Bird damage to tropical fruit in south Florida

Eric A. Tillman, United States Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services, National Wildlife Research Center, Florida Field Station, 2820 E. University Ave., Gainesville, FL 32641, USA

Annamaria Van Doorn, Department of Wildlife Ecology and Conservation, University of Florida, P. O. Box 110430, Gainesville, FL, 32611, USA

Michael L. Avery, United States Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services, National Wildlife Research Center, Florida Field Station, 2820 E. University Ave., Gainesville, FL 32641, USA

Abstract: In Dade County, Florida, the production of tropical fruit is a major component of the agricultural industry with total sales amounting to $73.5 million in the 1997-1998 season. Two types of fruit in particular, lychee (*Litchi chinensis*) and longan (*Euphoria longana*), are rapidly emerging in economic importance with a combined annual value of over $19 million. For many lychee and longan growers, bird damage is perceived to be a significant constraint to production, yet there is no published information on the extent of damage caused by birds. In 1999, we initiated research to identify the bird species responsible for longan damage, quantify the extent of bird damage, and estimate monetary losses. Estimates of fruit loss in 3 longan orchards ranged from 4% to 64% which resulted in losses of $536 to $18,182 per hectare. Common grackles (*Quiscalus quiscula*) were the most prevalent pest birds, but monk parakeets (*Myiopsitta monachus*) were equally if not more destructive, resulting in 30 times more damage at the orchard where they were present. In 2000, we expanded the study to include lychee. Estimates of bird damage to longan ranged from 1% to 28% ($259/ha to $17,623/ha) with the greatest damage occurring in the orchard subject to grackle and monk parakeet depredation. Bird damage to lychee was substantial (11%, $477/ha) in only 1of 4 the groves studied. Monk parakeets were not observed to feed on lychee. We conclude that damage to longan and lychee by grackles is common but usually not great. In longan orchards frequented by monk parakeets, however, damage increases dramatically. Long-term bird management strategies should include exclusion with netting in high-damage areas as well as consideration of reduction in monk parakeet populations.

Key words: common grackle, longan, lychee, monk parakeet, *Myiopsitta monachus*, orchard damage, *Quiscalus quiscula*, tropical fruit

Owing to its subtropical climate, south Florida is one of the few areas within the continental U.S. where a wide variety of tropical fruits can be grown commercially (Degner et al. 1997*a*). Approximately 90% of all tropical fruit orchards are concentrated in southern Dade County (Degner et al. 1997*b*) with additional orchards extending northward in a narrow band along both coasts of the state to about 28° latitude (Campbell et al. 1993). In Dade County, tropical fruit is a major component of the agricultural industry with total sales amounting to $73.5 million in the 1997-1998 season (R. L. Degner, Florida

Agricultural Market Research Center, Institute of Food and Agricultural Sciences, University of Florida, unpublished data). In 1998, >35 different fruit species were grown on >5,260 ha (Degner, unpublished data). Approximately 90% of all tropical fruit production is shipped out of the county, much of it to specialty markets (Degner et al. 1997*b*).

Of the potential limitations to commercial production of tropical fruit crops, bird damage has historically received little attention. However, two relatively recent changes have elevated the level of concern regarding bird damage: (1) emerging cultivation and economic importance of new species of tropical fruit that appear to be particularly vulnerable to bird depredation; and, (2) changes in the south Florida avifaunal community, particularly the establishment and spread of non-indigenous species.

This paper examines bird damage to 2 recently commercialized, high-value tropical fruit crops, longan (*Euphoria longana*) and lychee (*Litchi chinensis*). We identify the depredating bird species, investigate the extent of bird damage, estimate monetary losses, and discuss potential control measures.

Changes in the tropical fruit industry

Tropical fruit has been grown in south Florida since the early 19th century. The subtropical climate is suited to tropical fruit production and experimentation. Three of the most successful and commercially dominant introductions are the avocado (*Persea americana*) which first arrived in Florida in 1833 (Malo and Campbell 1967), the mango (*Mangifera indica*) which was first successfully introduced in the 1860s (Young and Sauls 1979), and the lime (*Citrus latifolia*) which was widely planted in the 1960s and 70s (Moseley 1990). In recent decades, interest has been directed towards new species of exotic fruit, possibly fueled by competitive pressures for some fruits from Mexico, particularly limes and mangos, and aided by the development of improved cultural practices and varieties for certain species of fruit (Degner et al. 1997*a*, Degner et al. 1997*b*).

In the mid to late 1980s, there were substantial increases in carambola (*Averrhoa carambola*) lychee, longan, atemoya (*Annona squamosa*), and passion fruit (*Passiflora edidis*) acreage (Crane 1989). This trend was temporarily halted by Hurricane Andrew in 1992 which resulted in a 40% decline in productive acres of all types of fruit (Degner et al. 1997*a*). Although traditional fruit types have not yet rebounded, there have been substantial increases in a number of the more exotic fruits (Table 1). Two commercially important species that exhibited the greatest increases are the lychee and longan. Area cultivated has increased by 65% and 282% respectively. In 1998, the lychee and the longan ranked 5th and 8th respectively in total area cultivated. However, in terms of total value sold within and outside of Dade County, they ranked 2nd and 4th respectively with reported total revenues of $10.4 and $8.9 million (Table 1).

Longan and lychee facts

The lychee originates from southern China (Campbell and Malo 1979). The fruit is similar in appearance and color to a strawberry but has a thick, leathery rind with raised dimples giving the fruit a bumpy texture. The edible portion is succulent, whitish, and translucent and surrounds one shiny, dark brown seed, usually somewhat large, though it

Table 1. Changes in acreage from 1990 to 1998 and 1998 estimated values of tropical fruit orchards in Dade County, Florida.

Commodity	Hectares, 1990	Hectares, 1998	Percent change	Total crop value
Avocados	3,658	2618	-28.4	17,234,761
Lychee	81	134	65.0	10,395,000
Carambola	244	204	-16.7	9,453,000
Longan	29	112	281.9	8,910,000
Persian limes	2471	1099	-55.5	7,518,037
Mamey sapote	109	132	21.7	6,500,000
Mangos	987	570	-42.2	5,953,500
Other	615	405	-34.2	7,534,364
Total	8193	5273	-35.6	73,498,662

Source: 1990 figures from Degner et al. 1997*b* and 1998 figures from R. L. Degner, Florida Agricultural Market Research Center, Institute of Food and Agricultural Sciences, University of Florida, unpublished data.

may be small and shriveled in some varieties (Campbell and Malo 1979). The fruit is borne in loose clusters on the trees outer branches and may number 2 or 3 to 20 or more (Moseley et al. 1990). Mature trees of both varieties are quite large at 12 m tall and wide (Crane 1989) but many growers plant them at densities that require pruning to improve productivity and facilitate harvest. Approximately one-third of the area cultivated in Dade County is the Brewster variety and the remainder is Mauritius (Crane 1989).

The longan is closely related to the lychee. It originates from south China and the Indochinese peninsula where it is highly esteemed and extensively cultivated (Phillips et al. 1978). The predominant cultivar grown in Florida is 'Kohala', the fruits of which are spherical to ovoid, vary from 2-4 cm in diameter, and have a thin, leathery, light brown skin. Similar to the lychee, the flesh is translucent, somewhat whitish, and gelatinous and surrounds a shiny brown seed. The fruit is borne on panicles in either loosely or tightly packed clusters of 20 to 200 fruit and are terminally located on the trees outer branches. Trees also get quite large at 11 m tall and 14 m wide (Crane 1989). One advantage of the longan is that it can withstand cooler temperatures and has other growth, handling, and storage characteristics that make it easier to harvest, process, and market (Degner et al. 1997*b*).

In south Florida, these two crops bear about a month apart. Both fruits must ripen on the tree for best flavor. 'Mauritius' lychee harvest in Dade County generally lasts about 2 weeks beginning in the last week in May through the first week in June (Moseley et al. 1990). Longan is generally harvested from mid-July through mid-August (Moseley et al. 1990). Both lychee and longan are unpredictable bearers leading farmers that attempt to grow them to be very sensitive to fruit yield. Some farmers use sophisticated equipment to maximize both flowering and

fruiting through watering and fertilizer regimes.

Birds as pests in tropical fruit orchards

Information regarding bird use of tropical fruit in Dade County is limited. Owre (1973) reports on the fruit-eating habits of several non-indigenous species that have become naturalized in South Florida. The canary-winged parakeet (*Brotogeris versicolurus*) is specifically mentioned for its "depredations of mangos and other fruits". Other frugivorous psitaccines which appear to be successfully established include the monk parakeet (*Myiopsitta monachus*), red-masked parakeet (*Aratinga erythrogenys*), mitred parakeet (*Aratinga mitrata*), dusky-headed parakeet (*Aratinga weddellii*), red-crowned amazon (*Amazona viridigenalis*), yellow-headed amazon (*Amazona (o.) oratrix*), orange-winged amazon (*Amazona amazonica*), and chestnut-fronted macaw (*Ara severa*) (Van Doorn 1997). Additional frugivorous passerines include the hill myna (*Gracula religiosa*) and red-whiskered bulbul (*Pycnonotus jocosus*) (Owre 1973).

Previous censuses of avocado, mango, carambola, lychee, and longan orchards in Dade County have found that 43 species of birds utilize these orchards (Tillman, unpublished data). Twenty-one of these regularly occur, 6 of which are non-indigenous (Table 2). However only one of the aforementioned species, the monk parakeet, is included. The latter deserves special attention because it is considered an agricultural pest in its native range in South America where it is known to feed upon produce and agricultural crops, in particular peaches (*Prunus persica*) and pears (*Pyrus communis*), and corn, sunflower, and sorghum (Spreyer and Bucher 1998). Efforts to control the monk parakeet in the U.S. were initiated by the U.S. Fish and Wildlife Service in the early 1970s on the basis of this reputation and were successful in reducing the population size prior to the program's end in 1975 (Van Bael and Pruett-Jones 1996). Since that time no additional control efforts have been undertaken. Eight states have made monk parakeet ownership or sale illegal and 10 additional states have placed restrictions on their ownership, import, and sale (Kathleen Carr, www.monkparakeet.com). Monk parakeet numbers have therefore risen; the increase in numbers fits an exponential model of population growth not only in Florida (Van Doorn 1997) but for the United States as a whole (Van Bael and Pruett-Jones 1996). Other parrot species also have the potential to be destructive, but they appear to be confined to urban areas.

Informal surveys of growers in Florida implicate 5 bird species as potential pests in lychee and longan orchards. The most frequently mentioned species are grackles, including the common grackle (*Quiscalus quiscula*) and the boat-tailed grackle (*Quiscalus major*). In orchards closer to suburban areas, monk parakeets are considered equally destructive. Other species suspected of damaging fruit are blue jays (*Cyanocitta cristata*) and red-bellied woodpeckers (*Melanerpes carolinus*).

Several types of damage are attributed to birds. These include consuming all or portions of the whole fruit, detaching the fruit as a result of pecking, pecking holes in or puncturing the skin, damaging or scratching the skin, and discoloring of the skin by drippings from other damaged fruits. In the case of lychee, bird activity may additionally exacerbate fungal damage, a pervasive

Table 2. Bird species commonly observed in Dade County tropical fruit orchards and their depredation status.

Common name (Scientific name)	Depredation status
Cattle egret (*Bubulcus ibis*)	No threat
American kestrel (*Falco sparverius*)	No threat
Killdeer (*Charadrius vociferus*)	No threat
Rock dove (*Columba livia*)	No threat
Eurasian collared-dove (*Streptopelia decaocto*)	No threat
White-winged dove (*Zenaida asiatica*)	No threat
Mourning dove (*Zenaida macroura*)	No threat
Monk parakeet (*Myiopsitta monachus*)	Observed feeding on longan
Red-bellied woodpecker (*Melanerpes carolinus*)	Suspected of feeding on longan & lychee
Barn swallow (*Hirundo rustica*)	No threat
Blue jay (*Cyanocitta cristata*)	Suspected of feeding on longan & lychee
Blue-gray gnatcatcher (*Polioptila caerulea*)	No threat
Northern mockingbird (*Mimus polyglottos*)	Unknown
Brown thrasher (*Toxostoma rufum*)	Unknown
Loggerhead shrike (*Lanius ludovicianus*)	No threat
European starling (*Sturnus vulgaris*)	No threat
Palm warbler (*Dendroica palmarum*)	No threat
Northern cardinal (*Cardinalis cardinalis*)	Unknown
Red-winged blackbird (*Agelaius phoeniceus*)	No threat
Boat-tailed grackle (*Quiscalus major*)	Suspected of feeding on longan & lychee
Common grackle (*Quiscalus quiscalus*)	Observed feeding on longan & lychee

Source: Species list from E. A. Tillman, unpublished data. Results of 122 8-minute censuses conducted during 1995-1996 at 8 separate orchards.

problem. Scratching, pecking, or sugary droppings from damaged fruit appear to provide areas for fungal development.

Most fruit growers in Dade County estimate losses to birds at 10 – 20%. To combat these losses, most growers employ some form of damage control. Typically, this involves patrolling the orchards and shooting or scaring depredating birds. Other methods include hanging carcasses of problem species, stretching reflecting tape over the trees, and netting individual panicles on small trees. Further, one lychee grower conducted a test using methyl anthranilate, a repellent compound approved for use on cherries, grapes, and blueberries. It did not prove successful however at the suggested rate of ~5%, and an estimated cost of $618/ha.

Methods

Site selection and description

For both lychee and longan assessments, we selected sites that represented different locations within the county. The landscape is a mosaic of business, high-

density residential, low-density residential, agricultural, and natural forest community uses, with generally less development as one moves east to west. Hence, we assigned site numbers such that number 1 represents the easternmost site and most developed area of our study and number 5 which lies just outside Everglades National Park in an area that is sparsely populated. Using this method, longan sites are numbered 1, 4, and 5, and lychee sites 1, 2, 3, and 4 (Figure 1).

We tried to evaluate the same sites in 1999 and 2000, but due to a lack of fruit set in longan sites 1 and 5 in 2000, new orchards had to be selected nearby. Each new site was within 0.4 km of the original site and although orchard size and tree maturity varied slightly, each had similar surrounding uses and was subject to the similar bird pressure. To account for this deviation, sites were thus labeled 1A and 5A for 1999 and 1B and 5B for 2000. Since longan and lychee orchards were co-located at sites 1A and 4, lychee site 1 will be referred to as 1A.

Identification of depredating species

To identify the species responsible for the damage, we interviewed participating growers and conducted observations totaling 18 hours within the test orchards. Observations were made by quietly observing from a concealed or inconspicuous location for periods of at least 30 minutes and by slowly walking through orchard rows looking for actively foraging birds. In addition, opportunistic observations were made in the course of setting up damage assessment trials.

Damage assessment

1999. From a list of growers supplied to us by the Tropical Fruit Specialist at the University of Florida's Tropical Research and Education Center, we selected 3 commercial orchards based on the following criteria: (1) sufficient fruit set to allow a meaningful study, (2) minimal use of bird control techniques, and (3) willingness of grower to participate. Within each orchard, we selected 5 trees such that the edges and center of the orchard were represented. On each tree, we selected 4 panicles at various heights which we labeled near the base of the branch with flagging. For each panicle selected, all visibly damaged fruit and underdeveloped fruit (<8mm in diameter) were removed. We counted the remaining fruit and recorded the height of each test panicle as in the top third, middle third, or bottom third of the tree. We also selected 8 control panicles on adjacent or nearby trees and covered each with netting to excludebirds. Netting was large enough to accommodate the panicles without interference and was sealed on three sides using staples and then loosely stapled or tied at the base with string. Fruit dropped in the bag during the test period was a measure of the number of fruit lost to natural abscission or other non-bird sources of loss such as fungal and insect damage. At the time of harvest, we revisited the orchards and counted all remaining undamaged fruit on each flagged panicle.

2000. We repeated the longan damage assessment with the following exception: 2 of the 3 original orchards did not bear sufficient quantities of fruit, so 2 surrogate sites with similar qualities located within 0.4 km of the original sites were selected. In addition we obtained initial counts of fruit on netted panicles and estimated maturity of fruit on each panicle at initial count.

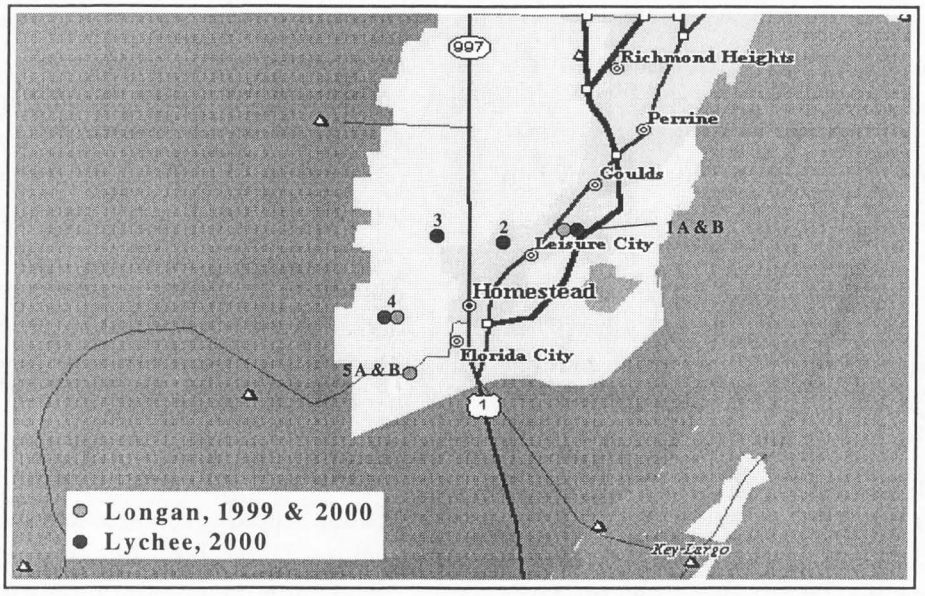

Figure 1. Location of orchards studied, Dade County, Florida.

We further expanded the study to include a lychee damage assessment. Due to the dominance of Mauritius variety trees in commercial production, our assessment was limited to orchards cultivating this variety. This assessment was set up as the longan assessments and we utilized four orchards. Two orchards were co-located with longan orchards used in the 1999 assessment. Since lychee panicles do not bear as many fruit as longans, we counted fruit on multiple panicles attached to a common branch. We selected 4 branches per tree. For each control panicle, fiberglass netting was used to exclude birds.

Determination of bird damage and resultant losses

In 1999, we estimated bird damage to longans for each panicle as the difference between the initial and final counts minus the average fruit drop from the netted panicles. In 2000, initial counts of the netted panicles were performed. We then calculated for each orchard the mean of the percentage of fruit drop from the netted panicles. For each test panicle, this mean was multiplied by the initial count to obtain the expected number of fruit lost to natural droppage. Damage was then determined for each panicle as the difference between the initial and final counts minus the expected loss. The damage figure was then divided by the initial count to generate a percent damage for each panicle. Damage for each orchard was then expressed as the mean of these individual panicle percentages.

For each orchard, we obtained from the growers the crop yield (amount sold to market), net revenue (gross revenue less picking and packing charges), and exact orchard area. We estimated the potential yield for each orchard by dividing the crop yield by 1 minus the damage rate. The total damage in kilograms of fruit was the difference between this potential yield and the actual yield. We performed a similar calculation to estimate the revenue lost.

Results

Identification of depredating species and foraging observations

Of the 21 species of birds known to occur in tropical fruit orchards, only 2 were observed feeding on fruit, 2 others are suspected of feeding on fruit, and the remainder appeared to utilize the orchards for roosting, nesting, and/or in the pursuit of other available food sources such as insects or grass seeds. The primary pest species common to all of lychee and longan orchards studied was the common grackle. In study sites 1A and 1B, monk parakeets were also present. Two additional species observed in most orchards and suspected of damaging fruit are blue jays and red-bellied woodpeckers. Both were observed perched on lychee and longan panicles, however no clear observations of depredation were made. Alternatively, they may have been feeding on insects attracted to already damaged fruit. Boat-tailed grackles were uncommon and did not appear to feed on fruit.

Common grackles ate both longan and lychee fruit. They showed a preference for mature lychees but began feeding on longans when the fruit was approximately ¾ mature. Some individuals separated, or attempted to separate, individual fruit from the panicle, let it fall to the ground, and then fed on it at the ground. Others appeared interested only in attached fruit and caused several fruit to fall before successfully breaking one open. Once a fruit was opened, the grackles often finished the fruit almost completely until only an empty shell remained. Upon landing on a tree, some grackles searched for and fed on unfinished fruit in the tree before attempting to break open a new fruit.

Monk parakeets consumed only longan fruit, even when it was immature. They were not observed to feed upon lychee fruit, although flocks were present in the vicinity throughout the fruiting season. Monk parakeets showed a preference for fruit attached to the panicle. Alternatively, they detached a fruit, held it in one foot, and ate. They did not follow fruit to the ground if it detached or was mishandled and dropped. They often abandoned unfinished fruit to begin eating a new one.

Both species caused damage in excess of actual feeding requirements. Damaged fruit accumulated beneath the trees, some completely intact or with only a peck mark or slight hole. Although both species fed in trees throughout the orchard, we observed more damage in trees on the edge or adjacent to a larger structure or tree. Most birds appeared to favor feeding in the upper portions of the tree.

Estimates of bird damage and monetary losses

In 1999, longan damage was greatest at orchard 1A with an estimated 63.7% loss per panicle (Table 3). Damage was concentrated in the upper two-thirds of the tree (Table 4). At the orchard level, estimated monetary losses at 1A were $18,182/ha (Table 5). Losses at orchards 4 and 5A were $620/ha and $536/ha, respectively.

The 2000 longan damage assessment revealed that the easternmost orchard (1B) and the southwest orchard (5B) suffered moderate levels of panicle damage while orchard 4 suffered almost none (Table 3). Although the percentage lost for 1B (25.0%) was much less than that for 1A in 1999, the orchard yield was

Table 3. Results of bird damage assessments for 6 longan and 4 lychee orchards, Dade County, Florida.

	Longan orchards 1999			Longan orchards 2000			Lychee orchards 2000			
	1A	**4**	**5A**	**1B**	**4**	**5B**	**1A**	**2**	**3**	**4**
No. test panicles	20	20	20	16	19	20	19	18	17	20
Initial panicle count (x)	74.9	97.4	122.6	76.8	84.4	74.1	60.0	94.3	77.7	58.0
End panicle count	27.1	88.9	114.8	54.8	82.0	52.6	56.2	89.8	75.1	49.4
Gross fruit loss	47.8	8.5	7.8	22.0	2.4	21.5	3.8	4.5	2.6	8.6
Non-bird related losses (%)	1.1	2.4	2.4	3.9	2.0	0.0	4.5	3.9	1.9	3.6
Net fruit loss per panicle (%)	63.7	6.5	3.6	25.0	1.4	28.2	1.5	.8	1.6	10.7

* Since initial counts of netted longan panicles were not performed in 1999, figures are average number of fruit dropped and damaged, not a percentage

Table 4. Bird damage relative to panicle position on tree for longan and lychee orchards sustaining significant amounts of bird damage. Figures represent actual percent damage.

Panicle position by height	Longan Orchards			Lychee Orchards
	1A	1B	5B	4
Top 1/3 of tree	72.9 %	19.3 %	26.4 %	18.0 %
Middle 1/3 of tree	71.4 %	18.5 %	31.7 %	8.2 %
Bottom 1/3 of tree	16.2 %	51.6 %	22.5 %	6.0 %

much greater in 2000 resulting in similar monetary losses between years. At orchard 1B, the bottom third of the trees received more than 50% of the damage (Table 4). Additionally, panicle damage for both 1B and 5B was found to be greater to fruit that was more mature at the initial count (Figure 2).

Panicle damage in lychee orchards 1A, 2, and 3, was estimated to be <2% (Table 3). In terms of revenue lost, this amounted to $259/ha, $126/ha, and $410/ha, respectively. Panicle damage for orchard 4 was higher (10.7%), however this is inflated by a low yield. When the yield is taken into account, the estimated loss was $477/ha (Table 5).

Table 5. Estimated revenue lost to bird damage for 6 longan and 4 lychee orchards, Dade County, Florida.

	Longan orchards 1999			Longan orchards 2000			Lychee orchards 2000			
	1A	4	5A	1B	4	5B	1A	2	3	4
Area (ha)	1.0	2.0	6.1	0.6	2.0	3.1	0.5	8.1	2.4	3.1
Yield kg/ha	1,344	1,120	1,617	6,832	2,912	1,532	6,272	3,360	9,333	1,643
Yield lost kg/ha	2,354	78	60	2,283	41	600	97	26	155	197
Avg. price ($/kg)[a]	7.72	7.94	8.82	7.72	6.28	7.17	2.65	4.96	2.65	2.43
Estimated revenue lost[b] ($/ha)	18,182	620	536	17,623	259	4307	259	126	410	477

[a] Net price paid per pound after picking and packing expense
[b] Figures rounded to nearest whole dollar

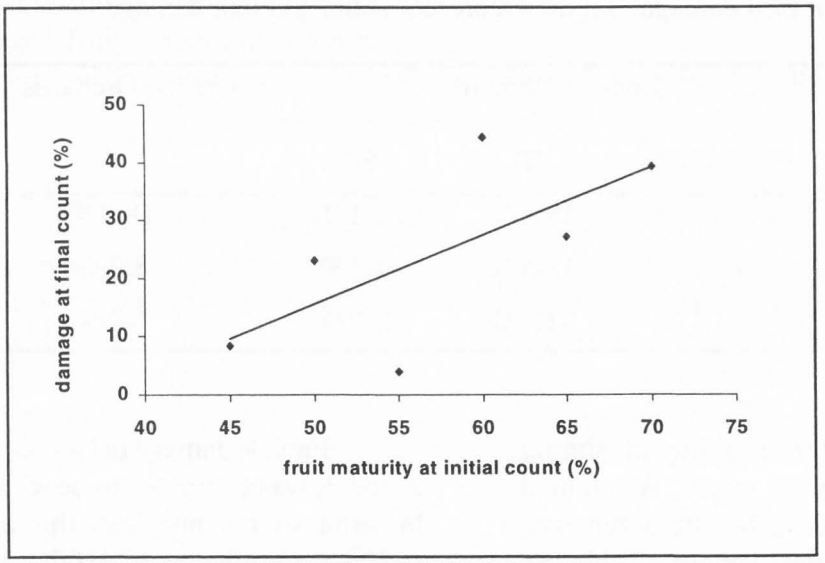

Figure 2. Bird damage to longan panicle increases with an increase in fruit maturity, Sites 1B & 5B, Dade County, Florida, 2000.

Discussion and management implications

Our findings suggest that most lychee and longan orchards incur a regular, but low level of damage by common grackles. The situation changes markedly, however, under two conditions. First, if monk parakeets use a longan orchard, then damage levels increase dramatically. This does not apply to lychees because our observations indicate that monk parakeets do not eat lychees. This could change, however, and it is important for lychee producers to monitor their groves for indications of parakeet damage. Second, under low-yield conditions, bird damage will represent a higher than normal proportion of the crop and will thus have a proportionately greater economic impact. Here again, vigilance by the grower will be key to cost-effective bird damage management. The value of each fruit lost to birds will increase as expected yield decreases. So, in large part, application of bird control methods will be predicated on the grower's assessment of the state of the crop. Most years, it might not be economical to employ anything other than the most inexpensive methods such as pyrotechnics or other scare devices.

There are few bird damage management options available to tropical fruit producers in Florida. Use of pyrotechnics and shooting to scare or kill depredating birds is limited by local noise and firearm ordinances. There is no chemical repellent currently registered for these crops. Even if a chemical repellent were registered, it might be ineffective because a repellent stays on the outer husk of the fruit whereas birds eat the pulp on the inside. In punching through or tearing open the husk of the fruit, it is unlikely that a grackle or parakeet would be exposed to sufficient quantities of repellent to deter feeding (Crabb 1979).

For high-value crops, such as longans and lychees, the use of netting systems to exclude depredating birds might be economically justified. Bird-exclusion netting is used for various commercial fruits such as early-ripening blueberries (M. B. Main, Southwest Florida Research and Education Center, Department of Wildlife Ecology and Conservation, University of Florida, Immokalee, Florida, personal communication) and grapes (Fuller-Perrine and Tobin 1993). The cost of such a netting system will depend on factors such as the size of the area covered and the type of net and associated structural support. If losses to birds are regular and substantial, such as where monk parakeets are established, it is likely that a cost-effective netting scheme can be devised, particularly if the costs were spread over the lifetime of the net.

Because monk parakeets appear to be the major problem bird species for longan growers, it would be worthwhile to consider means to reduce their numbers overall or at least in the vicinity of vulnerable fruit orchards. The high-damage longan sites in our study are within 5 km of a Florida Power and Light electrical substation where parakeets have built approximately 15 nests. The number of birds in this population is not known, but there is little doubt that it is the source of the damage. Perhaps destruction of the nests at the substation would disperse these birds and thereby markedly reduce the damage in the orchards. Monk parakeet population reduction on a larger scale would require a major public education effort to apprise the community of the current deleterious impacts of the parakeets as well as their potential for even greater economic

impacts if populations of parakeets continue to increase.

Acknowledgments. We thank the following tropical fruit growers whose generosity and cooperation made this work possible: Ed Castleberry, Marc Ellenby, Noble and Patti Hendrix, Mark Liesenberg, David Nash, Jr., and Reed Olszack. We also thank Jonathan Crane at the University of Florida Tropical Research and Education Center for his invaluable assistance in locating study areas and Robert Degner at the University of Florida Agricultural Market Research Center for providing information on the tropical fruit industry and economy. We are grateful to John Humphrey, Kimberly Phares, and Sonia Canavelli for assistance in the field.

Literature cited

Campbell, C. W., and S. E. Malo. 1979. The lychee. Fruit Crops Fact Sheet FC-6. Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, Florida, USA.

Campbell, R. J., C. W. Campbell, J. Crane, C. Balerdi, and S. Goldweber. 1993. Hurricane Andrew damages tropical fruit crops in South Florida. Fruit Varieties Journal 47:218-225.

Crane, J. H. 1989. Acreage and plant densities of commercial carambola, mamey sapote, lychee, longan, sugar apple, atemoya, and passion fruit plantings in South Florida. Proceedings of the Florida State Horticultural Society 102:239-242.

Crabb, A. C. 1979. A report on efficacy of methiocarb as an avian repellent in figs and results of industry-wide bird damage assessments. Bird Control Seminar Proceedings 8:25-30.

Degner, R. L., S. D. Moss, and J. H. Crane. 1997*a*. Market Development Strategies for the Florida Tropical Fruit Industry. Industry Report 97-2. Florida Agricultural Market Research Center, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, Florida, USA.

Degner, R. L., S. D. Moss, and W. D. Mulkey. 1997*b*. Economic Impact of Agriculture and Agribusiness in Dade County, Florida. Industry Report 97-1. Florida Agricultural Market Research Center, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, Florida, USA.

Fuller-Perrine, L. D., and Tobin, M. E. 1993. A method for applying and removing bird-exclusion netting in commercial vineyards. Wildlife Society Bulletin 21:47-51.

Malo, S. E., and C. W. Campbell. 1967. The Avocado. Fruit Crops Fact Sheet, FC-3. Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, Gainesville, Florida, USA.

Moseley, A. E., R. L. Degner, S. D. Moss, D. L. Hull, R. L. Clouser, and W. D. Mulkey. 1990. Economic Impact of Agriculture and Agribusiness in Dade County, Florida. Industry Report 90-4. Florida Agricultural Market Research

Center, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, Florida, USA.

Owre, O. T. 1973. A consideration of the exotic avifauna of Southeastern Florida. Wilson Bulletin 85:491-500.

Phillips, R. L., C. W. Campbell, and S. E. Malo. 1978. The longan. Fruit Crops Fact Sheet FC-26. Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, Florida, USA.

Spreyer, M. F., and E. H. Bucher. 1998. Monk Parakeet (*Myiopsitta monachus*). Pages 1-24 *In* A. Poole and F. Gill, editors. Birds of North America. No. 322. Academy of Natural Sciences, Philadelphia, and American Ornithologists Union, Washington, D.C., USA.

Van Bael, S., and S. Pruett-Jones. 1996. Exponential growth of Monk Parakeets in the United States. Wilson Bulletin 108:584-588.

Van Doorn, A. 1997. Factors influencing success and population trends of introduced parrots in Florida. Thesis, University of Florida, Gainesville, Florida, USA.

Young, T. W., and J. W. Sauls. 1979. The mango industry in Florida. Bulletin Number 189. Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, Gainesville, Florida, USA.