A TECHNIQUE FOR DETERMINING THE RATE OF DEVELOPMENT OF *LYGUS HESPERUS* IN FLUCTUATING TEMPERATURES[1]

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ABSTRACT

A computer program was prepared that utilizes developmental data determined in the laboratory at constant temperature to determine the duration of the stages of *Lygus hesperus* Knight at fluctuating temperatures. This program provides the basis for a generalized insect development and population model (WATBUG).

Laboratory studies of the effect of constant temperatures on the development of eggs and nymphs of *Lygus hesperus* Knight showed an increase in the rate of development with an increase in temperature (Butler and Wardecker 1971). Analyses of population trends of *L. hesperus* in California alfalfa fields indicated that heat input and temperature extremes played a dominant role in determining the rate of population increase (Butler 1971). Stitt (1940) made observations of the incubation period of the egg of *L. hesperus* and the duration of the instars in an outdoor insectary but these results are not amenable for the prediction of development under other outdoor conditions because the mean daily temperature sometimes does not take into account the fluctuations that occur in hourly temperatures. If we are to utilize field studies under fluctuating temperatures or predict future field populations, a technique is needed to convert developmental information obtained in the laboratory at constant temperatures to the developmental rate that prevails at fluctuating temperatures. The present paper reports such a technique and demonstrates that the observed duration of the different stages of *L. hesperus* at fluctuating temperatures compared favorably with those predicted by a computer program based on rates determined at constant temperatures.

METHODS AND MATERIALS

The concept basic to the present model is that the rate of development varies with temperature, any delay in the change when temperature changes is assumed to be negligible. The proportion of development of a stage of an insect during a given time period can be determined from the reciprocal of the time of development determined at constant temperatures (Fye et al. 1969). In our technique a computer program, written in FORTRAN, uses tables of development rate versus temperature to calculate the duration of the different stages of an insect under almost any given temperature flux. A flow graph showing the logic of the program is given in Fig. 1.

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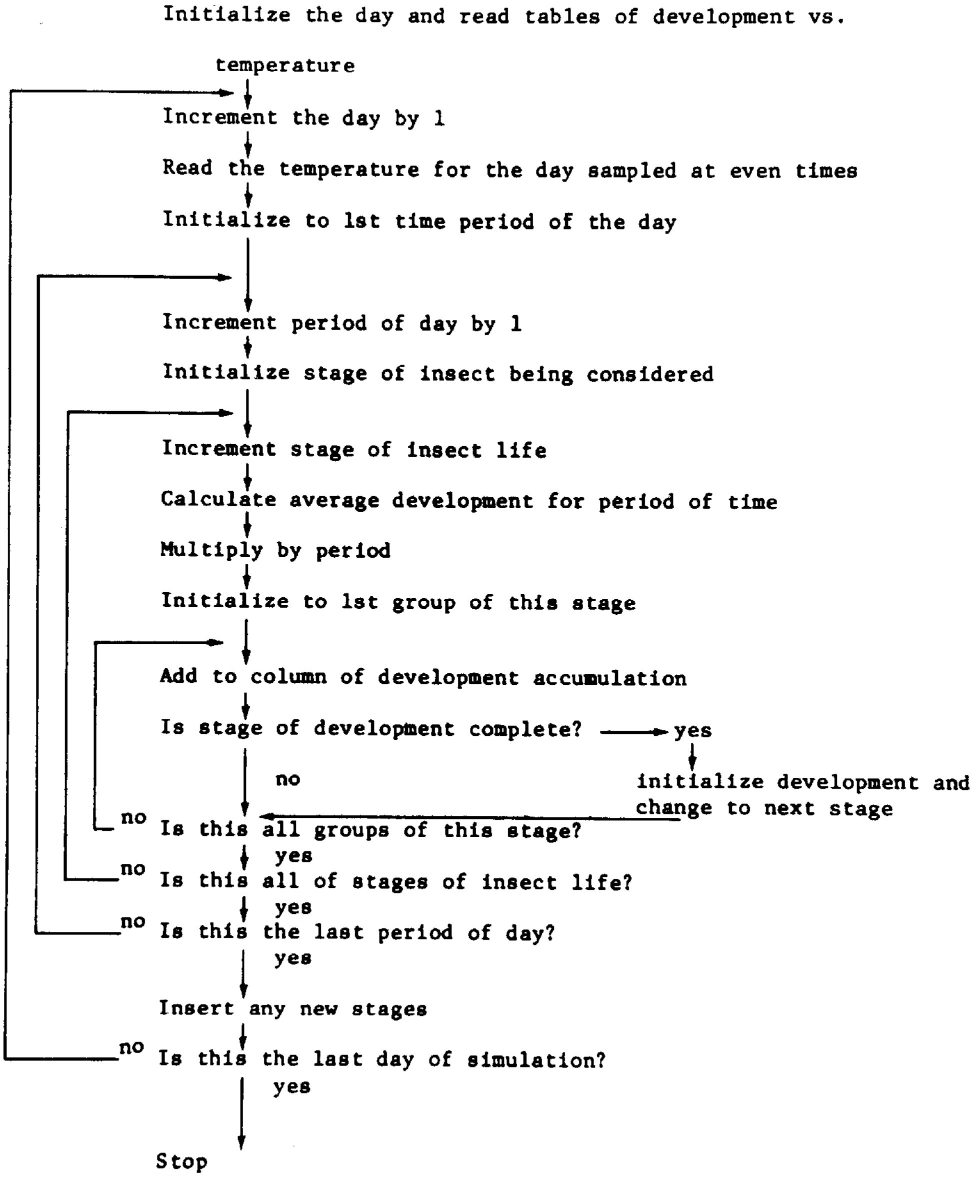

Fig. 1.—Flow graph of logic of WATBUG program.

One set of data used to test this technique was obtained when 3,150 eggs laid on 33 days and the nymphs from these eggs were reared in an outdoor insectary at fluctuating temperatures during a 71-day period from late January through April 1967 (Butler and Wardecker 1971). Another set of data was obtained from observations of nymphs hatched in the laboratory, dusted with colored pigment, and transferred to cages constructed of 1-qt cartons that were placed over alfalfa plants growing in the field. The cages were brought to the laboratory daily and the nymphs examined for pigment to

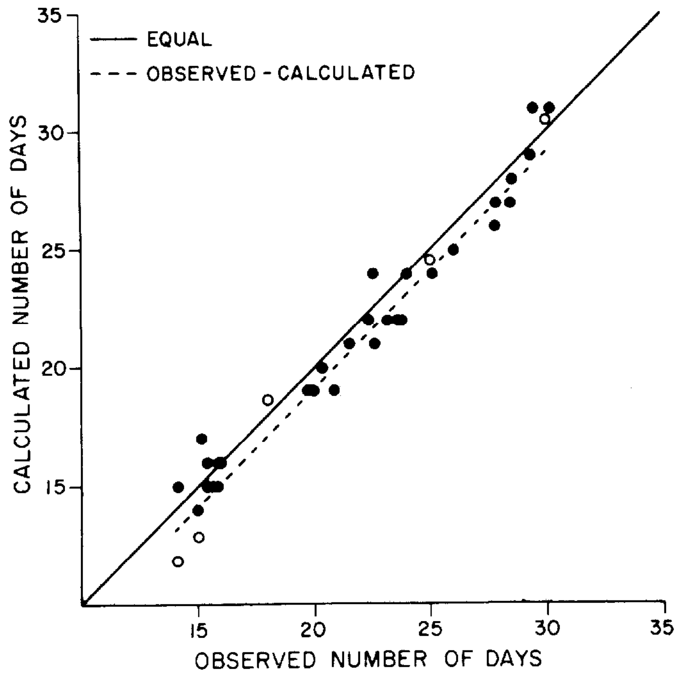

Fig. 2.—Comparison of the observed and calculated duration of the egg stage of *Lygus hesperus* in an insectary.

determine when molting occurred. Nymphs that had not molted were returned to the field. Thermograph records were obtained by placing a thermograph probe in one of the cages. Overheating in the direct sun was prevented by conducting the test in a large screen cage with a shade cloth across the top. Daily temperatures fluctuated from 17 to 30°C, and one daily high reached 35°C.

RESULTS

The duration of the egg stage in an outdoor insectary varied from 14.2 to 30.2 days. The program was set to calculate the duration of the egg stage by using the observed 3-hr temperatures. The calculated values had a range of 14 to 31 days. Fig. 2 shows the relation between a regression line of the observed and calculated observations and one of equal values.

The duration of the 5 nymphal stages in the outdoor insectary was also determined and compared with the duration calculated with the program utilizing observed 3-hr temperatures. Fig. 3 shows the relationship between the observed and the calculated times. The program was most successful in estimating the duration of the 1st, 3rd, 4th, and 5th stages, but most calculations were within the mean ± 1 day, the increment of time at which observations of change of instar were observed.

The duration of the nymphal stages in the field in cages on alfalfa during the heat of the summer was determined and compared with the results obtained with the program (Table 1). Most calculated values were within the

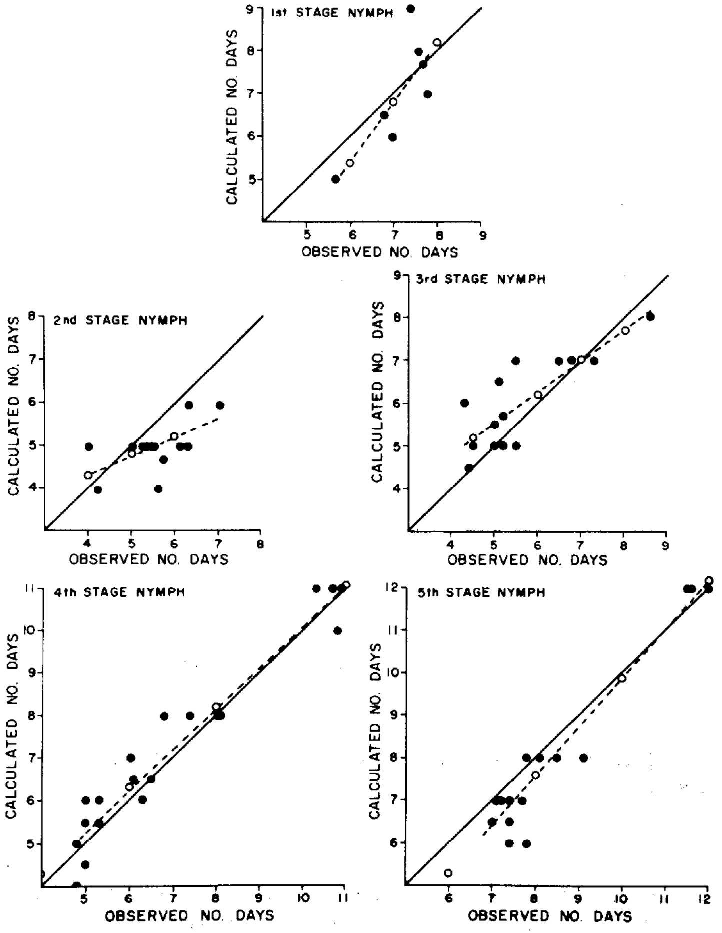

Fig. 3.—Comparison of the observed and calculated duration of the nymphal stages of *Lygus hesperus* in an insectary.

mean ± 1 standard deviation of the observed values. However, in this test, the limited range of temperatures and the small number of observations was not sufficient to justify the calculation of regression equations.

CONCLUSIONS

The duration of the life stages of insects in an insectary or in the field is difficult to predict by using an average mean temperature that prevailed during the stage because this average temperature does not take into account the fluctuations in the daily temperatures that may occur, particularly during the winter. However, the technique discussed here allows determination of the duration of the egg and nymphal stages of *L. hesperus* for almost any combination of fluctuating temperatures. This technique was further developed into a population model (WATBUG) by F. L. Watson (1973, unpublished dissertation) and used to predict an optimal control law for *L. hesperus* on cotton.

TABLE 1. DURATION OF THE NYMPHAL STAGES OF *Lygus hesperus* IN CAGES IN AN ALFALFA FIELD (1966) AND THAT CALCULATED BY THE WATBUG PROGRAM.

Date		No. nymphs	Observed mean no. days ± SD		Calculated no. of days
			1st stage		
June	21	91	4.7	0.7	3.2
	28	72	4.0	1.0	2.9
July	1	32	4.1	1.4	2.8
			2nd stage		
June	11	63	2.7	0.8	2.9
	13	35	2.9	0.6	2.7
	14	34	2.7	0.6	2.7
	15	10	2.4	1.0	2.8
July	8	42	2.6	0.8	2.2
			3rd stage		
June	13	28	3.2	1.0	3.0
	14	52	3.2	0.8	3.9
	15	50	2.9	1.1	3.0
	16	39	3.2	1.0	3.1
	17	28	4.1	0.9	3.2
			4th stage		
June	11	5	3.6		3.8
	15	9	4.2		3.4
	16	11	4.6	0.5	3.6
	17	5	5.6		4.7
	18	10	6.2	1.6	3.5
	19	20	4.8	1.0	3.8
	20	6	5.0		4.0
	21	8	5.0		4.0
			5th stage		
June	13	2	4.0		5.0
	16	3	4.7		5.1
	22	4	5.0		5.1

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BURSTING WORKERS: A NEW MEANS OF DEFENCE IN SOCIAL HYMENOPTERA—(*Notice.*) When disturbed mechanically, minor workers of *Camponotus (Colobopsis) saundersi* and of *C.* sp. near *saundersi* contract their gaster until it bursts at an intersegmental fold. The mandibular glands, which extend throughout the whole body, also burst releasing large quantities of a whitish yellow (*C. saundersi*) or bright yellow (*C.* sp. near *saundersi*) secretion. The secreted fluid is very sticky and attacking ants are unable to move when contaminated with it. The term "*autothysis*" (greek.: self sacrifice) is proposed for the phenomenon. Oecologia (Berl.), 1974, 14, 289-294; U. and E. Maschwitz, Univ. Frankfurt/M.