twelve species of black flies, the majority of which had not previously been recorded in the region, were found during a preliminary study in the Goose Bay, Labr., area, embracing sixteen rivers, streams, and stream systems. Collections of adults revealed 3 species to be dominant, namely, *Simulium perissum* D. & S. (49 per cent), *S. venustum* (35 per cent), and *Prosimulium hirtipes* Fries (11 per cent). The first adults appeared in mid-June, but heavy infestations did not develop until the latter part of July and continued through August.

Many species were studied and collected at several points in the Yukon (Plate 4) and northern British Columbia in 1949. This material has not yet been completely evaluated, but among the common species are *S. venustum, S. arcticum* Mall., and *P. hirtipes*. Several of the species appear to be new to science. Cage emergence studies of black flies in comparable streams at Whitehorse, Y.T., Churchill, Man. (Plate 5), Baker Lake, N.W.T., Goose Bay, Labr., and Algonquin Park, Ont., have produced valuable data on species occurrence, abundance, and life-histories under a wide range of climatic conditions.

Tabanids

Tabanids (variously called bulldog, moose, deer flies, etc.) are very abundant in forested regions of the North, especially in swampy areas. In general, their active season lasts for about six weeks, from the end of June to mid-August, their maximum numbers occurring in July. They do not bite man so readily as do mosquitoes and black flies; nevertheless their large size and persistent aggressive attacks make them extremely annoying and sometimes alarming pests.

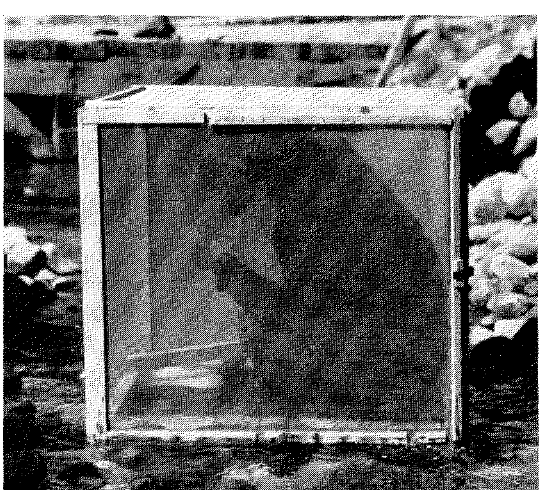

Plate 5. Collecting black flies from cage used in black fly emergence studies in small stream at Churchill.

Seventeen species, including 10 of *Hybomitra*, 5 of *Chrysops*, and 2 of *Atylotus*, have been found at Churchill. In 1949, 17 species were taken at Goose Bay, Labr., including 9 of *Hybomitra*, 1 of *Atylotus*, and 7 of *Chrysops*; specimens taken in northern British Columbia and the Yukon included 13 species of

Plate 6. Experimental spraying by R.C.A.F. Dakota (C-47) to control mosquitoes at Churchill, June, 1947. Luminescent panel on vehicle marks the spray plots.

Hybomitra and 4 of *Chrysops*.

Observations have been made on the succession and relative abundance of the species, their flight, mating, and feeding habits, and the effect of weather conditions on their activities. The immature stages have been studied, particularly at Churchill, where considerable numbers have been reared from the larval stage. *Hybomitra* larvae are carnivorous and cannibalistic and must be reared in isolation. *Chrysops* larvae were found to develop satisfactorily in damp moss rich in organic matter from their natural habitats.

Chemical Control Studies

Mosquito Control

During mosquito larvicide studies at Churchill in 1947 and 1948, about 250 experimental plots, ranging in size from 1000 square feet to 2 acres, were treated by ground spraying equipment with various dosages and formulations of DDT and seven other promising insecticides. Thirteen larger plots, from one-half to 2½ square miles in area, were sprayed by aircraft (Plate 6) with DDT preparations.

The results of these experiments have been published (2, 3). In general, they indicate the superiority of DDT as a mosquito larvicide over other chemicals tested, and show that 0.2 to 0.25 lb. of DDT in oil solution per acre is a practical dosage to obtain good control of *Aedes* larvae either as a prehatching or as a posthatching application, applied either by ground or by aerial equipment. At lower dosages, emulsions and water suspensions of DDT were somewhat more effective than oil solutions.

Spraying the larvicide on the snow- and ice-covered breeding areas in the spring before the thaw, 2 to 6 weeks before hatching became general, gave results comparable but not superior to conventional larvicide treatments. This practice, however, is advantageous in undertaking

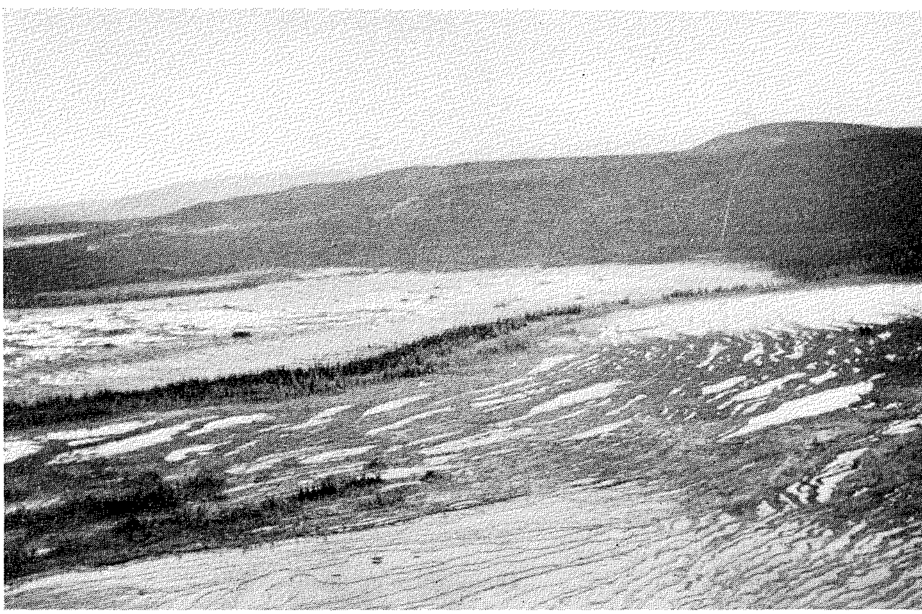

Plate 7. Aerial view of mosquito-breeding sphagnum bog at Goose Bay. Seventeen square miles of these bogs were sprayed with DDT in June, 1949.

ground measures in marshy or swampy terrain, which may be difficult or impossible to traverse after the thaw. It also extends the period during which control measures may be effectively applied.

The period of residual effectiveness of prehatching treatments, at the dosages used at Churchill, is limited. This was demonstrated by the reassessment in June, 1949, of 9 plots, each one-half square mile in area, sprayed by aircraft in the early spring of 1948 with dosages of DDT ranging from 0.05 to 0.35 lb. (average 0.18 lb.) per acre. The data indicated little or no residual larvicidal effect after the lapse of one year. However, there is some indication from small-plot tests that, under certain conditions, heavier treatments of DDT (0.5 to 1.0 lb. per acre) may reduce or prevent breeding the following year.

After the establishment of a satisfactory formulation and dosage, the effectiveness of aerial spraying in securing protection in limited areas was tested under a variety of conditions. This was made possible by the cooperation of the R.C.A.F. and the Defence Research Board, the spraying being carried out at R.C.A.F. stations at Whitehorse and Watson Lake, Y.T., Fort Nelson and Fort St. John, B.C., Rockcliffe, Ont., and Goose Bay, Labr., (Plate 7), during the spring and summer of 1949. The spray, 4 per cent DDT-fuel oil solution, was applied by R.C.A.F. Dakota (C-47) aircraft fitted with tanks and equipped to release the insecticide by gravity flow through a calibrated vertical emission pipe below the fuselage. The

Plate 8. Collecting mosquito larvae and making biological assessments in infested bogs at Goose Bay.

atomization of the spray was calculated to be 330 microns, mass median diameter, at an air speed of 150 m.p.h.

A total of 43 square miles was sprayed for the control of larvae, and 28 square miles for the control of adults, the dosage used throughout being approximately 0.25 lb. of DDT per acre. Assessments (Plate 8) before and after spraying indicated an average mortality of 91 per cent of larvae in the sprayed areas, and effective control in the vicinity of the R.C.A.F. establishments for periods up to several weeks. This result was undoubtedly influenced in the North West Air Command region by subnormal precipitation in 1949 which produced below-average mosquito populations. Where it subsequently became necessary to spray against the adults, a high degree of control of mosquitoes was obtained which persisted throughout the remainder of the fly season. However, the sprays were relatively ineffective in reducing populations of adult black flies (Simuliidae), and it is believed that sprays of smaller droplet size would be more effective against these insects.

Chemical assessments of deposits (Plate 9) in the larvicide applications were made by personnel of the Suffield Experimental Station under the direction of H. Hurtig. It was demonstrated that an unusually even and effective distribution of the spray was obtained when the height of the aircraft was adjusted to a height/wind product of 1700. It was also demonstrated that a height/wind product of 800 was not sufficient to

Plate 9. Mosquito-infested swamp at Watson Lake. White cards bearing petri dishes were used to assess spray distribution and DDT deposit.

give a satisfactory distribution and over-lapping of the deposit. Over two plots the aircraft was flown at heights of 600 to 1000 feet to achieve a height/wind product exceeding 2000 under light wind conditions. At these heights the smaller droplets failed to reach the ground because of evaporation of the solvent, and control was spotty and unsatisfactory.

Black Fly Control

The 1947 studies at Churchill of the value of various insecticides in controlling the immature stages of black flies led to the development of an effective formulation and dosage, namely, DDT in fuel oil solution, at a concentration of 0.1 parts per million maintained for 15 minutes at the point of application (4). The effectiveness of this method of treatment has since been demonstrated on a large scale in the South Saskatchewan River (5), in the Lewes River in the Yukon (Plate 4), by further tests at Churchill and Whitehorse, and by observations in streams flowing through large areas sprayed experimentally in mosquito control. Various formulations of other chemicals have been tested, including methoxychlor, toxaphene, chlordane, gamma-BHC, compounds 497 (dieldrin) and 118 (aldrin), 1, 2, 4 trichlorobenzene, a pyrethrum-piperonyl butoxide mixture, and parathion. With the exception of gamma-BHC, no other compound was found to be so effective, or so satisfactory as DDT. In field experiments none of the materials proved satisfactory as an ovicide or pupicide against black flies.

In 1948, tests were made at Churchill to ascertain possible harmful effects to fish from the use of DDT, BHC, and parathion in black fly-infested streams. Exposures were made at various concentrations for 15 minutes, with pike, northern suckers, lake trout, sticklebacks, arctic grayling fry, and spot-tailed minnows being used as test fishes. The data indicate that at the low dilutions required to control black fly larvae DDT is not harmful to these species of fish. Parathion was even less toxic than DDT. Benzene hexachloride was the most toxic, but caused no mortality to grayling fry at dilutions greater than 1:2,000,000 of gamma-BHC. Sticklebacks and suckers were apparently not affected by even higher concentrations of this insecticide.

The results of the tests with DDT may seem to be contradicted by the fact that large numbers of fish were killed during two experimental treatments of the South Saskatchewan River in 1949. In one treatment the dosage was 0.39 p.p.m. for 24 minutes; and in the other, 0.113 p.p.m. for 16 minutes. However, there was an important difference in the formulations used. In all the successful experiments in which no significant loss of fish was reported, the formulation consisted of 5 or 10 per cent DDT in a mixture of methylated naphthalenes and fuel oil or kerosene, the methylated napthalenes not exceeding 10 per cent. In the 1949 trials in the Saskatchewan River a 30 per cent DDT-methylated naphthalene concentrate was applied without dilution. Unlike the fuel oil or kerosene solutions of DDT, this preparation is heavier than water and has been observed to be carried along below the surface or along the river bottom in droplet form, some of the coarser droplets persisting in depressions for days after the application. Results of analyses of the stomach contents of fish killed by the application suggest that they had been poisoned by swallowing globules of the DDT concentrate. Furthermore, an experiment in the Lewes River at Whitehorse, in which a 35 per cent DDT-methylated naphthalene concentrate was used, demonstrated that in this form the DDT is much less readily available and thus initially less effective as a larvicide than the same dosage of the chemical applied in solution in fuel oil or kerosene. Analyses of water samples from the South Saskatchewan River taken at a depth of 3 feet, 3 miles below the point of application of the 0.39 p.p.m. dosage showed that the DDT content of the water was less than that indicated after the 1948 application of the much smaller dosage of 0.13 p.p.m.

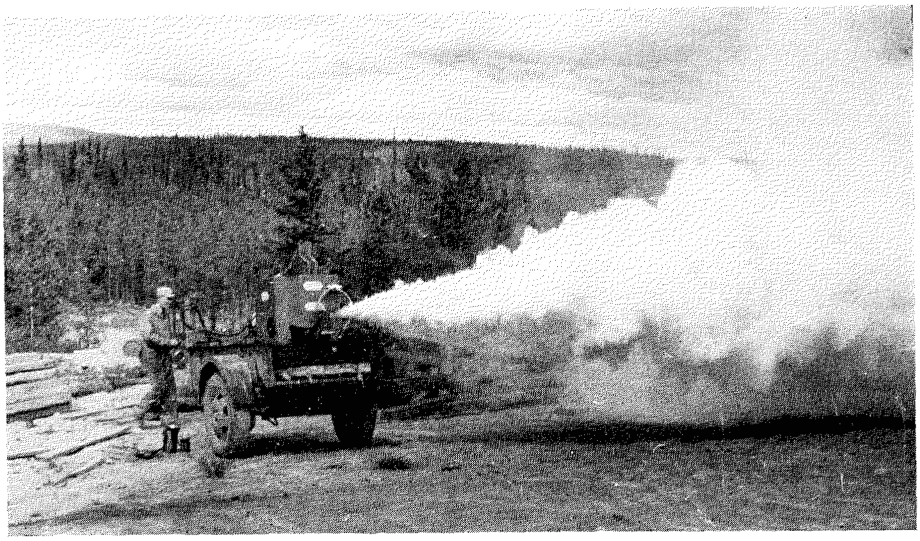

Plate 10. Aerosol generator mounted on vehicle discharging insecticide in control experiments against black flies and mosquitoes at Whitehorse.

Sprays, Aerosols, and Smokes

The effectiveness of ground measures of control against adult mosquitoes and black flies was tested at Churchill in 1947 (6). Fine mist sprays of DDT, pyrethrum, and pyrethrum-DDT aerosols, and smokes containing DDT-nicotine, and BHC proved of little value when applied in 1 to 2 acre plots in open, swampy forest under conditions of extremely heavy and widespread infestation. Temporary reductions were obtained but heavy reinfestation occurred within 15 minutes to 1 hour.

In 1949 a preliminary study of the value of aerosol generators (Plate 10) in controlling adult mosquitoes and black flies in localized areas was commenced at Whitehorse, Y.T. Preliminary results indicated that these machines have definite value when used properly under suitable conditions. Their chief disadvantage appears to be the narrow limit of meteorological conditions on which their use depends; a second is the need of roads to serve as base lines and to allow the operator to take advantage of prevailing winds.

An experiment was also carried out at Whitehorse with smoke generators, the contents of which were reported to have a 6 per cent gamma-BHC content. Two of them, each weighing 20 lb., ignited simultaneously and drawn at 1 to 2 m.p.h. along a frontage of 1200 yards, produced a dense smoke that extended from close to the ground to the tree tops and penetrated the bush to a depth of 1000 yards, covering an area of about 250 acres, and representing a dosage of approximately 0.01 lb. of gamma-BHC per acre. No significant reduction of the infestation resulted, but

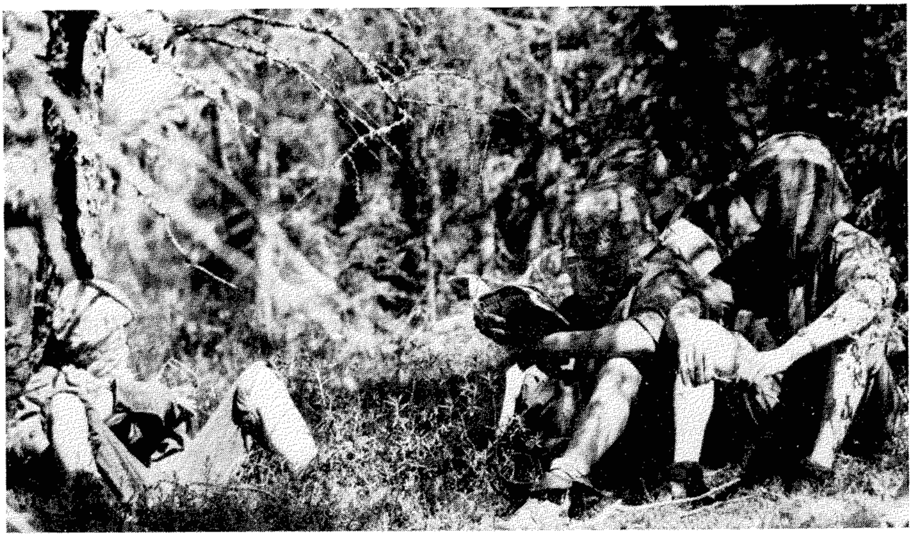

Plate 11. Testing biting fly repellents applied to forearms and legs in the forest south of Churchill.

complaints were received of the strong and pungent odour of the insecticide.

Repellents

In 1947 and 1948, at Churchill, a selection of promising repellent materials supplied by the Orlando, Fla., laboratory of the U.S. Bureau of Entomology and Plant Quarantine, were evaluated in field tests for effectiveness as skin treatments against mosquitoes and black flies (Plate 11). The so-called standard repellents, dimethyl phthalate, Rutgers 612, and 6:2:2 mixture, gave average protection times of 5 to 6 hours against mosquitoes. The most effective repellent was propyl *N*, *N*-dipropylsuccinamate, which gave an average protection time of $6\frac{3}{4}$ hours (to the first bite). Most of the repellents tested gave longer protection against black flies than against mosquitoes, but none appeared to be very effective against tabanids (moose and deer flies). It was concluded that none of the new repellents were sufficiently superior to warrant their adoption in place of the present standard materials.

In 1948, 30 repellents were tested as stocking impregnations against mosquitoes to compare their relative resistance to rinsing, wearing, and outdoor aging. One, impregnated at 3 grams per square foot, withstood 8 to 9 rinsings, and 2 others were almost as good; none showed outstanding stability in the wearing tests, the best being effective for only 30 to 40 hours of wear; none appeared capable of withstanding more than 1 week of outdoor exposure.

Tests in 1947 of wide-mesh headnets (¼ in. mesh) impregnated with dimethyl phthalate showed that they provided good protection against moderate infestations of mosquitoes, but were readily penetrated by black flies. The standard U.S. Army fine-mesh headnet proved the most effective against these pests.

Other Investigations

The important subject of biological control has not been neglected, and from time to time, as opportunity offered, observations have been recorded on the presence, identity, and activities of the natural enemies found attacking biting flies in their various life stages. With a view to expediting the investigation of this phase of the biting fly problem, a special project was set up to deal with it, and preliminary studies were carried out at Churchill in 1949 under the leadership of H. G. James, of the Dominion Parasite Laboratory, Belleville, Ont.

Other cooperative studies that are going forward assisted by Defence Research Board grants to universities include the following: determination of mammal and bird hosts of biting flies by precipitin tests, and of plant hosts by means of radioactive isotopes (A. S. West, Queen's University); the fundamental nature of attraction and repellency as affecting biting flies (A. W. A. Brown, University of Western Ontario); determination of the possible value of orally administered repellents (A. A. Kingscote, Ontario Veterinary College); black fly emergence studies (F. P. Ide, University of Toronto); flight range studies of biting flies (B. Hocking, University of Alberta); the psychological effects of biting fly attack (D. C. Williams, University of Manitoba); and the nature of insect toxins and the possibility of immunization (Queen's University).

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