Exotic fruit fly pests and California agriculture

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Because of their worldwide distribution and numbers, future introductions of fruit flies into California are inevitable. Infestations of economically important pests, including but not limited to the medfly, Mexican fruit fly, and oriental fruit fly, are expensive to treat, and their elimination is seldom certain. Researchers are seeking to improve detection and control methods.

The frequency of pest fruit fly introductions into the state is on the increase. From the time when records were first kept in the middle of last century until the mid-1980s, eight exotic, or non-native, species were captured, including the Mediterranean fruit fly (medfly), Mexican fruit fly, and oriental fruit fly. In 1987 alone, nine species of fruit flies were captured, three of which had never before been recovered. One of these—an Asian species related to the oriental fruit fly—had never been described by fruit fly taxonomists. That summer the California Department of Food and Agriculture (CDFA) initiated separate eradication programs on five species: the apple maggot, melon fly, medfly, peach fruit fly, and oriental fruit fly. The medfly has been recovered in the state seven times since 1982, when it was eradicated in Santa Clara County.

The 1980-82 eradication campaign against the medfly marked the beginning of a new era in fruit fly research and in the CDFA's detection, quarantine, and eradication protocols. There was a public outcry against chemical sprays, and growers became concerned over the possible permanent establishment of exotic fruit fly pests. Although there were and are no certain solutions, there has been progress on understanding fruit fly biology and ecology as well as advances in control and detection techniques, technologies, and strategies.

Establishment of a major fruit fly pest such as the medfly in California would have widespread effects on agriculture, because this species and others attack a large variety of high-value crops that are exported. Quarantines imposed by the major importing countries would require disinfestation procedures. These would increase costs 10% to 100%, depending on the fly species and commodities affected. The competitive balance of commodity trade would shift temporarily to other states. But a pest established in California is likely to spread rapidly to other states with similar climates and potential hosts. Because of the adverse effects such establishment would have on the U.S. agricultural economy, eradication programs are mandated by the federal government.

This article reviews the status of pest fruit flies in California agriculture. It includes general information on fruit fly ecology and biology and the state of basic and applied research.

Worldwide distribution

Virtually all pest fruit flies are in the dipteran family Tephritidae, whose members are known as the "true" fruit flies. They differ from the more common *Drosophila* species in that adults are relatively large (typically larger than house flies), and females tend to lay eggs in mature rather than in decomposing fruit. About 100 tephritid species are native to California. Most of these feed on flower heads or are gall-formers but do not attack fruit. The walnut husk fly and the apple maggot are the only fruit-attacking tephritids established in the state, having been introduced in the early 1920s and 1980s, respectively.

Most tephritids of economic importance fall into four genera: *Ceratitis*, *Anastrepha*, *Dacus*, and *Rhagoletis*.

The genus *Ceratitis* is one of the best known because of the notoriety of one of its members—the Mediterranean fruit fly. Over 100 *Ceratitis* species have been described, of which six are known pests. The genus is thought to have evolved in Africa, and most species are distributed in regions with Mediterranean climates.

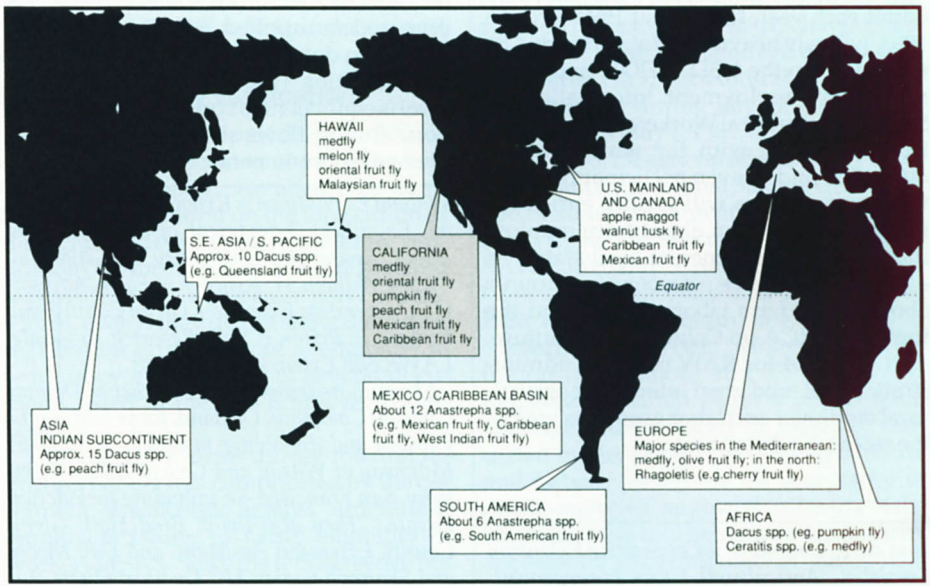
Anastrepha includes 150 to 200 species native to the Caribbean, Mexico, and Central and South America. Two species are now present in the southern United States, through either natural spread or introduction by humans—the Mexican fruit fly in southern Texas and the Caribbean fruit fly in Florida.

Of the approximately 500 *Dacus* species, 30 to 40 are known or potential pests, including the oriental fruit fly, the melon fly, and the Malaysian fruit fly. With the exception of the olive fruit fly found in Europe, most members of this genus are tropical or subtropical and native to Africa, Asia, Australia, and the South Pacific. A close relative of the oriental fruit fly is currently established in the South American country of Surinam.

Around 50 *Rhagoletis* species have been described. Most are widely distributed over the temperate and subtropical regions. These species have only one to two generations per year and tend to attack a narrow range of fruit species. The walnut husk fly and the apple maggot are two of the better known pests in this genus.

Host relations

Fruit flies have evolved to exploit virtually every type of fruit and vegetable found any place in the world. Some species, such as the apple maggot and papaya fruit fly, are highly specialized and attack only one host species or a narrow range of closely related



Worldwide distribution of fruit fly pests. Species listed for California are examples of recent introductions that have subsequently been eradicated.

ones. Other species attack a wide variety of hosts; these "generalists" include the West Indian fruit fly, the medfly, the Mexican fruit fly, and the oriental fruit fly. Some species attack extremely large hosts; for example, the jack fruit fly, a specialist from Southeast Asia, attacks jack fruit weighing several hundred pounds. Others, such as the medfly, may choose small hosts like coffee cherries that only contain enough food resources for one to three larvae to mature.

No fruit fly species have ovipositors adapted to directly penetrate thick citrus rinds, such as those on citron, or fruit with hard skins, such as pomegranates or avocados. These hard- or thick-skinned hosts are not immune to attack, however, because fruit fly females are usually able to find cracks or soft spots in the host for laying eggs. As a result, even marginal hosts are subject to the same quarantine regulations as more favorable ones.

Movement

Pest fruit flies may enter California by either "jump dispersal" or simple diffusion.

The first refers to movement across long distances in a short time, usually across inhospitable areas such as oceans or deserts. This method of entry is the most serious threat, in part because of its unpredictability. For example, infested fruit may be brought into the state in the mail, by road or railroad, and by air. Air travelers from overseas are among the greatest potential sources of infestations, because (1) fruits and vegetables carried by airplane passengers are often still fresh when they enter the state, so that fruit flies are able to survive, and (2) the sheer numbers of travelers place a heavy load on regulation at ports of entry. For example, in 1987 nearly 7 million air passengers entered California through the Los Angeles International Airport, over a million of whom arrived from Hawaii—a state with four serious pest species. If, as a purely hypothetical number, one passenger in a thousand carried fresh fruit, 7,000 could have been brought in during 1987 alone.

In simple diffusion, fruit fly populations move gradually across hospitable terrain over many generations. For example, the Mexican fruit fly or related species may eventually enter the state near San Diego. Movement of the apple maggot through diffusion from Oregon may partly account for its establishment in northern California.

Climatic requirements

There was controversy during the 1980-82 medfly eradication campaign over whether the medfly could survive the winter in the northern part of the state. Some people maintained that the population might die out naturally even without an eradication program. Part of the problem was that the results of laboratory temperature studies were extrapolated to the natural environment. Many involved in the program ignored the results of long-term studies of the medfly as an introduced pest in other regions of the world. The medfly occurs in regions with climates similar to three of the four major climatic zones in California: climates in most parts of the Sacramento Valley and the coastal regions are classified as Mediterranean, similar to those of Greece and Italy; parts of the San Joaquin Valley near Fresno have climates classified as steppe, similar to many parts of North Africa such as Tunisia; the climate near Barstow and Imperial is classified as hot desert like many parts of Middle Eastern countries such as Egypt and Israel. The medfly abounds in all of those countries.

A number of countries with other serious fruit fly pests have climates similar to those in California. For example, three major pests—the peach fruit fly, the melon fly, and the Ethiopian fruit fly—occur in Pakistan, many parts of which are hot and dry like California's Central Valley. The peach fruit fly and melon fly have both been recovered previously in California.

Irrigation complicates the picture, because it allows the production of crops that would not ordinarily grow in the state. Fruit fly species that specialize in these hosts may or may not be able to survive the climate, but one of the basic conditions is met—host plant availability.

Effect on agriculture

Fruit flies affect agriculture both directly through larval damage to the crop and indirectly through quarantine restrictions. In many parts of the world, fruit flies destroy 100% of the crop. For example, star fruit is a profitable export for Malaysia, but oriental fruit flies destroy every fruit not protected with paper bags. Virtually all unprotected mature peaches grown in backyards in Hawaii become infested with fruit flies.

The quarantine restrictions placed on commodities because of the presence of fruit flies are perhaps even more important. Major markets in other parts of the United States, such as Florida, Arizona, and Texas, and other countries, such as Japan, either totally restrict affected imports or require post-harvest disinfestation treatments.

California crops susceptible to fruit fly infestations are valued at over $4.5 billion and include stone fruit, citrus, safflower, and nuts. Several aspects of this situation merit comment. First, almost every major crop in the state is subject to attack by one or more species. For example, cotton is not noted to be a prime host for any species, but it could serve as a marginal host in the absence of more favorable hosts for fruit fly species such as the Ethiopian fruit fly. Second, not all commodities would be affected in the same way or to the same degree. A generalist species such as the medfly would affect stone fruits by direct attack as well as by quarantine measures. Many citrus varieties would be affected more by quarantine. Cotton would probably be only marginally affected by direct damage and not at all by a quarantine. Third, host records represent realized and not potential hosts and are incomplete for most flies. The reason is that human activity often results in new combinations of flies and hosts. The mango, for example, was not a host of the Mexican fruit fly until it was introduced into Mexico and the Americas in the last century from India. Similar situations certainly exist for many California fruit fly hosts, but in this case, the new pest is brought to the host.

We estimate that roughly 80 species of fruit flies found throughout the world are realized or potential threats to California agriculture. They fall into three categories: (1) introduced species that are currently established in the state (walnut husk fly and apple maggot); (2) introduced species that were subsequently eradicated or died out (total of 12 species including the medfly, Mexican fruit fly, and oriental fruit fly); and (3) species that have never been recovered in the state but are thought to have a high probability of establishment if introduced (including species found in dry, hot summer climates such the Ethiopian fruit fly.

Species not considered serious threats include ones such as the olive fly, whose hosts—raw olives—are seldom carried by air travelers. Species considered unlikely to become established, even if introduced, are those found exclusively in the tropics that specialize in hosts not grown in the state—the papaya fruit fly, for example.

The motive for import restrictions on commodities from an infested region is

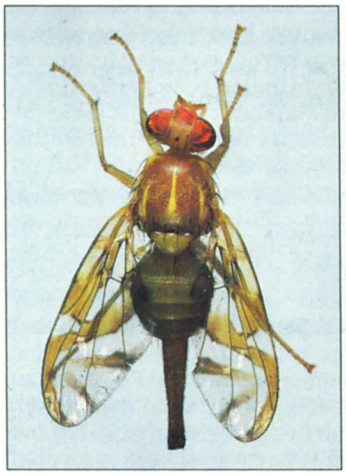
Major pest fruit fly species

***Ceratitis*:**
Mediterranean fruit fly, *C. capitata.*

***Anastrepha*:**
Mexican fruit fly, *A. ludens*
South American fruit fly, *A. fraterculus*
West Indian fruit fly, *A. obliqua*
Sapote fruit fly, *A. serpentina*
Guava fly, *A. striata*
Caribbean fruit fly, *A. suspensa*
Inga fruit fly, *A. distincta*

***Dacus*:**
Melon fly, *D. cucurbitae*
Ethiopian fruit fly, *D. ciliatus*
Oriental fruit fly, *D. dorsalis*
Malaysian fruit fly, *D. latifrons*
Peach fruit fly, *D. zonatus*
Queensland fruit fly, *D. tryoni*
Olive fly, *D. oleae*
Pumpkin fly, *D. bivittatus*
Chinese citrus fly, *D. citri*
Guava fruit fly, *D. correctus*

***Rhagoletis*:**
Apple maggot fly, *R. pomonella*
European cherry fruit fly, *R. cerasi*
Walnut husk fly, *R. completa*



Most major fruit fly pests fall into four genera. Representatives of the four are, from left: Mexican fruit fly (*Anastrepha*), apple maggot fly (*Rhagoletis*), melon fly (*Dacus*), and Mediterranean fruit fly (*Ceratitis*). (Photos by Jack Kelly Clark)

uncertainty about the extent of direct damage that a fruit fly species would cause if it were to become established. This unpredictability extends beyond the obvious cases. For example, melon flies are a more severe pest of tomatoes in Malaysia now than a decade ago because of a trend to grow tomatoes hydroponically. Plants grown by this method tend to have softer, more succulent stems than do plants rooted in soil. Melon flies in Malaysia now attack not only the tomato fruit but also the softened main stem, killing the entire plant. It would have taken a true visionary to have fully anticipated this problem. Similarly unpredictable situations could arise in California with the introduction of certain pest species.

It is also difficult to estimate the seriousness of a pest in its native region to predict how serious it might be if it became established elsewhere. The true pest status of flies is frequently unclear in their native regions. For example, the citrus fly is not a major pest in southern China where citrus orchards are common. But many orchards are sprayed with miticides up to 20 times annually. Without controlled studies, it is impossible to say whether the citrus fly is not a serious pest because of these sprays or for some other reason. Anecdotal information is all that is available for many species.

Detection and eradication

CDFA currently budgets $7 million for fruit fly trapping alone. Three types of traps are used to detect fruit flies: sex lure traps (for medfly, oriental fruit fly, and melon fly); color sticky traps (for apple maggot); and bait traps (for all others including *Anastrepha* spp.). The sex lure traps are the most species-specific but also are sex-specific (mostly males captured). The major shortcoming is the lack of attractants of any kind for a large number of exotic pest fruit fly species.

Eradication strategies are based on the simple premise that the death rate of the target pest must exceed its birth rate for a sustained period. This can be accomplished by increasing deaths, by decreasing births, or by a combination of the two. Basically four tactics are available for controlling or eradicating fruit flies: chemical control, male annihilation, the sterile-insect technique, and parasitoid inundative release.

Chemical control of fruit flies entails applying soil drenches against soil-inhabiting pupae or bait sprays against adults. For the bait sprays, a pesticide such as malathion is mixed with protein hydrolysate and applied by air or by ground rig. Flies are attracted to the bait, feed, and are killed. This approach is more selective than broad-spectrum spraying.

The second method uses a sex lure combined with a pesticide to attract and kill males on contact. If a large enough portion of the male population is killed, females will not find mates and thus will not produce fertile eggs. This method is effective only if a powerful attractant for males is available. It is most commonly used against the oriental fruit fly, which is attracted to an insecticide-laced methyl eugenol lure.

The sterile-insect technique eradicates the target pest through the release of large numbers of sterile flies. It works through direct mating competition between laboratory-sterile males and wild, fertile males for wild, fertile females and through "dilution" of the numbers of wild males. Large numbers of sterile males decrease the proportion of all males that are fertile. It is a nonpolluting technique that is increasingly effective as pest population levels decrease.

Parasitoid inundative release has received only limited attention so far. Massive numbers of parasitoids are required, and technologies for their large-scale production are just now being developed.

Conclusions

Two aspects of the fruit fly problem are fairly predictable: (1) future fruit fly introductions are inevitable because of the worldwide distribution and abundance of large numbers of important species; and (2) the number of introductions is likely to rise as the number of travelers entering the state and commodity imports increase.

Fruit fly eradication programs are constrained technically in the same way as all pest management programs. Progress in detection and control technologies will be almost certainly be made in steps rather than in large technological jumps. Research strategies designed to deal with introduced pests must be tailored accordingly to ensure that no major exotic fruit fly pest becomes established in the state.

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