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UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Research Administration
Bureau of Entomology and Plant Quarantine
Division of Fruit Insect Investigations

University of California | Hawaii Agricultural Experiment Station

Territorial Board of Agriculture and Forestry

Pineapple Research Institute | Hawaiian Sugar Planters' Association Experiment Station.

ORIENTAL FRUIT FLY INVESTIGATIONS

QUARTERLY REPORT

July 1 -- September 30, 1951

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Work Project I-o-1. Biology and Ecology of the Oriental Fruit Fly.

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SUMMARY *

Ecological studies on Maui over the past two years have been based on four main avenues of research.

First, climate stations were established from sea level up to 9200'. This gave a good cross section of the temperatures available on this island. One of these stations, Waikamoi (4250'), was selected primarily for its high relative humidity and rainfall. The flies were held at all stations in outdoor cages and the life cycles were followed closely, the biological data being correlated with meteorological findings. The purpose of these studies was to determine the limitations imposed on the fly by climate in order to predict properly where it might establish itself on the mainland.

Second, fruit collections were made to evaluate the role of different hosts in supporting dorsalis populations, the effectiveness of parasites in controlling dorsalis in different hosts, and to determine the hosts or host sequences that are necessary to maintain this fly at economic pest levels. This information, coupled with that on climatic limitations, would permit us to accurately foretell the mainland areas which have a suitable environment to support moderate populations of this fly should it be able to establish itself initially.

Third, population studies were carried on in ten different areas selected to provide ecological variation insofar as hosts, host sequence, temperature, rainfall, elevation and fly population level are concerned. Population trends in these areas were followed primarily by means of glass invaginated traps baited with citronella. The purpose of these studies was to see what combination of factors are necessary to support high fly populations and what factors individually or collectively are limiting ones.

Fourth, fly movement studies were made by marking and releasing flies and later recovering them in glass traps. The data obtained, supported by movement studies of our other projects, will be of great value in quarantine and area control projects that would be initiated should the fly become established on the mainland.

Briefly, here are some of the developments during this quarter discussed in relation to previous findings in this project. Meteorologically, the climate stations have demonstrated under what temperatures we may expect survival or maintenance of a population at low levels. In figure 1 the temperatures for five stations are graphically portrayed. Of the five stations Haleakala 9200' has a climate beyond the limits of tolerance of all three species of fruit flies. None of the flies has completed its life cycle at this station. At Haleakala 7030', the climate borders on the extreme limits where we would expect survival. This station became marginal for cucurbitae during the summer when the maximum mean reached 65° F. Dorsalis, which has a slightly higher threshold of development, was unable to complete her cycle at this station even in the summer. Capitata, during very favorable periods of temperature during the summer months, was sometimes able to complete her cycle.

*See Page 71 for summary of Line Project I-o-1-1.

In table 1 the relative length of the various stages are shown. The data are based on about 1,000 experiments. What the Haleakala stations have demonstrated is that the adult flies can live for long periods under cool temperatures, and in areas where such temperatures are a part of a seasonal trend, the flies can live through the cool weather and produce progeny when the season becomes more favorable.

At Waikamoi (4250'), characterized by rainfall in excess of 300 inches a year and relative humidity averaging over 90% with maximum temperatures usually below 63°, the results indicated that none of the flies would be able to survive in the field long enough to lay eggs. In small cages at Waikamoi, protected from the rain, the preoviposition period was bridged by cucurbitae after long periods. In the only case that dorsalis matured sexually at this station, the preoviposition period was 76 days.

At Kula (3750') all species were able to complete their development throughout the year. This area appears to be marginal for dorsalis which occurs here at extremely low population levels. The other two species are quite numerous in the field. The life history studies indicate that the cycle is so extended in the case of dorsalis that only a low percentage of females probably ever live to produce viable eggs. During the winter at this station the low twilight temperatures undoubtedly impose certain limitations on the species which mate at dusk.

At the lower stations, the temperatures are close to optimum, between 68° and 85° and the flies complete their development very rapidly. Cucurbitae could easily have twelve generations a year at the lower stations if host material were available.

Fruit collections made on Maui over the past two years included over 5,000 lots containing 187,625 individual fruits. Recent collections have indicated that parasitism of the oriental fruit fly has increased largely due to the work of oophilus. In 1949, nearly all of the parasites recovered were longicaudatus. During 1950 there was a gradual increase of vandenboschi parasitization of dorsalis, up to 60%. Toward the end of 1950 we began recovering oophilus in percentages less than 3%. In 1951, oophilus steadily increased until this is now the dominant parasite in most areas. The other two parasites still exert some pressure but they have decreased from their previous peaks.

Figure 3 shows the relative increase in parasitism during the past two years, in two different hosts, i.e., mango, a pulpy host, and rose apple, a thin-walled, small host. While the parasites have increased in both in two years, the increases have been much more spectacular in rose apple.

Because guava is the "prime mover" of the dorsalis population the fact that parasitism has steadily increased in this host and the dorsalis infestation in guava has decreased speaks well for the parasites. This trend is shown in figure 4.

The importance of any host must be judged on its overall density and fruit production capacity rather than on its ability to show priodic high degrees of infestation. In these respects guava surpasses all other hosts in the Hawaiian Islands. Even low degrees of infestation in this host will sometimes result in fly populations sufficiently high to cause economic damage to other fruits. It was for this reason that the writer pointed out in 1948 (The Oriental Fruit Fly on Guam, Jour. Econ. Ent. Dec. 1948, V. 41, No. 6, p. 991). that a Bud Moth (Spilonata holotephras) on Guam was preventing the setting of guava fruit. The plants observed there were stunted and scarce due to ravages of this insect. On Guam dorsalis was exceedingly hard to find although the temperatures for its development were close to optimum. These observations indicated that it would be worthwhile to investigate the biological control of guava fruiting in the Hawaiian Islands. If successful, this would knock out the main host of dorsalis and get rid of a bad range pest at the same time.

Infestations in peaches and loquat both have been greatly reduced from 1950 to 1951 (fig. 5), and parasitism has increased. The parasites are not only attacking dorsalis but also capitata in the field, above 3500'.

Population trends on Maui over the last two years are shown in figs. 8, 9, 10. They appear to fall in three groups based on elevation and host material. Population peaks invariably show good correlations with fruiting peaks in the immediate area. At higher elevations the greatest reduction in dorsalis populations has been noted. At the lower elevations while the trend is generally towards a lower population level, flies are still abundant and capable of serious damage to favored host plants. Infestation indices, while generally lower in most fruits, are actually higher in others. On the whole the reductions in fly populations have not been accompanied by proportionate reductions in fruit infestations. The reason for this may be that dorsalis formerly occurred at such high levels that most fruits were overloaded with eggs most of which could never develop to mature larvae. At lower population levels, when there are fewer eggs being deposited and all larvae have a good chance of developing to the pupal stage, changes in fly populations and infestation indices may show better correlations.

While dorsalis has been recorded infesting about 140 different fruits, many of these records were made when the populations were at their peak. Subsequent collections have revealed that many of the recorded hosts are not infested at the present time and that they are of little significance. The overall host list could be greatly reduced if it were limited to those usually infested and numerous enough to contribute substantially to the dorsalis population.

It has been the history of many insects which have arrived as migrants to the Hawaiian Islands that their populations "explode" quickly to very high densities. Then over a period of years, for reasons not well understood, the population levels gradually readjust to densities much lower than the early peak infestations. Dorsalis has followed this general pattern and in some areas there are indications that a more or less stabilized situation has been readied. Undoubtedly, the parasites and predators have been responsible in no small degree for this decline in the general population level.

The decline in densities of dorsalis has reduced somewhat the chances for an accidental introduction of this fly into mainland areas. The threat of the fly is still an urgent one, however, and we know of no factor in most subtropical mainland environments which would be likely to interfere with its successful establishment, at least during certain seasons of the year. In the event of establishment even in areas where this fly might never develop into an important economic pest, the fruit industry would undoubtedly be greatly affected because of quarantine measures which would have to be enforced. More information such as that now being provided by the bioclimatic cabinet studies is needed before accurate predictions can be made regarding the ability of dorsalis to develop to serious pest proportions in certain portions of subtropical areas on the mainland.

Line Project I-o-1-2. Effect of Climate on the Oriental Fruit Fly Under Field Conditions.

Climate Stations.--In fig. 1, the monthly maximum mean temperatures for five climate stations on Maui are shown. With the exception of Waikamoi (4250'), which was selected because of its high relative humidity and rainfall, the stations represent a good cross section of the variations in temperature conditions on this island.

An evaluation of temperature and biological data makes it apparent that minimum temperatures within certain limits are not the main limiting factor especially when they are accompanied by maximum peaks suitable for development. Low temperatures on Haleakala during our studies have dropped to four or five degrees below freezing and the flies have survived. The most important temperatures under these conditions are the maxima which determine the amount of fly activity and the rate of development. Temperatures above 70° F. are necessary for dorsalis to attain sexual maturity without the preoviposition period becoming greatly extended. Temperatures up to 80° F. will reduce the preoviposition period to near the optimum, or about ten days. At Haleakala, 7030', the minimum temperatures during the summer may go down to 40° F. but there are also peaks above 70° F. More activity is possible under these conditions than at Waikamoi, 4250', where the minimum seldom goes below 50° F., but where maximum temperatures over 63° F. are infrequent. Generally speaking dorsalis does better in areas which have temperature peaks suitable for some development regardless of the minimums, within certain limits, than in an area where the temperature does not fluctuate greatly above or below the threshold line.

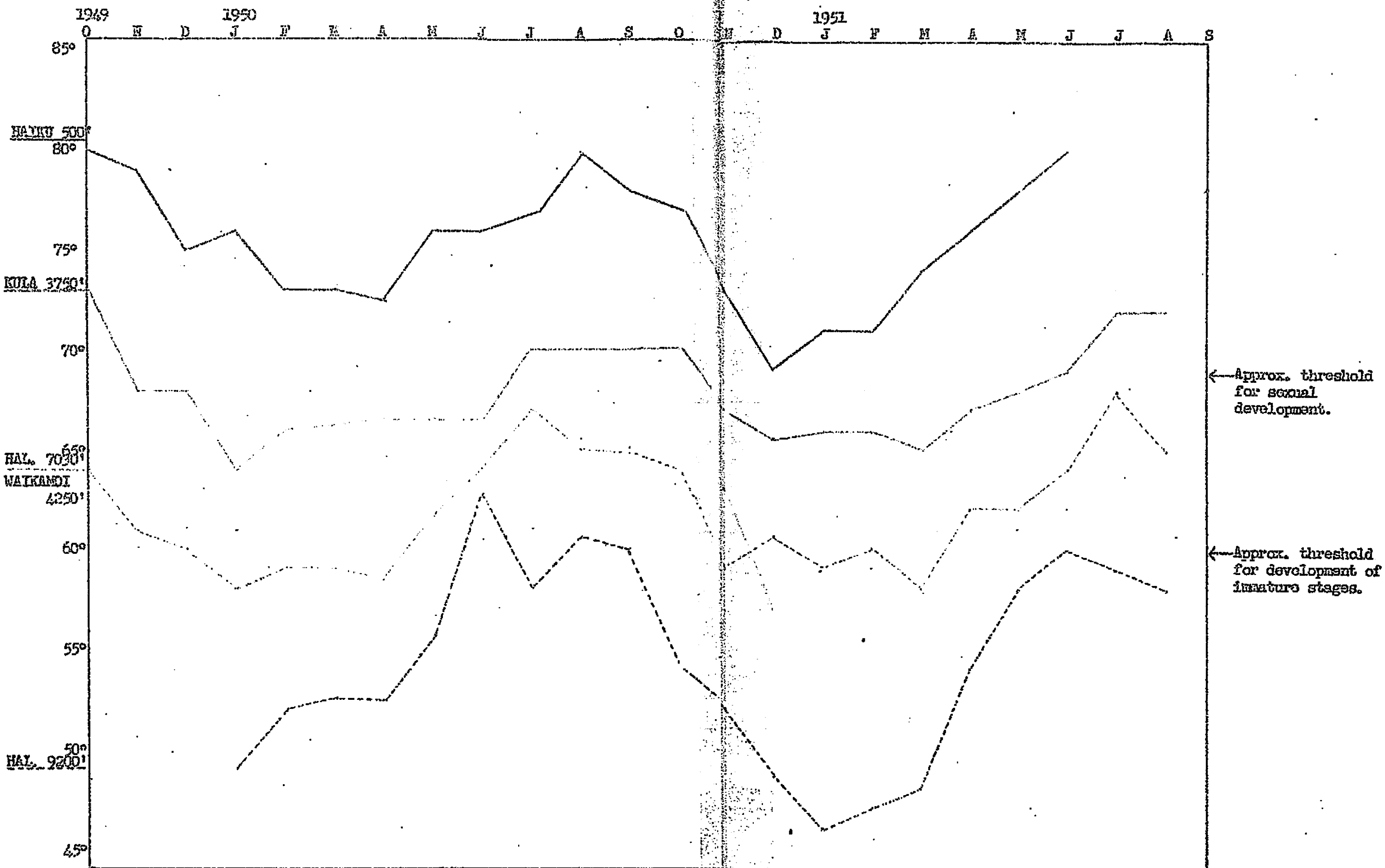
Of the five stations, the lower ones allow the fly to develop under close to optimum conditions. At Haiku (500') and Kihei (20'), where maximum temperatures higher than 85° in the shade occur, dorsalis completes her sexual development in ten to twelve days. The egg hatch requires two days, the larval period eight days, the pupal period twelve days, and the complete cycle is completed in about a month. Contrast this with Kula, which seldom has temperatures over 70° F., where the preoviposition period averages thirty days, the egg hatch three days, the larval period fifteen days, the pupal period twenty-five days, and the complete cycle requires over two months.

The Haleakala station at 9200' is a submarginal area for all three of the fruit flies, although some development of cucurbitae takes place there during the summer months. The monthly maximum mean in June was 60° F., that was the high for the year.

The station at 7030' is a submarginal area for dorsalis most of the year, but it borders on a marginal environment during the summer months. The summer temperatures at this station are comparable to temperatures at Kula during the winter.

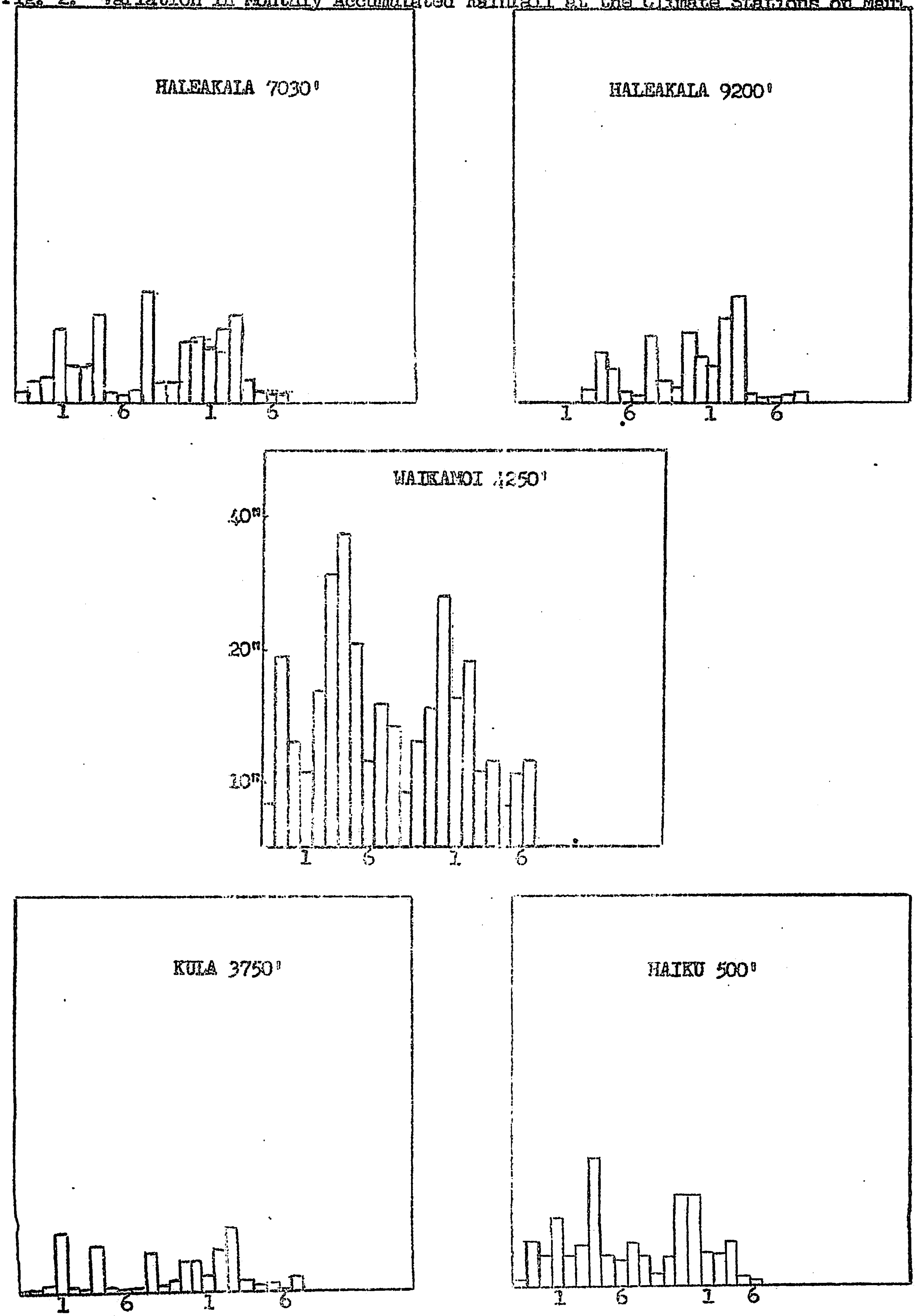
At Waikamoi (4250') the maximum temperatures in summer are below 65° and too low for the development of dorsalis but not too low for cucurbitae.

Fig. 1. Climate Stations on Maui.



Legend:
Lines running across graph from Stations represent monthly max. mean.

Fig. 2. Variation in Monthly Accumulated Rainfall at the Climate Stations on Maui.



Life History Studies.--Table 1 summarizes the studies of all stages of the three species of fruit flies over the past two years. These data are based on about 1,000 experiments which have been correlated with temperature data. Two types of studies were carried on: first, individual studies of the different stages were made by taking eggs, larvae, puparia and adults to the different climate stations; and second, generation studies were made in which the cycle was followed through at each station from generation to generation. In many cases it was possible to get positive results at an ecological station with each individual stage while negative results were obtained insofar as the complete cycle of the insects was concerned. This was attributable primarily to the fact that the percentage mortality was so high for each stage that it was not possible for the insect to go through from newly emerged adult to the F_1 generation. If it had been possible to use extremely large numbers of insects, ultimately a few adults of the second generation might have been produced. Where these high mortalities occur, the possibility of a third generation is extremely unlikely.

Since development proceeds at a different rate throughout the year, comparisons between winter and summer, as shown in the table, are of interest. Actually, there is a gradual extension or contraction of the life cycle which may be correlated with the thermal trend. The figures represent the duration of each stage in days based on the first individuals to mature. There is considerable variation among individuals, and these differences become magnified as the overall cycle is extended. For example, the emergence span of adults from puparia of the same age may be two or three days under optimum conditions but as long as two weeks where the development is slowed down as it is at Haleakala, 7030'. Since the climate stations were checked twice a week we were able to get figures within the normal span of individual development.

Developmental differences are evident between the three species at the lower and higher stations, and during summer and winter months. At Haleakala, 9200', none of the species was able to go through to the second generation although individual stages were sometimes completed. Eggs of cucurbitae and dorsalis hatched but the larvae never attained maturity. In a few cases adult emergence from puparia taken to this station was recorded. Cucurbitae was able to complete its sexual development and eggs of this species were consistently recovered. Mating of dorsalis was precluded most of the year by the low twilight temperatures and the eggs did not hatch. The conclusion we might draw from these studies is that the flies can survive the conditions at this ecological station as adults and, in areas where such temperatures are part of an annual cycle, could tide themselves over and produce progeny as the season becomes more favorable.

At Haleakala, 7030', during the summer positive results were obtained with the individual stages of dorsalis and second generations of cucurbitae were produced. We have been unable to run dorsalis through to the second generation although we have completed all stages individually. This station represents just about the extreme limits at which any of the species could be expected to survive at low population levels and it is doubtful if dorsalis could maintain herself here at all even if we started with ten of thousands of gravid flies.

At Waikamoi, 4250', due to the relatively low maximum temperatures, usually below 63°, a second generation of dorsalis depends upon where the cycle is started. In one experiment, eggs of dorsalis in fruits which were taken to Waikamoi on July 11 produced puparia by August 2 and adults by September 10. This was a total cycle from egg to adult of 61 days. However, if a start is made with newly emerged adults the maximum temperatures are insufficient to allow the fly to mature sexually and no eggs are deposited. Over the past two years we have placed over 6,500 adult dorsalis at this station and have obtained sexually mature adults in only one case. This particular instance happened very recently as a result of some freak weather at this station. If we refer to fig. 1, we will see that the highest maximum mean was in August of 1950 and that was 66°. In the month of September we had two days when the maximum went up to 70°. Dorsalis that had been placed at this station as newly emerged flies on June 21st produced viable eggs on September 6th, to complete its preoviposition period in 76 days. If this is added to the 61 days required for the development of the immature stages, the complete cycle from newly emerged adult to adult would be 137 days. These flies were held in small cages protected from the rain. In the field, dorsalis would never survive in this environment long enough to lay eggs. Cucurbitae completed its cycle from egg to adult (June 7 to July 30) in fifty-three days. The melon fly is able to mature sexually at this station in the summer in about thirty days. The complete cycle is 83 days and it is very doubtful if this fly could maintain itself under these conditions in the field.

At Kula, 3750', and the lower stations at Haiku, 500', and Kihei, 20', all species completed their development, and the presence of field infestations merely confirms observations made in the cage studies.

Data from life cycle studies are shown in tables 2 and 3. This quarter we have carried on about 200 of these studies. Table 2 shows the relative differences in length of cycle for cucurbitae at Haleakala, 7030', and Kula, 3750', with a control (74°-80°). The following table 3 contains data for dorsalis at Kula and for a control cage. The preoviposition period in this particular experiment actually was a little longer than normal for this time of the year.

Table 1. Seasonal Variation in the Development of the Fruit Flies on Maui.

Based on about 1250 experiments.
n = negative

Haleakala 9200'	D. dorsalis winter	D. dorsalis summer	D. cucurbitae winter	D. cucurbitae summer	C. capitata winter	C. capitata summer
Duration in Days						
Preoviposition period	n 1/	n	111	47	n	117
Egg stage	n	12	n	8	n	n
Larval period	n	n	n	n	n	n
Pupal period	n	n	n	n	n	n
Life cycle	n	n	n	n	n	n
Haleakala 7030'						
Preoviposition period	n	30	92	12	n	18
Egg stage	n	7	n	7		11
Larval stage	n	40	n	24		34
Pupal period	n	46	n	35		45
Life cycle	n	123	n	76		108
Waikamoi 4250'						
Preoviposition period	n	76	72	26	n	42
Egg stage	7	5	8	4		5
Larval stage	34	25	20	19		20
Pupal period	44	40	45	32		24
Life cycle	n	140	145	81	n	91
Kula 3750'						
Preoviposition period	41	16	37	12	39	13
Egg stage	5	3	3	2		5
Larval stage	16	14	15	14		15
Pupal period	30	25	30	20		20
Life cycle	92	58	85	48		53
Haiku 500'						
Preoviposition period	16	15	12	8	19	6
Egg stage	2	2	2	1.5		4
Larval stage	12	12	8	8		12
Pupal period	16	12	15	9		12
Life cycle	46	41	37	26		34

	9200'	7030'	4250'	3750'	500'
Winter Maximum mean	51	59	59	65	75
Summer Maximum mean	60	65	64	70	79
Winter Minimum mean	38	45	48	50	64
Summer Minimum mean	44	46	55	53	67

1/ Not completed.

Table 2.--Life Cycle Studies on Maui.

Experiment 1846	Dacus cucurbitae	Haleakala 7030'	
		Duration	Stage
Flies emerged	April 8	29 days	Preoviposition period
First egg recovered	May 7	7 days	Egg hatch
Fruit exposed	July 9	20 days	Larval period
Mature larvae	Aug. 5	37 days	Pupal period
Puparia	Aug. 6		
Adults	Sept. 12	93 days	Complete cycle
Experiment 2244	**Dacus cucurbitae**	**Kula 3750'**	
Flies emerged	July 14	12 days	Preoviposition period
First egg recovered	July 26	2 days	Egg hatch
Fruit exposed	Aug. 6	12 days	Larval period
Mature larvae	Aug. 20	18 days	Pupal period
Puparia	Aug. 23		
Adults	Sept. 10	44 days	Complete cycle
Experiment 2252	**Dacus cucurbitae**	**Control Temp. 76° - 80°**	
Flies emerged	July 14	9 days	Preoviposition period
First egg recovered	July 23	1 day	Egg hatch
Fruit exposed	Aug. 6	9 days	Larval period
Mature larvae	Aug. 16	8 days	Pupal period
Puparia	Aug. 17		
Adults	Aug. 25	27 days	Complete cycle

Note. The term "fruit exposed" refers to cucumber. The length of the preoviposition period is determined by putting slices of cucumber in the cage and examining these sections for eggs. Later, the whole fruit is placed in the cage.

Table 3.--Life Cycle Studies on Maui.

Experiment 1860	Dacus dorsalis	Kula 3750'	
		Duration	Stage
Flies emerged	May 22	41 days	Preoviposition period
First egg recovered	June 31	3 days	Egg hatch.
Fruit exposed	July 9	11 days	Larval period
Mature larvae	July 20	20 days	Pupal period
Puparia	July 21		
Adults	Aug. 10	75 days	Complete cycle

Experiment 2228	Dacus dorsalis	Control Temp. 76° - 80°	
Flies emerged	July 14	12 days	Preoviposition period
First egg recovered	July 26	2 days	Egg hatch
Fruit exposed	Aug. 9	7 days	Larval period
Mature larvae	Aug. 17	12 days	Pupal period
Puparia	Aug. 18		
Adults	Aug. 30	33 days	Complete cycle

Sexual Maturity.--An insect with stages having different developmental temperature thresholds will be most limited, in a cool climate, by the stages which requires the highest temperature for its completion. In the case of dorsalis, the temperatures necessary for the fly to attain sexual maturity are higher than those required for the completion of the immature stages. Under the same temperature conditions it is possible to obtain development of the larvae and puparia while the adult flies are unable to mature sexually. The establishment of dorsalis in a new location, or its successful spread into even cooler areas, therefore, would depend climatically upon suitable maximum temperatures for the completion of sexual development. In those localities where the maximum temperatures are insufficiently high (below 70° F.) to assure the female quickly attaining maturity no high population level would be possible. Mortality factors, as such, would have an effect on the ultimate number of females which live to lay eggs.

Table 4 shows the effect of temperature and diet on the rate at which the three species of fruit flies develop. These data are based on studies over the last twelve months in which 81,100 flies were used in 339 experiments. The techniques used in carrying out these studies have been described in previous reports and the discussion here will be limited to the implications and conclusions that may be drawn from the above table.

The studies were made at five climate stations, and at each station they were held under four different types of conditions. The flies were provided with two different diets, i.e., sugar and sugar supplemented with protein. These flies on diets were placed in cages under shade conditions (small cages) and in the sun (large cages). To obtain seasonal variation new studies were initiated every month.

The data in table 4 represent actual preoviposition periods observed in the experiments. They are not averages. Comparisons of the duration of the preoviposition periods under different conditions may be summarized briefly as follows: first, it is evident that neither dorsalis nor capitata are able to mature sexually on sugar diet regardless of temperature. This is not true of cucurbitae which attained maturity on the sugar diet plus the cucumber ovipositional material available in the cage. The results with dorsalis and capitata show that in the field, certain proteins must be available to these flies. One source, according to the studies of Dr. Hagen and his associates, might be honeydew.

The higher stations exhibited seasonal variation in development of sexual maturity and the preoviposition periods reflect the thermal trends. At the marginal stations, the temperature difference between shade and sun was considerable (10-15°) and generally flies required about 40% more time to mature in the shade, if they matured at all. At lower elevations, shade temperatures were well up into the optimal range and there was less of a clear-cut developmental difference between sun and shade locations.

Of the three species, cucurbitae demonstrated that it could tolerate much greater extremes of temperature and relative humidity and mature under lower maximum temperatures than the other two species. This was particularly striking at Haleakala 9200' where the maximum temperatures seldom exceed 60° F., and at Waikamoi 4250' where the average relative humidity is over 90% and where the maximum temperature rarely exceeds 63° F. Under these conditions cucurbitae was the only species to mature consistently.

TABLE 4. Sexual Maturity Studies on Maui.

Stations		Haleakala 9200'				Haleakala 7030'				Waikamoi 4250'				Kula 3750'				Haiku 500'			
		Sun		Shade		Sun		Shade		Sun		Shade		Sun		Shade		Sun		Shade	
Month	Diet	P	S	P	S	P	S	P	S	P	S	P	S	P	S	P	S	P	S	P	S
OCT.	dorsalis			n	n			n	n			n	n			48	n			18	n
	cucurbitae			111	n			24	111			29	152			20	25			-17	-17
	capitata																				
NOV.	dorsalis							73	n			n	n			n	n			29	n
	cucurbitae							70	n			114	n			26	69			34	58
	capitata			n	n											36	83				
DEC.	dorsalis											n	n			n	n			27	n
	cucurbitae							126	n			72	n								
	capitata							78	n												
JAN.	dorsalis			n,n	n,n			n	n			n	n	29		41	n			16	n
	cucurbitae							69	115			54	82			19	51			12	n
	capitata																				
FEB.	dorsalis			n			89	n				n	n		n	64				28	n
	cucurbitae				n,n			92				69				37				13	
	capitata							n								39	104			19	
MAR.	dorsalis	n		n	n			n	n			n	n					37		25	n
	cucurbitae			103	124			67	71			53	n			32	50			11	29
	capitata			n	n											45				11	35
APR.	dorsalis	n		n,n	n,n	60		n	n	n		n	n	21		n	n	18		20,21	n,3
	cucurbitae	n		62	76	29		49	77	66		41	64	16		28	35	11		19	30
	capitata	n		117	n	29		n	n	n		n	n	19		n	n			11,16	n
MAY	dorsalis	n		n	n	30		61	n	n		n	n	31		61	n	12		25	n
	cucurbitae	n				23		55	55	34		65	55	24	22	36	28	12		14	14
	capitata							37				n				12				12	
JUNE	dorsalis	n				32		41,45		n		n	n	29		23		12			
	cucurbitae			62		20		27				39		13		15					
	capitata							18				42		13		16		10			
JULY	dorsalis							30	n			n	n			16	n				
	cucurbitae			47				12				26	n			12	37				
	capitata																				
AUG.	dorsalis											n	n	25		11,13		18		15	
	cucurbitae													15		18		15		5,11	
	capitata															11,3		.		5,2	

Legend: Sun: Large cages unshaded
Shade: Small cages shaded (Weather shelter conditions)
Diet: P: Protein, S: Sugar
n: Flies died before maturing
Based on 339 experiments in which 81,100 flies were used.

Legend: The numbers above represent the preoviposition periods based on the recovery of the first egg. Each number represents one experiment in which 100 flies were used in the small cages and 1,000 in the large cages.

The duration of the preoviposition period are shown in the month the experiments started.

Longevity.--Considerable data have already been presented on longevity in previous reports and recent findings do little more than substantiate what has already been found. If we may conclude that caged flies give a fair indication of the average life of the fly in the field, then it is quite certain that all three species may live long enough to bridge host-free periods of three to four months. Actually caged flies have lived over a year but it is very doubtful if their counterparts in the field are able to do that. We do have a record of a marked melon fly recovered after 110 days. This species probably has a greater life span in the field than the other two species.

How long can the fly live and still produce viable eggs? One recent experiment shed some light on this question. An experiment of fifty of each sex of cucurbitae was set up on October 10, 1950 in a small cage. On September 10, 1951, twelve months later, a cucumber was placed in the cage which at that time contained only two living females of the original population. The flies immediately began ovipositing in the fruit and on September 16 puparia were found in the sand beneath the fruit. These one-year-old flies produced progeny after living through one winter at Kula. In another experiment dorsalis continued to lay eggs from the time they were 41 days old until they were 139 days old. Still another experiment showed dorsalis laying eggs when they were 71 days old. At Haleakala (7030') cucurbitae laid viable eggs after 150 days in one instance, and 229 days in another. These cited examples are from cool areas but at lower elevations with higher temperatures the longevity of the fly is reduced as is her egg-laying span.

Line Project I-c-1-4. Hosts of the Oriental Fruit Fly.

During this quarter on Maui we collected 7,615 fruits in 360 lots. Since the beginning of these investigations 187,625 fruit in 5,000 lots have been processed on Maui. A total of 621,931 puparia or three per fruit have been recovered.

Twenty-two different hosts were collected this quarter but the bulk of the collections were of mango, guava, peach and false kamani. These collections show that parasitism had increased, largely due to the effect of oophilus. The parasitism recorded in infestations in some hosts was as follows: mangoes (17%), false kamani (30%), guava (71%) of which 65% was oophilus, rose apple (79%) of which 40% was oophilus, mountain apple (85%) of which 65% was oophilus. In peaches collected at 3200' at Olinda the following percentages were recorded: dorsalis (8%), capitata (53%), longicaudatus (21%), vandenboschi (2%), and oophilus (15%).

Figure 3 shows a comparison between mango, a large, pulpy fruit, and rose apple (Eugenia jambos). The latter is a small, thin-walled fruit. It is evident that parasites are much more effective in the rose apple than mango although they have increased in both hosts during the last year. In spite of the parasites the actual infestation in rose apple was about 50% higher than a year ago while in mango it had been reduced. Rose apple has always been a very heavily infested fruit, allowing large numbers of larvae to complete their development and pupate. On Maui, rose apple is not particularly abundant and so its role is secondary while mangoes are numerous and contribute substantially to the overall fly population.

The changes in the dorsalis-parasite complex from 1949 to 1951 are shown in figure 4. The fact that guava is by far the most important mainstay of the dorsalis population makes the increased parasitism in this host of great significance. Although the average parasitism has been shown as 40%, many lots have parasitism up to 80%. Longicaudatus has never been very effective in guava but vandenboschi and oophilus seem to be doing a good job. Infestation in guava over the last three years has been reduced and this undoubtedly has caused a depression in the dorsalis population.

Figure 5 shows the differences in infestations in peaches at different elevations for two years. In this host the infestation has been reduced considerably even though parasitization has not been very effective on capitata or dorsalis in peaches. The histogram shows that at both elevations a decline in infestation has taken place in 1951. Dorsalis has actually increased percentagewise at the lower elevations due to the decrease in capitata. At higher elevations capitata has maintained infestations close to 80% although the lower infestation results in a fewer number of adults being bred from a given amount of fruit.

In figure 6 is shown the dorsalis-parasite picture in loquat for the last two years on Maui and Hawaii. On Maui, the index of infestation has declined about 79%. The index of 60 has been identical for both islands thus far in 1951.

FIG. 3.—Comparative Increase in Parasite Effectiveness In Two Different Hosts on Maui.

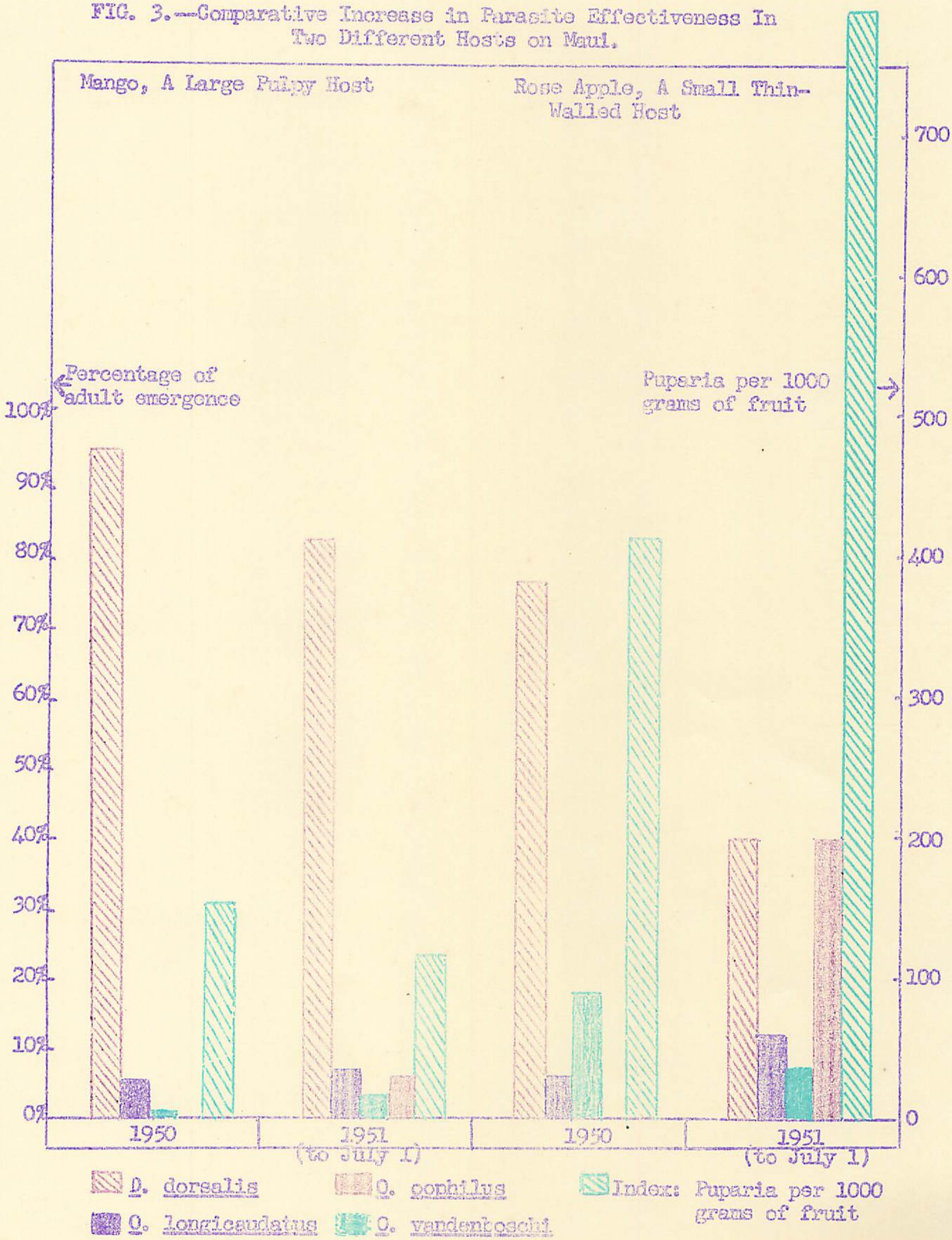


FIG. 4.--Changes in the Parasite-dorsalis Complex over Three Years, on Maui, in Guava.

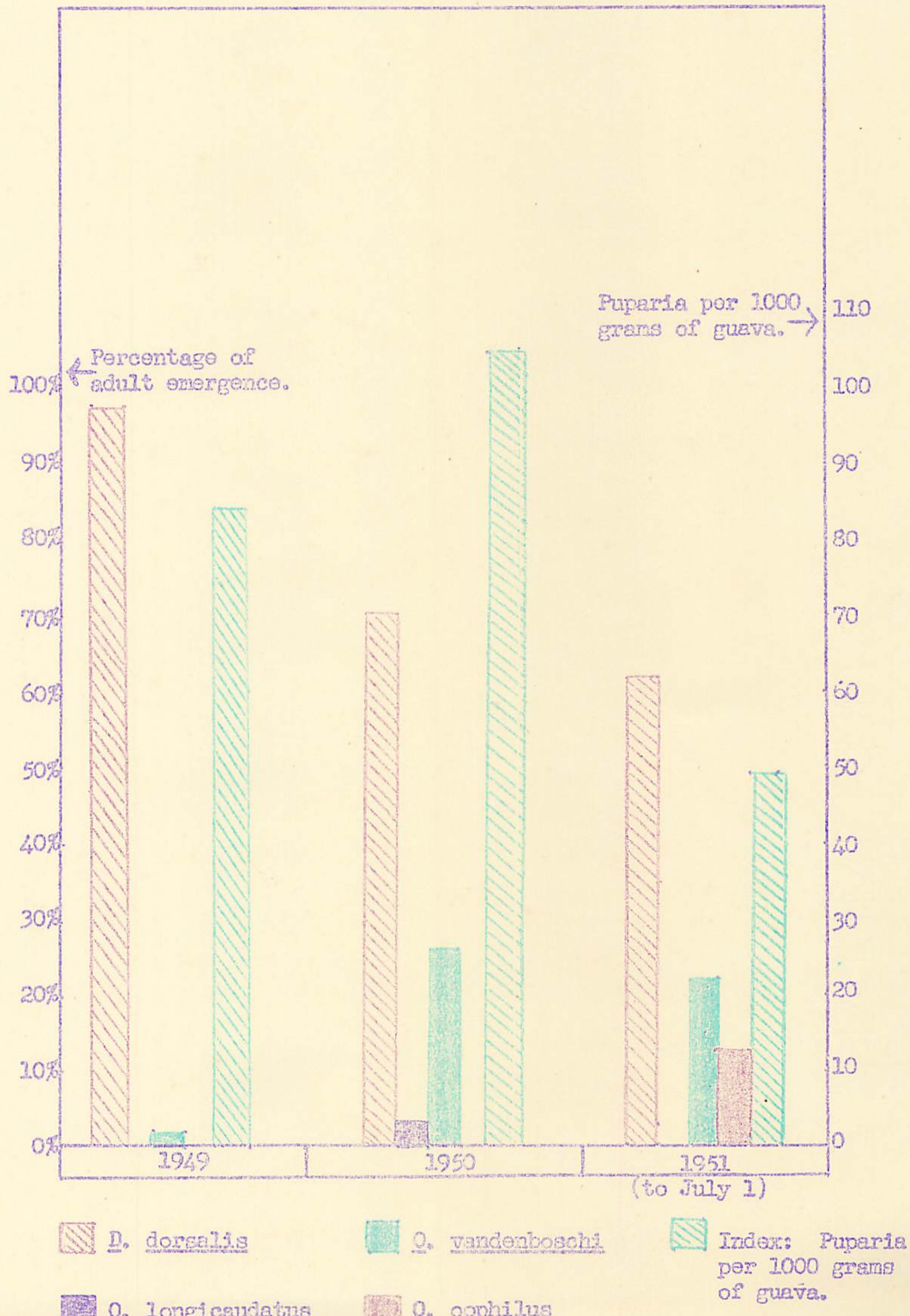


FIG. 5.—Competition and Parasitism at Different Elevations in Peaches.

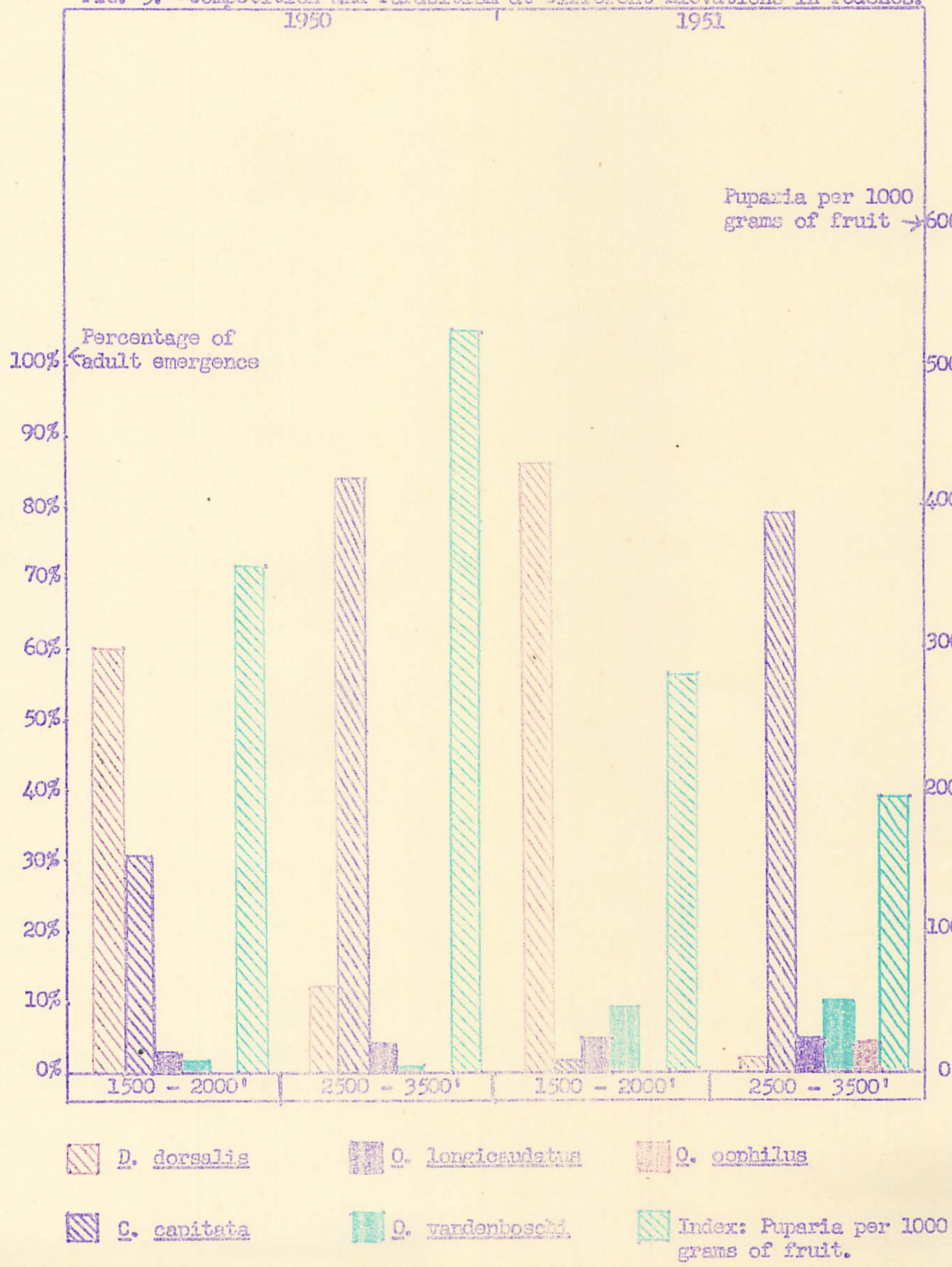
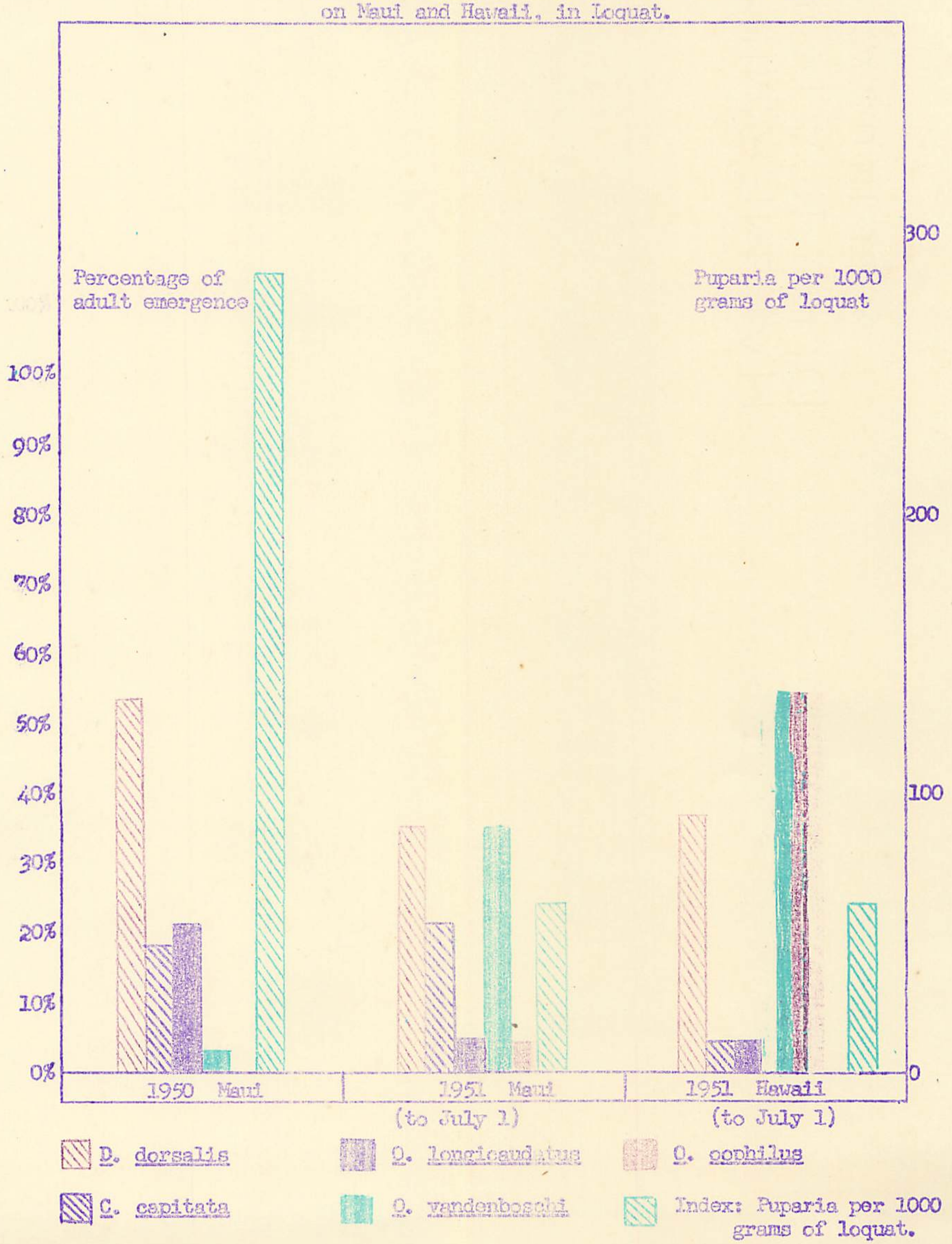


FIG. 6.— Changes in *Dorsalis*-Parasite Complex in Two Years on Maui and Hawaii, in Loquat.



Note: In the Hawaii collection O. vandenboschi and oophilus were not separated.

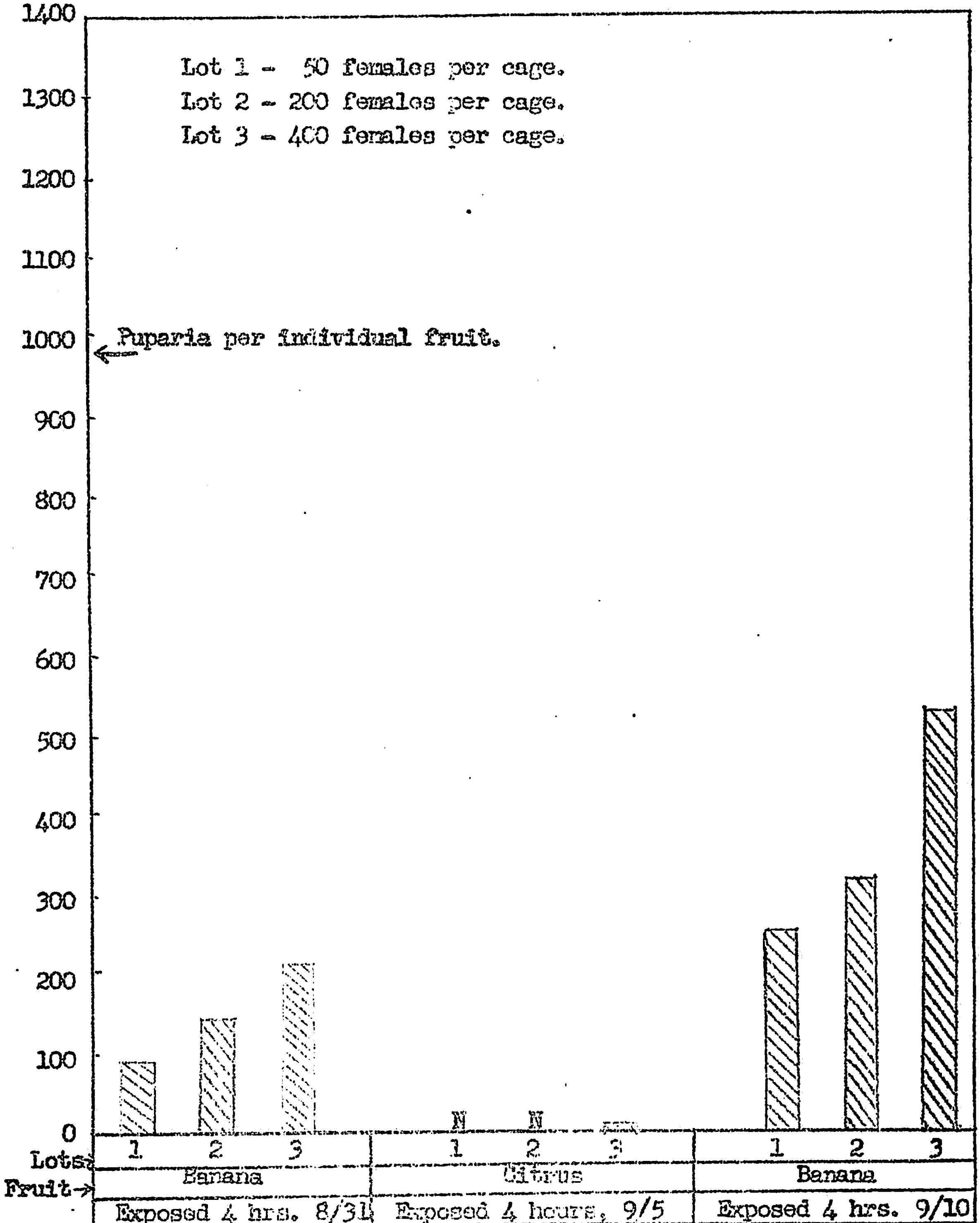
On Hawaii the per cent of parasitism has been slightly higher than on Maui for 1951. The parasitization for Hawaii includes both vandenboschi and oophilus. On Maui the combined parasitism of these species has been 49%. The fact that capitata is more abundant in the Maui collections merely reflects the elevation at which the fruit was collected. Most of the Maui loquat came from above 2500' while on Hawaii the collections were made near sea level. Parasitism in loquat on Maui has increased from 24% in 1950 to 44% in 1951. The relative percentages of capitata in loquat have remained just about the same.

Correlated with these drops in infestation are drastic reductions in dorsalis populations in Kula areas where the loquat collections were made. The adult fly population has declined about 90% for the general area and this has been accompanied by a drop in fruit infestation of 80%. This indicates that the low population level in 1950 while sufficient to cause a heavy infestation did not result in an excessive number of eggs in the fruit with resultant larval mortality.

In general it might be said that the importance of any host must be judged on its overall fruit production capacity in any area rather than on the extent to which individual fruits are infested. Santalum is the most heavily infested of all hosts on Maui, having population indexes up to 1,000. The fact that it is numerically negligible discounts it as an important host. Although dorsalis has been recorded attacking over 140 different fruits in the field many of these records were made at peak population levels. Subsequent collections of many of these hosts have shown them to be uninfested and probably of little significance. Hosts which serve a role of "alternate carriers" during periods when the main hosts of dorsalis are out of season have importance far exceeding their actual numbers or their contributions to the population. Citrus, in which the fly oviposits freely, but whose rind deters the entrance of young larvae into the pulp may serve in some localities in a "trapping capacity" and actually reduce fly populations (See figure 7).

While the tendency has been to place climate in the dominant role for protecting the mainland from the transgression of dorsalis, actually in many climatically suitable areas, host availability and sequence would be the main "stumbling block" for this fly in the event it should establish itself on the mainland.

FIG. 7.--Citrus and Banana as Hosts of Dorsalis on Maui.



Total puparia from one fruit in each lot. Total puparia, 436.

Lots 1 and 2 negative. Total puparia, 10.

Fruit placed in media. Total puparia, 1,093.

Line Project I-o-1-5. Population Trends of D. dorsalis Hendel.

Population studies made on Maui in the past two years are shown in figs. 8, 9, 10. Initially, areas were selected which presented ecological variation insofar as host sequence, rainfall, temperature, and elevation are concerned. The population trends were followed by means of glass invaginated traps baited with citronella. Fermented lure was also used in some areas, and comparisons indicated that both lures reflected the same trends. Since citronella traps are much easier to service the emphasis was placed on this lure.

Of all factors considered, host availability seems to play the paramount part. Population peaks are invariably correlated with great host abundance. No overall population trend for Maui is apparent but the populations seem to fall into three groups. The trends for three areas at the higher elevations of Kula are shown in table 8. In the latter part of 1949 the trend was downward during the winter months. In the first three months of 1950 there was a sharp rise attributable to a good, heavily infested loquat crop. At the end of the loquat season the population dropped abruptly to rise again slightly during the peach season (June, July, August). Since then the trend has been downward and the present population level is much less than what it was when the investigations were started. What has caused this abrupt drop in fly incidence? Parasites undoubtedly have contributed to the reduction, but they have not been able to reduce populations elsewhere to the same extent.

If populations in Kula need to be replenished by stray flies from lower elevations, particularly gravid females, then the generally lower population levels throughout the island would reflect on fly populations there. Maximum temperatures at higher elevations are not sufficiently high to allow the fly to mature quickly and lay eggs. The actual reduction in females which attain sexual maturity combined with the extension of all developmental stages result in a low replenishment index which is unable to compensate for population loss. Briefly then, the lower fly incidence seems to be the result of a combination of factors: the extension of the life cycle due to insufficiently high maximum temperatures combined with a limited host reservoir and poor host sequence plus the increased effectiveness of the parasites and the fact that replenishment from lower elevations has been curtailed somewhat.

The second population group (fig. 3) occurs at the medium elevations such as the Olinda area. These are supplied by guava gulches. Here, the fly is dependent almost solely on guava and the ebb and rise of the population reflects the season of this host. Increased catches during fruit peaks are the result of an influx of flies plus actual breeding in the area. The populations on Lanai reflect the same sharp rises and breaks which seem to be correlated with the main host there which is guava. The studies of populations in these areas indicate two things, first, high host abundance will not maintain a high population level unless it is also accompanied by a good host sequence; second, areas which have host-free periods are not guaranteed low infestation in the new crop since there will be an influx of gravid flies from perimeter areas with a consequent build-up to economic pest levels.

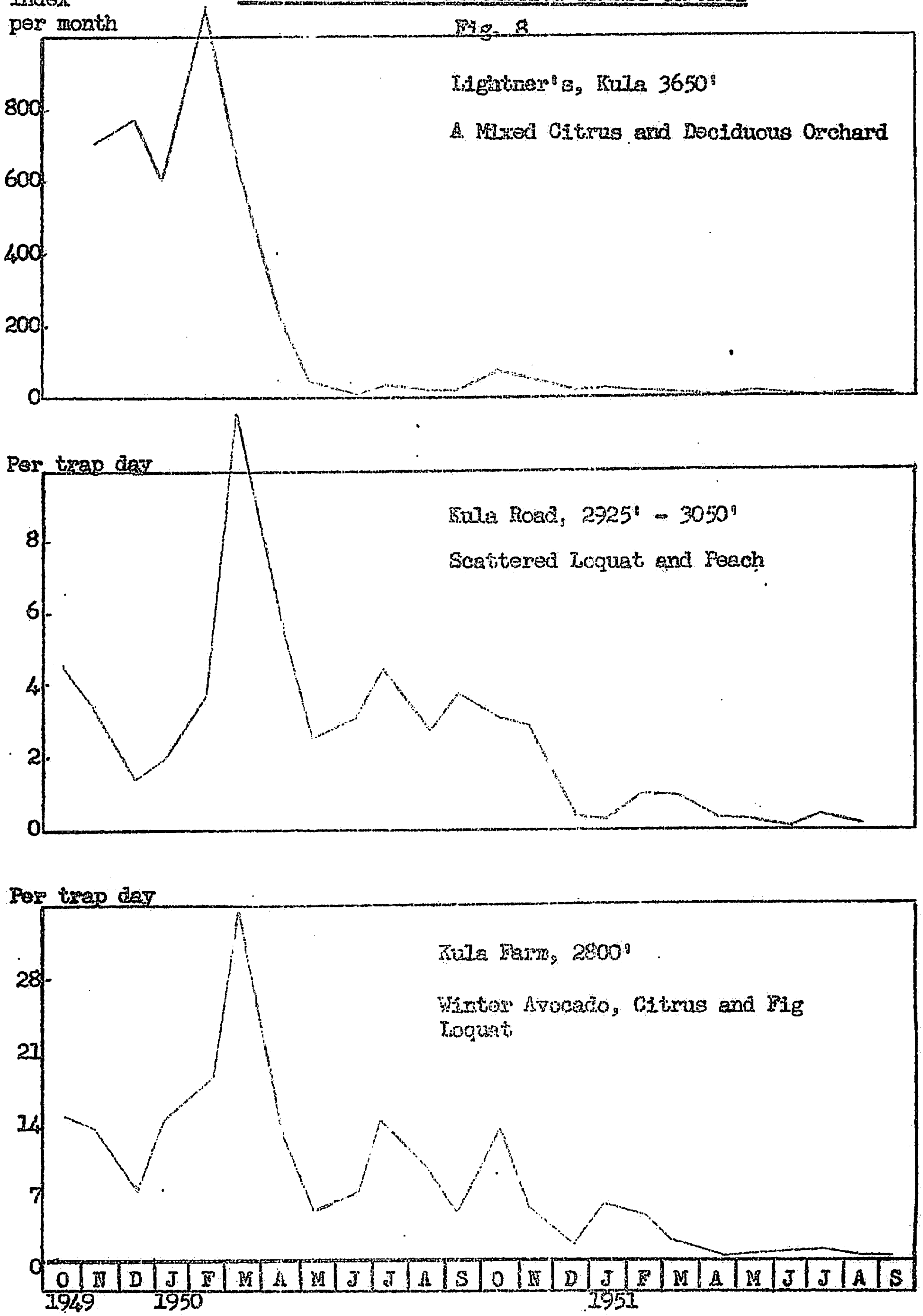
The third group of populations occur at the lower elevations where temperatures approach optimum, good hosts occur in numbers, and there are a large number of secondary hosts to maintain the fly during the off season. The main hosts in these areas on Maui appear to be guava, mango, and false kamani. In fig. 10 these areas are shown with their respective curves. Iao Valley, which has the highest population that we know of in the islands, has not had its fly incidence reduced although parasitism has increased from 5% to 85% in the last two years. What combination of factors are responsible for the high population levels here? First, the whole floor of the valley is covered with guava which has two fruiting peaks, one in the early spring (Feb, Mar.) and one in the late fall (Sept., Oct.). Sporadic fruiting occurs throughout the year. Many false kamani trees bear fruit from summer to January. Kamani is one of the most heavily infested of all dorsalis hosts. The temperatures are close to optimum and the valley is heavily vegetated, offering the fly good protection. High winds are precluded by the precipitous valley walls which also may serve to deter some fly movement. The rainfall normally does not exceed eight inches monthly. All of these factors appear to favor the fly.

At Haiku and Pauwela the trends are quite similar and undoubtedly the guava gulches surrounding these two sites are responsible for the bulk of the flies which are secondarily supported by mango when it is in season. The sharp rise at Pauwela, as the mangoes begin to ripen, is indicative of fly influx rather than actual breeding in the orchard.

In attempting to prognosticate where dorsalis might feasibly establish itself, the following might be listed as prerequisites to the maintenance of moderate fly population levels. The basic requirement is a reservoir host which would produce a great abundance of fruit over at least two or three months. It must be acceptable to dorsalis for oviposition and have no characteristics which deter the young larvae from entering the pulp. The pulp should be sufficient in quantity to assure large numbers of surviving larvae. To maintain a high population level it would also be essential to have available a fruiting sequence of a number of widespread plants. Orchard fruits, which are sprayed for other insects and which are normally harvested or otherwise disposed of, probably would not supply this demand. Citrus or apple probably would not support high dorsalis populations, but apricot, peach, and loquat would if all other conditions were right. The temperatures would have to be between 70° and 90° F. to assure the attainment of sexual maturity quickly and optimum development of the immature stages. Lower temperatures, within limits, would not eliminate infestations but would preclude a population build-up due to its extension of the preoviposition period. Freezing temperatures in winter if not too severe or prolonged in an area otherwise favorable would probably not destroy the fly. No factor that we are now aware of would prevent the initial establishment of dorsalis in some areas on the mainland at certain times of the year if it arrives there in sufficient numbers. However, unless a suitable combination of desirable environmental conditions such as mentioned above were present, a population build-up as it has occurred in the Hawaiian Islands probably would not take place. Of the three species of fruit flies studied, cucurbitae is by far the better adapted for survival in subtropical mainland areas than the other two, in spite of its more limited host range.

FLY ACTIVITY AND POPULATION TRENDS ON MAUI

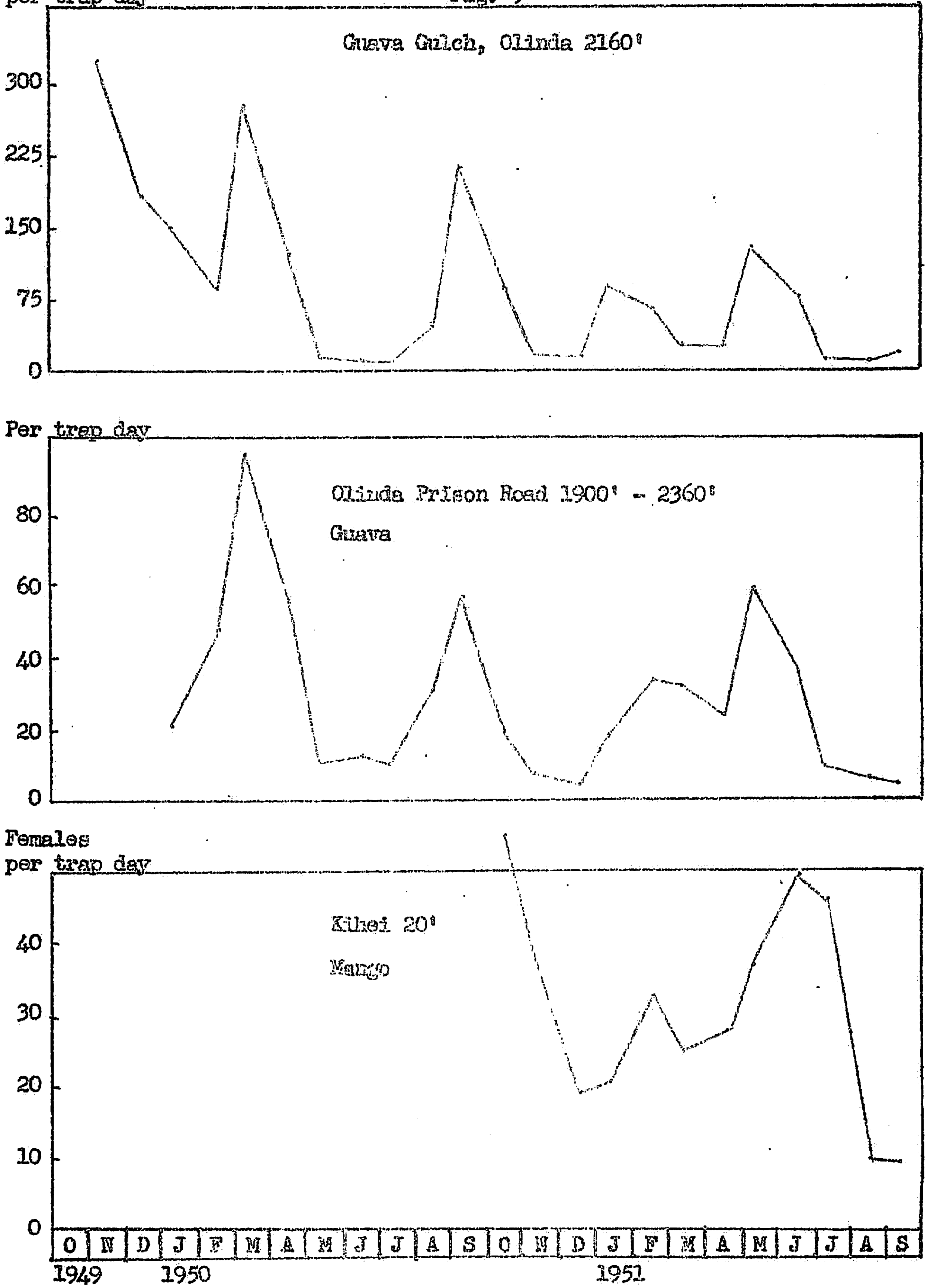
Fig. 8



Note: Citronella traps. Males per trap day.

FLY ACTIVITY AND POPULATION TRENDS ON MAUI

Fig. 9



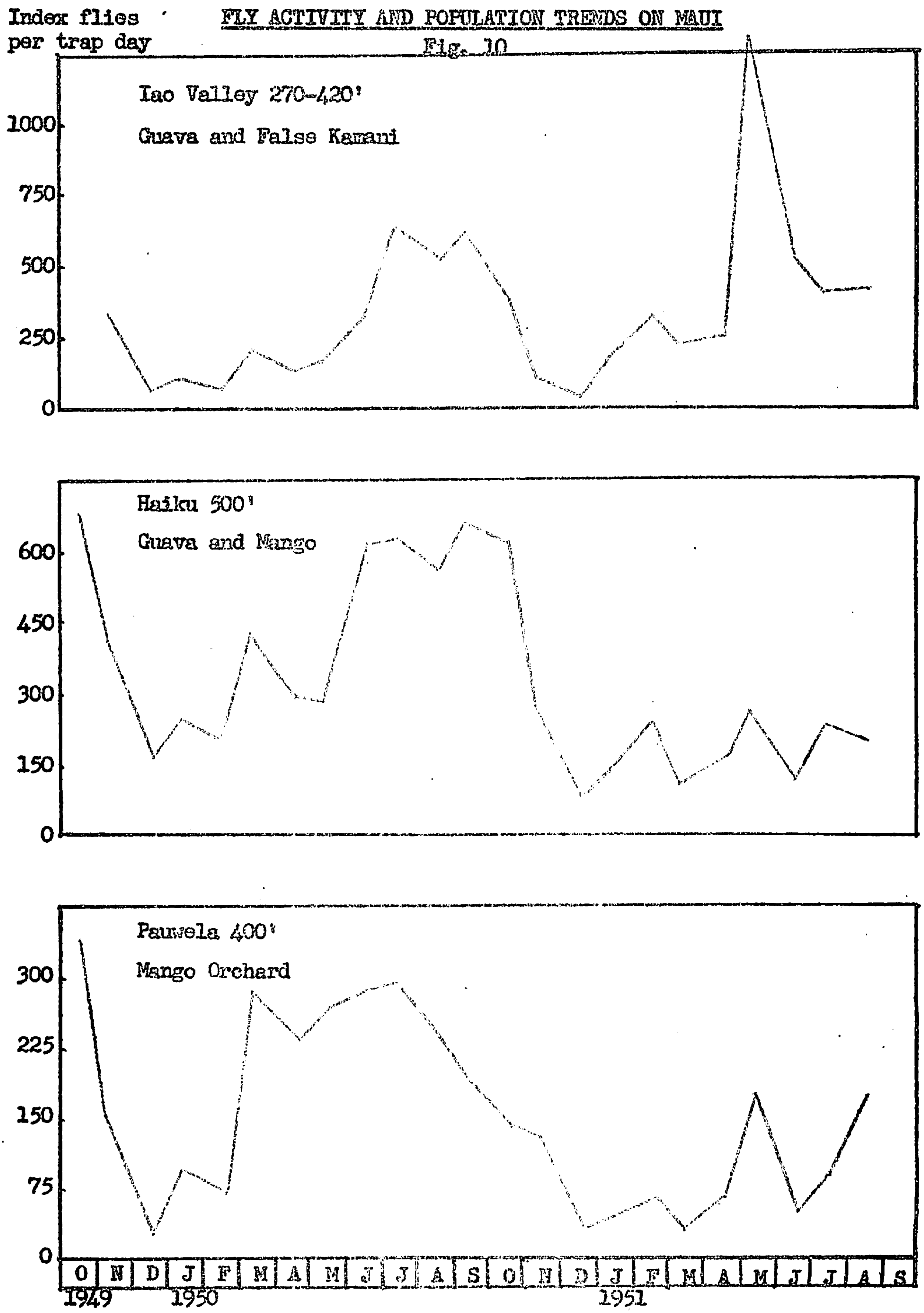

Index flies
per trap day
FLY ACTIVITY AND POPULATION TRENDS ON MAUI
Fig. 10
Iao Valley 270-420'
Guava and False Kamani
1000
750
500
250
0
Haiku 500'
Guava and Mango
600
450
300
150
0
Pauwela 400'
Mango Orchard
300
225
150
75
0
O N D J F M A M J J A S O N D J F M A M J J A S
1949
1950
1951

Table 5.--*Dacus dorsalis* males caught per trap day with glass invaginated traps and citronella lure on Maui.

Month	Iao Valley 270-420'	Haiku 500'	Pauwela 450'	Wailuku 200'	Kihei 20'	Olinda 2160'	Exp. Sta. 2160'	Olinda 1900-2360'	Kula Farm 2800'	Kula Road 2925-3050'	Lightner's 3650'	Ambrose's 3800'
OCT. '49		685	336				179		14	4.4		
NOV.	326	409	153			318	196		13	3.4	7.3	.2
DEC.	64	159	29			179	121		7	1.4	5.4	.2
JAN. '50	109	245	94			146	146	20	14	2.1	4.0	.16
FEB.	81	199	68			83	101	47	18	3.7	7.4	.40
MAR.	202	423	271			270	194	95	35	11.9	4.6	.64
APR.	144	290	232			117	83	54	12	5.8	1.6	.1
MAY	157	284	188			11	17	11	5	2.5	.2	.02
JUNE	323	614	285			4	5	12	7	3.1	.03	.0
JULY	637	623	291			1	3	10	14	4.4	.23	.01
AUG.	520	548	242			40	38	29	9	2.9	.18	.01
SEPT.	616	666	188			209	98	56	5	3.9	.07	.02
OCT.	326	617	141			81	40	19	13	3.1	.4	.09
NOV.	109	270	132			14	14	7	5	2.9	.48	.13
DEC.	45	81	39			11	11	4	2	.3	.20	.0
JAN. '51	167	140	44			82	47	15	6	.2	.19	.02
FEB.	320	240	67			63	48	33	5	1.1	.13	
MAR.	222	116	30		216	22	20	31	2	1.1	.04	
APR.	251	159	67	153	133	23		23	.6	.4	.17	
MAY	1,313	261	170	213	293	122		59	.9	.3	.05	
JUNE	521	123	49	81	143	71		31	1.2	.2	.01	
JULY	404	224	89	67	158	6		9	1.3	.4	.0	
AUG.	419	202	175	75	48	3		7	.7	.3	.0	
SEPT.				40	32	7		4	.5		.0	

WORK PROJECT I-o-1. Biology and Ecology of the Oriental Fruit Fly

Hilo, Hawaii, T. H. S. Nakagawa, In Charge

Because of reductions in personnel, the ecological stations at Kaumana (2000 ft.), Pohakuloa (6511 ft.), and Halepohaku (9200 ft.) were closed. The large outdoor cages at Hilo and Kaumana were moved to Ohaikea (3600 ft.) and to the Mauna Loa Truck Trail (5100 ft.), where most of the studies are now being carried on.

Fruit fly traps are being maintained at Costa's at Hilo (75 ft.), Sumada's at Hilo (100 ft.), Kupaahu (100 ft.), Kona (1700 ft.), Ohaikea (3600 ft.), and along the Mauna Loa Truck Trail (4000 to 5100 ft.). Host collections are also being continued. The program now underway, although very much curtailed, is believed to be adequate to keep up with population trends on Hawaii, and to round out our information on the affect of various climatic factors and host sequences on fruit fly abundance and development.

Favorable weather conditions occurred over most of the island during July through September. September was particularly warm at Hilo where a high of 90° F. was recorded. The lowest temperature, 35° F. was recorded at Halepohaku in July.

Fruit fly populations dropped along the Mauna Loa Truck Trail, and at Ohaikea and Kona. They increased at Hilo and Kupaahu. In general, the 1950 trend for a comparable period was duplicated at most localities during the report period.

Pupal emergences occurred at all stations except Halepohaku. The length of the pupal period at the various stations was as follows:

Hilo (75')	12 days
Kupaahu (100')	12 "
Kaumana (2000')	20 "
Ohaikea (3600')	21 "
M.L.T.T. (4250')	25 "
M.L.T.T. (5100')	31 "
Pohakuloa (6511')	28 "
Halepohaku (9200')	no emergence

In the sexual maturity studies, dorsalis attained maturity at all stations except Halepohaku. Favorable temperature conditions shortened the preoviposition period considerably.

Meteorological data for the Hawaii stations are summarized in table 1.

Table 1. Meteorological Data for Hawaii Stations.

Station	July	August	September	
Hilo Insectary 75'	85	87	90	Absolute Max.
	80.2	82.5	84.1	Max. Mean
	68.3	69.6	70.5	Min. Mean
	64	66	65	Absolute Min.
	14.45	11.09	3.1	Ppt.
	87%	85%	80%	Ave. Rel. Hum.
Kupaahu 100'	88	89	88	Absolute Max.
	84.5	84.7	86.1	Max. Mean
	70.8	70.9	71.0	Min. Mean
	66	68	68	Absolute Min.
	2.74	1.65	2.0	Ppt.
	87%	90%	91%	Ave. Rel. Hum.
Ohaikea 3600'	82	83	83	Absolute Max.
	76.2	77.2	78.3	Max. Mean
	55.8	55.7	53.0	Min. Mean
	50	50	47	Absolute Min.
	1.51	9.43	1.32	Ppt.
	76%	79%	75%	Ave. Rel. Hum.
M. L. T. T. 4250'	78	78	80	Absolute Max.
	73.1	73.1	75.1	Max. Mean
	55.0	54.7	52.8	Min. Mean
	50	49	46	Absolute Min.
	1.51	9.43	1.32	Ppt.
	75%	76%	72%	Ave. Rel. Hum.
M. L. T. T. 5100'	78	77	78	Absolute Max.
	72.0	71.9	73.7	Max. Mean
	51.2	51.3	48.6	Min. Mean
	44	42	43	Absolute Min.
	0.61	6.37	-	Ppt.
	79%	82%	78%	Ave. Rel. Hum.

cont'd

Table 1 cont'd - Meteorological Data on Hawaii Stations.

Station	July	August	September	
Kona 1700'	86	86	85	Absolute Max.
	81.6	81.8	82.1	Max. Mean
	63.5	63.6	63.6	Min. Mean
	62	61	60	Absolute Min.
	8.89	8.75	7.37	Ppt.
Kaumana 2000'	80			Absolute Max.
	74.6			Max. Mean
	60.4			Min. Mean
	55			Absolute Min.
	8.09			Ppt.
	90%			Ave. Rel. Hum
Pohakuloa 6511'	83	80		Absolute Max.
	76.3	74.3		Max. Mean
	47.7	46.5		Min. Mean
	41	36		Absolute Min.
	0.18	2.96		Ppt.
	65%	70%		Ave. Rel. Hum.
Halepohaku 9200'	71	68	68	Absolute Max.
	65.4	61.8	65.9	Max. Mean
	44.6	41.8	42.6	Min. Mean
	35	37	39	Absolute Min.
	0.45	4.44	0.50	Ppt.
	47%	58%	50%	Ave. Rel. Hum.

Note: Station Kaumana was closed on July 31, 1951
" Pohakuloa " " " August 24, 1951
" Halepohaku " " " September 12, 1951

Line Project I-o-1-4.--Hosts of the Oriental Fruit Fly.

Fruit collections on Hawaii during the quarter totalled 9,801 individual fruits. These weighed 82,677 grams. A total of 12,724 pupae were obtained from these fruits. This was an index of 154 per 1000 grams. The Mediterranean fruit fly dominated the collections on the Mauna Loa Truck Trail and in the nearby Ohaikea area which were mostly of Jerusalem cherry. This fly was practically non-existant in fruits collected at the lower stations. Approximately one-fourth of the pupae were parasitized, Opius oophilus accounting for approximately one-half of the parasitization.

A detailed summary of the fruit infestations is given in table 2. The records for the Mauna Loa Truck Trail and for the Ohaikea surveys are presented in the bar chart in figure 1.

Table 2. Hawaii Fruit Collections

Note:

Lots 3277 to 3445 included in this September report.

A "Lot" of fruit may include from a few to several hundred depending upon availability, size, etc.

Key:

Index: Puparia recovered per 1000 grams of fruit
S: Stage of fruit, G: Green, R: Ripe
W: Weight in grams
N: Number of fruit
gr: Ground fruit, usually over ripe

Emergence:
Dor: <u>Dacus dorsalis</u>
Med: <u>Ceratitis capitata</u>
Lon: <u>Opius longicaudatus</u>
Per: <u>Opius persulcatus</u>
Oop: <u>Opius oophilus</u>

Lot	Date	Locality	Elev.	Fruit	S	W	N	Pupae	Dor	Med	Lon	Per	Oop	Index
3277	6/4	M.L.T.T.	4250'	Jer. cherry	R	112	100	14		12			1	125
3278	"	"	"	" "	R	119	100	6		5				50
3279	"	"	"	" "	R	116	100	16		15	1			138
3280	"	"	"	" "	R	126	100	2		2				16
3281	"	"	"	" "	R	140	132	16		14				114
3282	6/5	Hilo	75'	Mango	R	868	10	27	17					31
3283	"	"	"	"	R	896	10	39	25				1	44
3284	"	"	"	"	R	756	10	3	3					4
3285	"	"	"	"	R	784	10	0						0
3286	"	"	"	"	R	770	10	8	3					10
3287	"	"	"	"	R	875	10	14	4				5	16
3288	"	"	"	"	R	924	10	14	6				5	15
3289	"	"	"	"	R	763	10	76	45				11	100
3290	"	"	"	"	R	854	10	6	4					7
3291	"	"	"	"	R	1204	14	19	11			1	1	16
3292	6/6	Piihonua	800'	Guava	R	1232	12	117	37			16	44	95
3293	"	"	"	"	R	1190	12	120	45			17	36	101
3294	"	"	"	"	R	896	12	22	7				6	25
3295	"	"	"	"	R	903	12	82	26			8	16	91
3296	"	"	"	"	R	1008	12	71	18		1	6	18	70

Table 2 cont'd--Hawaii Fruit Collections.

Lot	Date	Locality	Elev.	Fruit	S	W	N	Pupae	Dor	Med	Lon	Per	Oop	Index
3297	6/6	Piihonua	800'	Guava	R	840	12	76	27			7	18	90
3298	"	"	"	"	R	784	12	66	22			6	11	84
3299	"	"	"	"	R	847	12	98	41			6	16	116
3300	"	"	"	"	R	756	12	61	22			10	14	81
3301	"	"	"	"	R	854	12	61	23			8	8	71
3302	"	"	"	"	R	910	12	139	75			6	13	153
3303	"	"	"	"	R	826	12	57	25			1	8	69
3304	"	"	"	"	R	763	12	51	21			11	7	67
3305	"	"	"	"	R	700	12	63	24			9	13	90
3306	"	"	"	"	R	588	12	3	2			1		5
3307	"	"	"	"	R	952	12	76	25			8	15	80
3308	"	"	"	"	R	840	12	24	2			5	3	29
3309	"	"	"	"	R	952	12	147	28			13	40	154
3310	"	"	"	"	R	700	12	43	15			7	11	61
3311	"	"	"	"	R	616	12	8				1	6	13
3312	"	"	"	"	R	1008	12	78	33			6	3	77
3313	"	"	"	"	R	784	12	32	8		1	4	7	41
3314	"	"	"	"	R	840	12	91	27		1	12	6	108
3315	"	"	"	"	R	672	12	16	3			1	2	24
3316	"	"	"	"	R	588	12	83	23			10	14	150
3317	"	"	"	"	R	826	12	16	2		2	2	4	19
3318	"	"	"	"	R	644	12	48	10		19	1	1	75
3319	"	"	"	"	R	1008	12	33	7			3	6	33
3320	"	"	"	"	R	840	12	32	7			2	1	38
3321	"	"	"	"	R	672	12	88	45			6	6	131
3322	"	"	"	"	R	892	12	13	3			1	3	15
3323	"	"	"	"	R	644	12	12	3				2	19
3324	"	"	"	"	R	1036	12	91	16		3	22	15	88
3325	"	"	"	"	R	952	12	38	15		1	5	1	40
3326	"	"	"	"	R	924	12	21	6			6	3	23

Table 2 cont'd--Hawaii Fruit Collections

Lot	Date	Locality	Elev.	Fruit	S	W	N	Pupae	Dor	Med	Lon	Per	Oop	Index
3327	6/6	Kaumana	1500'	Mangosteen	R	700	10	24	15					34
3328	"	"	"	"	R	616	10	6	4				1	10
3329	"	"	"	"	R	784	10	6	4					8
3330	"	"	"	"	R	924	14	11	6				2	12
3331	6/8	"	"	Guava	R	1316	12	79	31		1	5	17	60
3332	"	"	"	"	R	840	12	112	28			23	19	133
3333	"	"	"	"	R	1148	12	90	4		1	12	21	78
3334	"	"	"	"	R	1260	12	190	50		9	34	41	151
3335	"	"	"	"	R	1092	12	67	9			15	16	61
3336	"	"	"	"	R	896	12	157	44			33	41	175
3337	"	"	"	"	R	1274	12	36	44			5	8	28
3338	"	"	"	"	R	1064	12	115	27		2	18	21	108
3339	"	"	"	"	R	1148	12	40	4			26	19	35
3340	"	"	"	"	R	1176	12	74	1		1	24	11	63
3341	"	"	"	"	R	1232	12	72	8		3	10	11	58
3342	"	"	"	"	R	784	8	65	8			18	9	83
3343	"	"	"	"	R	1176	12	335	140			10	20	285
3344	"	"	"	"	R	952	12	331	75			56	71	348
3345	"	"	"	"	R	980	12	285	118			40	74	291
3346	"	"	"	"	R	1288	12	330	128			59	88	256
3347	"	"	"	"	R	896	12	124	17			32	30	138
3348	"	Piihonua	800'	"	R	1064	12	44	7			11	11	41
3349	"	"	"	"	R	868	12	29	8			5	6	33
3350	"	"	"	"	R	854	12	104	20			19	27	122
3351	"	"	"	"	R	1232	12	80	10		1	19	22	65
3352	"	Hilo	75'	Mango	R	1120	10	185	87			5	3	165
3353	"	"	"	"	R	1036	10	107	25			3	8	103
3354	"	"	"	"	R	1204	10	175	83			3	3	145
3355	"	"	"	"	R	1127	10	64	33			1	2	57
3356	"	"	"	"	R	1239	10	95	64					77
3357	"	"	"	"	R	1092	10	38	20				5	35
3358	"	"	"	"	R	1078	9	175	63			6	5	162

Table 2 cont'd--Hawaii Fruit Collections.

Lot	Date	Locality	Elev.	Fruit	S	W	N	Pupae	Dor	Med	Lon	Per	Oop	Index
3359	6/11	M.L.T.T. Kipuka Ki	4250'	Jer.cherry	R	105	100	120	3	98	2			1143
3360	"	Ohaikea	3750'	"	R	98	100	152		140	1			1551
3361	6/18	M.L.T.T.	4000'	"	R	126	100	192	44	88	2	1		1524
3362	"	"	4250'	"	R	105	100	150		117	21		8	1429
3363	"	Ohaikea	3750'	"	R	196	100	130	2	128				663
3364	6/25	"	"	"	R	55	100	8		7				145
3365	"	M.L.T.T. Kipuka Ki	4250'	"	R	124	100	67	1	63				540
3366	"	M.L.T.T.	4000'	"	R	77	100	1	1					13
3367	"	"	"	"	R	35	28	1	1					29
3368	"	"	4250'	"	R	112	100	61	5	50	1			545
3369	"	"	3650'	"	R	175	200	86		82				491
3370	6/30	Keanakolu	5200'	Portuguese squash	R	65	1	26		23	Melon			400
3371	7/9	M L.T.T.	4000'	Jer. cherry	R	98	100	1	1					10
3372	"	"	4250'	"	R	119	100	10		8				84
3373	"	Ohaikea	3600'	"	R	112	100	16		14		1		143
3374	7/16	M.L.T.T.	4000'	"	R	105	100	29	6	12		1		276
3375	"	"	4250'	"	R	112	100	132		118		1		1179
3376	"	Ohaikea	3600'	"	R	119	100	24		21		1		202
3377	7/18	Keanakolu	5200'	Red plum	R	896	23	0						0
3378	"	"	"	"	R	165	4	0						0
3379	"	"	"	P.mollissima	R	192	3	0						0
3380	"	"	"	Poha	R	61	23	0						0
3381	"	"	"	Apple	R	54	2	0						0
3382	7/23	Ohaikea	3600'	Jer.cherry	R	93	100	12	1	3		1		129
3383	"	"	3550'	"	R	91	100	57	4	44		1		626
3384	"	M.L.T.T.	4000'	"	R	82	100	44	23	3				537
3385	"	"	"	"	R	85	100	30	16	4			1	353
3386	"	"	4250'	"	R	103	100	70	2	54				680
3387	"	"	"	"	R	104	100	126		101	5	5	1	1212
3388	"	"	4600'	"	R	103	100	18		15		1		175
3389	7/26	"	4000'	"	R	112	100	68	12	18		3	8	607
3390	"	"	"	"	R	119	100	99	37	5		7	8	832

Table 2 cont'd--Hawaii Fruit Collections.

Lot	Date	Locality	Elev.	Fruit	S	W	N	Pupae	Dor	Med	Lon	Per	Oop	Index
3391	7/26	Ohaikea	3650'	Jer.cherry	R	116	100	0						0
3392	"	"	"	"	R	126	100	1	1					8
3393	"	"	3700'	"	R	294	200	282	24	150	6	12	35	959
3394	"	"	"	"	R	273	200	329	17	191	3	23	41	1205
3395	7/30	"	3650'	"	R	110	100	28	8	14	1	2	1	255
3396	"	"	3600'	"	R	96	100	36	4	16		1	2	375
3397	"	M.L.T.T.	4000'	"	R	75	100	91	12	30		3	4	1213
3398	"	"	"	"	R	95	100	54	5	25		1		568
3399	"	"	4240'	"	R	106	100	136		113	7			1283
3400	"	"	4250'	"	R	98	100	181		140	21			1847
3401	"	"	4600'	"	R	116	100	25		22				216
3402	"	"	"	"	R	107	100	35		29				327
3403	"	"	5100'	"	R	108	100	0						0
3404	"	"	"	"	R	103	100	0						0
3405	8/6	Ohaikea	3600'	"	R	84	100	41	6	16		3	2	488
3406	"	"	3650'	"	R	119	100	158	23	108		3	7	1328
3407	"	M.L.T.T.	4000'	"	R	112	100	91	29	12	1	8	9	813
3408	"	"	"	"	R	105	100	58	17	5		5	2	552
3409	"	"	4240'	"	R	115	100	135	4	107	14			1174
3410	"	"	4250'	"	R	116	100	220		163	31		4	1897
3411	"	"	4600'	"	R	140	100	144		122	18			1029
3412	"	"	4600'	"	R	147	100	60	13	44	1			408
3413	"	"	5100'	"	R	107	100	0						0
3414	"	"	"	"	R	126	100	0						0
3415	8/13	Ohaikea	3600'	"	R	82	100	20	9	5	1	1		244
3416	"	"	3650'	"	R	96	100	121	24	63	3	8	8	1260
3417	"	M.L.T.T.	4000'	"	R	87	100	45	27	3	1	2		517
3418	"	"	4240'	"	R	94	100	102	4	59	22			1085
3419	"	"	4250'	"	R	103	100	167	3	108	32			1621
3420	"	"	4600'	"	R	113	100	126		118	1			1115
3421	"	"	"	"	R	131	100	91		88	2			695

Table 2 cont'd—Hawaii Fruit Collections.

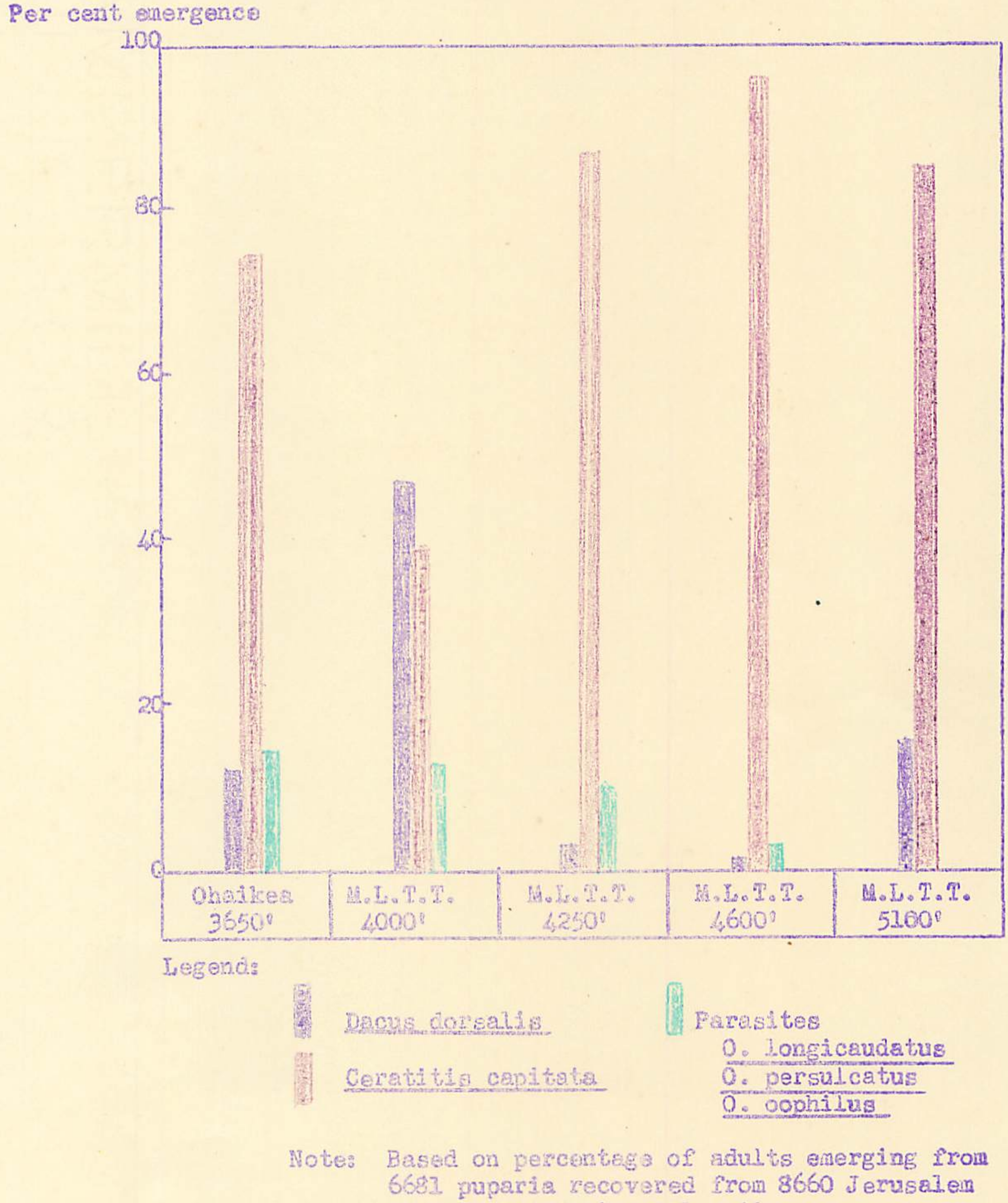
Lot	Date	Locality	Elev.	Fruit	S	W	N	Pupae	Bor	Med	Lon	Per	Oop	Index
3422	8/20	M.L.T.T.	5100'	Jer.cherry	R	81	100	0						0
3423	"	"	4600'	"	R	109	100	90		86	3			826
3424	"	"	"	"	R	114	100	109		95				956
3425	"	"	4250'	"	R	105	100	112	2	88	3			1067
3426	"	"	4240'	"	R	101	100	45		43				446
3427	"	"	4000'	"	R	93	100	46	19	7		3	1	495
3428	8/23	Ohaikea	3600'	"	R	112	100	16	2	11		1		143
3429	"	"	3650'	"	R	115	100	136	19	72	11	3		1183
3430	8/27	"	"	"	R	96	100	129	23	54		9		1344
3431	"	M.L.T.T.	4000'	"	R	97	100	13	5	2		2		134
3432	"	"	4240'	"	R	105	100	114		110				1086
3433	"	"	4250'	"	R	122	100	114	5	94	3	1		934
3434	"	"	4600'	"	R	131	100	167		161				1275
3435	"	"	5100'	"	R	94	100	3		3				32
3436	9/3	Ohaikea	3650'	"	R	79	100	96	15	54	1	4	2	1215
3437	"	M.L.T.T.	4240'	"	R	103	100	73	3	64				709
3438	"	"	4250'	"	R	123	100	207	7	161				1683
3439	"	"	4600'	"	R	125	100	112	2	104				896
3440	"	"	5100'	"	R	87	100	0						0
3441	9/10	Ohaikea	3650'	"	R	93	100	129	11	83	6	3	10	1387
3442	"	M.L.T.T.	4240'	"	R	99	100	126	12	104	2			1273
3443	"	"	4250'	"	R	112	100	186	5	157	12	2		1661
3444	"	"	4600'	"	R	136	100	188	1	162	1		6	1382
3445	"	"	5100'	"	R	93	100	19	3	14				204

FRUIT COLLECTION SUMMATION

No. lots	Weight	No. Fruit	Pupae	Dor	Med	Lon	Per	Oop	Index
169	82,677	9,801	12,724	2479 (26%)	4721 (50%)	286 (3%)	843 (9%)	1173 (12%)	154

Figure 1. Fruit fly and parasite emergences on the Mauna Loa Truck Trail and Ohaikea.

June 4 to September 10, 1951.



Note: Based on percentage of adults emerging from 6681 puparia recovered from 8660 Jerusalem cherries at various elevations.

Parasites believed to be of dorsalis origin.

Line Project I-o-1-5.--Population Trends of *D. dorsalis* Hendel.

Excellent weather conditions and a good crop of mangoes and guavas during the summer months resulted in an increase in fly populations at Hilo and Kupaahu, Puna. According to the U. S. Weather Bureau, the month of September, 1951 in comparison with past September months was the driest recorded in fifty years. Rainfall was 3.10 inches.

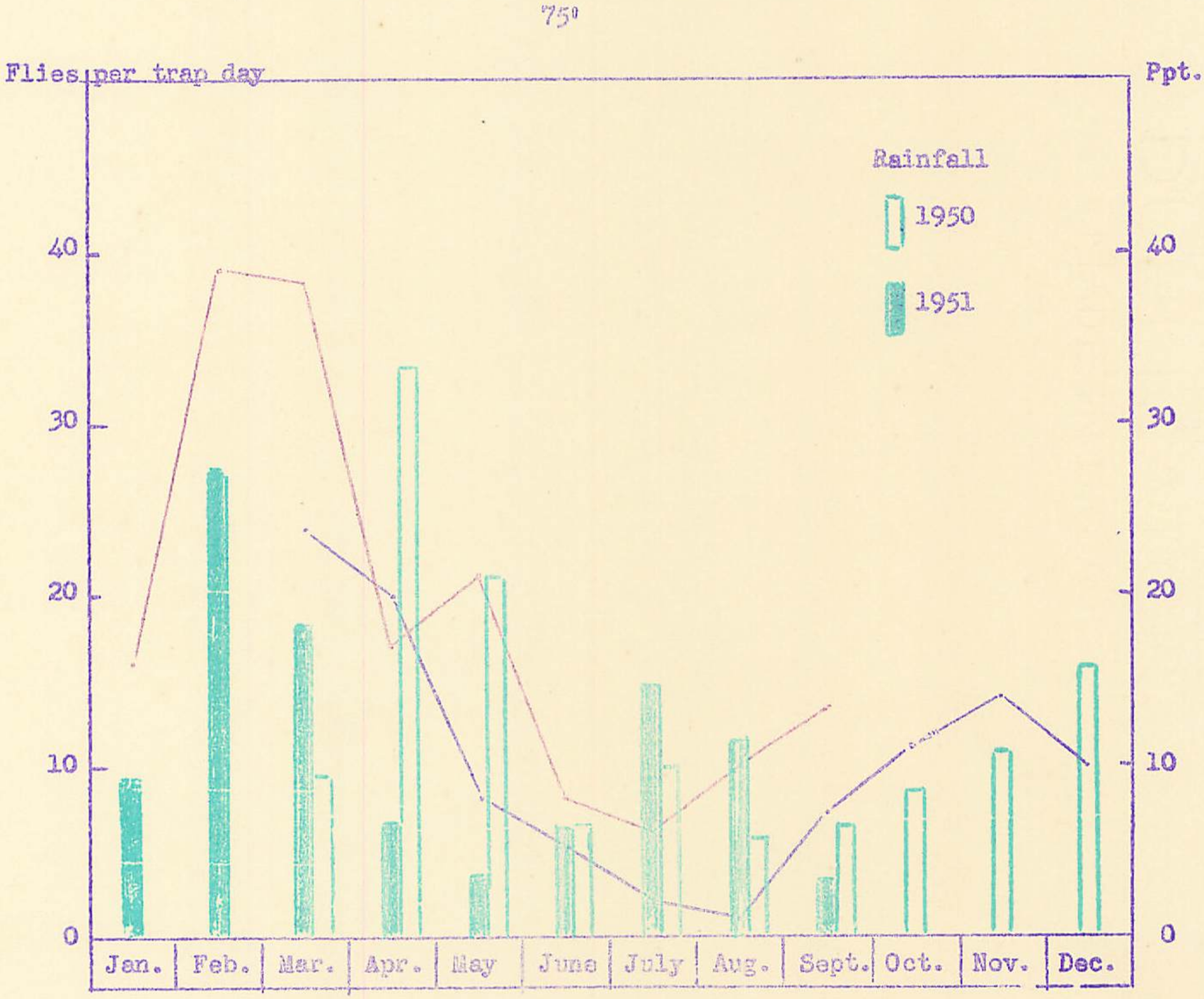
Fly populations at Hilo as determined by trap catches are a little higher this year than the preceding year. The trends, however, are remarkably similar. Kupaahu, the highest fly populated area on this island has maintained its high population although fluctuating in certain months. Because of favorable conditions, further increases in fly populations are anticipated at Hilo and Kupaahu.

Fly activity on the Mauna Loa Truck Trail and at Ohaikea declined during the past three months, and appears to follow the 1950 seasonal trend. Jerusalem cherries have been fruiting abundantly at the Truck Trail from 4000 to 5100 feet, but the fly catch has been disappointingly low. This area has been and still is an unpredictable area.

Kona's trapping and weather data have been furnished through the able assistance of Edward Fukunaga, Assistant Agriculturist with the University Experiment Station, Kona branch. Kona's fly populations as noted on the graph have dropped to a very low level.

The population trends at various locations on Hawaii are depicted in Figures 2 to 7 inclusive, and the data are summarized in tables 3 to 8, inclusive.

Figure 2. Population trends, Hilo Citrus Orchard.



Legend:

Population trends

1950

1951

Glass invaginated traps and citronella lure.

Graphic information based on 39,066 flies.

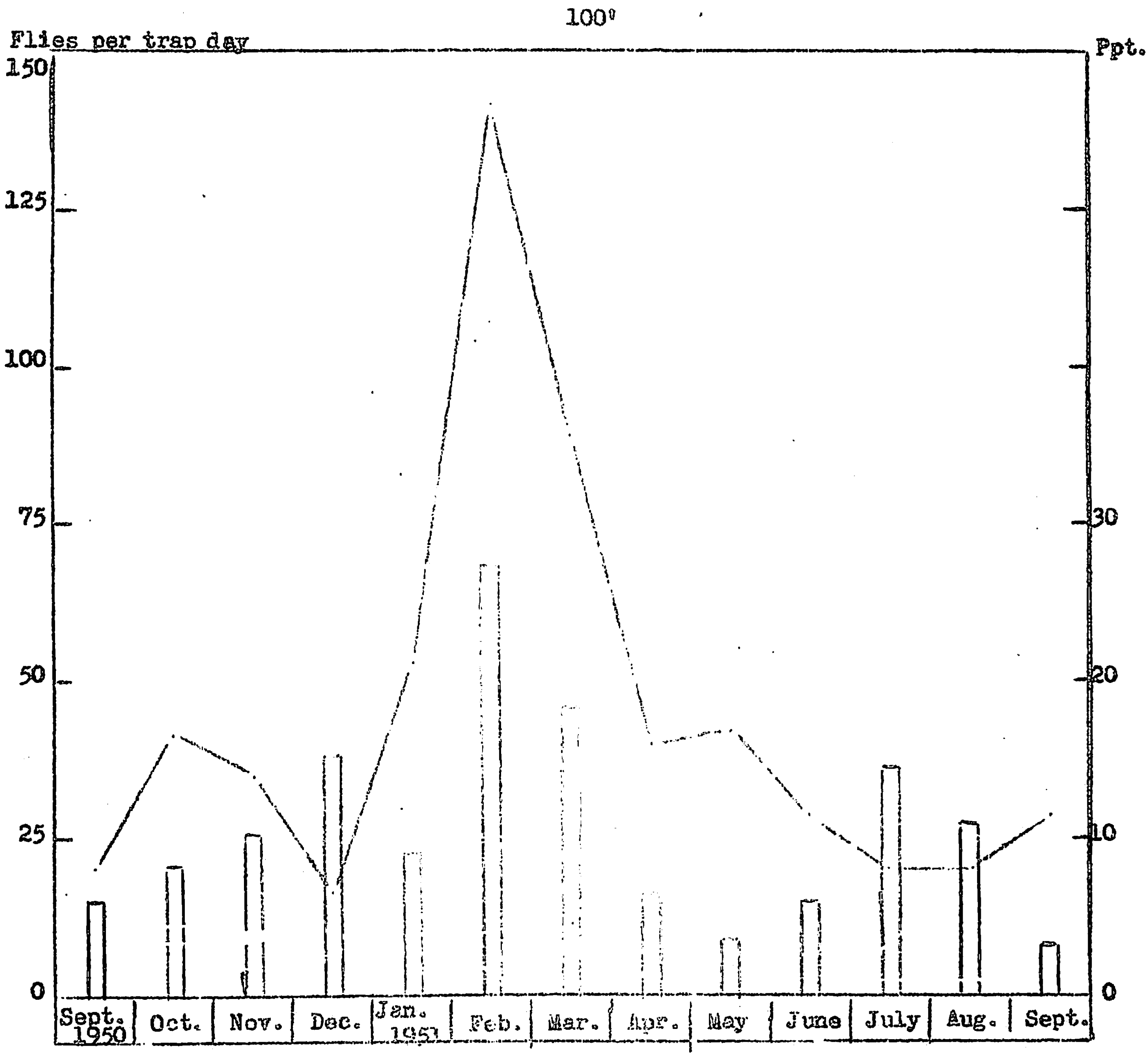
Excellent weather conditions and a good crop of mangoes and guavas during August and September resulted in the rise of fly populations.

Table 3. Population Trends, Hilo Citrus Orchard.

75'

Month	Ppt.	Trap Days	Fly Count	Index
March '50	9.04	115	2,779	24
April	33.45	140	2,796	20
May	21.04	175	1,455	8
June	6.27	140	698	5
July	9.88	140	251	2
August	5.63	175	176	1
September	6.30	140	955	7
October	8.45	170	1,899	11
November	10.67	140	1,947	14
December	15.55	140	1,344	10
January '51	9.28	175	2,718	16
February	27.78	140	5,436	39
March	18.39	140	5,386	38
April	6.48	140	2,324	17
May	3.46	175	3,693	21
June	6.01	140	1,149	8
July	14.45	175	1,062	6
August	11.09	119	1,237	10
September	3.10	140	1,761	13
Total	226.32	2,819	39,066	14

Figure 3.--Population Trends, Waiakea, Hilo



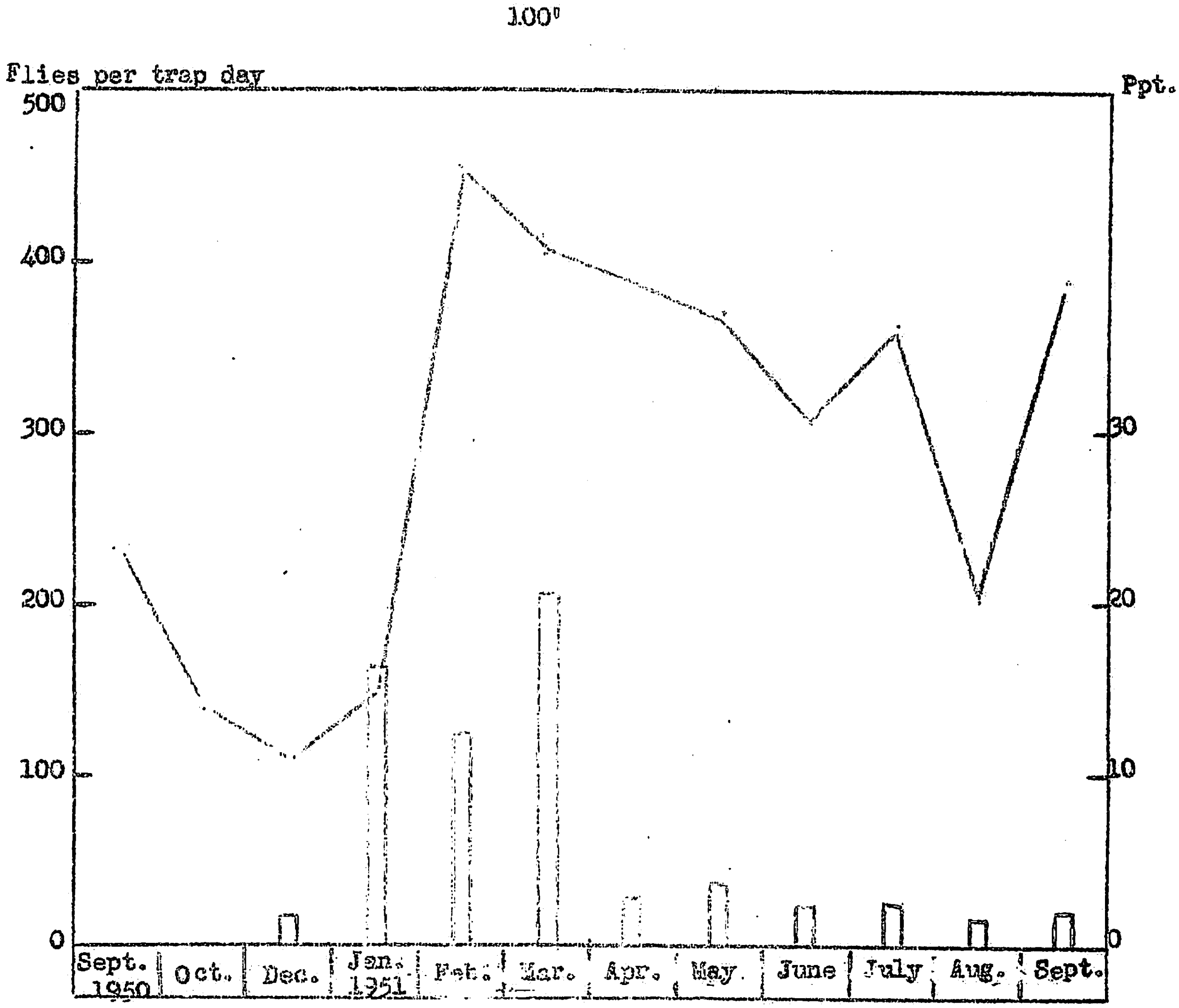
Legend:
Population trends
Monthly rainfall
Glass invaginated traps and citronella lure.
Graphic information based on 69,151 flies.
Fly population increased only in September, but with good host availability and continued good weather, an upward trend is predicted.

Table 4. Population Trends, Waiakea, Hilo.

100'

Month	Ppt.	Trap Days	Fly Count	Index
Sept. '50	6.30	112	2,352	21
October	8.45	140	5,951	42
November	10.67	112	3,944	35
December	15.55	112	1,956	17
January '51	9.28	140	7,360	53
February	27.78	112	15,919	142
March	18.39	112	9,962	89
April	6.48	112	4,462	40
May	3.46	140	5,916	42
June	6.01	112	3,103	28
July	14.45	140	2,835	20
August	11.09	112	2,279	20
September	3.10	112	3,112	28
Total	141.01	1,568	69,151	44

Figure 4.--Population Trends, Kupaahu, Puna



Legend:

—— Population trends

Monthly rainfall

Glass invaginated traps and citronella lure

Graphic information based on 502,108 flies.

Favorable weather conditions and a heavy crop of mangoes and guavas have maintained the fly populations at a high level. A total of 6.39 inches of rain was recorded for the period of July to September.

Table 5.--Population Trends, Kupaahu, Puna.

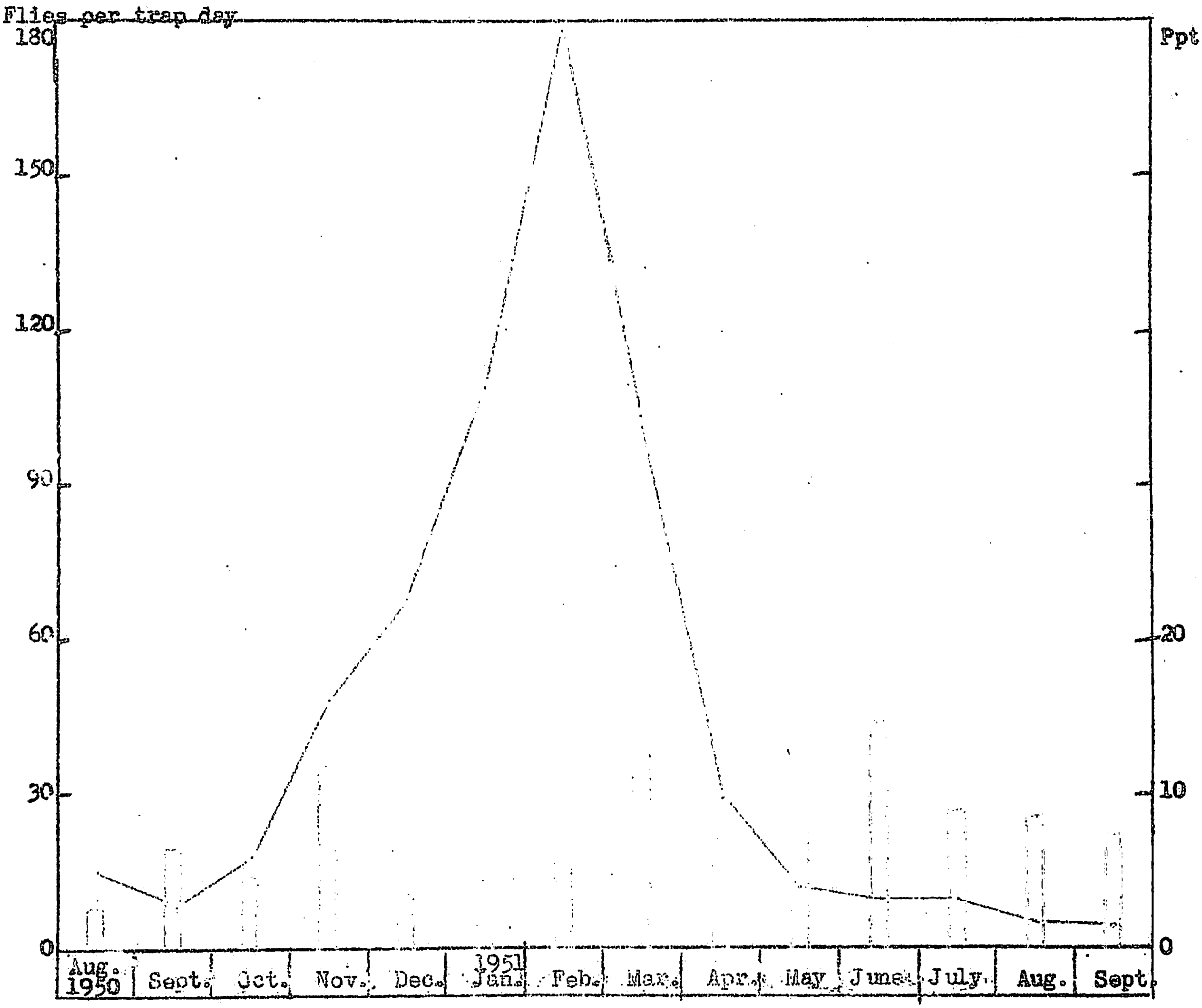
100'

Month	Ppt.	Trap days	Fly Count	Index
Sept. 1950	-	140	33,099	236
October	-	35	4,885	140
December	*1.77	150	16,462	110
January'51	16.11	160	23,894	149
February	12.62	140	63,291	452
March	20.67	140	56,792	406
April	2.91	161	62,475	388
May	3.62	140	51,566	368
June	2.36	145	44,861	309
July	2.74	175	62,880	359
August	1.65	140	28,390	203
September	2.00	140	53,513	382
Total	66.45	1666	502,108	301

*December 11 to December 28, 1950.

Figure 5.--Population Trends, Hawaii Experiment Station, Kona Branch, Kainaliu, Kona, Hawaii.

1700'



Legend:

Population trends

Monthly rainfall.

Glass invaginated traps and citronella lure.

Graphic information based on 73,444 flies.

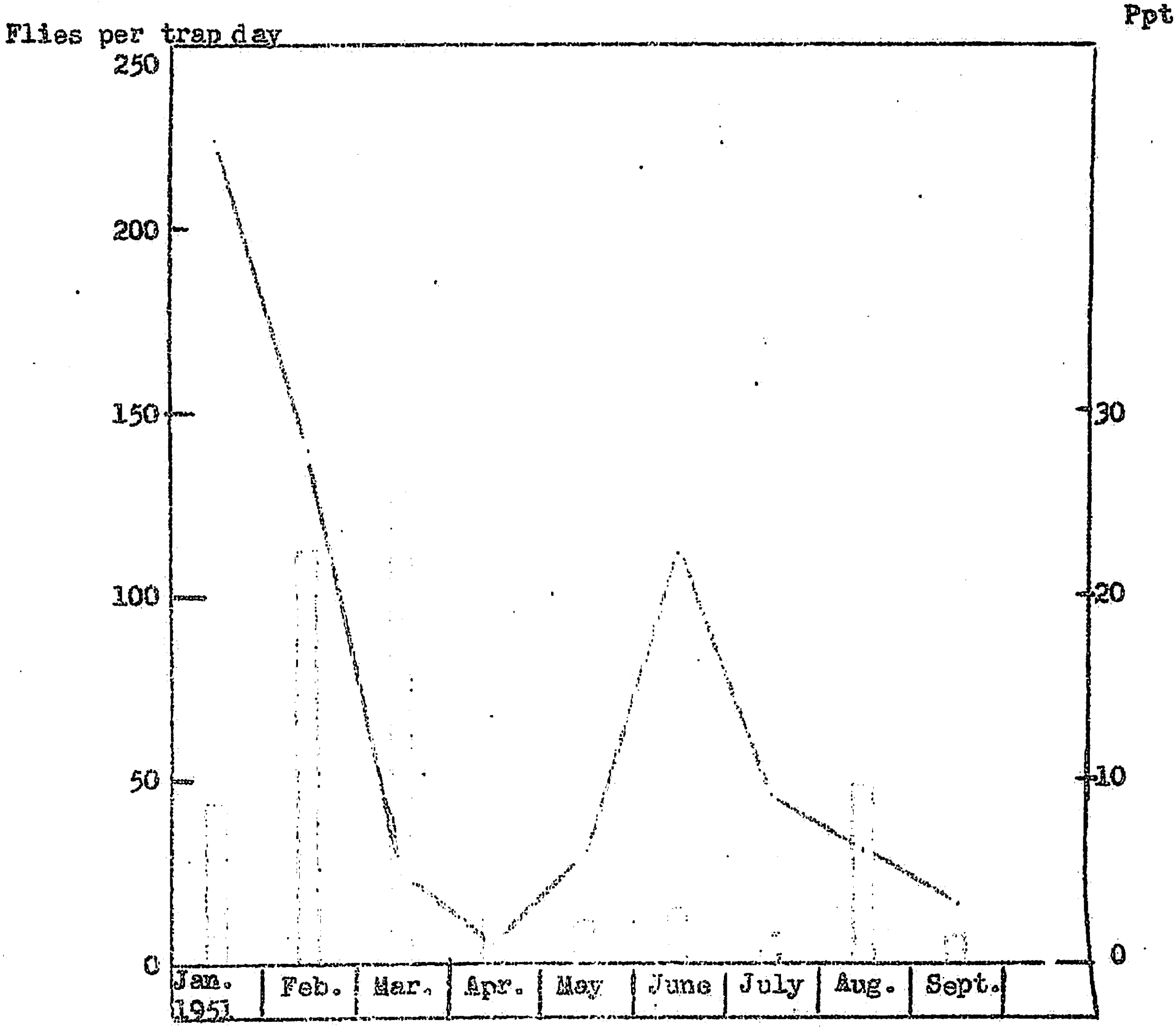
Fly trapping and weather data have been furnished through the courtesy of Edward Fukunaga, Assistant Agriculturist with the University Experiment Station, Kona branch.

Table 6. Population trends, Hawaii Experiment Station, Kona Branch, Kainaliu, Kona, Hawaii. 1700'.

Month	Ppt.	Trap Days	Fly Count	Index
August 1950	2.45	56	830	15
September	6.34	112	880	8
October	4.45	140	2,469	18
November	11.84	112	5,397	48
December	3.34	112	7,662	68
January 1951	4.27	140	15,244	109
February	5.71	112	19,920	178
March	12.50	116	12,045	104
April	6.97	136	3,991	29
May	7.24	112	1,302	12
June	14.72	112	1,159	10
July	8.89	140	1,509	10
August	8.75	112	573	5
September	7.37	112	473	4
TOTALS	104.84	1,624	73,444	45

Figure 6. Population Trends, Ohaikea, Kau

3650'



Legend:

Population trends
Monthly rainfall.
Glass invaginated traps and citronella lure.
Graphic information based on 22,546 flies.
Jerusalem Cherries are sporadic presently at Ohaikea and this may account for the drop in fly population.

Table 7. Population Trends, Ohaikea

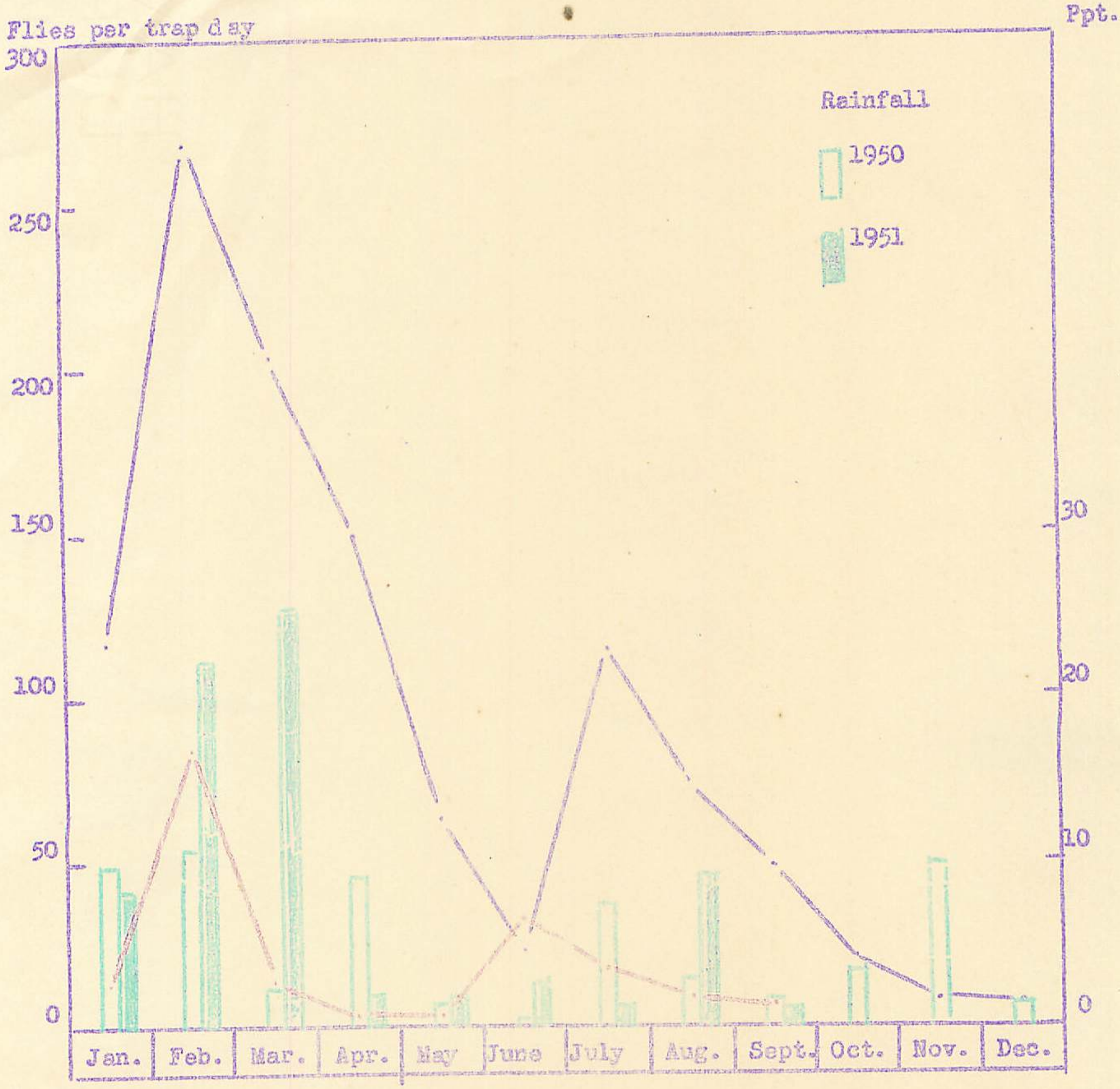
3650'

1951

Month	Ppt.	Trap Days	Fly Count	Index
January	8.41	7	1,561	223
February	22.37	42	5,851	139
March	25.72	56	1,393	25
April	2.10	56	353	6
May	2.00	56	1,668	30
June	2.99	56	6,245	112
July	1.51	63	2,880	46
August	9.43	56	1,710	31
September	1.32	56	885	16
Totals	75.85	448	22,546	50

Figure 7. Population trends, Mauna Loa Truck Trail, Hawaii National Park.

4000-5100'



Legend:

—— Population trends - 1950
- - - - " " - 1951

Glass invaginated traps and citronella lure.
Graphic information based on 233,048 flies.
Population trends appear to be similar to the 1950 pattern, although very much lower.

Table 8.—Population Trends on Mauna Loa Truck Trail.

4000-5100'

1950

Month	Ppt.	Trap Days	Fly Count	Index
January	10.00	196	26,127	133
February	10.96	231	62,069	269
March	2.56	196	39,850	203
April	9.34	196	29,344	150
May	1.56	245	15,736	64
June	.27	196	4,615	24
July	7.50	245	28,083	115
August	3.04	196	14,537	74
September	1.85	196	9,564	49
October	3.44	245	5,051	21
November	9.80	196	1,625	8
December	1.23	217	1,447	7
Total	61.51	2,555	238,048	93

1951

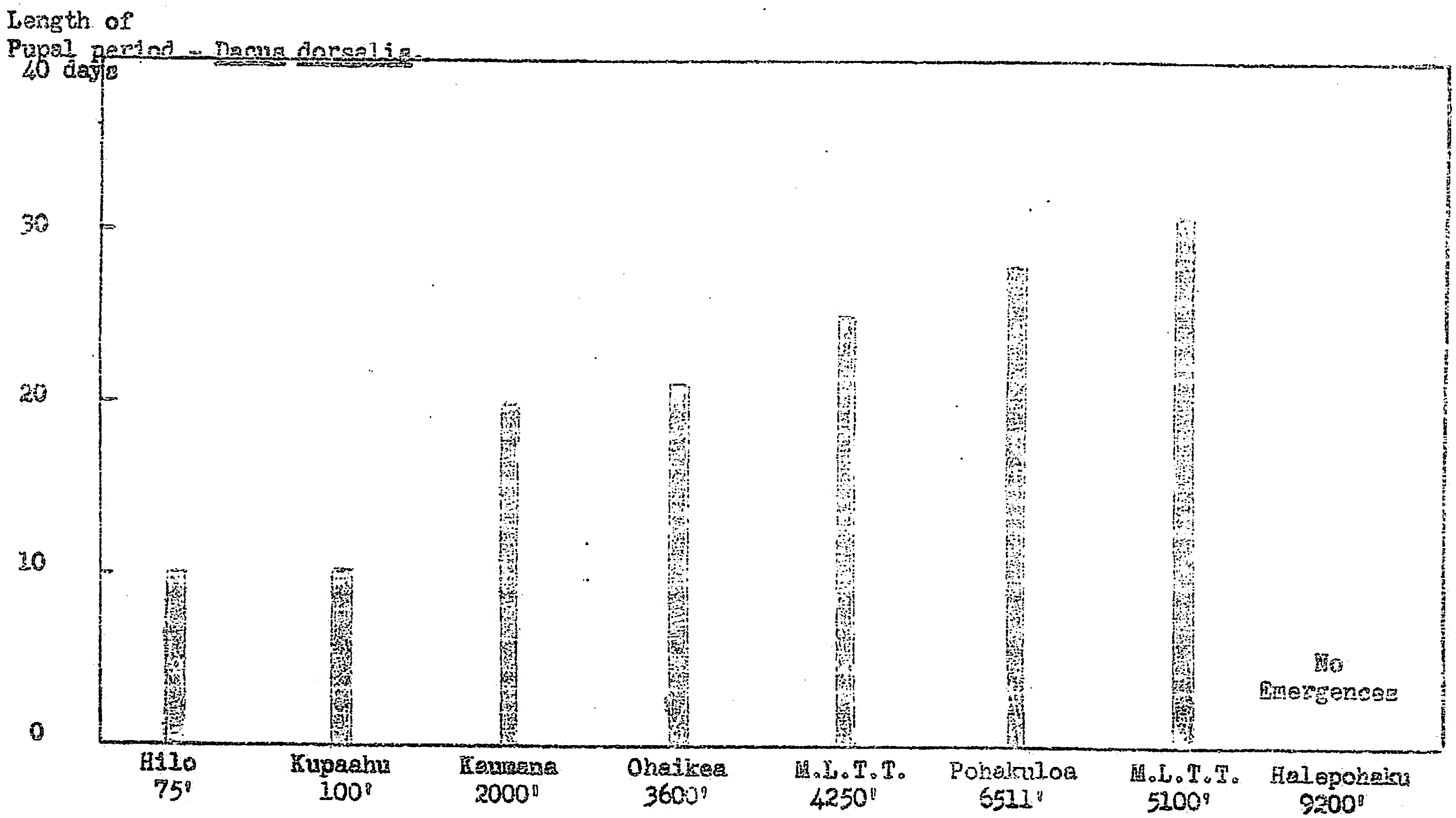
Month	Ppt.	Trap Days	Fly Count	Index
January	8.41	203	2,677	13
February	22.37	112	9,411	84
March	25.72	112	1,496	13
April	2.10	140	378	3
May	2.00	112	456	4
June	2.99	112	3,740	33
July	1.51	140	2,492	18
August	9.43	112	1,086	10
September	1.32	112	742	7
Total	75.85	1,155	22,478	19

Line Project I-o-1-2.--Effect of Climate on the Oriental Fruit Fly Under Field Conditions.

Pupal Studies.--The oriental fruit fly completed its pupal period at all field stations with the exception of the one at 9200 feet, during the quarter. The individual records for each of the experiments completed will not be given in this report. The general influence of the different temperature conditions found at the various elevations (see table 1) is depicted in figure 8.

Sexual Maturity Studies.--The influence of temperature on the development of the sexual maturity of the oriental fruit fly is presented in tables 9 to 16, inclusive.

Figure 8.--Summation of pupal studies, Hawaii. June 1951 - August 1951.



Note: Pupal studies were carried on with 25 puparia covered with dry sand and held in sandwich boxes inside the weather shelter.
Pupal duration for the above graph are for the months of June-September.

Table 9. Sexual maturity studies on Hawaii. HILO 75°

Legend:
* Diet supplemented with protein
○ Eggs recovered which did not hatch.
⊕ Viable eggs.

Legend:
---- D: *Dacus dorsalis*
—— M: *Ceratitis capitata*
- - - C: *Dacus cucurbitae*

	May		June		July		August		September	
Abs. Max. Mean Max.	82	79.6	86	81.1	85	80.2	87	82.5	90	84.1
Abs. Min. Mean Min.	63	65.5	65	67.9	64	68.3	66	69.6	65	70.5
* Exp. 2215 lot 1 D			⊢----⊕							
* Exp. 2215 Lot 2 D			⊢----⊕							
* Exp. 2289 Lot 1 D					----○⊕					
* Exp. 2289 Lot 2 D					⊢----○⊕					
Exp. 2289 Lot 3 D					⊢------○⊕					
* Exp. 2301 Lot 1 M					⊢—○⊕					
Exp. 2301 Lot 2 M					⊢—○⊕					
* Exp. 2333 Lot 1 D					⊢----⊕					
Exp. 2333 Lot 2 D					⊢--------		--⊕			
* Exp. 2367 D							⊢----⊕			
* Exp. 2375 M							⊢—⊕			
* Exp. 2391 D							⊢----⊕			
* Exp. 2431 D								⊢----⊕		
* Exp. 2479 D									⊢----⊕	
* Exp. 2495 D									⊢----⊕	
* Exp. 2505 C									⊢- - -⊕	
* Exp. 2519 D									⊢----⊕	
* Exp. 2531 D										⊢----⊕

Table 10.--Sexual maturity studies on Hawaii - KUPAAHU 100'

Legend:
- * Diet supplemented with protein
- O Eggs recovered which did not hatch
- ⊕ Viable eggs
- —— D: *Dacus dorsalis*
- —— M: *Ceratitis capitata*

		April		May		June		July		August	
Abs. Max.	Mean Max.	84	81.0	84	81.8	86	83.4	88	84.5	89	84.7
Abs. Min.	Mean Min.	64	66.8	66	67.9	67	69.1	66	70.8	68	70.9
* Exp. 2291 D							├	──⊕			
* Exp. 2291 Lot 1 D							├	──⊕			
Exp. 2291 Lot 2 D							├	────⊕			
* Exp. 2299 M								├──⊕			
* Exp. 2299 Lot 1 M								├──⊕			
Exp. 2299 Lot 2 M								├──⊕			
* Exp. 2331 D Large cage								├──⊕			
* Exp. 2331 Lot 1 D								├──⊕			
* Exp. 2331 Lot 2 D								├────	──┤		

Table 11.--Sexual maturity studies on Hawaii - KAUMANA 2000'

Legend:
* Diet supplemented with protein
O Eggs recovered which did not hatch
⊕ Viable eggs

Legend:
---- D: *Dacus dorsalis*
—— M: *Ceratitis capitata*

		March		April		May		June		July	
Abs. Max.	Mean Max.	85	71.7	76	70.8	76	74.0	78	74.4	80	74.6
Abs. Min.	Mean Min.	53	57.1	51	56.2	52	55.8	54	58.0	55	60.4
* Exp. 2293 D Large cage										|- - - -⊕	
* Exp. 2293 Lot 1 D										|- - - -⊕	
Exp. 2293 Lot 2 D										|- - - -⊕	
* Exp. 2325 D Large cage										|- - - -⊕	
* Exp. 2325 Lot 1 D										|- - - -⊕	
Exp. 2325 Lot 2 D										|- - - - -|	

Table 12.--Sexual maturity studies on Hawaii--OHAIKEA 3600'

Legend:
- * Diet supplemented with protein
- O Eggs recovered which did not hatch
- ⊕ Viable eggs

Legend:
- —— D: Dacus dorsalis
- ══ M: Ceratitis capitata
- -·-· C: Dacus cucurbitae

		May		June		July		Aug.		September	
Abs. Max.	Mean Max	76	72.4	79	73.6	82	76.2	83	77.2	83	78.3
Abs. Min.	Mean Min	47	51.0	48	53.3	50	55.8	50	55.7	47	53.0
* Exp. 2161 D											
* Exp. 2307 M						|——⊕					
* Exp. 2369 D Large cage								|——⊕			
* Exp 2369 Lot 1 D								|——⊕			
* Exp. 2377 M Large cage								|——⊕			
* Exp. 2377 Lot 1 M								|——⊕			
* Exp. 2397 D								|——⊕			
* Exp. 2433 D								|——⊕			
* Exp. 2481 D										|——⊕	
* Exp. 2497 D Large cage										|——⊕	
* Exp. 2497 Lot 1 D										|——⊕	
* Exp. 2505 C Large cage										|——⊕	
* Exp. 2505 Lot 1 C										|——O	
* Exp. 2521 D										|——⊕	

Table 13.--Sexual Maturity Studies on Hawaii.--M.L.T.T. 4250'

Legend:
* Diet supplemented with protein
○ Eggs recovered which did not hatch.
⊕ Viable eggs

Legend:
- - - D: *Dacus dorsalis*
——— M: *Ceratitis capitata*
- · - C: *Dacus cucurbitae*

		May		June		July		August		September	
Abs. Max.	Mean Max.	78	74.0	78	74.8	73	73.1	78	73.1	80	75.1
Abs. Min.	Mean Min.	45	46.5	46	47.8	50	55.0	49	54.7	46	52.8
* Exp. 2157 D				———	———						
* Exp. 2303 M						|——⊕					
* Exp. 2371 D								|——○⊕			
* Exp. 2379 M								|——⊕			
* Exp. 2393 D								|———	———	⊕	
* Exp. 2435 D									|———	——⊕	
* Exp. 2483 D										|———	——⊕
* Exp. 2499 D										|———	—⊕
* Exp. 2507 C										|———	—⊕

Table 14.--Sexual maturity studies on Hawaii.--M.L.T.T. 5100'

Legend:
- * Diet supplemented with protein
- ○ Eggs recovered which did not hatch.
- ⊕ Viable eggs

Legend:
- ------- D: *Dacus dorsalis*
- .... M: *Ceratitis capitata*
- -.-.-.- C: *Dacus cucurbitae*

		May		June		July		August		September	
Abs. Max.	Mean Max.	71	67.3	73	68.6	78	72.0	77	71.9	78	73.7
Abs. Min.	Mean Min.	38	45.4	42	48.3	44	51.2	42	51.3	43	48.6
* Exp. 2159 D				----------		⊕					
* Exp. 2305 M						|---○---⊕					
* Exp. 2373 D Large cage								|----------○⊕			
* Exp. 2373 Lot 1 D								| ---------⊕			
* Exp. 2381 M Large cage								|-------⊕			
* Exp. 2381 Lot 1 M								|-------⊕			
* Exp. 2395 D								|-------○			
* Exp. 2437 D								|------------		○⊕	
* Exp. 2485 D										|---------|	
* Exp. 2501 D Large cage										|-------------⊕	
* Exp. 2501 Lot 1 D										|--------|	
* Exp. 2509 C Large Cage										|--------⊕	
* Exp. 2509 Lot 1 C										|--------⊕	

Table 15.—Sexual maturity studies on Hawaii.—POHAKULOA 6511'.

Legend:
- * Diet supplemented with protein
- ○ Eggs recovered which did not hatch.
- ⊕ Viable eggs.
- ---- D: *Dacus dorsalis*
- —— M: *Ceratitis capitata*

		April		May		June		July		August	
Abs. Max.	Mean Max.	77	70.9	76	71.1	79	74.1	83	76.3	80	74.3
Abs. Min.	Mean Min.	32	39.9	34	40.4	36	41.9	41	47.7	36	46.5
* Exp. 2077 M											
Exp. 2081 M											
* Exp. 2109 Lot 1 D											
* Exp. 2109 Lot 2 D											
Exp. 2109 Lot 3 D											
**Exp. 2115 D Large cage											
*Exp. 2123 M Large cage											
* Exp. 2133 M											
* Exp. 2143 D											
* Exp. 2169 D											
* Exp. 2217 Lot 1 D											
* Exp. 2217 Lot 2 D											
* Exp. 2297 M Large cage											
* Exp. 2297 Lot 1 M											
Exp. 2297 Lot 2 M											
* Exp. 2329 D Large cage											
* Exp. 2329 Lot 1 D											
Exp. 2329 Lot 2 D											

Table 16.—Sexual maturity studies on Hawaii.—HALEPOHAKU 9200'.

Legend:
* Diet supplemented with protein
O Eggs recovered which did not hatch
⊕ Viable eggs

Legend:
D: *Dacus dorsalis*
—— M: *Ceratitis capitata*

		May		June		July		August		September	
Abs. Max.	Mean Max.	69	63.3	70	65.1	71	65.4	68	61.8	68	65.9
Abs. Min.	Mean Min.	36	41.5	36	42.9	35	44.6	37	41.8	39	42.6
Exp. 2071 D											
* Exp. 2101 M											
* Exp. 2107 Lot 1 D											
* Exp. 2107 Lot 2 D											
Exp. 2107 Lot 3 D											
* Exp. 2113 D Large cage											
* Exp. 2121 M Large cage											
* Exp. 2131 M											
* Exp. 2141 M											
Exp. 2171 D											
* Exp. 2295 M Large cage											
* Exp. 2295 Lot 1 M											
Exp. 2295 Lot 2 M											
* Exp. 2327 D Large cage											
* Exp. 2327 Lot 1 D											
Exp. 2327 Lot 2 D											

Line Project I-o-1-1. The Effect of Temperature and Humidity on the Oriental Fruit Fly Under Controlled Conditions. (N. E. Flitters, Bureau of Entomology and Plant Quarantine, P. S. Messenger, Univ. of California Agricultural Experiment Station.

SUMMARY

Seven climates were investigated in the bioclimatic cabinets during the past quarter, five of which were continuations of studies begun in the previous period. These latter stations are: Oceanside, Riverside, and Fresno, California, Fort Pierce, Florida, and Charleston, South Carolina and climates of these stations during the quarter passed from summer into early fall. Investigations of the climate of Vincennes, Indiana, was started at the beginning of the quarter, commencing with the early spring period. The climate of Haleakala, Maui, was discontinued due to insufficient yield of data, and the summer climate of the Kula ecological station, Maui, was substituted therefor.

In all climates simulated (with the exception of Haleakala) the climates have been noted for their increasing temperature trends. This has resulted in a concomitant increase in growth rate and fly reproduction in most cases, which in turn has necessitated a reclassification of suitability for fruit fly establishment and performance in one or two cases. In general the effect of rising average temperatures has been to increase the rate of growth of the larvae and pupae, to permit faster sexual development of adults, greater adult longevity, higher degrees of fruit infestation, and overall increases in progeny build-up. Divergent results were noted in certain climates. In cases where the diurnal range in temperature was relatively narrow longevity increased with average temperature. In cases where the diurnal range was wide longevities decreased as mean temperatures rose. This was due to the effect of lethal afternoon temperatures in these latter cases, though the average temperatures were ordinarily within the optimal range. In these cases of shortened adult longevities, a decrease in fruit infestation and resultant progeny recovery was also noted.

The Oceanside climate during the quarter was characterized by mild, gradually rising temperatures that mostly remained above 60°. Humidities were generally high. Adult longevity was increased with a maximum of 70 days in one instance. Fruit infestation was high, resulting in a heavy build-up of the progeny population. The progeny in turn produced an F-2 generation. The duration of the pre-imaginal growth period decreased from an initial 45 days to a low of about 35 days. In contrast with the approximately 400 progeny recovered during the previous quarter, over 5,500 flies were obtained in this quarter.

This has resulted in a reclassification of this climate relative to the evaluation of the last quarter. At that time, with the period of simulation being the spring and early summer seasons, the climate was considered borderline, or marginal. With the advent of the summer and early fall seasons the climate now is considered to be suitable for fruit fly growth and reproduction, though slightly suboptimal.

The Fresno climate, again characterized by wide diurnal fluctuations in temperature and by low humidities, remained optimal insofar as larval-pupal growth is concerned. However, the high afternoon temperatures during the quarter resulted in a considerable decrease in adult longevity, with a resultant decrease in fruit infestation. This was especially noted with the initially immature adult parents, which were killed off before very many reached sexual maturity. The progeny population built up to moderate levels early in the quarter, but began to decrease towards the latter half of this period. An F-2 generation was realized, though in small numbers. The growth rate of the larvae and pupae remained optimal until late in the quarter when it began to decrease due to falling fall temperatures. In contrast to more than 2,400 progeny recovered in the first quarter of study this quarter yielded less than 2,100.

Again this climate is considered optimal insofar as growth rate is concerned. On the other hand the lethal temperatures occasionally encountered, though apparently without effect upon growth rates, cause considerable adult mortality, and a resultant decrease in fruit infestation and progeny recovery.

The Charleston climate also remained optimal during the quarter, with mild temperatures and quite high humidities. Adult longevities were greater than previously. Fruit infestation was high, the immature stages developed at optimal rates throughout the quarter, and the progeny levels gradually increased until by the end of the quarter they reached over 3,800 in number. An F-2 generation was recovered. Almost 6,000 progeny were recovered in all, as contrasted with approximately 3,300 in the previous quarter.

This climate remains in the optimal class for the seasons simulated thus far.

The Vincennes climate was characterized by rather low temperatures initially, which gradually rose until at the end of the quarter they averaged about 80°. Humidities were relatively low throughout the quarter. Adult longevity was average. Although fruit infestation was fair progeny recovery was quite low until late in the quarter. Hence the progeny population level remained quite low. In all, just over 500 progeny were recovered.

The climate of Vincennes hence is considered marginal for the period simulated, much as was the Oceanside climate during a comparable period of the year. It is estimated, however, that the situation in this cabinet will gradually change toward greater suitability for fruit fly growth and reproduction with the coming summer season, again in a manner similar to that of Oceanside.

The Riverside climate, again characterized by wide diurnal fluctuations in temperature and humidity, also remained optimum as far as growth rate is concerned. Occasional high afternoon temperatures caused high adult mortalities and decreased fruit infestations. As a result the progeny level fell off during the last half of the quarter, until by the end of the period it had practically dropped to zero. An F-2 generation in small numbers was realized. The immature growth stages increased slightly at the end of the quarter with the approach of fall conditions. About the same number of progeny, 2,200, were recovered in this period as in the previous one.

This simulated climate again is considered optimum for fruit fly growth, but it was slightly too hot in the afternoons for any great amount of progeny build-up.

The Haleakala climate remained sub-marginal throughout, although several fruits were infested and pupae were recovered. In no case were pupae able to complete development to the adult stage. Hence no data were obtained on growth rates, preovipositional development, or reproduction. Adult longevity was average.

The Kula climate was not investigated in sufficient detail to obtain data on growth or reproduction. This will be given in detail in the next report.

The Fort Pierce climate remained optimum throughout the period of investigation. This climate enabled the highest degree of progeny recovery, the fastest rate of growth, and the highest degree of fruit infestation. During the quarter over 8,000 progeny were recovered, permitting the progeny population level to reach a record value of over 4,400 individuals. A high F-2 progeny level was also attained.

This climate is considered optimum for fruit fly development and reproduction and is expected to remain so for most of the fall period now being simulated.

By pooling the data from all the cabinets for the entire six months period of operation to date certain correlations are possible between average temperatures and fruit fly development and activity. It was found that below 58° no preovipositional development of adults occurs. At about 60° ~~for~~ this period takes around 35 days. The optimal period of sexual development occurs at 75° and above, taking about eight days. The rate of growth of the immature stages at 60° is about 60 days. Below this threshold growth is incomplete. The optimum rate of growth of the immature stages is reached at 84° and above and occurs in 20 days. Adult longevity increases with rising temperatures, but when the temperature during the day reaches 100° or more adult mortality greatly increases.

Of the five climates studied over the past six months only Fort Pierce and Charleston permitted the parent stocks to reproduce more than their own numbers of individuals. In the other cases reproduction only yielded moderate amounts of progeny. In most cases the recovery of adults from pupae amounted to about 50%, so that the possibility exists of even greater fruit fly reproduction.

It is concluded that for the seasons thus far investigated the climates of Fort Pierce, Charleston, and Oceanside are optimal for fruit fly development and reproduction, the climate of Vincennes is sub-optimal but has not yet entered the warmer, more suitable period, the climates of Riverside and Fresno are optimal for growth and development, but too hot for adult activity and resultant reproduction, and the climate of Haleakala is definitely sub-marginal.

Line Project I-c-1-1. The Effect of Temperature and Humidity on the Oriental Fruit Fly Under Controlled Conditions. (N. E. Flitters, B. E. P. Q., and P. S. Messenger, U. of Calif. Ag. Expt. Station)

Six months of practically uninterrupted climate simulation have now been accomplished in the bioclimatic cabinets. Starting with spring conditions for each locality under study the investigations thus far have proceeded through the more acceptable period of the year for the development and reproduction of Dacus dorsalis.

The data accumulated thus far clearly indicate an acceleration in the rate of development of the fruit flies coincidental with the increases in temperatures from spring through summer and into fall. Those climates that appeared sub-optimal for development and reproduction in the spring began improving with regard to temperature and humidity until at present a revision of their status has become necessary.

The most outstanding example of the influence of increased temperatures upon fruit fly development is in the cabinet simulating the climate of Oceanside, California. In the simulated months of April, May and June the total yield of progeny was 405, with an average period of development of about 50 days. The temperatures during this period ranged between average daily minimums of 45° F. and daily maximums of 70° F. However, in the months of July, August, and September a total of 5,616 flies were recovered from more than twice that many pupae. During this period the average length of the developmental period was reduced to 34 days. This change in reproduction and development can be correlated with the upward trends in temperature, for during this later period the average daily minimum temperatures had risen to 60° or more and the daily maximum temperatures reached better than 80°. Twilight temperatures were in general above the mating threshold.

In most cabinets the initially introduced mature parent flies were able to deposit fertile eggs, and the fruit fly was able to complete its life cycle during this past quarter. One exception was in the case of the Haleakala station on Maui where development was successful only up to the pupal stage, and only in a relatively few numbers of individuals. No adult progeny were realized at this station. For this reason this station was closed out during the quarter, and the more mild climate of Kula, Maui was substituted.

During the quarter a total of 12,586 flies were recovered from the initially introduced mature parent flies in the seven cabinets in operation. The percentage of emergence from the pupae was somewhat less than 50%. In certain instances the initial 1,500 adult parent stocks were able to reproduce themselves in number, while in most cases the parent stocks were only able to maintain a relatively high progeny level.

In most cabinets the initially introduced immature parent flies were finally able to mature sexually, and to successfully deposit viable eggs. As a result these initially immature parent stocks were able to produce a combined total of 5,353 progeny flies. The one negative return was from the Haleakala station.

In this quarter progeny were able to mature sexually and to produce a combined total of 6,882 flies. Since observations for mating were made each evening it was possible to determine the preovipositional period of the immature flies in each cabinet. When temperatures were optimal this preovipositional period was reduced to as low as 9-10 days.

The most optimal climates for development and reproduction are Fort Pierce, Florida, and Charleston, South Carolina. In both cases the climates have permitted every phase of fly development and activity to proceed in near optimum time. Other climates being simulated have produced high progeny returns at certain periods during the past six months (spring and summer seasons), but the rate of development has not been optimal. On the other hand, two of the stations being simulated (Fresno and Riverside, California) were warm enough to permit optimal pre-imaginal development, but there were several periods in these cabinets when the afternoon temperatures were lethal for adults.

The biotic potential of the fly during the past six months tends to illustrate the possibility of this pest developing to dangerous population levels in localities whose climates are comparable to some of those being investigated.

Complete records of infestation, development, emergence, adult mortality, and the climates being simulated are presented in the following detailed report, summary tables, and charts.

Cabinet No. 1. Oceanside, California.

While the combination of high humidity and moderate temperatures (with limited thermal peaks) accompanying the spring and early summer months at this station was not conductive to normal development of *D. dorsalis*, a complete reversal of the biological findings has occurred with the advent of higher thermal levels and more extended peaks coincident with the summer months.

This is a good example of the effect of seasonal temperature trends upon the development of an insect. Oceanside was definitely a marginal zone in the spring and early summer months, but a general increase in temperature has caused such a marked increase in the rate of sexual maturity, larval development and fly emergence that this locality can now be regarded as near optimal for the period presently under simulation. Some idea of the accelerated rate of development can be drawn from the fact that the average rate of development (egg deposition to fly emergence) in the early spring months was approximately 50 days whereas it is now reduced to about 34 days.

During the entire quarter (July-August-September) there have been few nights when the twilight temperatures were not optimum for copulation.

Adult mortalities were definitely reduced during the present quarter. In one case flies were able to survive for periods in excess of 70 days. This can be correlated directly with the upward trend in temperatures (see analysis of weather, below).

Immature adult flies reached sexual maturity in an average of 11 days.

In the case of the initially mature flies, from a total of 27 exposed fruits infestation was positive in each case and the total number of pupae recovered was 6,869 yielding 4,283 flies. The total emergence period from a fruit averaged about 6 days.

From a total of 24 fruits exposed to the initially immature parent flies 20 were positively infested and yielded a total of 1,427 pupae from which 899 flies emerged. Emergence from these fruits occurred over periods averaging 8 days.

From 20 fruits exposed to the fly progeny 13 became infested, yielded 685 pupae from which 434 flies emerged.

With six months of climate simulation completed it now appears very obvious that spring and early summer in localities with temperature and humidity conditions similar to Oceanside can be classed as marginal zones for fly development. On the other hand, climates similar to the summer and early fall conditions of Oceanside may be classified as near-optimal.

Oceanside is a typical example of the pitfalls that are ever present when making generalizations regarding the ability of the oriental fruit fly to establish itself in the principal agricultural areas of the mainland before complete data for the entire seasons under simulation have been acquired and evaluated.

Cabinet No. 2. Fresno, California.

Much the same pattern of climate behavior that characterized Fresno in the first three months of climate simulation was experienced again this current quarter. Lethal temperatures were experienced during July and again in August, and the minimum temperatures were above those of June most of the time. Humidity for the most part was relatively low, with daytime values often down to between 15 and 20%.

In the first week of July there occurred a series of eight days when temperatures were recorded in excess of 100° F. Relative humidity during this period ranged from a low of 15% to a high of 60%. The nightly thermal lows were 70° F.

During this period of high daytime temperatures very high adult mortalities were recorded, with the older, initially gravid flies suffering the greater mortality. A complete stock of 1500 initially mature flies were killed in four days during this period. Surviving flies were those fortunate enough to discover a moist site which afforded protection from dessicating action of the hot, arid conditions within the cabinet. It is of interest to note that, according to thermocouple measurements, these sites within the cages where moisture was prevalent were not cooler than the surrounding ambient air. This indicates that the flies are seeking sites of moisture in order to counteract water losses, rather than because these sites are cooler than their surroundings.

The remainder of July and on through the entire month of August provided a more agreeable climate with thermal peaks only occasionally exceeding 100° F. The minimum temperature dropped to 56° F. on several occasions.

September showed a marked decrease in the average daily minimum temperatures. This decrease was over-emphasized on one occasion when an error in cam plotting or cutting resulted in the temperature reaching a low of 32° F.

A decrease in progeny recovery from the initially mature adults was noted this quarter. From 24 papayas exposed, 23 became positively infested and yielded 4,320 pupae from which 1,640 flies emerged. Comparison of these figures with the corresponding data for the previous quarter indicates that this reduction in progeny recovery is due mainly to a decrease in per cent emergence. Actually, more pupae were recovered than before. The pre-imaginal developmental period increased from approximately 22 days in July to 28 days in late September.

In the introduced immature stock sexual maturity and successful copulation resulted in the infestation of 14 out of 17 papaya fruits. From a total of 700 pupae recovered from these fruits, 404 flies emerged. Recoveries were all made in the first two months of the quarter, September providing negative results.

From 25 fruits exposed to the progeny 17 yielded a total of 98 pupae. Emergence amounted to 37 flies.

In retrospect it can be said that while the spring and summer seasons in Fresno were optimal for development of D. dorsalis, and the flies were able to reproduce in considerable numbers, there were certain periods during this time when the daily temperatures reached lethal limits for the adult flies. However, with the decrease in temperatures accompanying late summer and fall reproduction has been affected and the recovery of progeny has been materially reduced. Longevity, on the other hand, was favorably influenced.

The six months of climate progression just completed provide data showing that flies are able to reach sexual maturity and reproduce, and that the immature stages are capable of surviving extremes in temperature. For the full six months 114 papaya fruits exposed to all groups of flies were infested with 8,649 pupae. From these pupae 4,554 flies emerged. The introduced flies were able to reproduce only in sufficient quantity to maintain a relatively small population level. From a total of 20,000 introduced flies (gravid and immature) progeny just in excess of 4,500 were recovered indicating that should sufficient host fruits be available it is entirely possible that a low population level might be maintained during this period of climate simulation.

Cabinet No. 3. Charleston, South Carolina.

This site continues to provide the highest humidity of the climates presently being simulated. Hence it not only affords the opportunity of studying its continued effect on all stages of D. dorsalis development, but enables observations on the efficiency of the humidification system and cabinet controls under such extremes. Conditions of temperature and humidity for the months of July and August were very similar. Minimum temperatures never fell below 60° F. and invariably high humidities were attendant each night.

Daytime temperatures seldom exceeded 90° F. The average temperature was about 80° F. and conditions on the whole were near optimum for D. dorsalis.

September initially followed a somewhat comparable climate pattern to the preceeding months, but average temperatures began decreasing slightly with the onset of autumn. Humidity was generally high, particularly so in the last week of the month, when it averaged more than 92%.

While it is true that humidities were high accompanying temperatures were such that development was not materially affected. Host fruits broke down at a greatly accelerated rate, sometimes before they could be removed to the holding boxes. Consequently many larvae were lost through exposure before they had completed their development. Some pupae were affected by the presense of too much moisture, largely the result of the exudation of fruit juices caused by rapid decomposition. However, climatic conditions were such that the flies were able to reproduce in sufficient numbers to maintain a very high progeny population level.

Temperature levels never fell below the threshold of copulation at sun-down. Freshly emerged flies, when introduced into the cabinets, completed their sexual development, and produced viable eggs in a period of 10 days. Adult longevity was quite extended, usually beyond 40 days.

Fruits exposed to all three groups of flies (initially immature, gravid, and progeny) have become infested and yielded very high fly emergence. From a total of 26 papayas exposed to the introduced gravid flies, 23 were infested with 4,297 pupae from which 2,039 flies emerged. The initially introduced immature flies infested 17 out of 20, which in turn yielded 4,417 pupae, followed by the emergense of 1,912 flies.

Singularly, the progeny stock infested 24 of 26 papayas which together gave a total pupal recovery of 5,419 which yielded 1,942 flies. This latter recovery from the progeny clearly indicates the suitability of this climate for the development of the oriental fruit fly and illustrates the potential fly population that could be expected in conditions paralleling those under simulation. Not only are fruits infested and life cycles optimal, but the egg and larval densities are particularly high. In fact the highest infestation level recorded occurred in this cabinet, wherein a single papaya was infested with 1,043 pupae from which 665 flies emerged.

The recovery of pupae from 64 infested papayas that were exposed to all three groups of flies during the current quarter was 14,133 and emergence from these pupae totaled 5,893.

Now that six months of continuous simulation of this station are completed it is interesting to review some of the more important findings. While it is true that relative humidities have been very high the thermal levels have not fallen much below what are accepted as optimal for D. dorsalis. Development has been rapid and uniform throughout the entire cycle of the fly, and reproduction has been good. A total of 9,600 flies (gravid and immature) have been introduced into the cabinet which have reproduced 19,398 pupae and 9,258 adults. This has balanced the population, and has thus kept it at a potentially dangerous level. Therefore Charleston can probably be classed as an optimal zone for the establishment and development of the oriental fruit fly for the period for which climate has been simulated.

Cabinet No. 4. Vincennes, Indiana.

As outlined in the previous quarterly report a delayed start was made on the simulation of the climate at Vincennes. Consequently the last report dealt only with adult mortality during the simulated month of April.

From April through late May little improvement in temperatures was noted. The daily minimum temperatures were seldom over 45° F., and the daily maximums rarely reached 80° F. Twilight temperatures were not favorable for copulation.

However, with the simulated month of June a marked improvement in fruit fly performance took place coincident with rising temperatures. The daily minimum temperatures increased to around 60°, and the daily maximums steadily rose until at the end of the month they almost reached 100°. Relative humidity was low for most of this period, with night-time peaks rising to about 60%. Most of the biological findings for this period will not be available until later, due to the retarding effect of temperatures upon larval-pupal development. However, the effects of the increasing trend in temperature has been reflected in observations of copulation and reduction in adult mortalities.

The first flies recovered in this cabinet were from fruit exposed in the simulated month of May, and the rate of development for these progeny was about 25 days. Recoveries were not very high. It is significant to note that progeny were also recovered from the initially immature adult parent stock, indicating the effect of improving temperatures upon the sexual development of fruit fly adults.

From 22 fruits exposed to the initially mature parent stocks 12 were infested with 1,013 pupae, from which emerged 261 adults. Five of ten fruits supplied to the initially immature parent stocks yielded 703 pupae, which in turn yielded 244 adult flies.

While April was a month not conducive to the development of reproduction of the fly, the following months were more favorable. With similar improvement during the summer and early fall it is expected that progeny levels, which had just begun to build up at the end of the quarter, may reach important values.

Cabinet No. 5. Riverside, California.

Throughout the simulated month of July very little change in the daily minimum temperatures was noted. They remained between 55° and 60° F. most of the time, and at twilight were high enough to permit mating. Daily maximum temperatures occasionally exceeded 100° F., with consequent heavy adult mortalities.

September began with similar conditions but later grew cooler. In this latter period minimum temperatures dropped to less than 45° F. Again maximum temperatures occasionally exceeded 100°, and in this month the record for the cabinet was reached with a temperature of 110°. The diurnal range in humidities during the month was from a daily average of less than 20% to a nightly average of more than 90%.

The average conditions during the quarter were such that the pre-imaginal stages of the fruit fly developed in near optimal time, and in large numbers. The initially mature parent stocks infested 22 of 25 papayas from which 2,469 pupae were recovered, which in turn yielded 1,073 adults. The rate of pre-imaginal development was about 24 days. Emergence of flies from a given fruit averaged four days, with most emergence periods within the range of 2 to 5 days. This indicates a high degree of uniformity among developing larvae.

The originally sexually immature parent stocks were able to mature, mate, and lay viable eggs in periods of about ten days. They infested 12 of 17 fruits, which yielded 1,468 pupae, from which 466 adults were recovered. The rate of development, and the variation in emergence from a single fruit were similar to the observations for the mature parent stocks.

The F-1 flies were able to mature sexually and to reproduce during the quarter. From 21 out of 24 fruits placed within the progeny cage 1,503 pupae were collected, which yielded 699 adults, representing the F-2 generation.

Longevity of the adults within this cabinet was materially affected by lethal afternoon temperatures, but on the average adult stocks were able to survive for periods averaging 25 days.

With six months of climate simulation for this station completed a resume of the findings indicates that the spring and early summer months, while sub-optimal for larval-pupal development, permitted high infestation levels in fruits followed by a moderate degree of fly emergence. The rate of pre-imaginal development averaged over 50 days. Adult sexual development did occur, but only at slow rates, and hence reproduction of the initially immature parent stocks was quite low. During this spring-early summer period the combined fly production amounted to 2,320 adults from 3,066 pupae. The succeeding period of summer and early fall accompanied by increasing temperatures, caused the developmental period of the larval and pupal stages to be reduced to about 24 days. Although fruit infestations increased and a total of 5,440 pupae were produced, progeny emergence decreased slightly to 2,238 individuals. It is possible that this reduction in per cent emergence was caused by the occasional periods of excessively high temperatures which were known to be lethal to adult flies.

From 16,300 flies introduced into this cabinet over the past six months a total of 4,558 progeny were recovered from 8,506 pupae. However, these figures bear less significanse when it is recalled that in one afternoon a temperature of 100° or more can cause the mortality of over 1,000 adult fruit flies. Aside from this fact the last six months' operation provide sufficient data to substantiate the conclusion that the oriental fruit fly is capable of successfully maintaining itself during the spring, summer and fall seasons in areas of climates similar to those dealt with in this cabinet.

Cabinet No. 6. Haleakala, Maui.

The previous quarterly report mentioned why this station was simulated, and also a possible explanation for the absence of any notable amount of fruit fly activity, development, or reproduction. This climate was not favorable for fruit fly build-up primarily due to the effect of cool temperatures upon the sexual development of immature flies, and upon the development of pupae.

It was noted in the last quarter, as well as the one just past, that host fruits tended to become mummified before the larvae therein could complete their development. Any fully developed larvae may have been forced to pupate directly within the fruit rather than in the sand beneath. However, examination of these fruits indicated that no adult flies had emerged from the pupae within such fruits, and therefore it is concluded that regardless of whether pupae formed there no adults were produced.

Climatic conditions in this cabinet were taken from records in the field from the period June 5 to November 13, 1950. This period included the most favorable temperatures of the year at this station, insofar as fruit fly activity is concerned. Even so, this climate permitted no emergence of flies from pupae through November, though an occasional infested fruit was noted indicating some activity on the part of sexually mature adult females. In this last month of the period, November, the daily temperatures ranged from 40° to 60° F. From data collected from other cabinets it is now realized that this entire temperature range is beneath the threshold for fly activity and reproduction, and as a result this climate was terminated in July.

From a total of 10,300 parent flies 421 pupae were recovered from seven of 108 fruits. These fruits were from those exposed to the initially mature parent stocks. From these 421 pupae adult emergence was negative. The fact that gravid female fruit flies, affected by strong ovipositional urges and egg pressures, will deposit eggs in any suitable or unsuitable medium, nitch, or crack would tend to suggest that more fruits were infested than pupal recoveries would indicate. If this be the case heavy egg and larval mortalities were produced by factors, either biological or meteorological, or both.

Adult longevities were quite extended in this cabinet, probably due to depression of the metabolic activity of the flies due to the low temperatures. Quantitatively the comparison between cabinet longevities and field longevities is not good, but, relative to the other stations being simulated, this comparison is better. When sufficient data are collected to enable accurate comparisons between field and cabinet longevities for those stations where biological data on the oriental fruit fly are available, it will be possible to predict the general degree of adult longevity in mainland stations. It must be pointed out, however, that field longevities are based upon the survival of the last fly in an initially small population, whereas cabinet longevity is based upon reduction of populations to practical levels of 10 to 25 individuals.

In summation it may be said that the correlation of field studies with the data collected for this station as simulated in the cabinet shows that this simulation more or less approached the natural conditions of temperature and humidity in the field. This strengthens the reliability of the conclusions made with respect to other stations for which no biological data on D. dorsalis is available. This will be supported with the simulation of the Kula climate, which is now being carried out within this cabinet.

Cabinet No. 6. Kula, Maui.

To further compare climate simulation and its effect upon fruit fly behavior, development, and reproduction with known biological records compiled in the field, the climate at the insectary at Kula was selected. This station is lower in altitude, and though sub-optimal, is suitable for fruit fly development.

It is expected that, after investigating the summer and fall climate at Kula, a further Maui station will be simulated that lies in the optimal regions for fruit fly activity. Such a selection of sites should provide a good deal of information on the ability of the fruit fly to successfully infest similar areas in the mainland.

Since the present experiment being conducted in the cabinet, the Kula climate, has only been in progress for about a month there is little to report at this time. Consequently the next quarterly report will contain all the data obtained at this station up to that time.

It may be of interest to note that with the advent of the Kula station studies are being conducted with D. cucurbitae as well as D. dorsalis. Eventually it is expected to study this species in the mainland climates as well. This will permit a comprehensive study of these two economically important pests now present in Hawaii and potentially dangerous to the mainland.

Cabinet No. 7. Fort Pierce, Florida.

The climate conditions under simulation in this cabinet continued to be optimal for D. dorsalis during the past quarter. With the temperatures rarely falling below 68° or above 90° F., and with high relative humidities, the simulated climate approached a sub-tropical nature that proved ideally suited for the development of all stages of the fruit fly.

The rate of development for all stages of the fly, from egg deposition through larval and pupal development to final adult emergence was quite rapid. The months of July and August provided pre-imaginal developmental periods of about 20 to 22 days. This compares favorably with the optimal period of 20 days for D. dorsalis reared in local insectary conditions in Hawaii. In the simulated month of September the stocks of parent flies gradually became depleted, and not as many fruits became infested. The developmental period during this time slowly became extended, reflecting the falling trend in temperature with the approach of the fall season. The minimum elapsed time between egg deposition and adult emergence was 22 days, while the average was 25 days.

The initially mature parent stocks infested all of 24 fruits during the entire quarter, from which were realized 8,042 pupae yielding 3,290 adults. The initially immature parent stocks became sexually mature in an average of 10 days. This group of parents infested all of 16 fruits, from which were recovered 3,033 pupae and 1,428 adults. The progeny cage, containing flies recovered from both parent stocks, infested all of 24 fruits, yielding 6,951 pupae and 3,770 flies.

These recovery figures, especially those for the progeny, represent the largest returns from any climate under simulation.

The large F-1 recoveries necessitated holding successive generations in extra cages. Smaller replicas of the parent cages were installed in the cabinet and the F-2 generation was held therein. With the inclusion of this cage it is expected that the isolated F-2 generation, and any subsequent generations, will afford the opportunity of discovering whether or not any resistance to lower temperatures has been produced. Although study of the climate to be simulated in the coming winter season does not show submarginal conditions, the temperatures do drop to sub-optimal values in this cabinet. Hence any degree of weather resistance that develops in the F-2 and successive generations will be detected on the basis of the pre-imaginal developmental rates, and possibly on the basis of pre-ovipositional rates for the adults.

The composite picture provided by the past six months of climate simulation is outstanding with regard to fruit fly activity. During the entire period the initially mature parents infested 47 fruits, producing 13,396 pupae and 6,389 adults. The initially immature parents, with an average preovipositional period of 10 days, infested 28 fruits, yielding 3,755 pupae and 1,993 adults. The F-1 generation produced 7,701 pupae and 4,165 adults from 33 infested fruits.

The total flies recovered (12,479) were in excess of the number of parents introduced into the cabinet (10,100). This is a striking illustration of the ability of the fruit fly to establish itself, develop rapidly, and build up to high levels in this quite optimal climate.

Analysis of Climate Effects.

An attempt has been made to correlate the progressive variations in fruit fly development and activity with the trends in daily average temperatures from early spring through summer into early fall. A partial relationship has already been established in the curves of the summary plates for the individual cabinets. Such curves are those showing the variations in minimum pre-imaginal development during the quarter, and also the effect of temperature and time on adult longevity. It is considered, however, that useful information can be obtained by correlating the data from all the cabinets together. Where such analyses are possible they have been included here.

In each analysis the data from each cabinet have been combined, without regard for the time of year. The average temperatures were computed from the daily means, which were in turn determined by averaging the daily maximum and minimum values. Where possible the effect of temperature upon development or activity has been illustrated by means of graphs.

Figure 1 shows the effect of temperature upon the duration of the pre-ovipositional period of adult flies. No sexual activity was noted when temperatures averaged 58° F. or less. This temperature level has therefore been designated as the lower temperature limit for this phase of fruit fly development. As the temperatures have risen the duration of this period has decreased accordingly in a manner indicated by the curved line in the figure. The optimal (shortest) period for pre-ovipositional development was 8 days. From the figure it may be seen that with average daily temperatures of 75°, or more, sexual development is practically optimum. The highest average temperature recorded over a period of a week or more has been 86°, and consequently the effect of supra-optimal temperatures, or of lethal thermal levels, is not known.

Figure 2 illustrates the effect of the gradually increasing temperatures upon the duration of pre-imaginal development, or time from egg deposition to adult emergence. The lowest average temperature at which emergence has occurred was 60°. As the temperature rose the pre-imaginal developmental period shortened according to the curved line of the figure. The majority of flies emerged in approximately optimum time (20-21 days) when temperatures averaged 84° or more. In this analysis the temperatures during each period of development were higher in the latter stages (pupal stage) than in the earlier stages (egg and larval stages). This was due to the steadily rising trend in temperatures from spring into summer. Because it is possible that there may be different effects due to the reverse situation, i.e., under decreasing temperature trends where the egg and larval stages are subject to warmer periods than the pupal stages, the analysis includes only data taken during the upward temperature trend. The decreasing trends shall be analysed in a similar manner later.

An analysis of the effect of temperature upon adult longevity was also attempted. In longevity there are several factors involved which are difficult to correlate into a smooth pattern, such as has been done above. Therefore, rather than to illustrate this analysis by means of graphs, the data have been itemised in tabular form. In general, adult longevity averages about 30-35 days, as measured from the time of stocking in the cabinet until the population has been depleted to 25 or less individuals. When the program was first initiated longevities averaged about 30 days at temperatures of 65°. However, succeeding longevities became both greater and lesser than this value as the temperatures rose. In the case of such climates as Oceanside, Charleston, and

Fort Pierce, the longevities increased with warmer weather, until an average of 50 days was attained at around 80°. On the other hand the Fresno and Riverside climates produced an opposite effect. In these cases the temperatures fluctuated over wide daily ranges. Mortality due to extreme afternoon temperatures resulted in shortened longevities without comparable changes in the daily average temperatures. Thus at average temperatures of 80° adults in the Fresno cabinet lived for periods averaging 10 days.

There was a similar effect of temperature upon the longevities of the older, initially mature parent flies and the younger, initially immature stocks. In most cases the younger flies were able to last longer at the higher temperatures (70° or more) than were the older flies. On the other hand at lower temperatures (below 70°) this effect was not apparent. This effect was influenced to a large extent by the results in Fresno climate. In this climate the occasional lethal temperatures caused a reduction in the longevities of the older flies by as much as 50% of that of the younger flies. This same effect was noted to a considerably lesser extent in all the other climates.

In figure 3 are histograms showing the total adult fly input contrasted with the progeny output for each cabinet over the past six months of operation. The lower histograms represent the total numbers of parent flies, both mature and immature, that were placed within the respective cabinets. The stations have been arranged in order of decreasing number of fly input. Thus, Fresno has required the largest number of adult parents, no doubt due to the short longevity of these adult stocks in this climate (see above). Riverside follows with the next least favorable climate from the standpoint of adult parent longevity and input. The other stations all required about the same number of flies, between 10,000 and 11,000, indicating the similarity of these climates from the point of adult longevity. Vincennes must be considered separately because this station has only been under investigation for half the time that the other stations have.

The upper series of histograms represent the total progeny output of each cabinet. The total height of the histogram represents the pupae produced, while the shaded portion of the histogram is the adult production. It can be seen from the relative heights of these two portions of the histograms that adult emergence has amounted to about 50%. Fort Pierce produced the most pupae, as well as adults, and in fact more than reproduced the input number of flies. Charleston followed, reproducing more than its own number of pupae, but with only about the same number of adults. The other stations fell off from this performance, and were not able to reproduce their own number, either of pupae or of adults. Haleakala produced few pupae, and no adults whatsoever. Again, Vincennes must be considered alone since it has been in operation but half as long as the other stations.

These analyses therefore indicate that fly activity and reproduction does not occur below average temperatures of 58-60°. Above this level the development of the immature stages of the fruit fly is affected quantitatively by the level of temperature. Although the investigation thus far does not permit an estimate of the maximum average temperature for fly development, the optimal temperature range begins at about 75° and extends at least above 86°. Temperatures above 100° for several hours in any given day are lethal to adult flies, but apparently not to the immature stages. Although these temperature threshold values are tentative, they enable a certain amount of prediction as to the time in the year when fly development and reproduction shall cease (in the case of the fall and winter seasons) and when this activity should commence (in the spring and early summer).

Based on the above analyses, and by studying the forthcoming temperatures that will be simulated in the cabinets the next quarter, it is predicted that fly production shall cease in the Charleston cabinet sometime in the middle of the simulated month of November. All the other stations should result in suppressed activity by the end of November, with the exception of the Fort Pierce station. In this latter station it is predicted that fly reproduction and development will not cease during the oncoming winter, but that such activity will only be somewhat below optimum.

Table 1. Summary of Infestation, Development, Pupal Mortality, and Fly Emergence

Cab.	Globe Cage No.	Total host fruits	No. fruits infested	Duration of Development (Days) July Avg.	July Max.	July Min.	August Avg.	August Max.	August Min.	September Avg.	September Max.	September Min.	Avg. duration emergence period	Total pupae	Total adults	Per cent emergence
OCEANSIDE, CALIF.	1	27	27	39 (11)	46	32	36 (11)	41	33	34 (5)	38	31	5.8	6,869	4,283	62
	2	24	20	42 (5)	46	38	37 (10)	40	33	37 (5)	40	35	7.7	1,427	899	63
	3	20	13	— (3)	—	—	37 (2)	37	37	40 (6)	43	36	4.8	685	434	63
	Total	68	60											8,981	5,616	63
FRESNO, CALIF.	4	24	23	23 (8)	25	20	25 (8)	42	18	28 (5)	30	27	3.3	4,320	1,640	38
	5	17	14	22 (6)	26	19	28 (6)	44	24	— (0)	—	—	4.0	700	404	58
	6	25	17	25 (3)	30	22	28 (2)	29	26	30 (2)	31	28	1.3	98	37	38
	Total	66	54											5,118	2,081	41
CHARLESTON, S.C.	7	26	23	23 (6)	28	21	30 (8)	18	23	23 (6)	25	20	4.6	4,297	2,039	47
	8	20	17	20 (9)	23	17	27 (7)	39	22	22 (5)	23	20	3.4	4,417	1,912	43
	9	26	24	19 (9)	23	16	22 (7)	28	18	22 (5)	25	20	4.0	5,419	1,942	36
	Total	72	64											14,133	5,893	42

Table 1 cont'd.

Cab.	Globe Cage No.	Total host fruits	No. fruits infested	Duration of Development (Days) July Avg.	July Max.	July Min.	August Avg.	August Max.	August Min.	September Avg.	September Max.	September Min.	Average duration emergence period	Total pupae	Total adults	Per cent emergence
VINCENNES, IND.	19	22	12	—	—	—	—	—	—	25 (6)	26	23	2.2	1,053	261	25
	20	10	5	—	—	—	24 (1)	24	—	23 (2)	25	21	3.7	703	244	35
	21	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Total	32	17											1,756	505	29
RIVERSIDE, CALIF.	10	25	22	26 (9)	29	23	29 (6)	32	26	31 (5)	32	30	3.9	2,469	1,073	43
	11	17	12	26 (6)	32	23	28 (2)	30	29	—	—	—	5.1	1,468	466	32
	12	24	21	28 (7)	30	26	28 (8)	33	24	31 (1)	31	—	5.0	1,503	699	46
	Total	66	55											5,440	2,238	41
HALEAKALA MAUI	13	17	1	—	—	—	—	—	—	—	—	—	—	103	0	0
	14	15	0	—	—	—	—	—	—	—	—	—	—	0	0	0
	Total	32	1											103	0	0
FT. PIERCE, FLA.	16	24	24	25 (7)	34	20	24 (10)	32	30	25 (4)	29	20	4.6	8,042	3,290	41
	17	16	16	23 (6)	27	19	26 (6)	30	20	29 (5)	36	26	6.9	3,033	1,428	47
	18	24	24	23 (8)	27	19	26 (3)	30	21	24 (8)	26	22	6.6	6,951	3,770	54
	Total	64	64											18,026	8,488	47
Grand Total		400	315	79% Fruits Infested										53,557	24,821	46

FIGURE 1.

Effect of Temperature on Pre-Ovipositional Development.

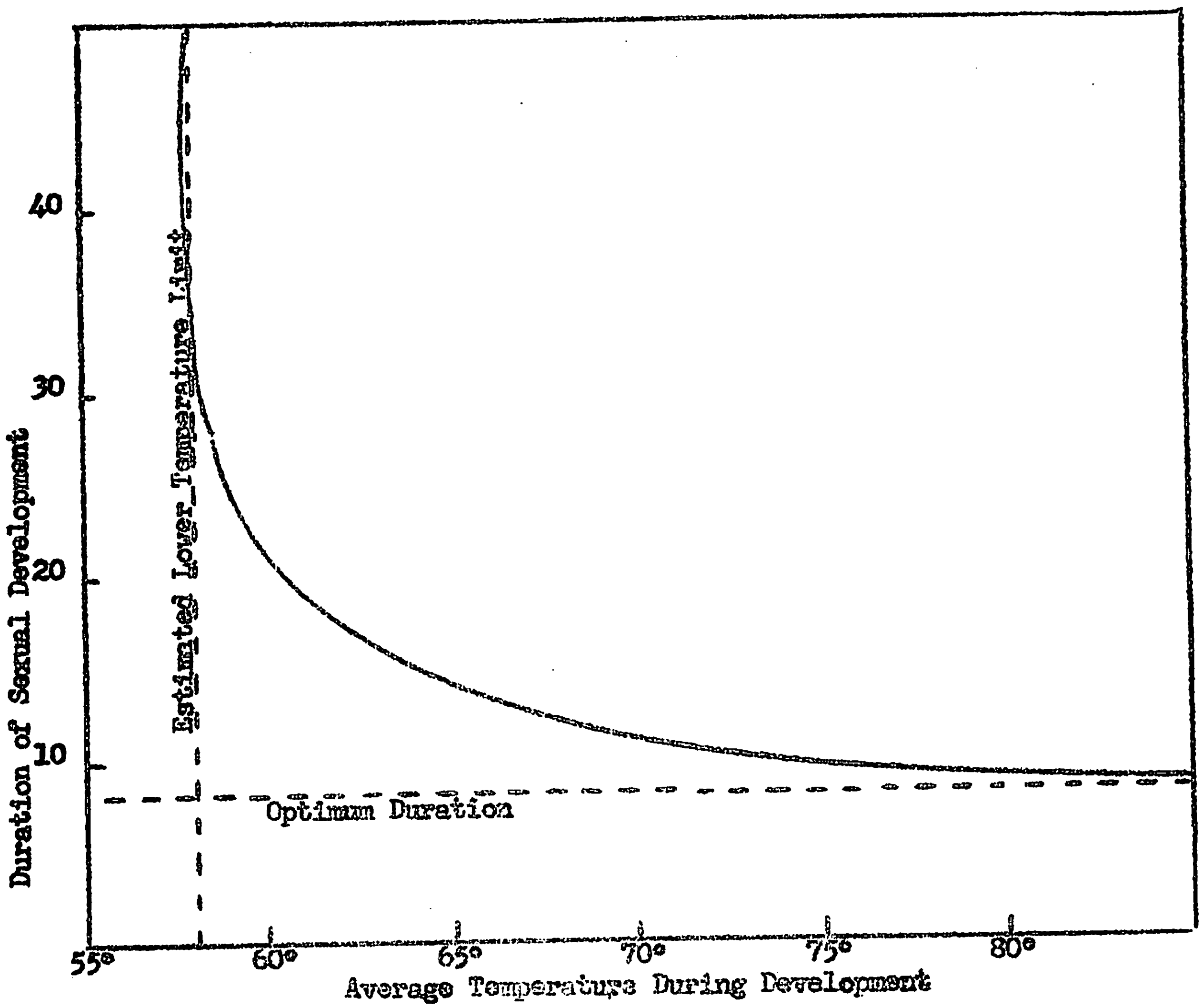


FIGURE 2.

Effect of Temperature on Pre-Imaginal Development.
(Computed from data from all stations.)

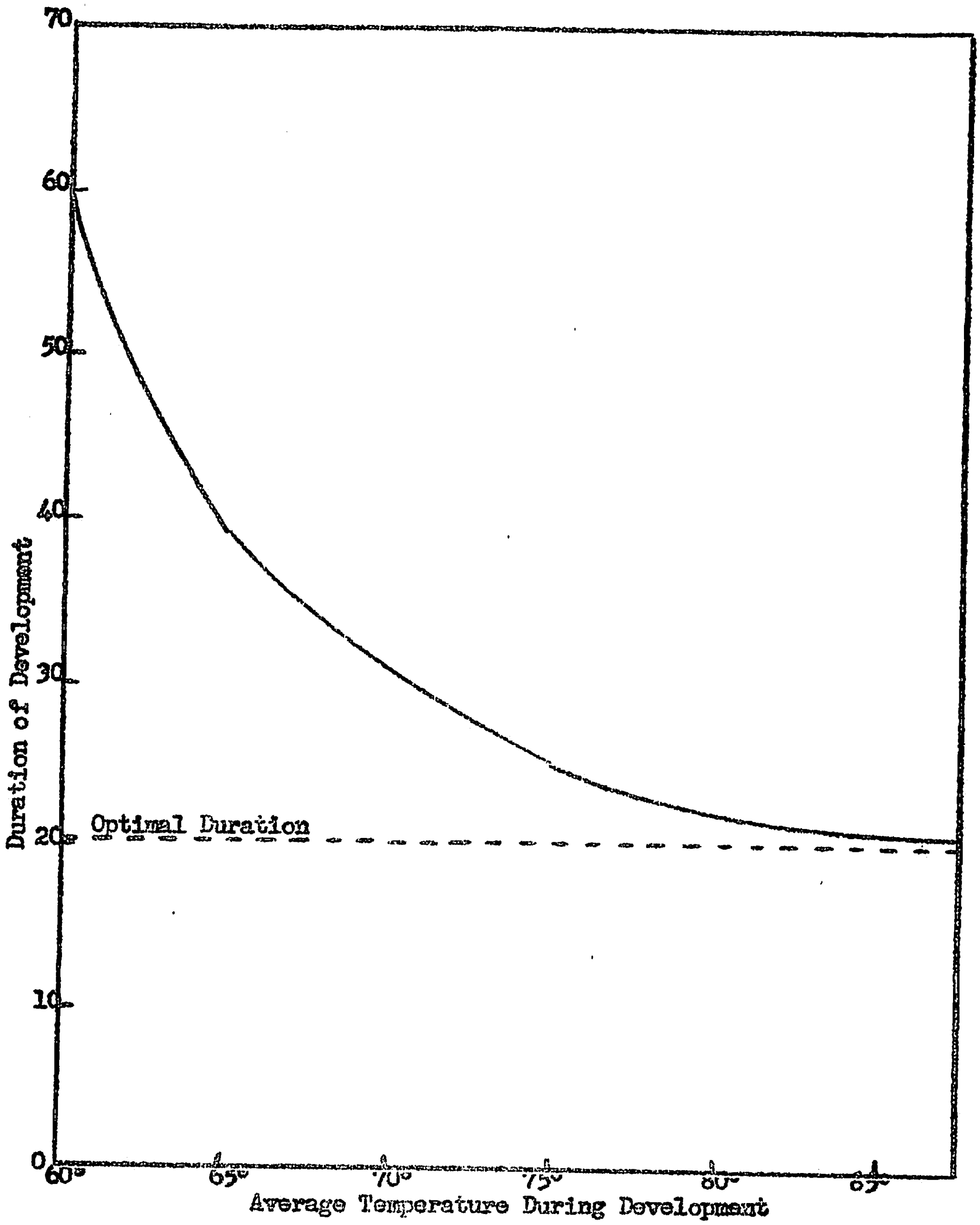
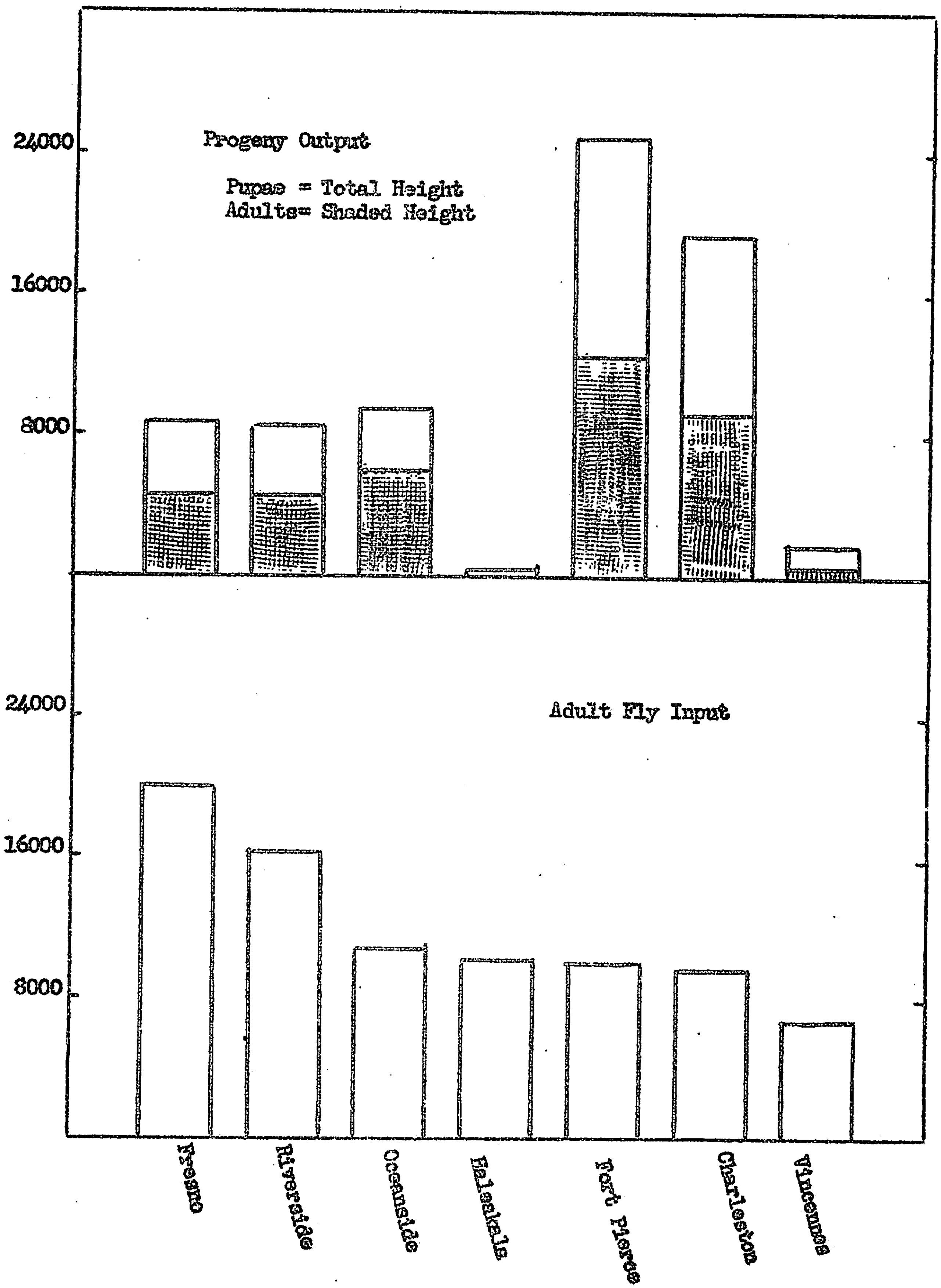


Table 2. Effect of Temperature Upon Adult Longevity.

Station	Mature Parents		Immature Parents	
	Max. Longevity	Avg. Temp.	Max. Longevity	Avg. Temp.
Oceanside	28	58	28	58
	38	61	37	61
	50	66	74	66
Fresno	36	67	36	67
	20	70	29	74
	16	80	33	81
	4	86	37	79
	12	79	24	75
Charleston	38	64	38	64
	36	77	36	77
	42	79	64	80
Vincennes	50	62	51	62
	28	70		
Riverside	27	62	27	62
	20	63	20	63
	28	71	26	71
	42	75	58	75
	19	74	30	74
	33	74		
Haleakala	20	54	20	54
	36	57	37	57
	46	56	45	56
	52	55	52	55
Fort Pierce	22	70	22	70
	42	73	56	75
	55	79	66	79
	63	78		

FIGURE 3.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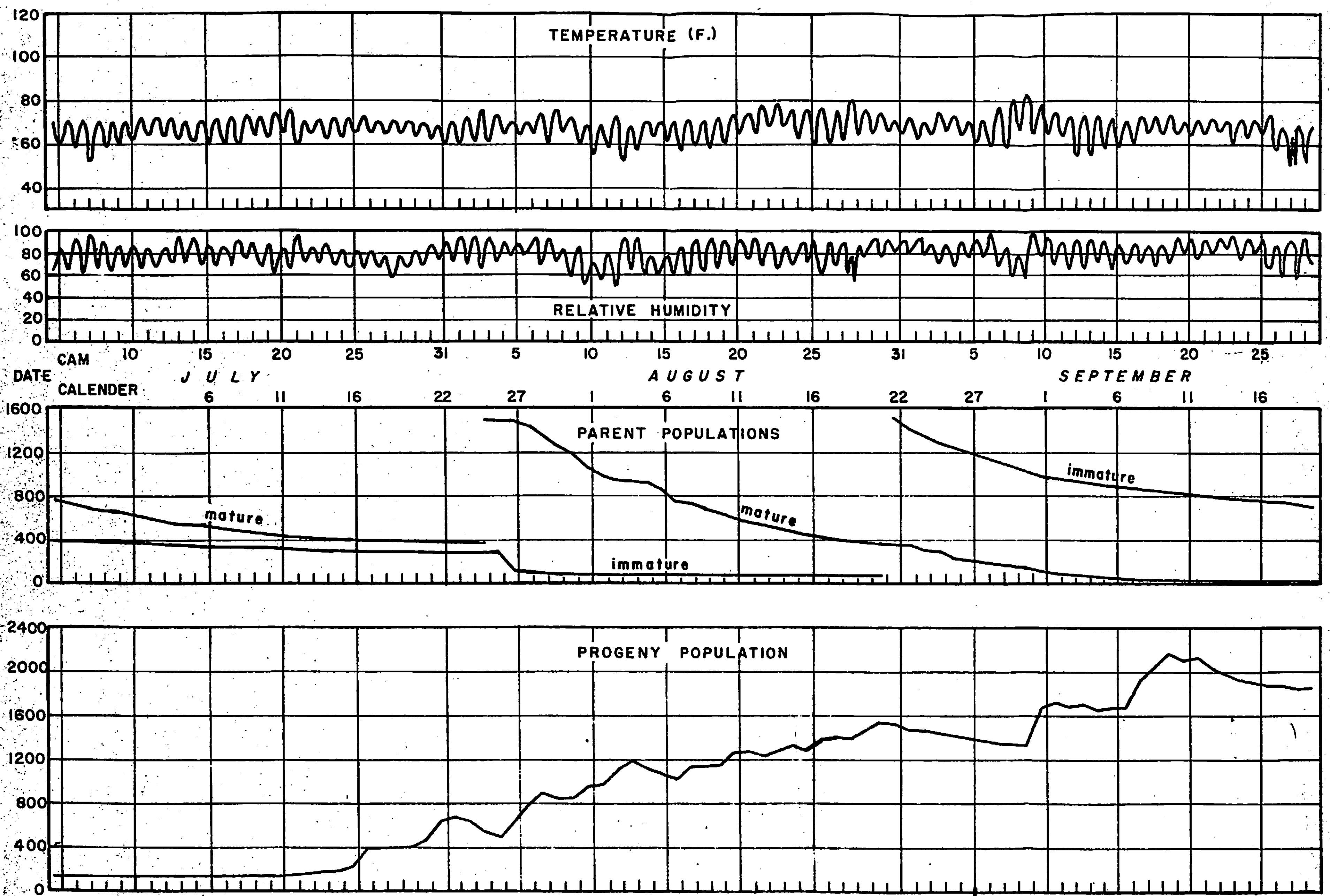
16000
8000
Progeny Output
Pupae = Total Height
Adults= Shaded Height
24000
16000
8000
Adult Fly Input
Fresno
Riverside
Oceanside
Haleakala
Fort Pierce
Charleston
Vincennes



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PARENT POPULATIONS
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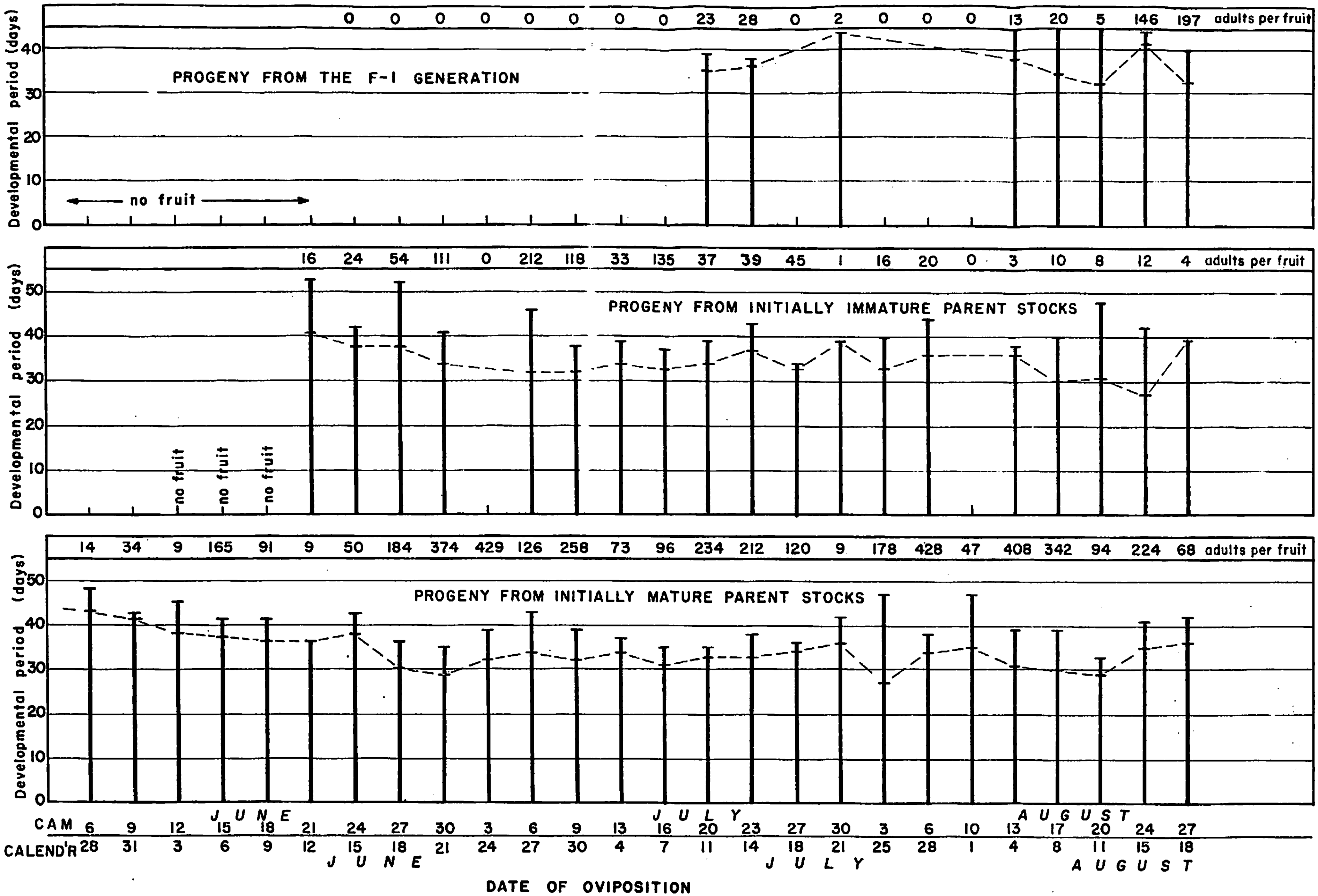
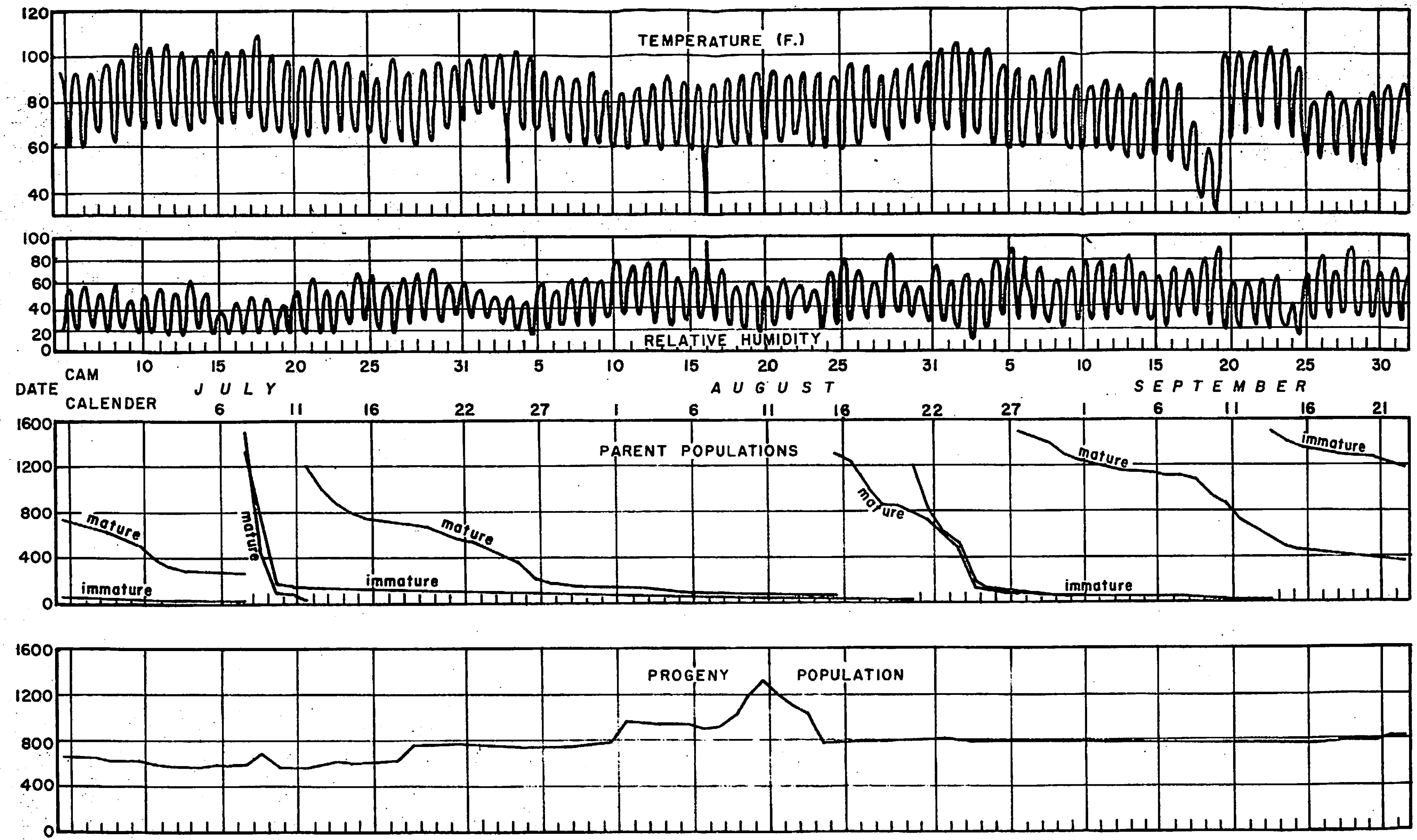
OCEANSIDE



DEVELOPMENTAL PERIODS — OCEANSIDE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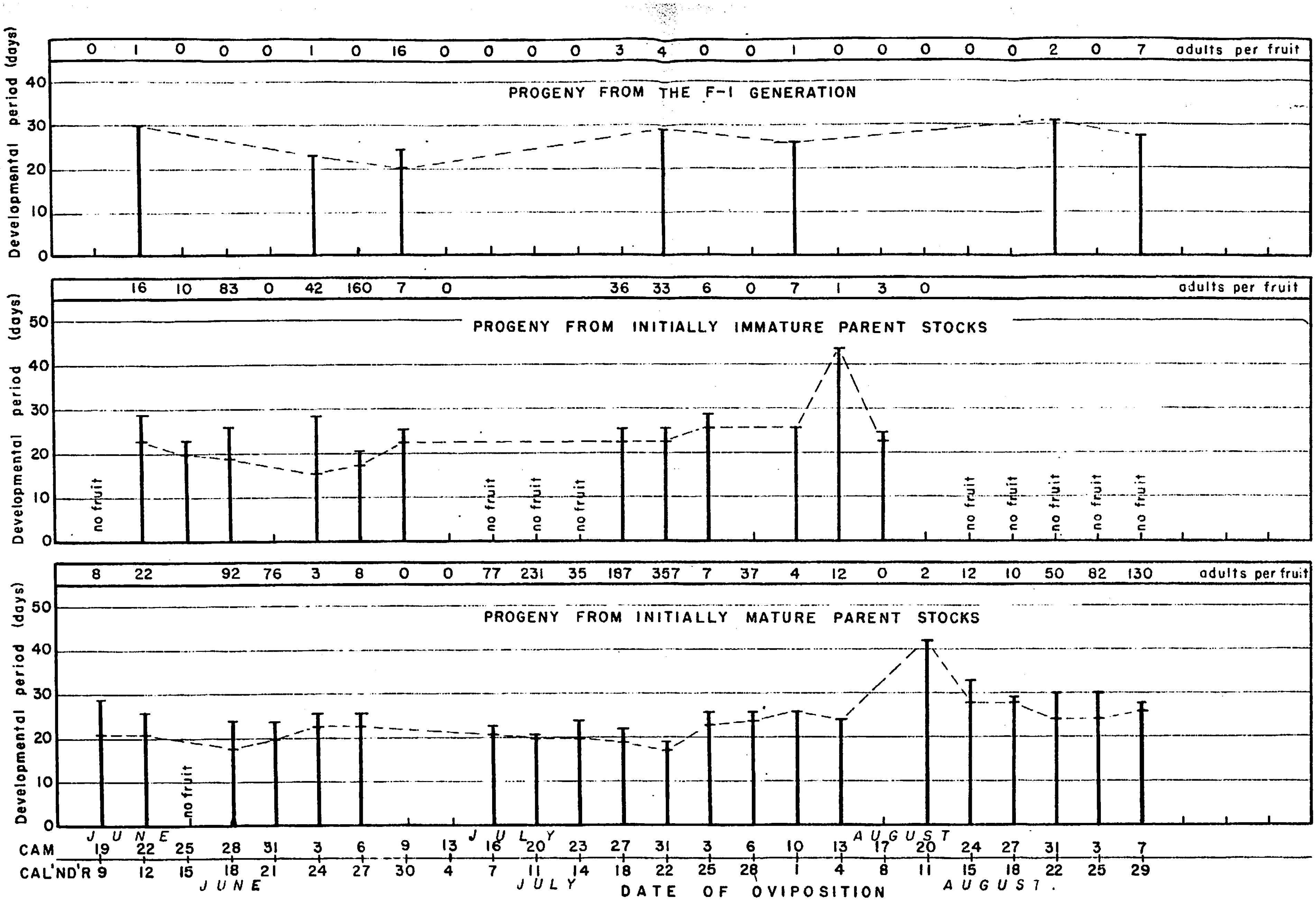
FRESNO



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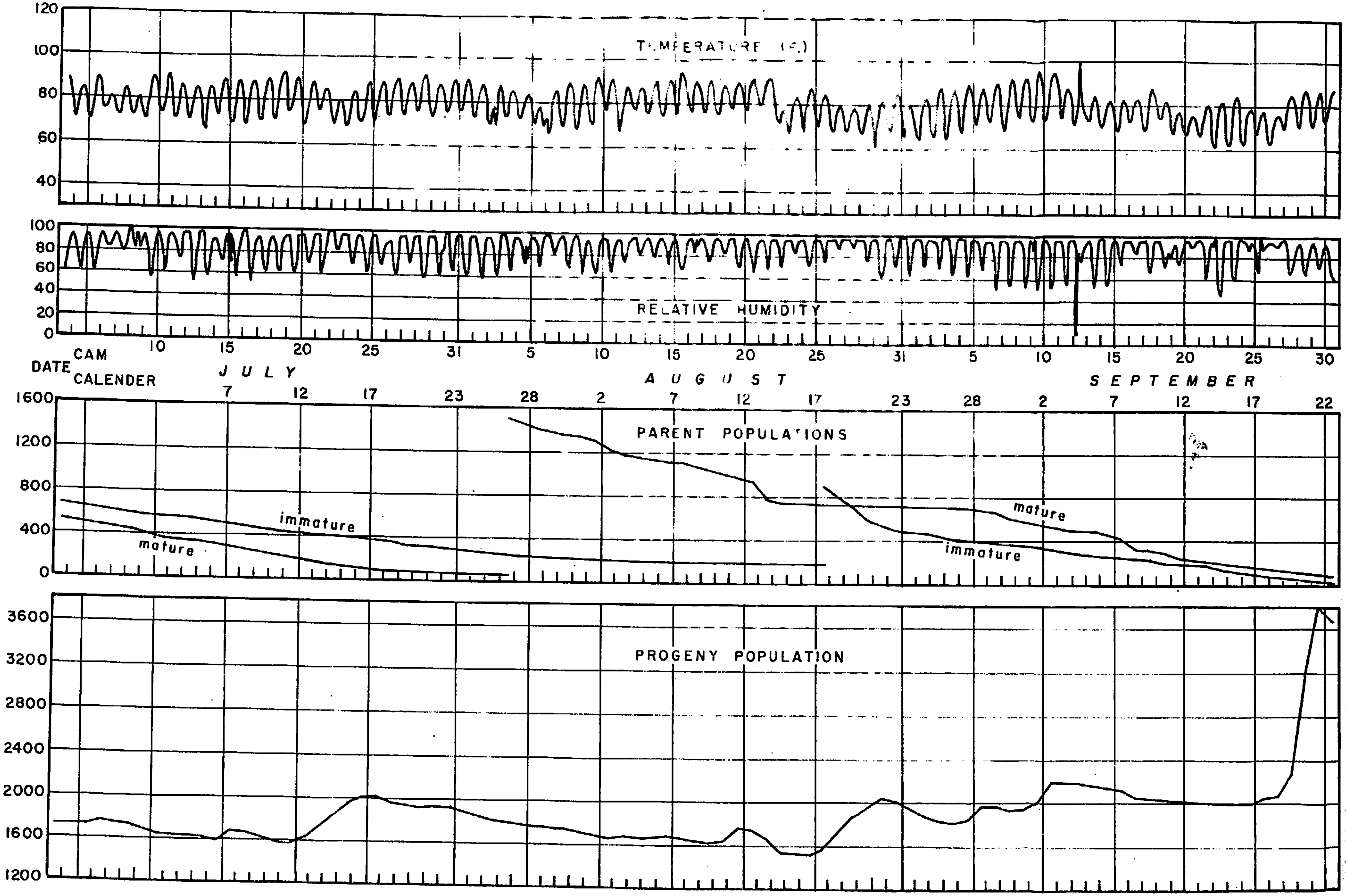

TEMPERATURE (F.)
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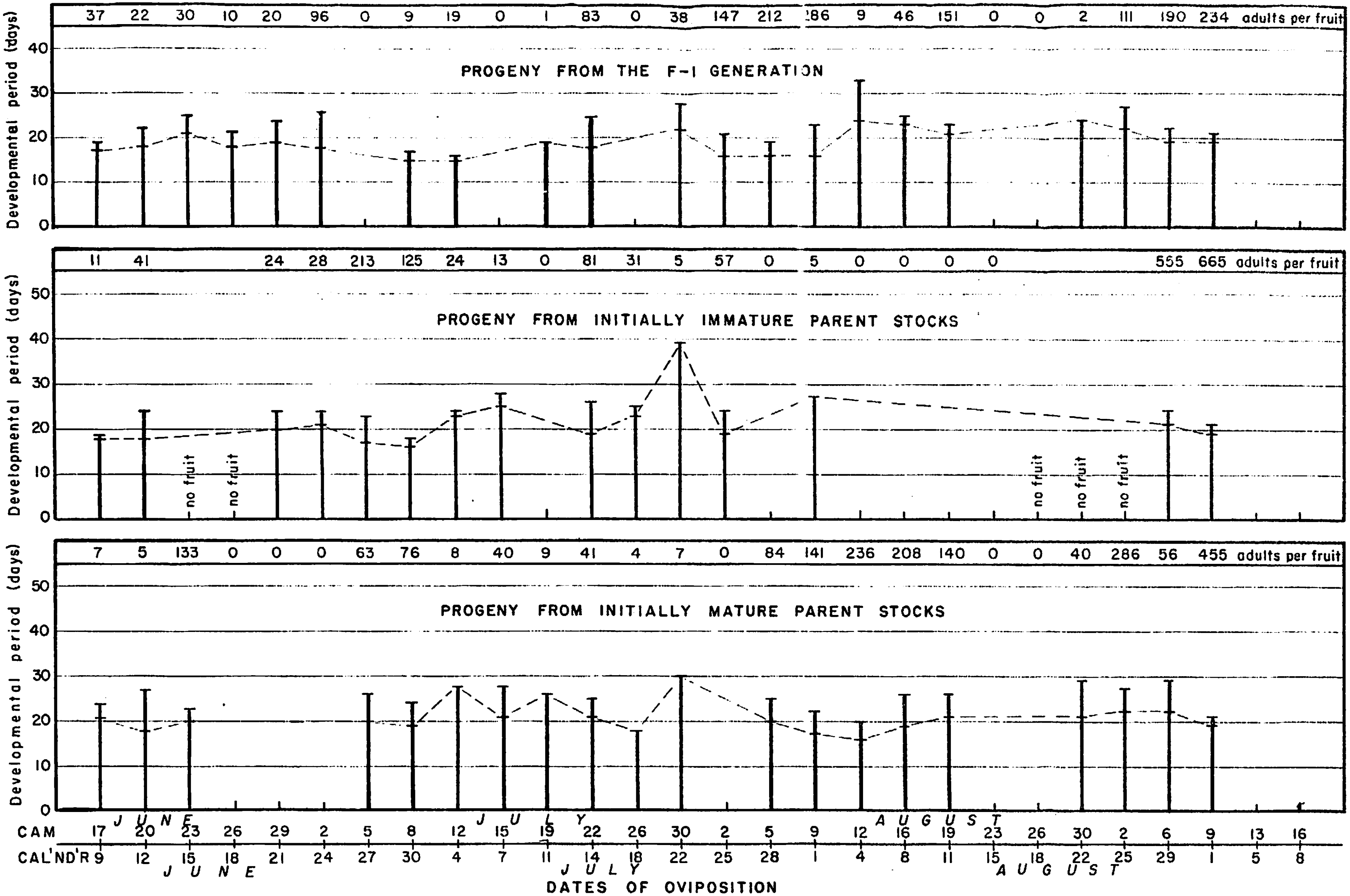
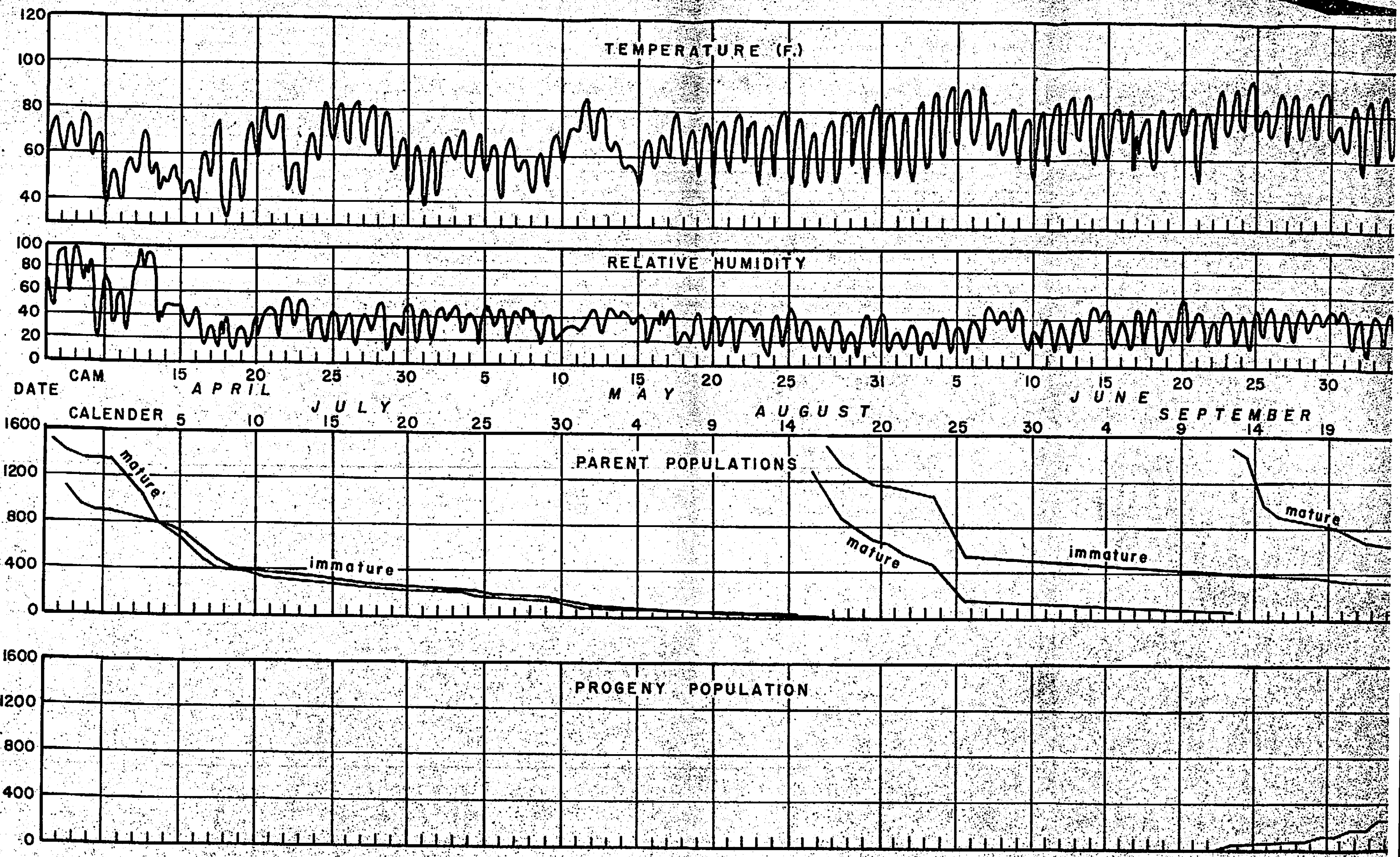
PROGENY POPULATION

CHARLESTON



DEVELOPMENTAL PERIODS — CHARLESTON



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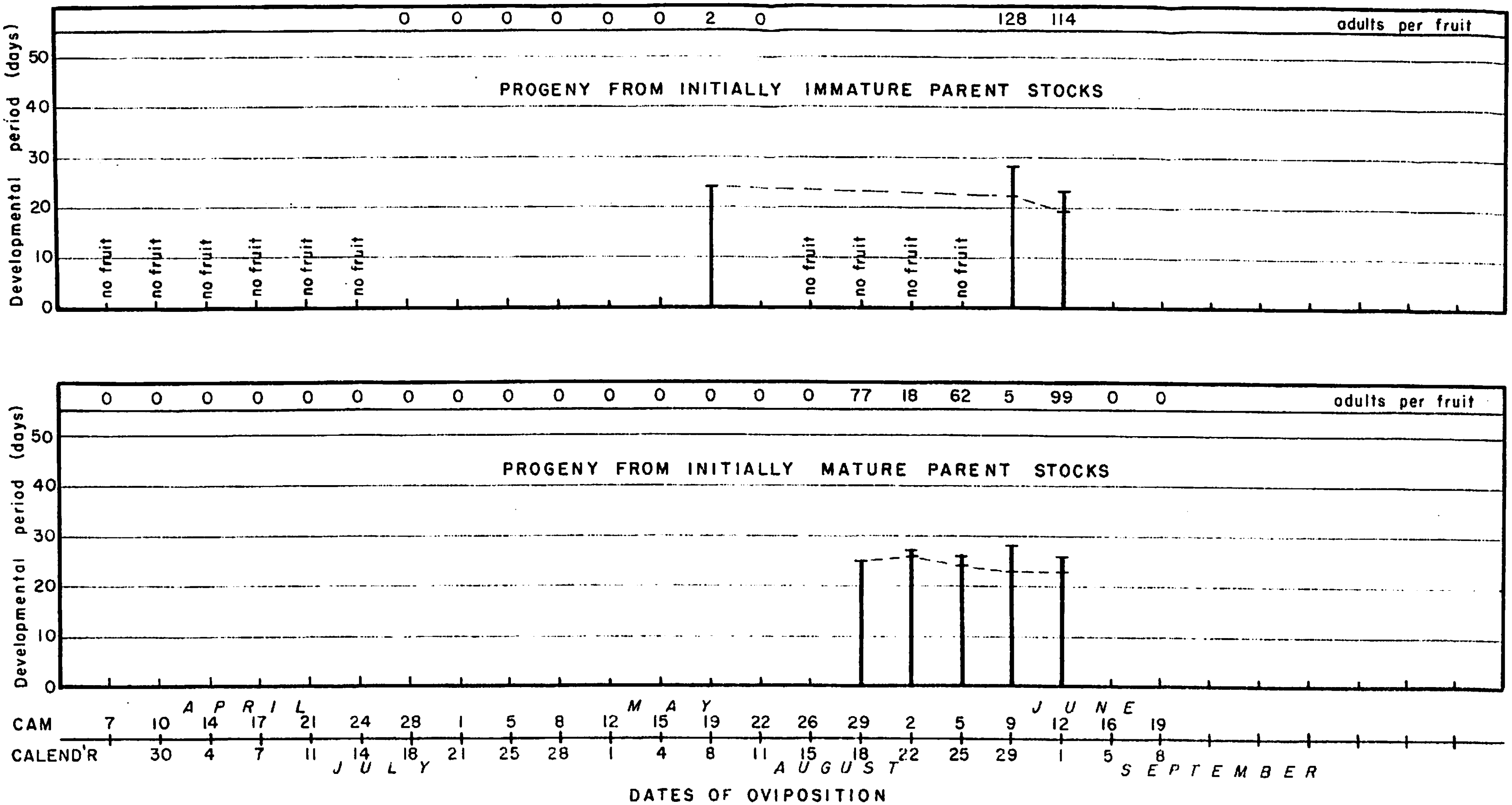
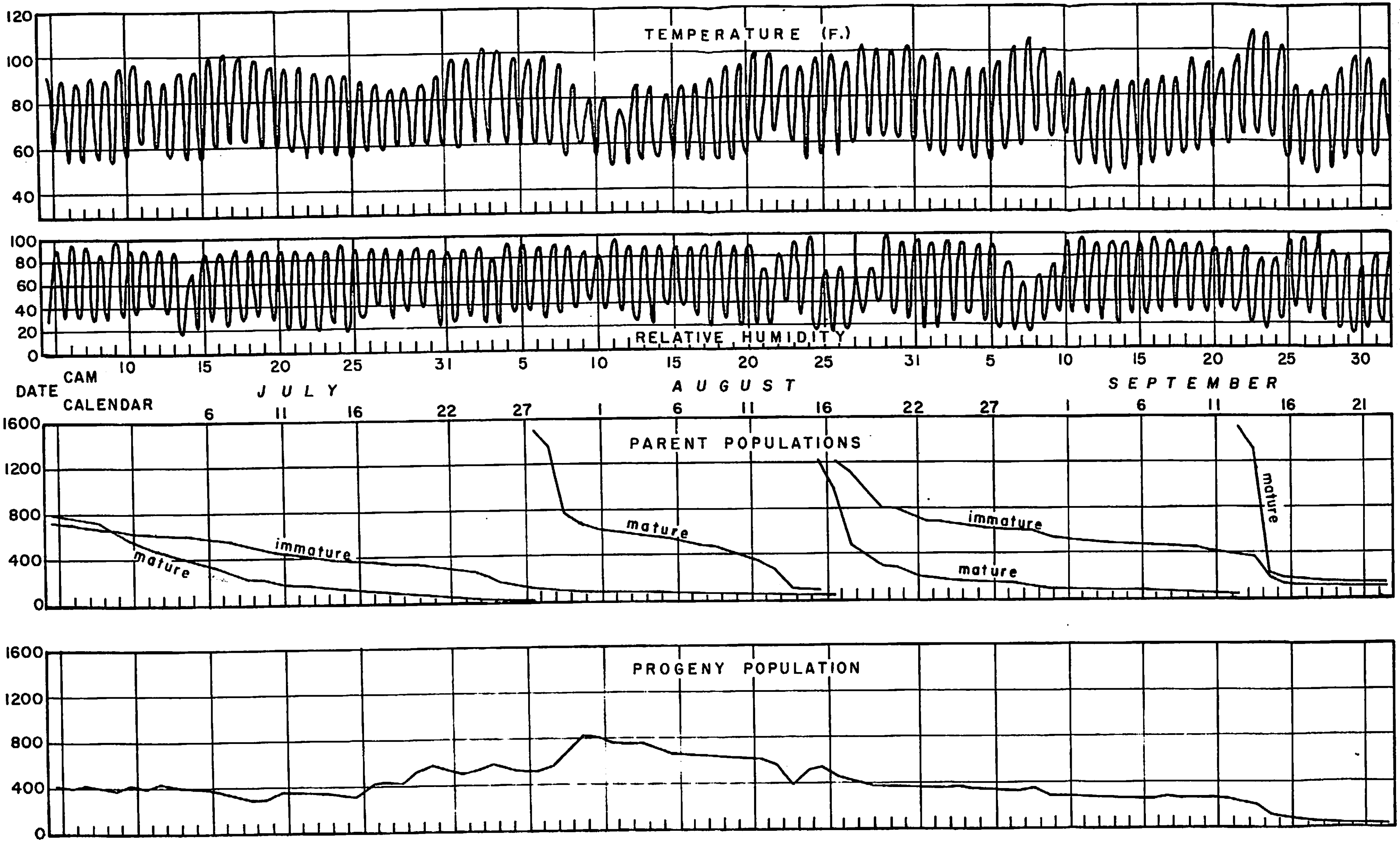
VINCENNES



DEVELOPMENTAL PERIODS — VINCENNES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JULY
AUGUST
SEPTEMBER
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PARENT POPULATIONS
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1200
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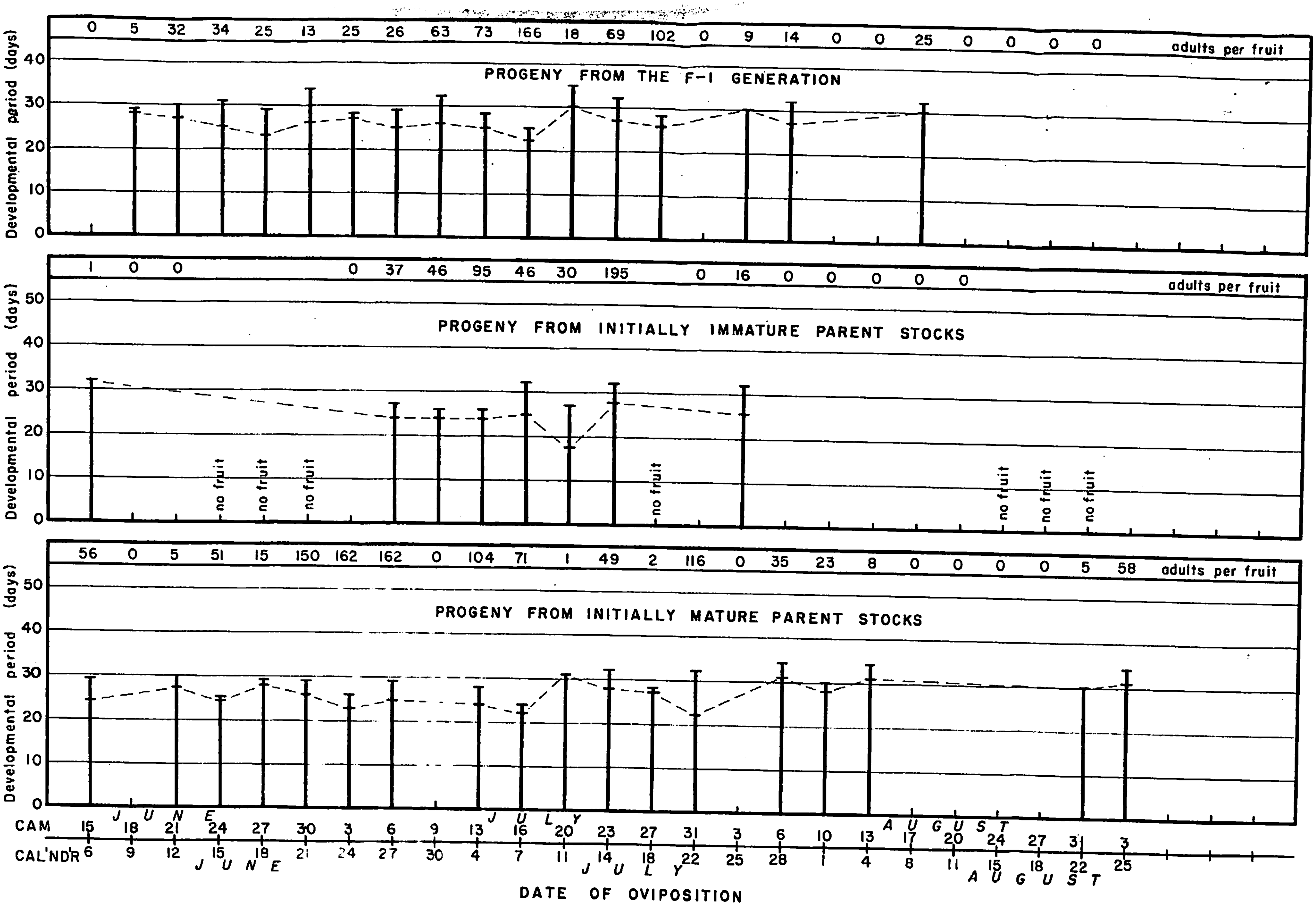
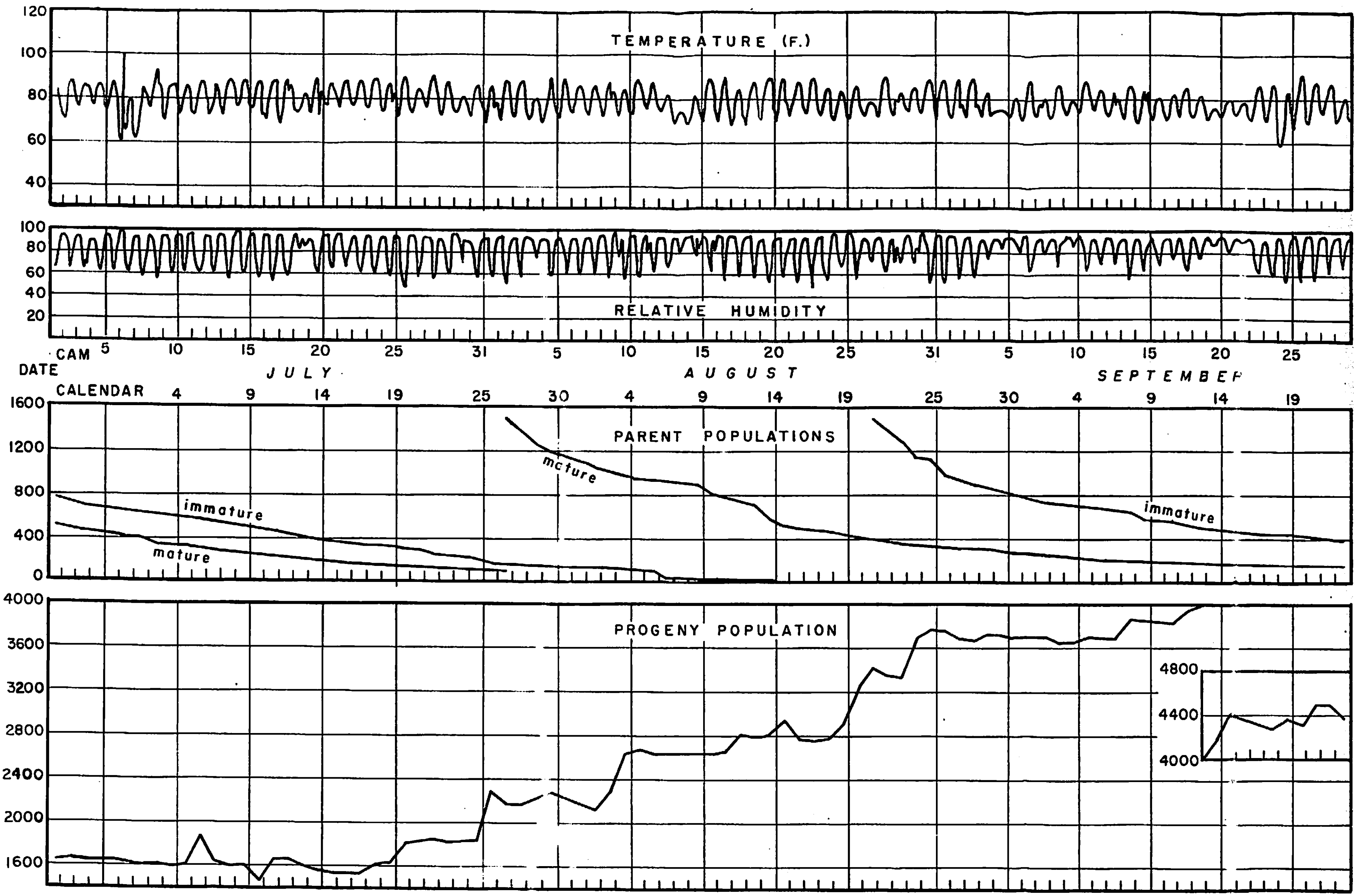
mature
immature
PROGENY POPULATION

RIVERSIDE



DEVELOPMENTAL PERIODS — RIVERSIDE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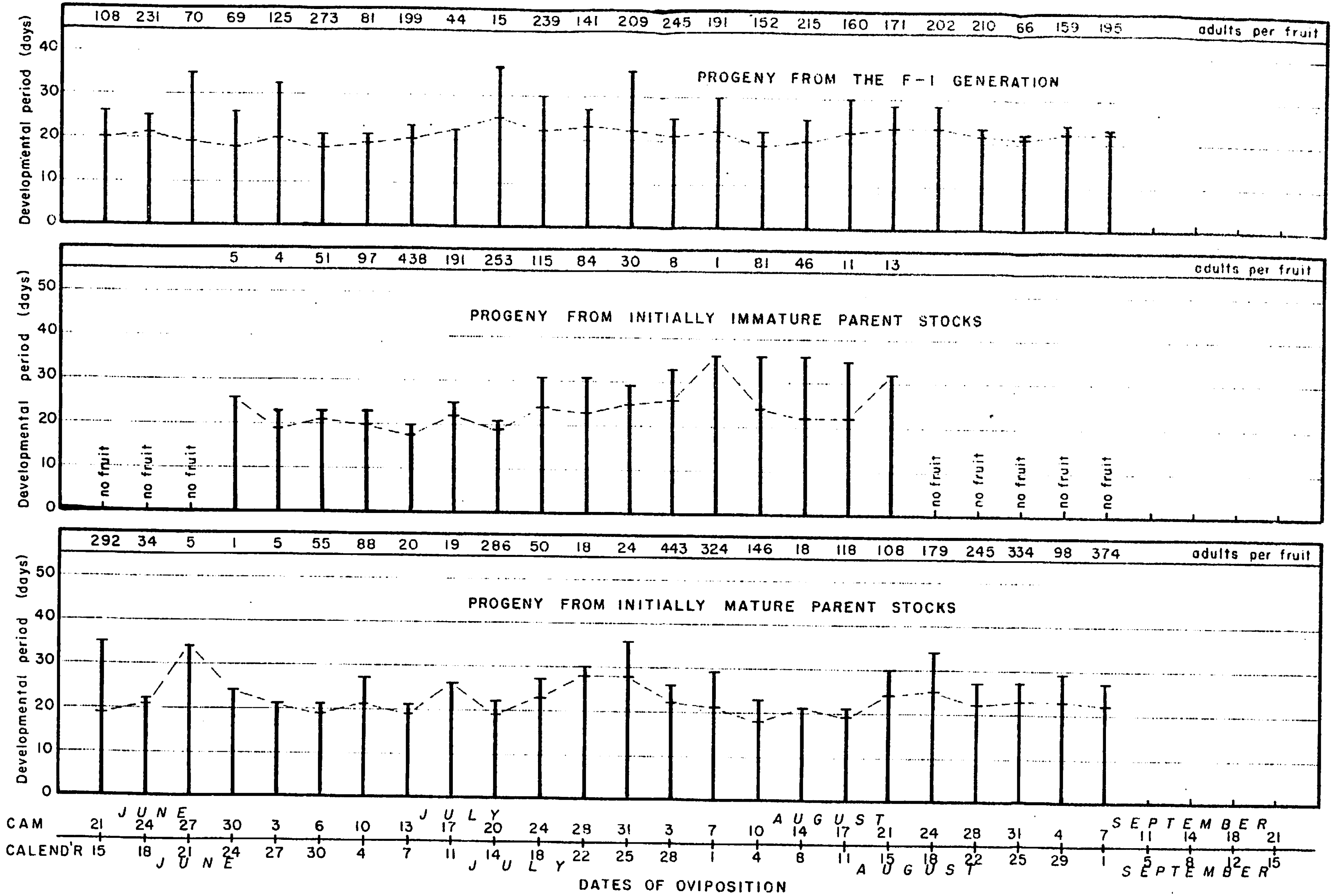
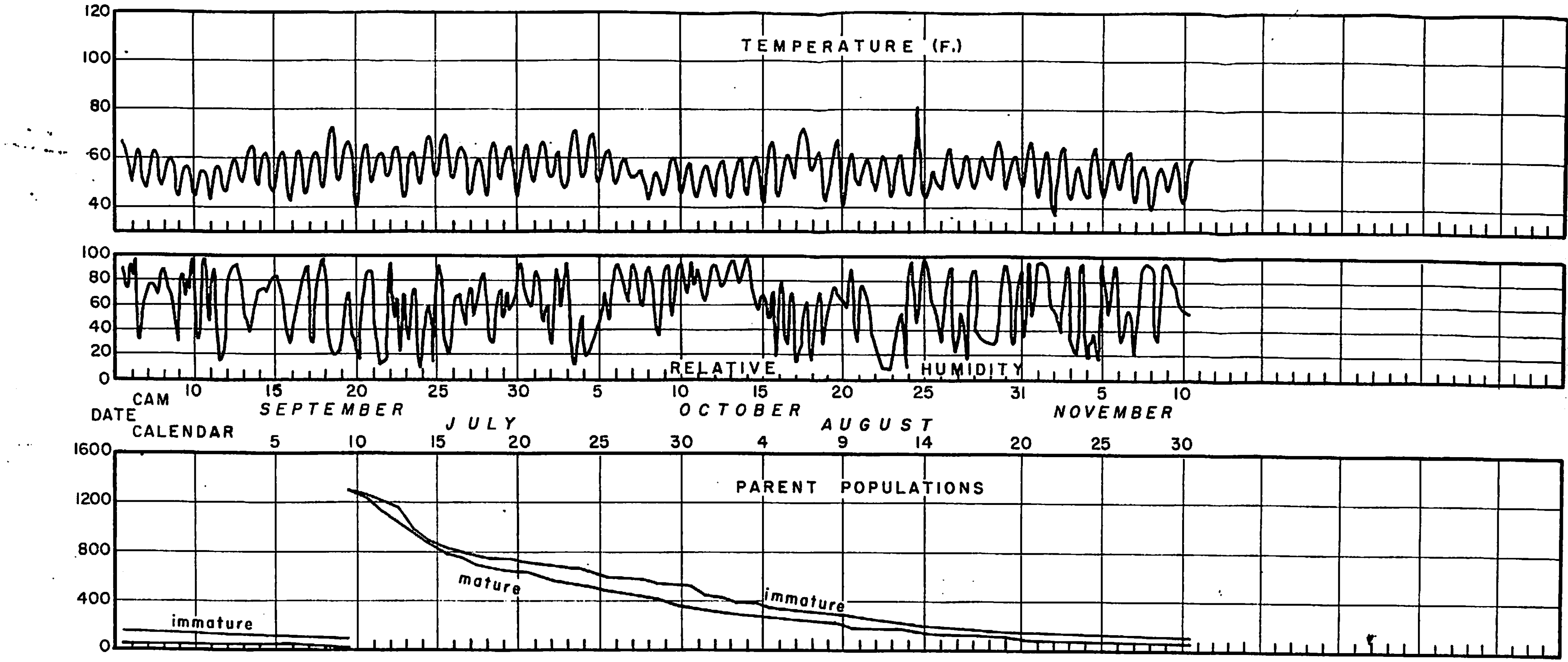
100
80
60
40
RELATIVE HUMIDITY
100
80
60
40
20
CAM
DATE
5 10 15 20 25 31 5 10 15 20 25 31 5 10 15 20 25
JULY
AUGUST
SEPTEMBER
CALENDAR
4 9 14 19 25 30 4 9 14 19 25 30 4 9 14 19
PARENT POPULATIONS
1600
1200
800
400
0
immature
mature
mature
immature
PROGENY POPULATION
4000
3600
3200
2800
2400
2000
1600
4800
4400
4000

FORT PIERCE



DEVELOPMENTAL PERIODS — FORT PIERCE



TEMPERATURE (F.)
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100
80
60
40
RELATIVE HUMIDITY
100
80
60
40
20
0
CAM DATE
10 15 20 25 30 5 10 15 20 25 31 5 10
SEPTEMBER
OCTOBER
NOVEMBER
CALENDAR
5 10 15 20 25 30 4 9 14 20 25 30
JULY
AUGUST
PARENT POPULATIONS
1600
1200
800
400
0
immature
mature
immature

HALEAKALA