GRAPHIC MODELS AS INTERMEDIATE STEPS TO COMPUTERIZED SIMULATIONS OF STABLE FLY POPULATIONS

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ABSTRACT. Laboratory studies of egg hatch, larval and pupal survival, oviposition, loss rate, and longevity were conducted with the stable fly *Stomoxys calcitrans* (L.). The resulting data and previous research provided the information necessary to construct an elementary life-budget model that provides a better understanding of the dynamics of field populations.

The increased complexity in approaches to pest management emphasizes the need for a better understanding of insect population dynamics. Many factors related to control including diapause, migration, rates of increase, and developmental survival rates of immatures and adults, must be considered and evaluated. The interrelationships between these various factors are complex, and analysis of their influence on selecting the optimum method of control is extremely difficult, whether such measures include insecticides, the release of sterile males or the introduction of parasites or predators. Computer technology appears to be the tool to use to resolve these problems, but unfortunately, except for a few species, adequate biological data for most pest populations are not yet available. This would seem to be the situation in regard to the stable fly *Stomoxys calcitrans* (L.); nevertheless for the past 10 years numerous studies have been designed and carried out to supplement existing data or to fill voids concerning the biology and control of this economic pest. Some of the contributions and areas covered include: *behavior and population dynamics* (Harris et al. 1966, Hoffman 1968, LaBrecque et al. 1972c, Weidhaas et al. 1972, LaBrecque and Weidhaas 1975, and LaBrecque et al. 1975a,b); *sterility induction* (Castro 1967, Offori 1969, 1970, White 1971, LaBrecque et al. 1972a, LaBrecque and Meifert 1975); *dispersal* (Williams 1973 and Bailey et al. 1973); *hormones* (Wright 1970, 1972); *sterile releases* (Jones 1966, LaBrecque et

al. 1972b, Patterson et al. 1975 and Bailey et al. 1975); *insecticide resistance* (Stenerson 1966, Mount et al. 1966a); *insecticide control* (Mount et al. 1966b, 1966c, 1967, 1968, Clements and Rogers 1967); and *biological control* (Legner et al. 1967, Legner and Olton 1968a, b). Likewise, excellent studies devoted primarily to basic biology have been reported by Mitzmain (1913), Hafez and Gamal-Eddin (1959), Bishopp (1920), Simmons (1944), Parr (1962), and Newstead (1906). They serve as an ideal point for basic studies directed towards population dynamics, however, much more information is still necessary.

Therefore to confirm earlier studies and to derive additional information on which to construct life-budget models, we conducted laboratory investigations at Gainesville, Fla., on egg hatch, larval and pupal survival, oviposition, loss rate, and longevity. A graphic model of stable fly populations was then constructed.

TESTS AND RESULTS

EGG HATCH. The degree of hatch and the number of 1st instar larvae (L_1) produced was determined by placing 100 eggs, <4 h old, on moist cloth patches (4 x 6 cm) over a moistened sponge (1 x 5 x 10 cm) in petri dishes. The eggs were held at 26° C and 90% RH and inspected for hatch after 24 and 48 h. No eggs hatched by 24 h, but all of those that did hatch had done so by 48 h. The hatching time is similar to that reported by Mitzmain (1913), Glaser (1924), Doty (1937), Simmons (1944) and Bailey et al. (1975), who found that it occurred between 1 and 3 days. Our 31 replicated tests indicated that hatch averaged 87.9%, thereby producing 88 L_1 larvae/100 eggs.

LARVAL INSTARS. The number of 2nd (L_2) instar larvae produced from a specific number of eggs in the laboratory was determined by placing 100 eggs <4 h old on a moistened cloth patch that was then laid on larval medium in a 0.5 liter container. The medium was composed of 5 parts tap water, 3 parts wheat bran, and 1 part pelletized sugar cane bagasse. When the larvae had reached the 2nd instar, the number in each container was isolated and counted. Each evaluation was replicated at least 9 times. The same procedure was followed in determining the number of 3rd instar larvae. Averages of 80.2 L_2 and 77.0 L_3 larvae were obtained.

PUPAE. The number of pupae derived from 100 eggs was determined by seeding 31 containers holding 0.5 liter of larval medium with 100 eggs each. When pupation was complete, the pupae were isolated by water flotation and counted. An average of 74.9% pupal survival was derived.

ADULT ECLOSION. The number of adults produced by a specific number of pupae was determined by placing 31 samples of 100 pupae from the laboratory colony in petri dishes and holding them for 1 wk. When complete adult eclosion was assured, the number of adults in each dish was counted. An average of 94.2 adults was obtained from each 100 pupae.

In a strain of stable flies reared under similar laboratory conditions, it can then be expected that 100 eggs would produce 88 L_1 larvae, 80 L_2 larvae, 77 L_3 larvae, 75 pupae, or 71 adults. The observations of stadia duration made concurrently showed periods of 2 days for egg maturation and hatch, 2, 3, and 4 days for L_1, L_2, and L_3 larvae, respectively and 5 days for pupae. Females were receptive to insemination within 2 days, and oviposition occurred at about 6 days. However, oviposition was sporadic, without any predictable number of eggs laid at any time following initial deposition. This age of oviposition was slightly less than that observed by Killough and McKinstry (1965), Mitzmain (1913), Glaser (1924), Doty (1937), and Parr (1962) who reported a range from 7 to 13 days. The duration of the larval stages and pupal stages were similar to their observations.

LONGEVITY. Mortality in females was studied by placing 20 newly emerged females <1 day old in cages (15 x 23 x 24

cm), offering fresh citrated bovine blood daily and recording mortality at 2-day intervals. The median female mortality (MT-50) for the laboratory strain occurred at 18.3 days, indicating a daily loss rate (DLR) of 3.5%. This rate is strikingly lower than that observed in field-cage tests in which the DLR averaged 25.0% and the MT-50 and MT-90 were computed at 2.3 and 7.8 days, respectively (LaBrecque et al. 1975b). The field values were higher than those reported by Hafez and Gamal-Eddin (1959) and Bishopp (1920) who found that survival was 10.5 to 22 days. However, we have observed released marked stable flies at least 2 to 3 wk old in the environment in field release studies in which the DLR was calculated to be 35% (LaBrecque et al. 1975b).

OVIPOSITION. The procedure followed in the longevity studies was also used to determine the number of eggs laid by the female flies. Thus throughout the life span of the flies, oviposition medium (citrated blood on cotton balls) was offered at daily intervals for 24 h, and the eggs were removed daily. In 8 replicated tests, 67,137 eggs were collected over a 28-day period involving 2,828 female days. (A female day was considered to be 1 day in the life of 1 living female.) By this procedure the number of eggs laid/female/day averaged 23.7. However, as the females do not oviposit until the 6th day, it would be more realistic to calculate oviposition on the number of eggs/ovipositing female/day. A total of 2,251 ovipositing female days was involved for an average of 29.8 eggs/ovipositing female/day. Thus a 16-day-old female could be expected to lay an average 298.3 eggs within her 10-day egg-laying period. This number agrees with the estimates of Bailey et al. (1975) and Killough and McKinstry (1965) but is slightly lower than those obtained by most investigators. Our low number was based on a 10-day ovipositional period, slightly less than the MT-50 observed. However, if the ovipositional period was extended to a 28-day adult life period, the number of eggs laid would be close to that obtained by most investigators.

POPULATION MODELING

One approach to population modeling that would use the type of information presented is the life-budget approach. Factors such as survival at specified ages, production of progeny at given times, and the development times of these stages can be interrelated to produce models of population dynamics.

The data now available for stable flies provide development times of the immature stages and progeny production at a specified temperature. We also have data on survival of adults in laboratory and field cages for survival of immature forms in laboratory rearing. Finally, we have data available concerning growth rates of field populations as they occur naturally and when they are reduced by the release of sterile males (Weidhaas et al. 1972, LaBrecque et al. 1972b,c, 1975a).

Ideally, information concerning survival, development times, and progeny production should be available for a range of temperatures and from a variety of field populations. However, until they are available, we should be able to illustrate graphic models of stable fly populations that can serve as the basis for computer simulations.

To illustrate, our laboratory population (Figure 1) would start with 100 adults (males and females) eclosing daily. Females do not oviposit for the first 5 days of life, and we assume all are mated. Since survival of the adult females in the laboratory averaged 0.965 (0.035 DLR), 635 females are capable of oviposition per day. Then at the rate of 29.8 eggs/ovipositing female, the daily egg production is 18,923. However, laboratory studies indicate a loss of 29.5% from egg to emerging adult over a period of 16 days and the cumulative mortalities occurring in each stage in the laboratory were: egg, 12.1%; 1st instar larvae, 19.8%; 2nd instar larvae, 23.0%; 3rd instar larvae, 25.1%; and pupae, 29.5%. These values are equivalent to a

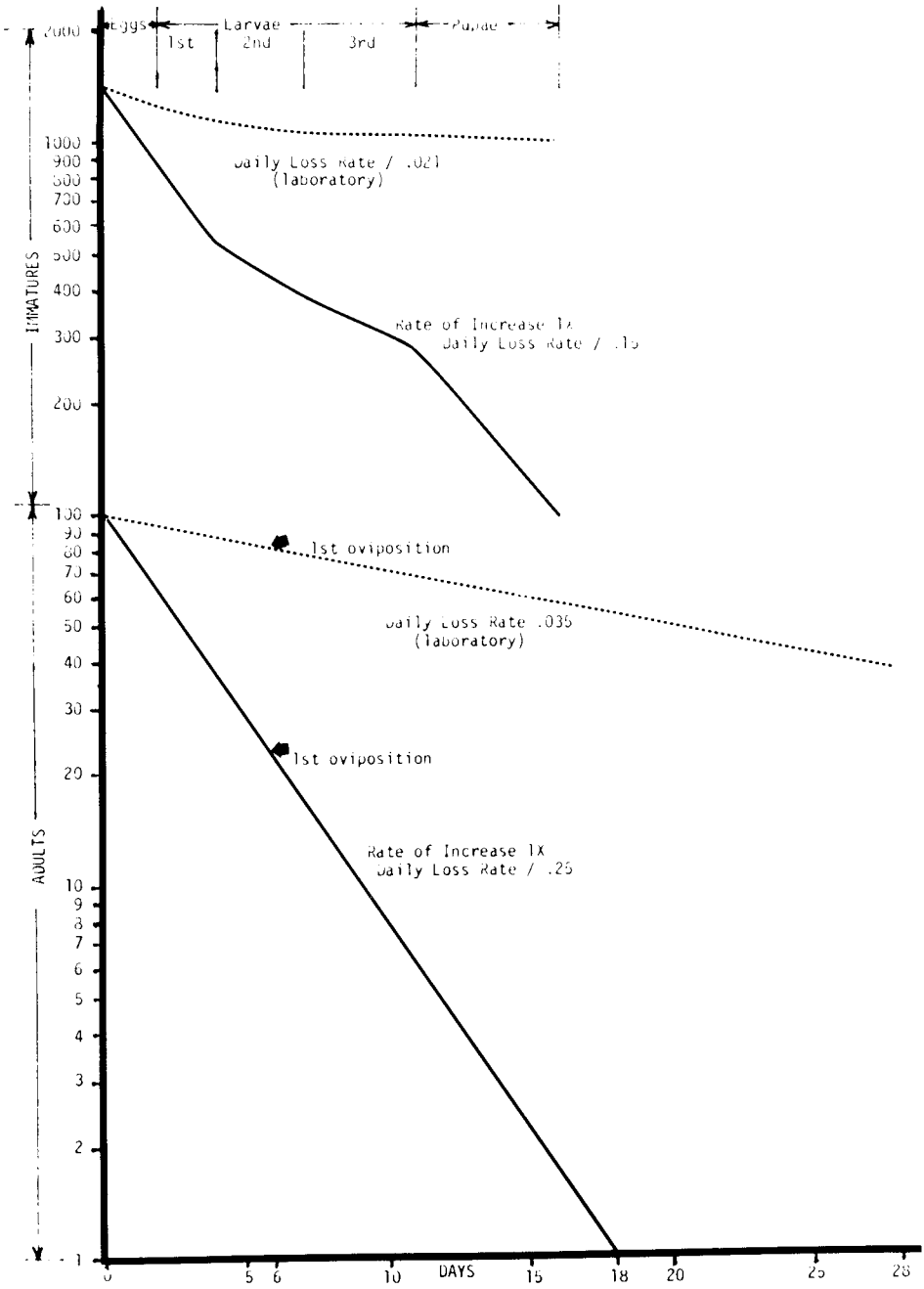

Fig. 1. Rates of increase and daily loss rates of a laboratory population and a model population of stable flies.

daily loss rate (over the 16 days of the immature developmental time) of 2.1%. Thus, 13,360 adults would emerge from 18,923 eggs, a growth rate of 133.6× for a laboratory colony. This rate confirms the existence of a high biotic potential for this insect.

Figure 1 further illustrates the interrelationship of population parameters for the laboratory population we studied and the field population modelled. Although the biotic potential of stable flies is extremely high, the rate of increase we selected for field populations was 1×. In a 1-year study at a dairy barn, a hog pen, and a horse stable in central Florida (LaBrecque et al. 1972c), the yearly average rate of increase ranged from 1.25 to 1.36×. Stable flies seldom exceed 2× per generation and for the most part, hover at the 1× rate. Growth rates in populations reduced by the release of chemosterilized males (LaBrecque et al. 1972c), ranged from 1.05 to 3.09× when the rates of increase were derived from $RI = F_1/[P(1-S)]$ where F_1 represents a density observation one generation in time removed from the original observation P, and S represents the sterility incurred during this period (Weidhaas et al. 1972).

In other words, the data indicate that growth rates of naturally occurring populations are relatively low in field populations, probably because of a much lower survival of the early immature stages coupled with low and late oviposition in the females. Thus, Figure 1 includes a DLR of 25% for adults and 15% for the immature stages.

Then a parent field population with 100 adults emerging daily would consist of 398 adults of which 47 females would be capable of ovipositing daily. At a rate of 29.8 eggs per ovipositing female, the daily egg production would be 1,398. When we extrapolate the mortalities of the immature forms derived from the laboratory studies to compensate for a rate of increase of 1×, the cumulative mortalities at the egg, larval (L_1, L_2, and L_3), and pupal stages are 38.3, 62.5, 72.7, 79.4, and 93.1%, respectively. These mortalities reflect an overall loss from 1,398 eggs to 100 eclosing adults and daily loss of immature forms of ca. 15.0%.

In summary, when some data on population dynamics are added to existing information concerning stable fly biology, we can derive a basic life-budget model. Then chemical control—larvicidal or adulticidal—of various degrees of efficiency, sterile male releases at various ratios of sterile to fertile males, or parasite releases can be introduced into the system to determine the potential of each. The model described is obviously too elementary to be used for such a purpose. However, with the inclusion of such parameters as temperature, rainfall and humidity it could be used to assess the relative effectiveness of various management measures.

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