The introduction of new exotic species of larval and pupal parasites (probably from the Eastern Hemisphere) and the artificial distribution of existing parasites appear to offer the most immediate means for a more successful biological control effort in southern California, especially against Musca domestica, the most common of the house flies. Existing parasites are, however, not as effective against this species as they are against Fannia and certain other species.

Research with parasites BIOLOGICAL CONTROL HOUSE FLIES Southern

E. F. LEGNER · E. C. BAY · H. W. BRYDON · C. W. MC COY

MANY SPECIES of flies breeding in filth habitats have been called house flies, but throughout the scientific world the term usually refers to *Musca domestica* L. and to a lesser degree to *Fannia* species.

Since 1962, southern California observers have found that a number of parasitic wasps will attack house flies but it has been difficult to ascribe definite percentage parasitization figures to individual species. *Muscidifurax raptor* Girault and Sanders, *Spalangia endius* Walker, and *Stilpnus anthomyidiperda* (Viereck) seem most widespread in the area, however. *M. raptor* is frequently found parasitzing a variety of flies before the month of July, and *Spalangia endius* generally becomes dominant thereafter. Parasitization is generally lower in all areas in winter. *Stilpnus anthomyidiperda* is active in the spring and fall of the year.

Studies were begun to determine the effectiveness of both *M. raptor* and *Spalangia endius* as parasites on house fly pupae in poultry manure, and to study the effects of mass releases of parasite species introduced from the midwest and West Indies. A commercial poultry ranch was chosen for these studies to provide a relatively constant fly breeding environment, and to allow evaluation of the practical control implications that might result from finding an effective parasite.

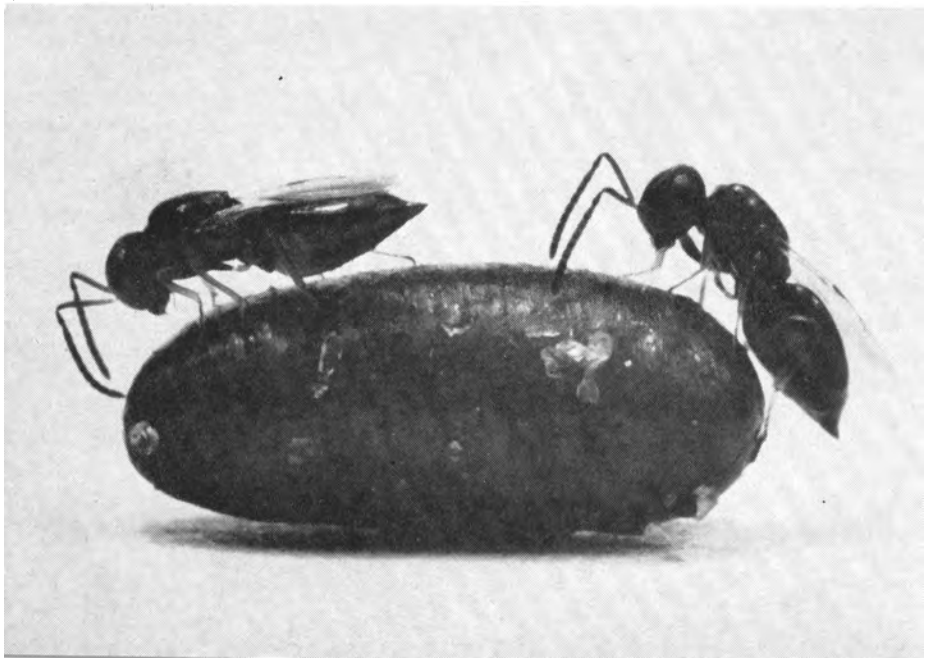
Natural enemies of the pupae of house flies were selected in 1963 from a number of parasitic wasps that were found to be very active on three islands in the West Indies and in central Wisconsin. Living cultures were established by the Department of Biological Control, U.C., Riverside. From April 10 to July 7, 1964, four species of the introduced pupal parasites were released periodically on the 250,000-bird Demler Poultry Ranch near the coast in Orange County (see photo). Species released were biparental strains of *Spalangia endius* from Puerto Rico (51,300), *S. cameroni* Perkins from Trinidad (6,500), and *S. nigroaenea* Curtis from Wisconsin (11,400); and one uniparental strain of *Muscidifurax raptor* from Puerto Rico (20,100) (see photo). The latter species reproduces parthenogenetically. Parasites were liberated as newly emerged adults from specially designed containers equipped with honey and water, and placed at three release sites on the ranch.

Thirty one-quart samples of poultry manure had been taken weekly from February through April 1964 on a random selection basis to pre-test the fly population. Following the first release of parasites in April, weekly sampling procedures were initiated: 30 (one-quart) random samples of manure were taken from within 100 feet of parasite release sites, and 30 check samples were taken from greater distances. The sampling was continued until July 1965.

Samples were dried in Berlese funnels. The pupae collected were mostly of six species of flies: *Fannia canicularis* (L.), *F. femoralis* Stein, *Musca domestica*, *Ophyra leucostoma* (Wiedemann), *Phormia regina* (Meigen), and *Muscina stabulans* (Fallen), The pupae were then incubated in screened plastic vials for parasite emergence. Samples were also taken from the Feathercrest Ranch, located about 10 miles inland from the Demler Ranch, but no parasite releases were made there.

The predominant house fly species found breeding in samples of chicken droppings from both ranches during the experimental period was *Fannia femoralis* —comprising over 95% of all the house

Two females of Muscidifurax raptor examining a puparium of the common house fly, Musca domestica, preparatory to oviposition.



for of in California

Locating parasite release containers in position over chicken droppings at the Demler Poultry Ranch, Orange County. Parasitized pupae are contained within screened polyethylene quart containers equipped with honey and water dispensed through cotton wicks and glass vials at the top. Adult parasites emerge and many mate inside the containers before emerging into the surrounding environment.

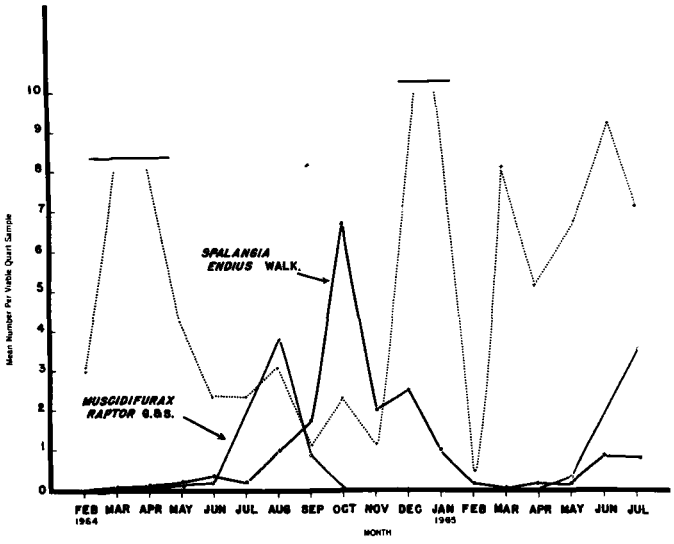
flies sampled at any given time of year. The remaining 5% included *F. canicularis*, collected from early spring until early summer, and *Musca domestica*, present only in the late summer.

Parasite species already present on both ranches prior to release of the introduced strains in April 1964 were *Spalangia endius*, *S. cameroni*, *S. nigroaenea*, *S. simplex* Perkins, *Nasonia vitripennis* (Walker), *Muscidifurax raptor* and *Stilpnus anthomyidiperda* (Viereck). All these species attacked pupae of *Fannia femoralis* externally except *Stilpnus anthomyidiperda*, which parasitized larvae of *Fannia canicularis*, with no definite relationship to *F. femoralis* being established. *Ophyra leucostoma*, the principal predatory fly species, served as host for three wasp species, *Spalangia endius*, *M. raptor*, and *S. nigroaenea*.

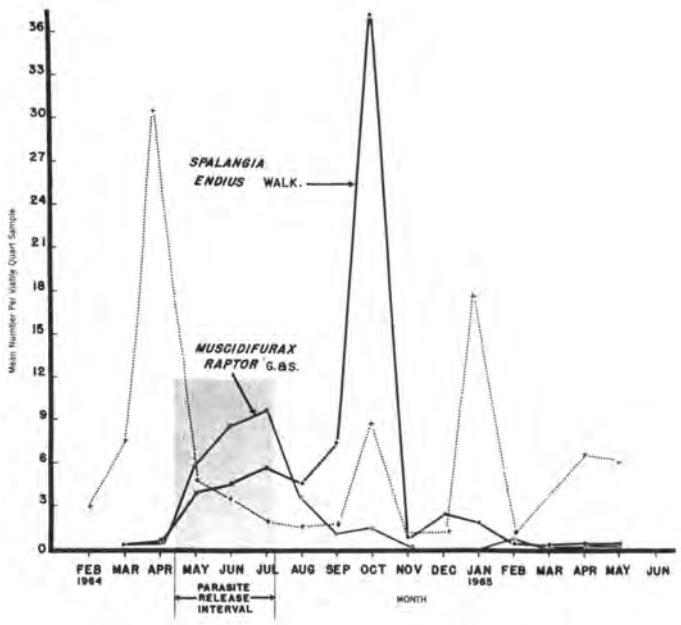
The highest populations of *Fannia femoralis* occurred during the colder months of each year on both ranches (graphs 1 and 2). Parasitization was lowest during the coldest months, when the host population was at its yearly peak, suggesting that parasitic activity is curtailed by low temperatures. During the warmer months (July to November) more host pupae were parasitized than not.

Graphs 1 and 2 show parasitization by the two most active parasites on both check and release sites at the Demler Ranch. In the check environment, *M. raptor* was the predominant parasite during the cooler and damper portions of the summer (June to August), followed by

Graph 1. Population of Fannia femoralis pupae parasitized by Spalangia endius and Muscidifurax raptor in the check environment on the Demler Ranch in survey periods of 1964–1965. The dotted line is the unparasitized F. femoralis pupal population.



Graph 2. Population of Fannia femoralis pupae parasitized by Spalangia endius and Muscidifurax raptor within 100 feet of three parasite release sites on the Demler Ranch in survey periods of 1964–1965. The dotted line is the unparasitized F. femoralis pupal population.



S. endius which finally dominated the warmer and drier months (August to October). Laboratory experiments using differential temperatures indicated that final-stage larvae and adults of *S. endius* are more resistant, and demonstrate greater activity, at higher temperatures than *M. raptor*.

All parasite as well as fly activity was sharply reduced with the advent of very cold weather in the middle of November 1964. A simultaneous decline of the fly population in the same month cannot be correlated with parasite activity, but was probably also the result of the sudden drop in temperature to below freezing—mean minimum below 33° F. Subsequent recovery and tremendous build-up of this fly was shown in December 1964 and January 1965 when the mean minimum temperature rose to above 35° F.

During the warm part of the year, fly pupae and larvae were generally more numerous in the central portion of the Demler Ranch where manure was more moist than near the ranch periphery. Moisture favors *Fannia* development and it was in these moist areas of higher fly infestation that parasites were released.

Introduced wasps

Parasitized pupae were more prevalent in release areas than in check areas throughout the season (see graphs 1 and 2). As expected, increased parasitization of fly pupae corresponded with the release of introduced parasite species. For example, the build-up of *Muscidifurax raptor* in the check sections of the Demler Ranch did not begin until after June 1964, whereas a significant increase was noticeable in the release sites after April of that year. Also, the incidence of *Spelangia endius* in the check sections was low before July, whereas greater activity of this species was evident two months earlier in the release sites.

Ophyra larvae are predaceous upon the larvae of both *Fannia* and *Musca* species, and were particularly abundant on the Demler Ranch directly following large populations of *F. femoralis*. It was assumed that *O. leucostoma* was feeding mainly on larvae of *F. femoralis* since other suitable prey appeared to be largely absent. *O. leucostoma* will feed on *Fannia* spp. in the laboratory, but it apparently prefers larvae of *M. domestica* when these are available.

Parasitization of *Ophyra* at any time was well below 50%, and there was no appreciable increase noted in the parasite release sites. This was considered fortunate since these flies are beneficial as predators and therefore might well be favored in biological control.

Generalizations on parasites

Results of this study and those conducted at other fly breeding sites in southern California during the past three years on all principal species of dung inhabiting flies show that the three principal parasite species involved in natural control in this area are *Muscidifurax raptor, Spalangia endius,* and *Stilpnus anthomyidiperda.* Other species, as previously noted, occur at extremely low population densities over most of the year throughout this subtropical region.

Both *Muscidifurax raptor* and *Spalangia endius* at other sites demonstrate an activity similar to that shown in the present study, although the periods of activity are related to phenological events in each separate locality. For example, in the inland areas where mean temperatures are higher earlier in the year than on the coast, *S. endius* supplants *M. raptor* correspondingly earlier (apparently a climatic influence), the latter species preferring a more humid, cool season. The principal host species in the inland areas of southern California is *M. domestica* and parasitization never reaches the same high average as demonstrated with *Fannia* in the present study. The effectiveness of these two species appears proportional to the availability of host pupae in the breeding site—*M. domestica* pupae, which are generally found deeper in manure deposits than *Fannia* pupae, are not attacked to as high a degree. Modifications of poultry house construction and bird caging could help to enhance the effectiveness of these parasites against *Musca* by using a concrete base to eliminate pupation in the soil and disperse the droppings over a wider area. *Stilpnus anthomyidiperda* activity on *Fannia canicularis* appears to be restricted to the cool spring and late fall months, with parasitization figures often exceeding 90%.

E. Fred Legner and Ernest C. Bay are Assistant Entomologists, Department of Biological Control, University of California, Riverside; H. W. Brydon is Director, Fly Control Research, Orange County Health Department; and C. W. McCoy is Research Assistant, Department of Biological Control, Riverside.

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Water In

N. C. WELCH

A. W. MARSH

Planting grain in furrows of strawberry fields counteracted compaction and increased water penetration in Riverside County tests. Adequate irrigation of the strawberries was maintained—along with frequent picking schedules—without holding water in the furrows for extended periods of time.

FURROWS IN STRAWBERRY fields are continually being compacted by foot traffic and the movement of machinery. With labor becoming scarce, the wider use of machinery will further increase the amount of traffic in each furrow. This surface compaction reduces water infiltration and can aggravate a salt problem.

Water infiltration rates decrease as the season progresses. Thus, the greatest demand for water by the plants comes at a time when the weather is hottest and water infiltration is slowest. Some growers cultivate before each irrigation to help increase infiltration. Leveling soil, shortening irrigation runs, and increasing the length of irrigation time are other methods used. However, with sloping runs, growers are reluctant to increase the length of irrigation time because of excess runoff.

Experiments aimed at increasing infiltration rates were conducted in a commercial strawberry field near Chino, San Bernardino County, during the 1964 and 1965 growing seasons. The first experiment was of a preliminary nature, while the second was more extensive in design.

1964 field test

About the middle of March, wheat of the Ramona variety was seeded at ½ lb per acre in randomly selected furrows 100 ft long. Both the planted furrows and