Recent Studies on the Abundance of the Oriental and Mediterranean Fruit Flies and the Status of Their Parasites[1]

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The Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann), became established in Hawaii in 1910, some 35 years prior to the Oriental fruit fly, *Dacus dorsalis* Hendel. Within one year following their establishment they multiplied rapidly and soon became serious pests of many tree fruits. Steps were taken promptly to combat each of these flies through the introduction of biological control agents. Investigations of the status of the Mediterranean fruit fly and its introduced parasites were made by a number of investigators during the period from 1910 to 1933 (Back and Pemberton, 1918; Pemberton and Willard, 1918 A, 1918 B; Willard, 1920; Willard and Mason, 1937) and of both flies and their parasites from 1948 to 1959 (Bess, 1953; Bess and Haramoto, 1958, 1961; Bess, *et al.*, 1950, 1961, 1963; Clausen *et al.*, 1965; Haramoto, 1953; Newell and Haramoto, 1968; van den Bosch, *et al.*, 1951; van den Bosch and Haramoto, 1953). After an elapse of several years a follow-up study was made during 1966, 1967 and 1968 to ascertain the status of the flies and parasites during this period. The recent findings are presented in this paper and compared with those obtained during the earlier period, 1949 to 1959, to determine what major changes, if any, occurred in the abundance and status of the flies and parasites during the past decade.

Procedure

Guava, *Psidium guajava* L., was the host fruit used to obtain the basic data presented on infestation and abundance of tephritid fruit fly larvae and their parasites. Fruit samples were obtained periodically from approximately 50 collecting stations or localities on each of the islands of Oahu, Hawaii and Maui, 25 on Kauai, 15 on Lanai and 12 on Molokai and the samples were collected from essentially the same guava stands during 1966–68 as during the 1950–59 period. Providing tree ripe fruits were present at a station on the collection date, 20 fruits were picked for the sample and promptly transported to the laboratory on the campus of the University of

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Hawaii in Honolulu. In the laboratory each fruit was dissected and the tephritid fruit fly larvae, if present, were removed, counted and transferred for rearing to a container provided with papaya pulp and sand as media for food and pupation, respectively. After emergence the adult parasites and flies were counted and the data used to determine the numerical relationships of the flies and parasites.

Other kinds of fruits, such as avocado (*Persea americana* Mill.), coffee, (*Coffea arabica* L.), peach (*Prunus persica* (L.) Batsch.), mango (*Mangifera indica* L.), papaya (*Carica papaya* L.), loquat (*Eriobotrya japonica* (Thunb.) Lindl.), false kamani (*Terminalia catappa* L.), Surinam cherry (*Eugenia uniflora* L.) and mock orange (*Murraya paniculata* (L.) Jack), were collected to obtain additional information. Counts of adult flies and parasites were made in the field at several localities on the various islands on different dates. Also, traps baited with methyl eugenol, a male lure, were operated continuously during 1967 and 1968 at 4 localities on Oahu. The traps used in 1967 and 1968 were similar in design to those described by Newell and Haramoto (1968) and they were placed in the exact positions within the guava stands where traps were maintained from July 1950 to December 1956. Once a month the flies were removed from the traps, measured volumetrically (1 cc = 24 flies), and the methyl eugenol bait replenished.

Fruit Abundance

Guava grows naturally on all of the major islands in Hawaii (Hosaka and Thistle, 1954; Ripperton and Hosaka, 1942) but is not uniformly distributed. It is estimated that approximately 40% of the guava in the State is on the island of Hawaii, 25% on Oahu, 20% on Maui, 10% on Kauai, 2.5% on Lanai and 2.5% on Molokai. Extensive stands of guava occur in gulches and other uncultivated land in areas with relatively high rainfall such as along the Hamakua coast of Hawaii, Hana coast of Maui and the windward side of Oahu. Individual trees and small natural stands occur widely distributed from sea level to 1,060 m elevation and higher in a few localities but do not occur in unirrigated xeric habitats.

Ripe guava fruits are available throughout the year in some guava stands on all of the islands but they become scarce during 2 to 3 months or longer in spring as shown for Oahu by Bess and Haramoto (1961). Therefore, no attempt was made during 1966–68 to collect samples on the outer islands during this season. Each guava stand usually has a clearcut annual fruiting cycle, with periods in which fruits are abundant, scarce and absent. In most of the collecting stations fruits reached their peak abundance between June and October and, in general, fruits were relatively common or abundant from June to November and relatively scarce from February to May. However, even though the majority of the stands were not in fruit in the early spring, there were always a few localities where there were individual trees in fruit. Although no detailed data on fruit abundance were obtained on a monthly basis during the 1966–68 period, observations and collections made on Oahu at different seasons showed that the fruiting cycles were similar, with relatively minor exceptions, to those previously reported. One of these was the unusually late fruiting season in 1968. In May of that year, on the trees in all of the regular collection sites on Oahu only flowers and small immature fruits were present. Nevertheless, at that time, some ripe fruits were observed in a few guava stands near the established collecting stations. Another exception to previously observed fruiting cycles was the abnormally high abundance of ripe fruits on all of the islands in the winter of 1966–67. In January of 1967, ripe fruits were obtained from 92% of the collection stations on Oahu, Maui, Hawaii and Kauai, but in January of the following year, ripe fruits were present in only 47% of the collection stations on Oahu.

Despite the general scarcity of ripe fruits during the spring, ripe fruits were readily available in the majority of the stands at other seasons. In June and July of 1966, 1967 and 1968, ripe guava fruits were obtained from 54% of the collection stations on the 6 islands and in September and October of these years, fruits were obtained from 87% of them. Another indication of differences in the seasonal abundance of fruits is the number or percentage of the samples that contained the full 20-fruit quota. Ninety-nine percent of those collected during August–October, 83% of those in January and 74% of those in June were full 20-fruit samples. In late summer and early fall, samples were obtained with relative ease, while at other seasons often considerable time and energy were expended in finding and picking fruits, even when full 20-fruit samples were eventually obtained.

Fruit infestation

Fruit infestation by tephritids was primarily by *D. dorsalis* but *C. capitata* was also present in some samples. Since the maggots of these 2 species are difficult to differentiate without critical microscopic examination, no attempt was made to segregate the species in the larval stage. Three indicies of infestation were obtained from the individual fruit dissection data (Table 1). These were: % of samples with and without tephritid larvae, % of individual fruits with and without tephritid larvae, and number of tephritid larvae per fruit. Two hundred thirteen of the 243 samples collected between June and October when fruits were plentiful contained 1 or more infested fruits, while only 55 of the 141 samples collected in January were infested. This means that approximately 12% of the summer-fall samples were free of tephritid larvae, whereas 61% of the winter samples were uninfested.

As might be expected, seasonal differences in infestation were more pronounced when % of the individual fruits infested was used as an index

TABLE 1. *Infestation of guava fruits on the different islands*, 1966–68

	Summer—Fall					*Winter*				
			Infestation indicies					*Infestation indicies*		
Island	*No. samples*	*No. fruits*	*I Percent samples infested*	*II Percent fruits infested*	*III No. larvae per fruit*	*No. samples*	*No. fruits*	*I Percent samples infested*	*II Percent fruits infested*	*III No. larvae per fruit*
Oahu	60	1,077	88	33	2.4	28	489	61	8	0.4
Hawaii	83	1,566	86	45	5.6	59	1,063	37	6	0.2
Maui	55	1,051	94	48	5.5	31	576	35	7	0.3
Kauai	23	448	100	70	7.9	14	160	21	2	0.1
Lanai	14	280	57	18	1.8	5	93	0	0	0
Molokai	8	125	100	78	12.4	4	89	50	9	0.5
Total	243	4,547	88	45	5.0	141	2,470	39	6	0.3

of infestation. An average of 45% of the fruits in the summer-fall samples contained tephritid larvae while only 6% of the winter fruits were infested.

The third index of infestation, number of tephritid larvae per fruit, showed an even greater seasonal difference in infestation than either of the preceeding indicies. Larval counts per fruit during the summer and fall were some 7 to 80 times those during the winter. Several of the summer-fall samples contained 15 to 30 larvae per fruit while only 2 of the 141 winter samples had more than 3 larvae per fruit and these had only 3.2 and 4.5.

The occurrence of higher infestation indicies in the summer and lower ones in the winter held true for all of the islands but due to the wide diversity in ecological conditions represented on each of the islands, often there were wide differences in infestation among localities on each island. The samples from the lower elevations of the windward humid localities were more heavily infested than those from other localities. Furthermore, the winter infestations in the former localities were usually greater than the summer infestations at higher elevations. For example, at Hilo, representative of a windward, warm, humid, low elevation locality, 100% of the fruits collected in the summer of 1968 were infested with 12.8 larvae per fruit, while at Captain Cook, representative of a leeward, cool, high elevation locality, only 15% of the fruits collected during the same period were infested with only 0.2 larva per fruit. In the winter of the preceeding year, 35% of the fruits collected in the former locality (Hilo) were infested, and contained 1.4 larvae per fruit, while less than 2% of the fruits collected at Captain Cook were infested with 0.01 larva per fruit. It may be important to note that fruits were more abundant during the summer when these higher indicies of infestation occurred than during the winter when the lower ones occurred.

TEPHRITID LARVAL ABUNDANCE

The larval populations per 20-fruit sample varied a great deal among the different islands and also between seasons (Table 2). On each of the islands there were some areas with appreciably higher larval populations than others. For example, on Hawaii the samples collected during the summer and fall from the localities along the Hamakua coast contained 181 larvae per 20-fruit sample, those from Puna 69 and those from Kona 48, and the winter samples contained 2, 3 and 5, respectively. The summer-fall larval populations were some 15 to 20 times that of the winter larval populations. Nevertheless, a few of the samples from certain localities yielded no tephritid larva; 4.8% of the summer-fall fruit samples had no larva, while 41.8% of the winter fruit samples were free of tephritid larvae.

On the basis of the adult flies and parasites that emerged from the larval samples, approximately 40% of the tephritid larvae within both the summer-fall samples and winter samples were unparasitized but since the larval populations in the summer-fall samples were 15 to 20 times more than those in the winter samples, the flies produced per sample during the summer-fall period also exceeded those of the winter period by 15 to 20 times (Table 2). It was also found from the total larval rearings that 96% of the flies produced were *D. dorsalis* and only 4% *C. capitata.*

TABLE 2. *Fruit fly larval abundance in guava fruits on the different islands*, 1966–68

	Summer–Fall		*Winter*	
	No. larvae per 20-fruit sample		*No. larvae per 20-fruit sample*	
Island	*Total*	*Unparasitized*	*Total*	*Unparasitized*
Oahu	47.1	15.3	8.2	3.9
Hawaii	111.4	52.9	4.6	1.7
Maui	110.3	42.1	6.5	3.4
Kauai	157.1	51.1	1.1	0
Lanai	36.8	34.3	0	–
Molokai	247.4	79.2	10.1	2.0
Average	99.4	39.9	5.6	2.1

In most areas *D. dorsalis* was the only tephritid recovered from guava fruits at both seasons but in a few localities, notably Kunia, Oahu; Iao Valley and Ulupalakua, Maui; Kalae, Molokai; Lanai City, Lanai; and at higher elevations in Kona, Hawaii, *C. capitata* co-existed with *D. dorsalis* in guava fruits the year around. *C. capitata* was reared from only 11 of a total of 138 guava fruit samples: 2 out of 19 on Oahu, 3 out of 31 on Maui, 3 out of 59 on Hawaii, 2 out of 10 on Lanai, 1 out of 4 on Molokai and 0 out of 15 on Kauai. The flies obtained from the summer-fall larval samples from Oahu, Hawaii and Maui were predominantly *D. dorsalis*. However,

TABLE 3. *Relationship of* D. dorsalis *to* C. capitata *in the 1966–68 larval samples from guava fruits*

	Summer–Fall			*Winter*		
		Percent[1]			*Percent*[1]	
Island	*No. flies emerged*	*D. dorsalis*	*C. capitata*	*No. flies emerged*	*D. dorsalis*	*C. capitata*
Oahu	512	98	2	75	49	51
Hawaii	2,749	99	1	35	41	59
Maui	1,221	99	1	68	6	94
Kauai	723	100	0	0	—	—
Lanai	226	98	2	0	—	—
Molokai	279	76	24	6	67	33
Total	5,710	98	2	184	40	60

[1]Percentages calculated on the basis of the adults reared from the larval samples.

in the winter samples from these islands *C. capitata* outnumbered *D. dorsalis* (Table 3).

TRAP CATCHES OF D. DORSALIS MALES

Trap catches of *D. dorsalis* males on Oahu at the 4 localities, Manoa, Nuuanu, Kunia and Helemano, were variable but the maximum and minimum catches, and the upward and downward trends in numbers caught, occurred more or less in the same months (Figs. 1 and 2). There were 2 major peaks in the catches each year. In 1967 the first peak occurred in all 4 traps in the February-April period and the second in the September-November period. In 1968, the first peak occurred in 3 of the traps in March and in the other one, Kunia, in June, and the second peak again occurred in all 4 traps in the September-November period as in 1967. There were also periods characterized by low catches. Each year during January and December, and for a period of 5 months during late spring and summer, the catches for the 4 traps were below the mean for the year, even though, as stated above, the first peak in the catches in the Kunia trap in 1968 was at variance with the others and occurred in June. The magnitude and rapidity of the changes to and from peak catches were usually 5 to 15 fold within 2 months. In 1967 the highest catch for the 4 traps during a month was 4.0 times that of the lowest and in 1968 the highest was 6.2 times that of the lowest, while the total catches during 1967 were approximately twice those during 1968. On an individual trap basis, the highest catch during both 1967 and 1968 was obtained in the Helemano trap. During October 1967 this trap caught 54,000 flies and during September 1968 it caught 55,800 flies. The lowest catch during 1967 was 1,900 flies in September in the Nuuanu trap and during 1968 it was 200 flies in June and again in July in the Helemano trap.

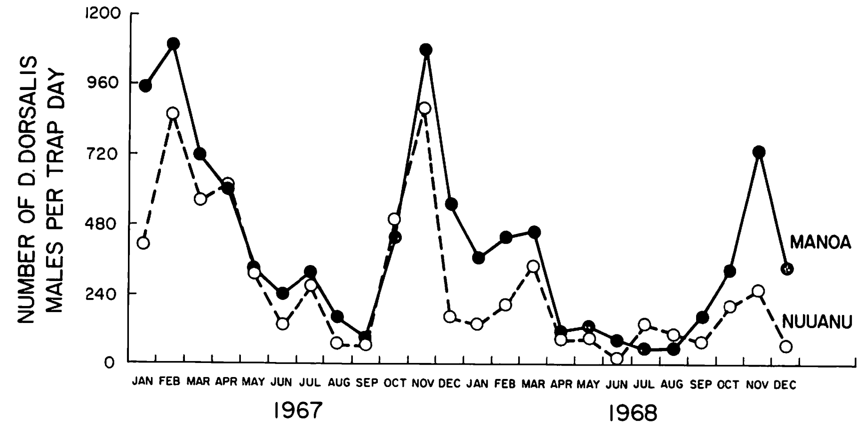

FIG. 1. *Trap catches of male* Dacus dorsalis *Hendel in Manoa and Nuuanu, Oahu during 1967–68.*

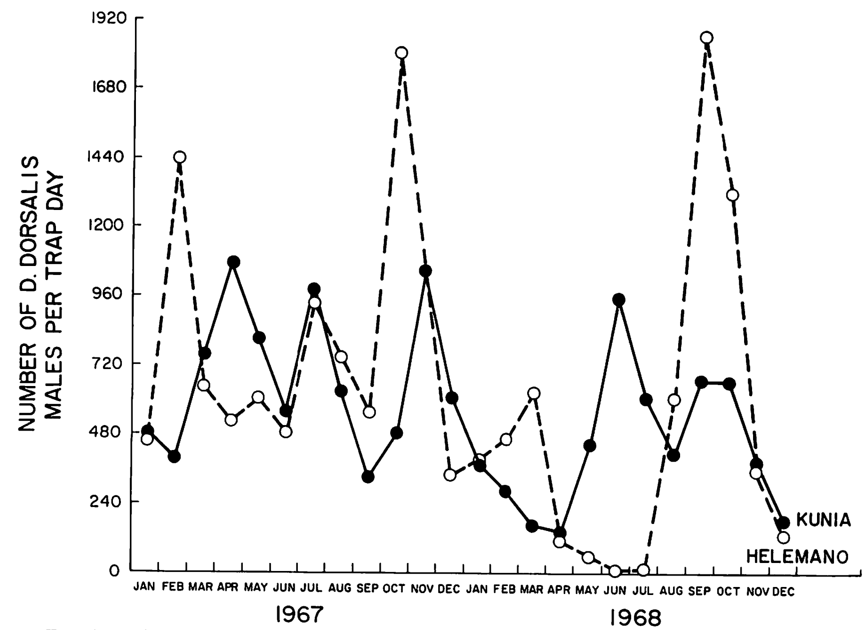

Fig. 2. *Trap catches of male* Dacus dorsalis *Hendel in Kunia and Helemano, Oahu during 1968–68.*

The numbers of flies caught and the amount of lure, methyl eugenol used were not related. During the 2-year period the numbers of flies caught and the quantities (cc) of lure used were as follows: Manoa, 149,100 flies and 214.0 of lure; Nuuanu, 98,900 flies and 186.0 of lure; Kunia, 203,000 flies and 214.0 of lure; Helemano, 234,000 flies and 213.5 of lure.

Parasite Abundance

The number of parasitized host larvae per 20-guava fruit sample was much greater in the summer and fall than during the winter but the number of parasitized larvae per 100 host larvae was essentially the same at both seasons (Table 4). The latter was true even though the host larvae in the summer and fall samples were several times those in the winter samples, and in some cases there was also an appreciable difference in the ratios of *D. dorsalis* to *C. capitata*, both of which serve as hosts but may be differentially attractive to the parasites.

Three opiine species, *Opius oophilus* Fullaway, *O. persulcatus* (Silvestri) = *O. vandenboschi* Fullaway[1], and *O. longicaudatus* (Ashmead), were reared from the tephritid larvae removed from the samples of guava fruits during the 1966–68 study. The first of these species oviposits in eggs, the second in first-instar larvae, and the third in second- and third-instar larvae of tephritid hosts (van den Bosch and Haramoto, 1953). Of the 8,530 adult parasites reared from the samples 7,954, 93.2%, were *O. oophilus*, 565, 6.6%, were *O. persulcatus*, and 11, 0.1%, were *O. longicaudatus*.

TABLE 4. *Parasite abundance in the larval samples in guava fruits on the islands of Hawaii 1966–68*

	Summer–Fall		*Winter*	
	No. parasitized host larvae		*No. parasitized host larvae*	
Island	*Per 20-fruit sample*	*Per 100 host larvae (=percent)*	*Per 20-fruit sample*	*Per 100 host larvae (=percent)*
Oahu	31.8	67	4.3	52
Hawaii	58.5	53	2.9	63
Maui	68.2	62	3.1	48
Kauai	106.0	67	1.1	100
Lanai	2.5	7	—	—
Molokai	168.2	68	8.2	81
Average	59.5	60	3.5	63

O. oophilus was recovered in larval samples from guava fruits collected from sea level to 1,060 m elevation and occurred on all of the islands (Table 5). It was the only species of parasite reared from the winter larval samples and also the only one present in most of the summer-fall samples. *O. oophilus* was reared from 85% of the summer-fall larval samples. It was approximately 18 times more numerous in the summer-fall samples than in the winter samples. The maximum number of adults reared from a 20-fruit summer-fall sample was 231 and from a winter sample 86. Females outnumbered males 1.3 to 1 in the summer-fall samples and 1.1 to 1 in the

±[1]Considered synonymous by Fischer. (1966).

TABLE 5. *Relative abundance of the different opiine parasites in the larval samples from guava fruits from the islands of Hawaii, 1966–68*

	Summer–Fall				Winter			
		Percent				Percent		
Island	*No. parasites reared from larval samples*	*O. oophilus*	*O. persulcatus*	*O. longicaudatus*	*No. parasites reared from larval samples*	*O. oophilus*	*O. persulcatus*	*O. longicaudatus*
Oahu	1,047	99.7	0	0.3	85	100	0	0
Hawaii	3,035	86.1	13.8	0.1	137	100	0	0
Maui	2,240	93.8	6.2	0.1[1]	62	100	0	0
Kauai	1,577	99.5	0.2	0.3	3	100	0	0
Lanai	35	85.7	14.3	0	–	–	–	–
Molokai	594	100	0	0	25	100	0	0
Total	8,523	93.2	6.6	0.2	312	100	0	0

[1]Three of 2,240 adult parasites that emerged.

winter samples. The average parasitization by this species was above 50% and in 60 of the 382 larval samples, only *O. oophilus* emerged. Parasitization was as high, or possibly somewhat higher, in the winter samples than in the summer and fall samples, even though the host density, in terms of number of larvae per sample, was much lower in the winter samples. Adults of *O. oophilus* were commonly seen in the field where host fruits of *D. dorsalis* and *C. capitata* were present.

O. persulcatus was relatively restricted in its distribution and abundance. It was not recovered from either Oahu or Molokai and was only reared from the summer-fall samples collected on Hawaii, Maui, Kauai and Lanai. It was reared in greatest numbers from larvae in fruits collected at 5 localities in the Puna district on Hawaii and at 5 localities along the Haiku-Hana coast on Maui. Samples obtained in June 1966 from these Puna and Haiku-Hana localities produced 356 and 111 *O. persulcatus* adults, respectively, with a maximum parasitization of 85% within a sample. In 5 of the 10 samples, *O. persulcatus* outnumbered *O. oophilus*. Of the total 565 *O. persulcatus* reared during 1966–68, 87.3% were obtained from localities within these 2 areas. Of the 565 adults, 329 were females, giving a sex ratio of 1.4 to 1. On 17 June 1969, guava fruits were examined for adult parasites in a guava orchard at Malama Ki in the Puna district and 31 *O. persulcatus* were counted during a period of 25 minutes, from 11:35 to noon.

Only 7 female and 4 male *O. longicaudatus* adults were reared from tephritid larvae removed from guava fruits collected on Oahu, Hawaii, Maui, and Kauai during 1966–68. However, since this parasite oviposits primarily in large host larvae associated with soft ripe and decaying fruits, the samples which were composed of firm ripe fruits picked from the trees did not provide an adequate measure of the true parasitization by this species. In a number of areas *O. longicaudatus* females were observed probing soft ripe and decaying fruits of guava, mango, papaya, mock orange, and false kamani, especially those fallen to the ground. These observations and the rearing data from fruits other than guava, indicate that *O. longicaudatus* was more widely distributed and possibly more abundant than *O. persulcatus* on each of the islands.

Two other opiines, *O. incisi* Silvestri and *O. tryoni* (Cameron), which were formerly recovered from tephritid larvae in guava fruits (Bess, 1953; Bess and Haramoto, 1961; Bess, *et al.*, 1961) were not reared from the larval samples taken from guava fruits during the 1966–68 study. However, adults of both species were observed probing guava fruits and were reared in small numbers from other kinds of fruits, including coffee, peach, and mock orange.

Comparison of Present and Past Status

Information on the status of the Oriental and Mediterranean fruit flies and their parasites in guava fruits has been presented and in this section we propose to briefly compare their status in 1966–68 with that of the earlier period, 1949–59. This is made with full awareness that there are many variables in addition to the seasonal and yearly variations in fruit abundance which complicate the problem of attempting to make valid comparisons.

No additional biological control agents of tephritid fruit flies have been introduced and no insecticides have been applied to natural stands of guava which would have affected the bionomics of the flies during the past 15 years. However, in some sections there has been considerable reduction in the acreage of guava due to the extensive clearing of lands for agricultural, residential and recreational uses. Furthermore, in some areas there has been some reduction in guava fruits as a potential breeding medium for the tephritids due to increased utilization of fruits for processing into purée, jam, jelly and juice. In other areas there have been some small guava orchards established in recent years but the fruits are harvested, thus preventing the multiplication of tephritids in them. The decrease in the guava population during the past 2 decades apparently did not appreciably affect the numbers of tephritids within the remaining guava areas where the major portion of *D. dorsalis* populations is produced.

Prior to the arrival of *D. dorsalis* in 1946, *C. capitata* was known to commonly infest guava and other fruits throughout the Hawaiian Islands. However, simultaneous to the spread of *D. dorsalis* throughout the State, infestation of guava fruits by *C. capitata*, especially in lowland areas, became nil (Bess, 1953). By December 1949 less than 5% of the guava samples from Oahu produced *C. capitata* and these were from a few localities where the climate is noticeably cool. In these localities *C. capitata* has continued to persist in small numbers over the past 20 years.

Between 1947 and 1951, infestation was relatively high in guava fruits in all areas on the different islands. During this period all samples of guava fruits collected contained 1 or more infested fruits, nearly 100% of the individual fruits were infested and there were many larvae per fruit. The infestation in the lowland areas was by *D. dorsalis* but in some of the cooler areas it was by both *D. dorsalis* and *C. capitata*. Infestation and abundance of tephritids were much greater in 1947 and 1948 than in 1949 and also greater in 1949 than in 1950. The extensive monthly collections of guava fruits made on Oahu from November 1949 through December 1956 revealed that the mean infestation for the first 6 months of 1950 was 248 larvae per sample, only 55 for the same period in 1951, and that the high for any of the following 5 years was 133. The mean infestation for the whole of 1955 was 52 larvae per sample, the same as for 1951, but it was somewhat higher for each of the other 4 years, 66 to 138. In January 1950 the infestation was 82 larvae per sample, in the same month the following year it was only 8 and again the same in 1956 but it was higher in the other years, 16 to 42. In contrast, the recent investigations on Oahu revealed that the infestation was 44.3 in July 1966, 119.0 in July 1967 and 38.9 in September 1968 and that it was 8.5 in January 1967 and 7.6 in January 1968. Thus it appears that despite the ecological changes or disturbances which have resulted due to urbanization and other factors, the stability of the guava-tephritid ecosystem has remained relatively unchanged in Hawaii for the past 17 years.

The decline in *D. dorsalis* infestation in other fruits paralleled the decline in guava and coffee fruits during the same period but was much more spectacular in fruits such as avocado, banana, citrus, mango, and papaya. In coffee the mean number of *D. dorsalis* larvae per sample of 300 cherries collected monthly during the period from August 1949 to December 1949 was 42.4, during 1950 declined to 24.0, during 1951 declined to 24.0, during 1951 declined further to 4.2 and did not exceed the latter number in subsequent years, 1952–68 (Table 6). *D. dorsalis* is now of relatively little economic importance on most kinds of fruits other than guava, even though many were formerly heavily infested by this fly. Furthermore, *D. dorsalis* was recovered from very few fruit samples collected at elevations of 758 m and above where the fly was formerly commonly present as a pest along with *C. capitata*.

The infestation by *C. capitata* also declined along with that of *D. dorsalis* in the upper elevation areas where the 2 species occurred together in large numbers in certain fruits during 1948 to 1950. For example, the mean numbers of tephritid larvae, *D. dorsalis* and *C. capitata*, per sample of 300 ripe coffee cherries during the peak harvesting season, September, October and November, were 63.2 in 1949, 41.2 in 1950 and in subsequent years varied between 2.2 and 15.9. There was a major reduction in abun-

TABLE 6. *Infestation by and parasitization of* D. dorsalis *and* C. capitata *in the coffee samples from Kona, Hawaii, August 1949–November 1968*

Period	*Number adults per sample* (300 *coffee cherries*) *D. dorsalis*	*C. capitata*	*Total* (*flies* + *parasites*)	*Percent Parasitized*
1949	42.4	22.1	70.7	8.7
1950	24.0	30.3	77.7	30.1
1951	4.2	19.1	47.7	51.1
1952	1.8	7.1	27.3	67.3
1953	1.8	5.2	20.9	66.8
1954	2.9	9.2	34.1	64.7
1955	1.2	1.4	7.9	66.3
1967	0.5	3.4	17.3	76.6
1968	3.8	1.3	15.6	66.8

dance and infestation by 1951 (Fig. 3) and since then they have been relatively stable at less than 30% of the 1949 level (Table 6). This is true even though *C. capitata* is more abundant than *D. dorsalis* in the high elevation plantations and *D. dorsalis* outnumbers *C. capitata* in those at low elevation. In 1949 87.7% of the flies reared from the samples from the 758 m elevation were *C. capitata* with 12.3% *D. dorsalis*, while only 7.1% of those reared from the samples from the 212 m elevation were *C. capitata* with 92.9% *D. dorsalis*. In 1968, although the infestation was only about 1/4 of what it was in 1949, the 758 m elevation samples produced 15 times as many *C. capitata* as *D. dorsalis*, and those from the 212 m elevations produced 5 times as many *D. dorsalis* as *C. capitata*. At the intermediate elevation,

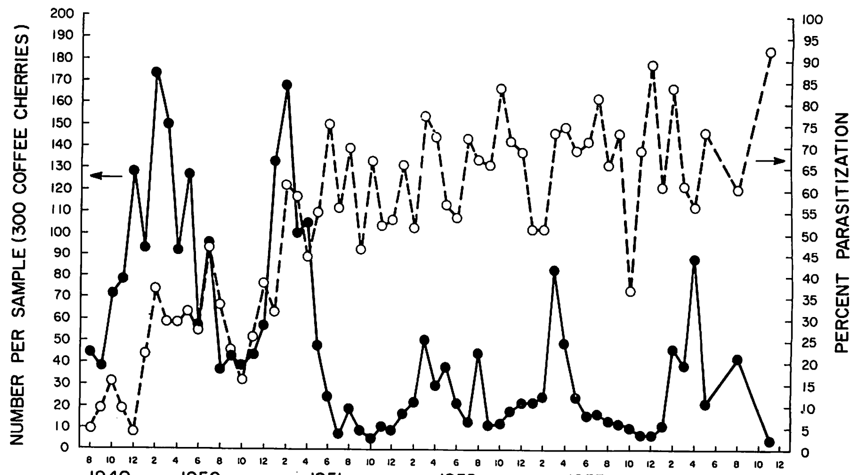

FIG. 3. *Infestation by and parasitization of* Dacus dorsalis *Hendel and* Ceratitis capitata (*Wiedemann*) *in coffee cherries, Kona, Hawaii 1949–54.* ●—● *infestation;* O---O *parasitization.*

365 m, in 1949 *D. dorsalis* outnumbered *C. capitata* 7 to 1 but since 1951 the ratio between the 2 species has been approximately 1 to 1. Therefore, even though the greater portion of the niches occupied by *C. capitata* were subsequently taken over by *D. dorsalis*, indicating that the former species was less successful as a competitor, there are some niches where the reverse is true and *C. capitata* is more successful than *D. dorsalis*. Furthermore, the present distribution and abundance of these 2 tephritids in Hawaii suggest that *C. capitata* is better adapted than *D. dorsalis* to temperate climates but that the 2 species can co-exist in certain ecological conditions.

The numbers of male *D. dorsalis* caught in the 4 Oahu traps during 1967 and 1968 were similar to those obtained from traps set at the same localities during the earlier period. These also indicate that *D. dorsalis* abundance probably reached equilibrium in 1951 and has remained at essentially the same level since then. Each year the lowest catches were obtained during the spring when fruits were relatively scarce and had been for some time but there was a pronounced increase in the catches by August, with peak catches in September or October, followed by a steep decline by December (Fig. 4). This was true even though fruits continued to be relatively abundant through November, December and January. However, the steep decline in catches does not necessarily mean that there was a similar decline in the male adult populations in the field for many te-

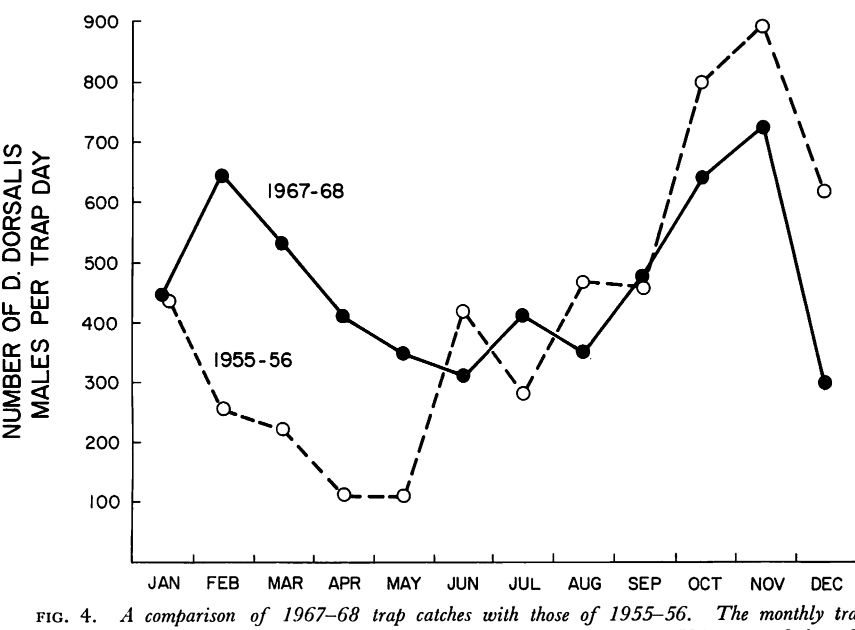

FIG. 4. *A comparison of 1967–68 trap catches with those of 1955–56. The monthly trap catch shown represents amean for the 4 traps, Manoa, Nuuanu, Kunia and Helemano, Oahu, for* 2 years.

TABLE 7. *Relative abundance of the different opiine parasites in the coffee samples from Kona, Hawaii, August 1949-November 1968*

Period	Number parasites reared from samples	Percent					
		O. fullawayi	*O. tryoni*	*O. longicaudatus*	*O. persulcatus*	*O. incisi*	*O. oophilus*
1949	98	48.0	7.1	35.7	9.2	0	0
1950	732	19.7	1.5	38.8	32.4	0	7.6
1951	782	9.2	0.6	0.4	13.3	0.3	75.2
1952	477	0	1.7	0.6	0	0	97.7
1953	405	0.2	0.7	0.5	0	0	98.5
1954	353	0.3	0.6	1.7	0.8	0.6	96.0
1955	63	0	0	3.2	0	0	96.8
1967	126	0	0	0	0	0	100
1968	187	0	0	3.7	0	0	96.3

phritids overwinter as adults in temperate areas and apparently *D. dorsalis* does to some extent in Hawaii. This may account in part for the low egg and larval populations in the fruits during the fall and winter months and also the reduced male catches during this period. Although all stages of *D. dorsalis* are present during the winter months in guava fruits, the adults produced from these extremely low populations appear to be too few to account for the rapid upsurge in the infestation in the spring. Therefore, presumably many of the female adults produced during the previous summer and fall survive the winter and are involved in the rapid increase in infestation in the spring and summer.

As already shown there were large fluctuations in the larval host density between seasons and localities and the fluctuations in the numbers of parasites were closely related to those of the hosts. Therefore, the % parasitization was relatively stable despite the large fluctuations in the populations of fruits, tephritids, and parasites. Also, there were no significant differences in parasitization where the tephritids present were all *D. dorsalis*, all *C. capitata*, or a combination of the 2. Parasitization has averaged 60% or more since 1951 following the establishment and buildup of *O. oophilus* on all of the islands. Since July 1951 *O. oophilus* has been the most abundant and important parasite of both *D. dorsalis* and *C. capitata* in most larval samples from guava fruits and all of those from coffee cherries (Table 7). However, a number of the parasites introduced to combat these flies are still present. In addition to *O. oophilus*, the following species were seen as adults in the field or reared from tephritid larval samples during the 1966–1968 study: *O. persulcatus*, *O. longicaudatus*, *O. tryoni*, *O. incisi* and *O. fullawayi* (Silvestri). *O. longicaudatus* and *O. tryoni* adults were observed in many localities while *O. persulcatus* and *O. fullawayi* were seen in only a few localities. *O. persulcatus* outnumbered *O. oophilus* in some of the guava fruit samples from the Kalapana area on Hawaii. Although *O. incisi* was not obtained from the larval samples from guava fruits or coffee cherries, it does parasitize *D. dorsalis* larvae in other kinds of fruits such as kamani and mock orange. *O. fullawayi* was only found in the Kona, Hawaii area in coffee plantations where *C. capitata* commonly occurs. As far as known, *O. fullawayi* does not develop successfully in *D. dorsalis* larvae. This parasite along with *O. tryoni* and *O. humilis* were introduced in 1913 and 1914 to combat *C. capitata* and the average combined parasitization by the 3 species for 1916, 1917 and 1918 was 32.6, 40.3 and 49.6, respectively (Willard, 1920). *O. humilis* was then the dominant parasite during the cooler months and *O. tryoni* the dominant one during the warmer months. However, *O. humilis* was not seen in the field or reared from the numerous samples of various kinds of fruits processed during the past 2 decades. *O. tryoni* oviposits in *D. dorsalis* larvae but is unable to develop in this tephritid. However, it successfully develops in *C. capitata* larvae in fruits and also in the larvae of 2 stem gall-forming tephritids, the eupatorium gall fly, *Procecidochares utilis* Stone, and the lantana gall fly, *Eutreta xanthochaeta* Aldrich. The changes in the composition of the parasite fauna of tephritids in coffee in Kona, Hawaii since 1949 and the rapid ascendancy and persistence of *O. oophilus* as the dominant parasite (Table 7) are very closely similar to those that occurred in larval samples from guava fruits on all of the islands (van den Bosch, *et al.*, 1951).

Summary

During 1966–68 data were obtained from collections of guava fruits on all 6 of the major islands of Hawaii to establish the present status of *Dacus dorsalis* Hendel and *Ceratitis capitata* (Wiedemann) and their introduced parasites and used for comparison with that during 1949–56. In addition, supplementary data were obtained from field observations, trappings of *D. dorsalis* males, and miscellaneous fruit collections and used in making the comparison. It was found that the status of both flies and their parasites during 1966–68 was much lower than prior to 1950, but essentially the same as during the 1952–56 period.

The infestation in guava fruits during 1966–68 varied with years, seasons and localities. It averaged 99.4 tephritid larvae per 20-fruit sample for the summer collections and only 5.6 for the winter collections. Infestation in the summer was almost exclusively by *D. dorsalis*, however, in a few localities, especially in higher and cooler situations, *C. capitata* was present. During the winter where the infestation was much lower than in the summer, *C. capitata* outnumbered *D. dorsalis*. The combined infestation by the 2 tephritids, *D. dorsalis* and *C. capitata*, during 1966–68 was considerably lower than by *C. capitata* alone prior to the establishment of *D. dorsalis* in 1946 and the subsequent establishment of additional tephritid parasites.

Parasitization during the 1966–68 period as determined from rearing

the larval samples obtained from guava and coffee fruits was about 65–70%, or essentially at the same level as during the 1952–56 period. This parasitization was due primarily to *Opius oophilus* Fullaway, but some individuals of *O. longicaudatus* Ashmead, *O. persulcatus* (Silvestri), *O. incisi* Silvestri, *O. tryoni* (Cameron) and *O. fullawayi* (Silvestri) were recovered or seen in the field.

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