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TEPHRITID FRUIT FLIES IN CHINA: HISTORICAL BACKGROUND AND CURRENT STATUS

PINGJUN YANG,[1,3] JAMES R. CAREY,[1,4] AND ROBERT V. DOWELL[2]
[1]Department of Entomology, University of California,
Davis, California 95616
[2]California Department of Food and Agriculture,
Sacramento, California 95814

Abstract.—China has 400 species of tephritid fruit flies of which 10 are crop pests: *Bactrocera cilifer* (Hendel), *B. cucurbitae* (Coquillett), *B. diversa* (Coquillett), *B. dorsalis* (Hendel), *B. latifrons* (Hendel), *B. minax* (Enderlein), *B. occipitalis* (Bezzi), *B. scutellata* (Hendel), *B. tau* (Walker), and *B. tsuneonis* (Miyake). Historically, only *B. minax, B. cucurbitae,* and *B. tau* caused sufficient crop damage to be of concern. With increasing trade, the presence of these fruit flies constitutes a barrier to the export of Chinese agricultural products to a number of countries including Japan. Background on cultural and chemical controls are given, as are suggestions for future research on Chinese Tephritidae.

Key Words.—Insecta, *Bactrocera minax, B. tsuneonis, B. cilifer, B. cucurbitae, B. diversa, B. dorsalis, B. latifrons, B. occipitalis, B. scutellata, B. tau, B. citri,* biological control, cultural control

The Tephritidae (Diptera) is a large, diversified family with approximately 4500 known species (White & Elson-Harris 1992). The Dacinae is a tephritid subfamily with approximately 700 recorded species. With the exception of the olive fruit fly, *Dacus oleae* (Gmelin), which occurs in southern Europe, Dacinae are endemic to Africa, Asia, Australia, and the South Pacific; they include such well known pests as the oriental fruit fly, *Bactrocera dorsalis* (Hendel), and melon fly, *Bactrocera cucurbitae* (Coquillett). Together with the other pest tephritids, these flies comprise an important group of pests causing direct loss of fruits and vegetables, and trade restrictions because of agricultural quarantines (White & Elson-Harris 1992).

China is a large country with biotic and abiotic environmental conditions suitable for many fruit flies. About 400 species of tephritids have been recorded from China. Economically important species include widespread species, such as *B. cucurbitae* and *B. dorsalis,* plus native species, such as the Chinese citrus fly, *Bactrocera minax* (Enderlein) (formerly *B. citri* (Chen) White & Wang 1992) (Chao & Ming 1986).

Early Chinese fruit fly research emphasized taxonomy and control. Zia and Chen recorded about 150 species of tephritids including 80 new records in the 1930s (Zia 1937, 1939; Chen 1940). Another 200 species were added by 1954 (Zia & Chen 1954). These species belong to about 40 genera in the subfamilies: Dacinae, Trypetinae and Tephritinae, and include the pest species *B. minax, B. cucurbitae, B. dorsalis,* and *Bactrocera tau* (Walker). Other reports on crop damage and control measures dealt mainly with *B. minax* (Chen & Wang 1943, Chu 1948,

[3] Current address: 2729 Kapiolani Boulevard. #203 Honolulu, Hawaii 96826; submitted in partial fulfillment of the requirement of the degree of Doctor of Philosophy, University of California, Davis, California.

[4] To whom reprint requests should be sent.

Sun 1961, Sun & Du 1957). Work on biology, ecology, and behavior of the other major pest species was neglected.

Since 1980, the Chinese "open door" policy has rapidly increased trade of agricultural products and tourism. Concurrently, the presence of quarantine pests has become an important problem for China. Exports of litchi [*Litchis sinensis* (Sonnerat)] and muskmelon [*Cucumis melo* L.] to Japan were restricted because of the presence of *B. dorsalis* and *B. cucurbitae.* China has restricted the importation of North African fruits because of the presence of *Ceratitis capitata* (Wiedemann). A fruit fly survey was conducted in 105 prefectures and cities of 10 provinces from 1982 to 1985 (Chao & Ming 1986). An integrated pest control program is now successfully controlling *B. minax* in Huaihua Prefecture, Hunan Province. The effect of temperature on *B. cucurbitae* was studied to determine if it could survive in Xinjiang Autonomous Region (located in northwest China) as a prelude to exporting melons to Japan (PY, unpublished data). Studies of fruit fly biology and ecology that are needed to understand basic population characters include the life history of *B. dorsalis* and *B. tau,* and host preference of *B. cucurbitae* (Yang & Zhou 1988, Yang et al. 1990).

Here, we present information on fruit production, and the distribution and control of fruit flies in China. We then discuss research needs related to fruit fly biology, ecology, quarantine, and control in China.

Major Fruits Grown in China

Total Chinese fruit production grew from 6.5 million metric tons in 1976 to 13.6 million tons in 1986. Vegetable production (including watermelons) grew from 71 million tons in 1976 to 105 million tons in 1986. A small proportion of the fruit and vegetable production is exported to Hong Kong, Macao, Russia, Mongolia, North Korea, and Japan. Some tropical fruits, such as litchi, will be exported to Japan when acceptable quarantine treatment procedures are established (G. Liang, personal communication).

Pome fruits, such as apple and pear, stone fruits, such as peach and apricot, and citrus fruits are commonly planted. Tropical fruits, such as mango, guava, and banana, are grown in the tropical and subtropical areas (Table 1).

China can be divided into seven regions according to local vegetation and production of commercial fruits. These are: I. Northeast China, II. North China, III. Central and East China, IV. South China, V. South-West China, VI. Nei Mongol and Zinjiang, and VII. Qinghai and Tibet region (Fig. 1) (Yu 1979). Although fruit fly susceptible fruits and vegetables are grown in most of these regions, data are not available about fruit fly occurrence for many of them. We will discuss only those regions where fruit flies are known to occur.

North China.—This region includes Hebei, Shandong, Shanxi Provinces and the major part of Shaanxi, Henan, Ningxia, Gansu, and Liaoning Provinces. The climate is hot and rainy in summer, and dry and cold in winter with an annual average temperature of 10° to 16° C. The average temperature in January is 0° to 13° C, and 22° to 24° C in July. Annual rainfall is 500 to 700 mm. The major fruits are pome fruit (apple and pear) and stone fruits (plum and peach). In the south of this region there are several species of both wild and cultivated citrus.

Central and East of China.—This region includes middle and lower reaches of Yangtze River including Sichuan, Hunan, Hubei, Jiangxi, Anhwei, Jiangshu, and

Table 1. List of economically important fruits in China.[a]

Family	Common name	Scientific name
Actinidiaceae	Kiwi	*Actinidia chinensis* Planchon
Anacardiaceae	Mango	*Mangifera indica* L.
Bromeliaceae	Pineapple	*Ananas ananassoides* (Baker)
Caricaceae	Papaya	*Carica papaya* L.
Ebenaceae	Persimmon	*Diospyros* sp.
Fagaceae	Chestnut	*Castanea* sp.
Juglandaceae	Walnuts	*Juglans* sp.
Musaceae	Banana	*Musa* sp.
Myrtaceae	Guava	*Psidium guajava* L.
Oxalidaceae	Carambola	*Averrhoa carambola* L.
Palmae	Coconut	*Cocos nucifera* L.
Punicaceae	Pomegranate	*Punica granatum* L.
Rhamnaceae	Jujube	*Zizphus* sp.
Rosaceae	Apple	*Malus* sp.
	Hawthorne	*Crataegus* sp.
	Pear	*Pyrus* sp.
	Peach	*Prunus* sp.
	Plum	*Prunus* sp.
	Apricot	*Prunus* sp.
Rutaceae	Citrus	*Citrus* sp.
Sapindaceae	Litchi	*Litchis sinensis* Sonnerat
Vitaceae	Grape	*Vitis vinifera* L.

[a] Yu (1979).

Zhejiang Provinces. The climate is characterized by hot, rainy summers and warm winters with an annual average temperature of 15° to 22° C. The average temperature is over 0° C in January and 20° to 28° C in July. Annual rainfall is 1000 to 1500 mm. In the mountain areas, deciduous and evergreen forest are replaced by orchards. The major fruits are citrus and stone fruits.

South China.—This region includes the southern parts of Guangdong and Guangxi Provinces as well as Taiwan Province. The area is hot and humid during most of the year. There is a long hot summer and a short warm winter. The annual average temperature is 21° to 25° C and the annual rainfall 1500 mm. The climate is similar to that of southern Florida and Hawaii. The types of vegetation include tropical evergreen forests and rain forests. Citrus and tropical fruits such as mango, guava, and banana are the major fruits grown in this region.

South-West China.—This area includes Yunnan Province and part of Sichuan Province. The geography and climates are varied and complex. There are many high mountains and deep valleys, which affect the attitudinal vegetation distribution. Fruits grown in this region include those grown in the North China Region, such as pear and apple, and those in the South China Region, such as banana and mango.

Distribution, Host Range, and Biology of Injurious Fruit Flies

There are 10 Dacine fruit fly pests in China: four important species are discussed below.

*Oriental Fruit Fly (*B. dorsalis*).*—This species is widely distributed throughout

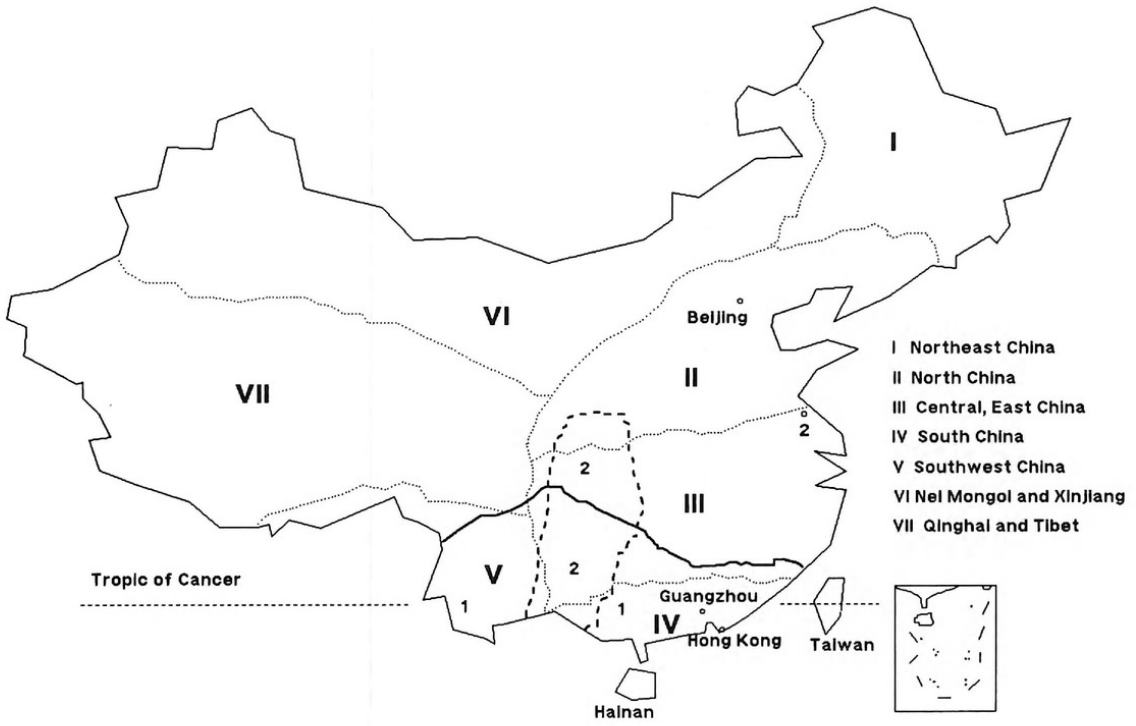

Figure 1. Distribution of *B. dorsalis*(1) and *B. minax*(2) in China.

southern Asia, Southeast Asia, and many major Pacific islands. It is one of a number of closely related species placed in the *dorsalis* complex, only some of which are pests (White & Elson-Harris 1992). *Bactrocera dorsalis* is a polyphagous, multivoltine species with a wide host range and over-lapping generations. It is found in the South China and Southwest China Regions (Fig. 1), where it damages guava, carambola, peach and pears (Guangzhou area) (Yunnan and Guangxi Provinces). There are no reports of infested citrus. Although males were trapped in a guava orchard in the campus of Zhongshan University from August to December, 1987, no infested fruit was found in this orchard. No detailed ecological or pest management investigations of this pest in China have been published.

*Chinese Citrus Fly (*B. minax*).*—It is found in North China, Central East China, South China, and Southwest China Regions (Fig. 1), where it attacks wild and cultivated *Citrus* species (Donghai County, Jiangsu Province, and southern Shaanxi Province respectively).

Bactrocera minax is a monophagous, univoltine species found in temperate and subtropical areas. Adults begin to emerge in late April, with mating and oviposition occuring from the middle of May to the end of July. The eggs hatch in 15 to 25 days, and the larval stage takes 60 to 75 days. Infested fruits drop in October. Larvae then leave the fruit and pupate in the soil. Each female lays an average of 48 eggs (Wu 1958). *Bactrocera minax* is highly injurious to most citrus hosts including *Citrus sinensis* (L.) Osbeck and *C. aurantium* L. with infestation rates estimated at 50 to 80 percent (Chen 1940).

Bactrocera minax has invaded new areas since the 1940s, when it was found in two provinces (Chen & Wang 1943). By 1960 it had spread to another four provinces (Sun 1961), and added two additional Provinces by the late 1980s

Table 2. Injurious of Dacine species, their hosts, and distribution in China.

Species[a]	Hosts	Distribution
Bactrocera minax (Enderlein)	*Citrus sinensis* (L.) Osbeck *C. aurantium* L. *C. tangerina* Hort. ex Tanaka Pomelo, lemon, and others	Sichuan, Guizhou Guangxi, Southern Shaanxi, Western Hunan and Hubei, Donghai County (Jiangsu), and Yunan
Bactrocera tsuneonis[b] (Miyake)	*Citrus aurantium* *C. tangerina* *C. reticulata* Blanco and *Fortunella margarita* (Lourerio) Swingle	Guangxi, Sichuan, Western Hunan, Donghai County in Jiangsu
Bactrocera cilifer (Hendel)	*C. aurantium* *C. tagerina*	Guangxi, Taiwan
Bactrocera cucurbitae (Coquillett)	bitter melon, cucumber, and *Luffa aegyptiaca* Miller	Yunan, Guangxi, Guangdong, Fujan and Southern Sichuan
Bactrocera diversa (Coquillett)	Citrus, Cucurbitaceous plants	Sichuan
Bactrocera dorsalis (Hendel)	guava, peach, pear, and *Averrhoa carambola* L.	Yunan, Guangxi Guangdong, Sichuan Guizhou, and Fujian
Bactrocera latifrons (Hendel)	*Solanum incanum* L.	Taiwan, Guangxi
Bactrocera occipitalis (Bezzi)	Mango	Hainan
Bactrocera scutellata (Hendel)	Pear	Yunan, Guangxi, Guangdong, Fujian, Guizhou, Hunan, Jiangxi, Zhejiang, Sichuan, and Southern Shaanxi
Bactrocera tau (Walker)	bitter melon, cucumber, squash, and watermelon	Yunan, Guangxi, Guangdong, Fujian, Guizhou, Sichuan

[a] Chao & Ming (1986).
[b] *Bactrocera cheni* (Choa) (White & Wang 1992).

(Chao 1987). It survives in cold climates and may spread to all areas where citrus grows freely.

*Melon Fly (*B. cucurbitae*).*—This species is a destructive vegetable pest in many regions of the world, particularly Southeast Asia and some Pacific islands (White & Elson-Harris 1992). In China, it is found in the South China and Southwest China Regions (Fig. 2), where it attacks cucurbitaceous crops, preferring bitter melon (*Momordica charantia* L.), cucumber (*Cucumis sativus* L.), and Chinese gourd (*Luffa aegypticaca* Miller). There are four to five generations annually in the Guangzhou area.

The larva can be found in *L. aegyptiaca* in December, and adults survive the winter (PY, unpublished data). In the 1960s, this species was an important pest: in the last 20 years its infestation rates have declined. In some mountain areas, bitter melon is heavily attacked because growers do not use insecticides to protect the plant.

*Pumpkin Fly (*B. tau*).*—This species is widely distributed in South Asia and

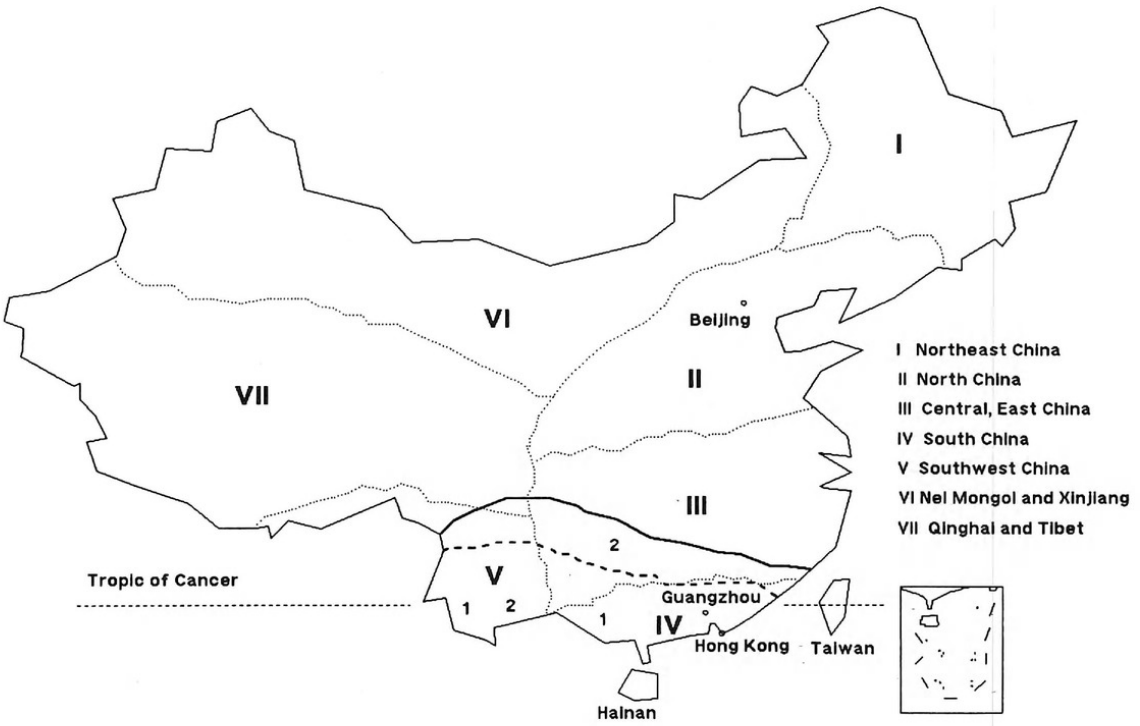

Figure 2. Distribution of *B. cucurbitae*(1) and *B. tau*(2) in China.

some Pacific islands (White & Elson-Harris 1992). In China, it is found in the South China and Southwest China Regions (Fig. 2). *Bactrocera tau* is found farther north than *B. cucurbitae.* Its hosts are similar to *B. cucurbitae.* It is the dominant species in melon fields (Chao & Ming 1986). At Zhongshan University, bitter melon was heavily infested by both *B. cucurbitae* and *B. tau.* In May, 1987, the early fruits of bitter melon were infested by *B. tau* and *B. cucurbitae,* however, in the following days only the larvae of *B. cucurbitae* were found. Two Steiner traps, baited with Cuelure, were set up on the campus of Zhongshan University located in the south part of Guangzhou, and only *B. cucurbitae* were trapped from August to December 1987. However, both *B. cucurbitae* and *B. tau* were trapped in the northeast part of the city (G. Liang, personal communication). From this preliminary survey it seems that the distribution of *B. tau* changes with time or it occurs only in selected areas. The life history of this fly has been studied recently (Yang & Zhou 1988, Yang 1992). The basic population characters of *B. tau* are similar to those of *B. cucurbitae.*

There are two other species that attack cucurbitaceous crops; *B. caudatus* (Fabr.) in Sichuan Province, and *B. caudatus nubilis* (Hendel) in Taiwan Province (Zhang 1981). Little is known about their biology or the level of infestation.

Control of Fruit Flies in China

Before 1960, fruit fly control was mainly by cultural and mechanical methods, such as ploughing and hand picking. Since the 1960s, chemical and integrated control methods have been employed. Three species of fruit flies are used as examples of these control measures.

Cultural Control.—Bactrocera minax pupae in soil are destroyed by ploughing in the winter or spring. Most *B. minax* pupae are distributed three to 6 cm deep

under citrus trees. In Anjang Township, Chanyang County, vegetables were continuously planted in citrus orchards and the fields were regularly ploughed and hoed. This changed the pupal environment and enhanced the effectivness of natural enemies (G. Liang, personal communication).

Mechanical and physical methods are employed to destroy *B. minax* larvae in fruits. *Bactrocera minax* lay eggs in young citrus fruits from late July to early August. The tissue near the puncture grows a protuberance that is easly identified. In 1951 and 1952, more than eight million infested fruits were destroyed in Jangjen County, Sichuan Province. In 1953, the infestation rate decreased to 0.5 percent. In Chenggu County, Shaanxi Province, more than 170,000 infested fruits were destroyed during 1953 and 1955. The infestation rate in 1956 decreased to five percent. This method was also used to control *B. cucurbitae* and *B. tau* (G. Liang, personal communication; Zhang 1981). Crops, such as watermelon, cucumber, and bitter melon, can be protected by covering them with straw or paper bags to avoid oviposition by *B. cucurbitae* and *B. tau.*

Chemical Control.—A mixture of dry banana or pumpkin powder mixed with pineapple juice or sugar and insecticide (BHC) at a ratio of 35:1:1 was put on papers, which are hung in vegetable fields at a rate of 20 to 30 pieces per hectare to control *B. cucurbitae* and *B. tau.* Sugar solution, sometimes mixed with several drops of vinegar, and an insecticide is used to kill adult *B. minax.* This bait is held in straw bars and distributed weekly in orchards from May to September (Zhang 1981).

Integrated Control.—An integrated pest control program for *B. minax* has been successful in commercial citrus in Huaihua Prefecture, Hunan Province. The control program includes the measures previously described and quarantine regulation. It has been carried out through three steps. First, reduce the population of flies to a low level throughout the area. Second, control measures were used in the infested areas until no infestation was found. Third, quarantines were implemented to prevent the movement of infested fruit into these fly-free orchards.

Bactrocera minax cannot be detected now in seven out of 12 counties in the Huihua Prefecture. In another five counties, the infestation is under control and the infested areas are restricted to only a few locations (G. Liang, personal communication).

Suggestions for Studies

Many aspects of fruit fly biology in China lack basic information. Further studies should include the following.

Biology and Ecology.—There are many interesting and important biological and ecological questions about fruit flies in China. (1) Why is the geographical distribution for some species restricted? *Bactrocera minax* is distributed in certain areas and causes economic losses, but adjacent regions can be free from infestation, even though there are no natural barriers separating them. (2) Why is *B. minax* univoltine despite occurring in both temperate and subtropical regions? (3) Why do some species, such as *B. tau,* have different infestations patterns and damage levels in different regions? (4) Why do *B. dorsalis* and *B. cucurbitae,* which cause serious damage in other countries, have such low population levels in China? (5) Where is the northern limit for *B. dorsalis* and *B. cucurbitae?* (6) Demographic

analysis should be employed to establish the life history traits of major fruit fly species under different biotic and abiotic conditions.

Genetics.—Genetic studies can involve many aspects that are related to basic and practical problems, such as insecticide resistance, genetic sexing, and quality improvement for sterile insect release (White & Elson-Harris 1992). Genetic analysis can be used to determine relatedness of flies captured in different regions, and global patterns of invasion and spread (Carey 1992). Such work on fruit flies in China is completely lacking.

Sterile Insect Technique (SIT).—SIT has successfully eradicated *B. cucurbitae* and *B. dorsalis* from Pacific islands (White & Elson-Harris 1992). Generally, it is impossible to eradicate a species of native insect from a continent. However, for some monophagous species such as *B. minax,* SIT may be successful in isolated areas. Eradication is necessary for citrus export because of quarantines.

Biological Control.—Fruit flies are attacked by an array of parasites and predators. The Chinese fauna of fruit fly natural enemies should be rich because the Oriental Region is the origin of many *Bactrocera* species (White & Elson-Harris 1992). Investigations should be conducted to determine the species composition, abundance, and distribution of these predators and parasites.

Agricultural Quarantine.—China is unique in that both Hong Kong and Macao import fruits and vegetables without quarantine restrictions, including tropical fruits from Malaysia. There are no geographical or host barriers preventing these pests from leaving these two areas and invading the interior of China. A species of pine needle scale has been established in the coastal area of Guangdong Province and spread to more than 10 counties since 1980 (C. Zhou, personal communication). It has already destroyed large areas of pine forests and caused huge economic and environmental losses. This pest was carried to Hong Kong on Christmas trees that were imported from Okinawa. Surveys are needed in Hong Kong and Macao to determine if exotic fruit flies are present. The results will not only provide important information to the Chinese quarantine organization, but will also show the invasion pattern of fruit flies in these two areas, which will be meaningful to other countries.

China offers unique opportunities to develop basic and applied research programs on native and exotic fruit flies. Fruitful areas include demographics, biological controls, systematics, genetics, and basic ecology. These studies will become more important as China expands both its importation and export of agricultural products.

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