ECONOMIC IMPACT OF A MEDITERRANEAN FRUIT FLY OUTBREAK IN FLORIDA

By

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A DISSERTATION PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

2007

To my wife, Alaine and my son, Andy.

ACKNOWLEDGMENTS

First and foremost, I am indebted to Drs. P. K. Nair and Michael Bannister for providing me the opportunity of beginning my doctorate studies in the School of Forest Resources and Conservation.

I wish to express my sincere appreciation and gratitude to my entire supervisory committee: Drs. John VanSickle (chair); Thomas Spreen (co-chair); Edward Evans; Norman Leppla; Moss Charles; James Seale; and David Mulkey. They all provided useful criticisms and suggestions, thereby contributing greatly to the quality of this dissertation.

Drs. John VanSickle and Edward Evans deserve special mention for allowing me to complete my doctoral studies in the Department of Food and Resource Economics. They granted me a graduate research assistantship at a time when I was badly in need.

Drs. Thomas Spreen, Norman Leppla, and Charles Moss deserve special recognition for their unwavering support and guidance. They gave freely of their time and advice. I have been very fortunate to have their expertise available to me.

I wish also to recognize tremendous support from Dr. Gary Steck, Dr. David Dean, Mr. Mike Shannon, Mr. Terry McGovern, Mr. R.E. Burns, and Mr. Loren Carpenter. I am very appreciative of the opportunity to have worked with them throughout the research process. They were willing to provide the crucial information needed to conduct this study.

My life in Gainesville would have been dreary and unbearable without a friendly environment sustained by SFRC and FRED buddies. I am especially grateful for the unwavering friendship of Lurleen Walters, Alain Michel and Vony Petit-Frere.

I am also lucky to have had the understanding of a wonderful and supportive friend, Myrtha Jean-Mary. I am truly indebted to her for help and encouragement throughout my doctoral studies at the University of Florida.

Finally, I would like to express my love and deepest admiration for my wife, Alaine Jean, and my son, Andy Pierre, to whom this dissertation is dedicated. Their moral support and commitment have inspired me to achieve this accomplishment.

TABLE OF CONTENTS

APPENDIX

LIST OF TABLES

page

LIST OF FIGURES

Abstract of Dissertation Presented to the Graduate School
of the University of Florida in Partial Fulfillment of the
Requirements for the Degree of Doctor of Philosophy

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May 2007

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We evaluated the potential impact of a Mediterranean fruit fly infestation in Florida. We developed a Bayesian decision framework to analyze the costs of Florida Medfly prevention, detection and eradication programs under early versus late detection scenarios. Modeling results support the hypothesis that optimal trapping density varies across locations and seasons. Because of the low probability of detecting small Medfly populations, the corresponding optimal trapping densities are high, ranging from 82 to 465 traps per ha for McPhail traps and from 9 to 80 traps per ha for Jackson traps. It would be extremely costly to maintain such high trap densities over a wide area. Alternative solutions lie in the search for an increase in pesticide efficacy and an improvement of the trapping technology. Development of more effective female-targeted trapping systems will provide a new dimension to the detection of small Medfly populations.

Partial equilibrium models were also used to investigate welfare changes for the major fruit and vegetable crops under scenarios of a 3 mo, 6 mo, and 1 y quarantine period. Our analysis provides insight regarding the magnitude of welfare changes associated with a Medfly outbreak and/or infestation in Florida. These changes vary across crops, depending on the competitive position of Florida growers for the crop, size of the infested area, and length of quarantine period.

Finally, we tested the effects of changing the entry conditions on the level of Medfly risk in Florida. Our sensitivity-analysis tests showed the increasing number of international passengers entering Florida to be the driving parameter affecting Medfly introduction and establishment in Florida. Additional passenger baggage-clearance costs will be continuously needed to keep pace with the increasing number of international travelers entering Florida. Another way to mitigate the risk of Medfly introduction into Florida is to encourage and support suppression and eradication activities against fruit fly populations in Caribbean basin countries.

CHAPTER 1
INTRODUCTION

Problematic Situation

Fruit and vegetable production is an important industry in the state of Florida, with an estimated value of $4 billion as farmer cash receipts, including considerable exports. Florida farmers used a little more than 10 million of the state's nearly 35 million acres and made more than a $12 billion direct impact on the state's economy (Florida Department of Agriculture and Consumer Services 1998). Citrus sales topped $1.3 billion, accounting for more than 22 % of state agriculture sales in 1997. Florida farmers provide more than 70% of the nation's citrus and nearly 10% of its vegetables. They produce 80% of the country's domestically grown vegetables during the winter months.

The Mediterranean fruit fly (popularly known as Medfly[1]) poses a serious threat to fresh fruit and vegetable production throughout Florida and southern Florida. Since its first detection in Florida in 1929, the pest has been intermittently introduced in the state. Most of its introductions can be traced to accidental or intentional (smuggling) human interventions; Florida is the path for large volume of commodities and international travelers (APHIS 1995a, 1999, 2001, 2003a).

Because of its wide range of hosts, its explosive reproductive capacity, and its extreme adaptability to adverse ecological conditions (Klassen et al. 1994), Medfly is considered one of the world's most destructive fruit pests and is the subject of strict

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[1] The molecular data on the genetic variability of the Mediterranean fruit fly confirm that the name "Medfly" may be inappropriate because the ancestral home of C. capitata is Africa, so it ought to be called "Africafly." (Malacrida et al.1998; Hoy 2003).

quarantine and comprehensive control programs. Countries are allowed to impose technical barriers to the free movement of fresh fruit and vegetable commodities to protect national production from pests, diseases, and contaminants; but the Sanitary and Phytosanitary (SPS) Agreement requires that any regulatory measure be based on scientific assessment of risks associated with introducing these invasive species. Regulatory and eradication[2] measures are justified because the pest significantly increases production costs; and fruits grown in Medfly-infested regions cannot be exported to Medfly-free areas (thereby affecting national and international trade).

APHIS and the State of Florida spend millions of dollars each year on research and exclusion[3] (risk-assessment studies, clearing imported cargos, inspecting and regulating passenger baggage, restrictions on imports) to prevent a wide complex of exotic animal and plant diseases and pests, including Medfly. The Medfly-detection program was designed for early detection of Medfly introductions. Florida is considered Medfly-free thanks to periodical eradication campaigns combining non-chemical and chemical control methods. Prompt aerial applications of malathion bait over Florida cities regarded as major entry points of Medfly have been key to the success of these campaigns.

However, public concern has been growing about the intensive use of malathion in eradication operations. Some critics advocate the abandonment of all chemicals. Florida's legislation is likely to restrict aerial applications of pesticides over heavily populated areas (APHIS 1999). Alternative detection, prevention, and eradication programs

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[2] Eradication is a process used to achieve a fruit-fly free area. Trapping surveys are carried out to measure the efficacy of control measures (such as bait sprays, SIT, biological control, and MAT) used to eliminate a pest from an area (IAEA 2003).

[3] Exclusion is a process used to minimize the risk of introduction or re-introduction of a pest in a free-area. Trapping survey are carried out to determine the presence of species that are under exclusion measures and to confirm (or reject) the free-area status (IAEA 2003).

involving intensive trapping and regulatory measures, preventive sterile-release programs, and ground-only pesticide applications are being studied in a context of increased trade and human travel.

Problem Statement

Medfly incursion and establishment in Florida involve factors beyond the control of APHIS' policy makers. Medfly infestations in Florida might become likelier with increased trade and movement of people from infested countries. In such a context, timely detection is crucial to effective management and control of a Medfly population at the earliest possible stage. However, discovering low populations of wild Medflies in continuous plantings of a host species is exceedingly difficult (Calkins et al. 1984). Optimal control may require greater density of traps to better detect low populations, but maintaining a high trap density over a wide area is extremely costly. Decisions to increase trap density must consider the consequences of failing to detect low populations.

Another area of concern is the potential impact of a Medfly outbreak in the Florida fruit and vegetable sector. Economic studies (APHIS (1993, 1999) conservatively measure producer losses, ignoring the uncertain effectiveness of detection and eradication program effectiveness, potential changes in retail prices, and costs to consumers. An appropriate modeling framework is needed for a welfare analysis of a Medfly outbreak in Florida.

Hypotheses

There is a trade-off between early and late detection in cost management of the Medfly-eradication program. Early-detection costs are high for trapping, but low for eradication (with a low probability of establishment). Late detection costs for eradication are high (with a high probability of establishment).

- **Hypothesis 1**

  Optimal trapping density varies across locations and seasons; it minimizes the expected cost of the prevention and eradication program

A Medly outbreak in Florida would probably cause a decrease in export markets, an increase in pre- and post-harvest production costs, and a yield reduction from the infested areas.

- **Hypothesis 2**

  The magnitude of welfare changes associated with a Medfly outbreak will vary from one crop to another, depending on growers' competitive position for the crop, size of infested area, and length of quarantine period.

Objectives

Our overall objective was to analyze the cost implications of a Medfly outbreak in Florida for APHIS and the State of Florida in general, and for producers and consumers in particular. We analyzed a variety of outbreak scenarios. Specific objectives are to:

1. Review the policy framework for using the Sanitary and Phytosanitary (SPS) Agreement
2. Evaluate costs of Medfly detection and eradication programs under different pest-detection scenarios
3. Use estimated probabilities of detection to determine the optimal trapping strategy specific to each location and season of the year
4. Evaluate welfare changes associated with outbreak scenarios of 3 mo, 6 mo, and 1 y quarantine periods
5. Formulate alternative policy measures to reduce the risk of Medfly introduction and establishment in Florida.

Thesis Outline

The plan of this thesis is as follows. The next chapter presents an overview of biological profile of the Mediterranean fruit fly, Florida fruit and vegetable sector, and

Medfly-detection and eradication programs. The third chapter follows with an analysis of the World Trade Organization (WTO) Agreement on the application of the SPS measures. This review focuses on phytosanitary protocols and regulated postharvest treatments for the domestic and international movement of fresh fruit and vegetable commodities.

Chapter 4 describes the components of the Bayesian decision framework: spatial-temporal model of infestation, models of probability, and cost minimization model. These models were used to estimate (1) probabilities of detecting a Medfly infestation in Florida under different outbreak scenarios and (2) optimal trapping densities minimizing total expected cost of prevention and eradication programs. Chapter 5 follows with the description of optimization models used for analyzing welfare changes associated with a Medfly outbreak in Florida. We analyzed scenarios of 3 mo, 6 mo, and 1 y quarantine periods.

Chapter 6 deals with the determination of Medfly risk by combining the results of Chapters 4 and 5. Sensitivity-analyses are conducted to evaluate the effects of changes in the major factors leading to the introduction and establishment of Medfly into Florida. The paper concludes with the formulation of alternative policy measures to reduce the risk of a Medfly endemic situation in Florida.

CHAPTER 2
REVIEW OF MEDFLY INTRODUCTIONS AND INFESTATIONS IN FLORIDA

Biological Profile of the Mediterranean Fruit Fly

The Mediterranean fruit fly (Ceratitis *capitata*) is the most notorious member of the family Tephritidae (Narayanan and Batra, 1960). It originates from sub-Saharan Africa and is now widely distributed in many countries of the Mediterranean coast. It has no near relatives in the western hemisphere. Adult Medflies are slightly smaller than a housefly and are very colorful. They can be readily distinguished from any native fruit flies of the new world. Females have a characteristic yellow wing pattern and the apical half of the scutellum is black (Figure 2-1), and males can be separated from all other members of his family by the black pointed expansion at the apex of the anterior pair of orbital setae (Figure 2-2).

Medfly is one of the most destructive agricultural pests in the world (Papadopoulos et al. 2001, 2002). Medfly reduces the yield of fruit and vegetable crops and it affects their quality. Ripened fruits infested with the Medfly may be unfit to eat, as the female pierces the soft skin and deposits eggs in the puncture. A female Medfly may lay as many as 800 eggs during her lifetime. The average daily oviposition rate is 11 eggs (Thomas et al. 2001; Papadopoulos et al. 2002). Those eggs produce maggots or wormlike larvae that feed on the pulp of the fresh fruit, drop to the ground, and transform into pupae in the soil or elsewhere. Many researchers report high mortality in Medflies, particularly in citrus hosts (Back and Pemberton 1918; Bodenheimer 1951). However, high fecundity and adult longevity generally more than compensate for high larval mortality (Carey 1982a). If only 10% of larvae survive, the population can double every 10 days.

Life expectancy and insect development depend on climatic conditions. Under typical Florida summer weather conditions, the life cycle of the medfly (which also includes maturation of the pupae into adults) varies from 21 to 30 days (Thomas et al. 2001). Optimum temperatures for the most rapid development and high potential for spread range from 70 to 90^{o} F. Adults emerge in the largest numbers early in the morning during warm-temperature and longer freeze-free periods, and emerge more sporadically during cool weather. According to Buyckx (1994) and Bodenheimer (1963), Ceratitis *capitata* is confined to regions where cold weather combined with low humidity interrupts development in egg, larval, and pupal stages for less than 100 days. Low temperatures greatly increase the duration of the egg stage. Nevertheless, field studies report that pupae can carry the species through unfavorable conditions such as lack of food, or water, or temperature extremes (Thomas et al. 2001). Pupae can develop at temperatures as low as 50^{o} F (10^{o}C), making the Medfly extremely adaptable and a serious pest-control challenge.

Ceratitis *capitata* is a polyphagous and multivoltine tropical species that has spread to all countries bordering the Mediterranean region, southern Europe, western Australia, Central and South America, and Hawaii. It has been recorded in more than 200 different types of fruits and vegetables. Medfly was first discovered in Central America in April 1955 near San Jose, Costa Rica. It then spread into Panama, Nicaragua, El Salvador, Honduras, Guatemala, and the southern border of Mexico (Gonzales 1978). Primary hosts of Medfly in Central America are coffee, tangerine, orange, grapefruit, peach, and tropical almonds. Medfly populations there mainly vary according to seasonal factors, reaching a peak during the dry season and with the maturation period of the host fruits, particularly coffee (Henning et al. 1972; Eskafi and Kolbe 1987). Low populations coincide with increased rainfall but vary depending on elevation.

Much of Florida would maintain high Medfly populations because of both favorable climate and availability of preferred host materials throughout the year. Average mean monthly temperatures for the city of Miami (Dade County) are in the optimal range 8 months a year, and above the minimum temperature for Medfly development all year. Almost all major crops produced in Florida (oranges, grapefruit, lemons, tangerines, and tangelos) could be heavily infested by Medfly (Table 2-1). Some vegetables and melons are classified as occasionally or rarely infested hosts. Medfly also could be attracted to patches of ornamental trees that provide shelter in otherwise barren areas (Buyckx 1994). Thorough knowledge of the hosts in one country often can help predict the hosts most likely to be infested in a newly infested country.

Movements of flies seemed to be influenced more by the distribution of hosts than by wind direction (Buyckx 1994; Wakid and Shoukry 1976; Hafez et al. 1973). Flies do not move great distances under favorable climatic conditions and where fruits and vegetables are available. Movements appear to be restricted to a few hundred meters per week. Long distance flights of over 20 km are associated with some behavioral surviving mechanism for Medly populations in areas where fruit suitable for ovipositing are unavailable during certain times (Harris and Olalquiaga 1991). Thus, population density and the economic damage would vary from area to area, depending upon the seasonal availability of hosts and the presence or absence of unfavorable climatic conditions.

The biggest factors in dispersal and spread of Medfly populations are fruit transport and trade (Buyckx 1994). Modern roads allow fresh fruit to be transported throughout the states. International passengers might also bypass detection and enter the United States with high-risk Medfly host material. Medfly surveys conducted by APHIS (1995a) show that the major pathways for Medfly into Florida are passenger and crew baggage from foreign countries. Approximately 93% of all high-risk and infested host materials enter Florida at the ports of Miami and Orlando. JFK International Airport is the only other airport with a significant volume (4%) of high-risk and Medfly-infested material destined for Florida.

The risk of Medfly entering the U. S. via Mexico is small, because Mexico is Medfly-free. However, there is a potential risk for Medfly introduction from infested fruit carried into the United States by travelers from a third country. About 2.17 % of people crossing the Mexican border illegally each year are not of Mexican descent, and most of them (78%) are from Central American countries where Medfly occurs (APHIS 1992). Many of these illegal aliens carry food with them that could be infested with fruit fly.

These findings are consistent with historical data on Medfly occurrences and infestations in Florida (Table 2-2). Several Medfly occurrences are closely associated with ship and boat traffic in Miami (1964, 1967, 1984, 1985 and 1988); Tampa (1981); and Fort-Lauderdale (1990). Five of the nine Florida infestations occurred in or around Miami Springs, a small upper-income housing area at the northern edge of Miami International Airport. Seasonal distribution of Medfly occurrences in Florida (Figure 2-3) seems not be related to colonization potential for Medfly, as temperatures and host availability are favorable all year in southern Florida (APHIS 1992). Seasonal distribution of interceptions from Latin America is the same as seasonal distribution of Medfly detection in Florida. However, seasonal distribution of interceptions from Hawaii (where Medfly is permanently established) markedly differs from seasonal distribution of Medfly detection in Florida (Figure 2-4). These observations strongly suggest that Latin American countries (instead of Hawaii) could be a high-risk source of Medfly infestations in Florida.

Overview of the Florida Medfly Detection and Eradication Program

Florida is a managed Medfly-free area[4] in which the pest has been intermittently eradicated. As argued previously, no limiting natural factors prevent its establishment in Florida. The State is permanently protected by federal regulatory actions (quarantine inspection, surveillance networks, import restrictions) controlling the movement of people and commodities. Some of these measures target specific importing countries where the Medfly is established or not completely eradicated. [5] Under GATT and WTO rules, APHIS is compelled to ensure that quarantines are imposed for sound biological reasons, rather than for protectionist trade barriers.

A cooperative agreement between APHIS and the State of Florida provides early detection of Medfly introductions. Timely detection of small Medfly populations greatly helps management of this pest (Dowell et al. 1999), but recent studies show that early

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[4] Malavasi et al. (1994) distinguish two types of fly-free areas, a “natural” and a “managed” free area. In a natural fly-free area, the species naturally does not occur (because of ecology, host preference, geographical distribution, etc). Managed fly-free areas are production zones from which the target fruit fly has been eradicated. These areas must be permanently protected by regulatory actions.

[5] For instance, cooperative partnership agreements are signed with Mexico and other countries of the western hemisphere (like Guatemala and Costa Rica) with a view to diminishing their pest problems, thus reducing the risks of Medfly introductions into the United States.

detection can be difficult (Papadopoulos et al. 2000). The lure for Medfly (called Trimedlure) is weak and has little ability to attract the flies to the trap (Scribner 1983). The Jackson trap (the most effective and commonly used Medfly trap) can only catch 1 in 2000 Medflies in the area.

Current national protocol requires 21 traps per square mile for high-risk areas, 12 traps for medium-risk areas, and 3 traps for low-risk areas. [6] About 47,404 traps are currently placed in 49 counties in Florida. About 54% of the traps are concentrated in high-risk areas in the following counties: Pinellas, Hillsborough, Orange, Palm Beach, Dade, and Broward. In FY 2003-04, the total cost of the Medfly detection program was approximately $7 million, with salaries and supplies accounting for 86.8% (Table 2-3). Drawing on the 1997/98 Medfly infestation, potential budget changes in case of emergency (about $ 398,500 per month of emergency) represent significant increases in employees' overtime hours, travel expenses, and services.

The success of any Medfly-eradication program depends on early-detected infestation (an infestation where the area under quarantine is 110 square miles or less). Once detection traps capture one or more Medfly adults, additional traps are placed to determine whether an outbreak has occurred and/or to limit the outbreak. Drawing on the potential mobility of Medfly adults, this trapping strategy occurs in an 81-square-mile area around the fly find, which is divided into a core area (1 square mile for a single fly capture) and several buffer areas. The whole area is placed under strict quarantine to prevent the movement of any regulated articles to non-infested areas of the state. All host fruits on the property and those properties immediately adjacent are stripped promptly

[6] Five ML traps and 16 TML traps are placed in high-risk areas, two ML traps and 10 TML traps in medium-risk areas, and one ML trap and 2 TML traps in low-risk areas.

and disposed of according to APHIS protocols. However, extensive fruit stripping may stimulate dispersal of gravid females, thereby making eradication more difficult.

Treatment occurs when a Medfly infestation is determined[7] to occur. Generally, eradication procedures combine mechanical, chemical, and biological controls. Table 2-2 summarizes the total eradication costs from 1929 to 1997. Eradication costs have been drastically reduced since the early 1960s by the development of trapping technology and because of the intensive use of aircraft during eradication operations. Mass spray applications of malathion bait have been made possible over heavily populated areas, often within minutes after discovery of an infestation. This approach has been key to the success of these eradication programs, providing complete coverage of the epicenter of Medfly infestation. Ground applications continue to be used for the treatment of soil with dieldrin to kill emerging adults and larvae entering the soil.

Chemical control is used mostly to reduce Medfly populations to a low level before the sterile insect technique (SIT) can be used. Currently used to prevent and eradicate, SIT uses the ability of factory-produced insects to disrupt the normal mating patterns of wild Medflies. Sterile Medflies mate with their wild counterparts, resulting in the production of infertile eggs. Preventive sterile release program is more successful when the number of wild flies introduced is very low. In Florida, about 125,000 flies per week per square mile are currently released over the high-risk areas[8] to provide prevention control. In cases of emergency, another 400,000 flies per week per square mile would be

[7] The deliberative process is based on the following: 1) presence of two flies within a three-mile radius; 2) presence of one mated female; or 3) presence of larvae or pupae (APHIS 2003a).

[8] Area-wide sterile release would include the following criteria: areas where Medflies were detected in the past, areas in proximity to ports of entry, and/or urban or suburban areas where frequent movement of imported and exotic Medfly host occurs.

released over each standard block of 100 square miles to support eradication operations. In 2004, the cost of the Preventive Release Program (PRP) was roughly $3.34 million (Table 2-3). In an emergency, PRP costs would increase by about $ 82,000 per block.

Sole reliance on SIT for prevention has been unsuccessful, mostly because program managers cannot maintain the necessary release ratio of sterile to wild fruit flies. For curative purposes, a minimum ratio of 10:1 (sterile to wild) is required to halt Medfly population growth and achieve complete eradication (Carey 1982a). Eradication using SIT is ineffective in production areas because sterile insects are killed by grower applications of insecticides. Entomologists have also become aware of behavioral deficiencies of sterile insects versus their wild counterparts. Artificial conditions of the mass-rearing reduce mating performance, producing Medflies that compete poorly for females (Jang et al. 1994; Jang 2002). Various approaches to improving the mating success of SIT flies have been studied.

The future effectiveness of Medfly control programs is inextricably bound to public concern about pesticide use and potential adverse effects. Ample data on environmental impacts (fish kills, invertebrate losses, and human health effects) were collected during the 1997 program in Florida to show that malathion is not safe (APHIS 1999). These issues raised divergent beliefs about whether the benefits of eradication operations outweigh the environmental costs, and whether the risks associated with pesticide use are manageable to acceptable levels. Our study helped elucidate these controversies by examining the probabilities of risk and related economic consequences associated with a Medfly outbreak in Florida.

Overview of the Florida Fruit and Vegetable Sector

Florida produces a wide range of fruit and vegetable crops, responding to increased consumer demand driven by population growth and growing concern over a healthy diet. In 2001, Florida farmers used approximately 900,000 acres to produce 5.28 billion pounds of fruits and vegetables. These crops provide revenues of $4 billion to Florida growers. Tables 2-4 and 2-5 report the acreage, yield, and use of Florida fruit and vegetable crops for the 1999-2000 season. Oranges, fresh tomatoes, and grapefruits are the leading crops, accounting for 68.13% of the total acreage allotted to this sector. Other important crops include bell peppers, cucumbers, tangerines, tangelos, watermelons, and eggplants.

Florida is known for its citrus fruits, primarily grown in the central and southern parts of the state. State farmers lead the nation in the production of oranges, grapefruit, tangerines, and tangelos. About 75% of the nation's oranges are grown in the state: more than 90% was used to make more than 1.5 billion gallons of juice in 1997. Florida and Brazil are the major competitors, accounting for over 20 and 60% of world production, respectively. Florida orange growers suffer particularly from large fluctuations in orange juice prices, for demand is highly sensitive to consumer income (Spreen 2001).

Florida also produces 77% of the U.S. domestic grapefruit and nearly 47% of the world supply. This production is grossly split in half: one half is processed, and the other half is marketed in fresh form. Florida grapefruit growers are highly dependent on export markets in Europe, Canada, and Japan for fresh grapefruit. In particular, the opening of the Japanese fresh citrus market has resulted in large increases in shipments of fresh white seedless grapefruit to Japan (Spreen et al. 1995).

Tangerine production in Florida has increased from 222.3 million pounds in 1986/87 to 522.5 million pounds in 2002/03. An average of 70 percent of the tangerines produced are sold in the fresh market, with the remainder going to the processing sector for juice, sections, or other uses (USDA 2003). U.S. domestic production is supplemented by tangerine imports mainly from Mexico and Spain. While imports of Mexican tangerines have remained relatively stable over the last six years, imports of clementines from Spain have increased from 33 million pounds in 1994/95 to 119 million pounds in 2000/01.

The state also ranks second nationally in the value of its vegetable crops that account for more than 25% of Florida agriculture sales. Florida winter fresh vegetables are produced mostly in the southern half of the state where adequate conditions prevail (VanSickle et al 1994). Although the state has faced a growing array of problems in the winter fresh vegetable industry, growth in vegetable production for the last two decades has been mostly related to the use of hybrid cultivars and improved management practices. In 2002, Florida growers used less than 290,000 acres and received $ 506 million in sales from tomatoes, $ 245 million from green peppers, $ 122 million from snap beans, $ 107 million from cucumbers, and $ 105 million from sweet corn. Fresh vegetables generally move from the field to the packing shed for packing, pre-cooling, and storage before shipment to wholesale markets. Industry sources estimate a total of 60 to 70 packers/shippers throughout the state.

Florida growers held a competitive edge over their traditional Mexican competitors in the U. S. markets for field-grown vegetables. However, the development of greenhouse technologies has brought recent changes in U.S. vegetable markets. Florida growers are now facing growing competition with the largest greenhouse producing areas in Spain, Italy, France, and Greece. Productivity in European greenhouses is nearly three fold comparable to Florida field production and product quality is generally higher from greenhouse versus field-produced vegetables (Cantliffe & VanSickle 2003). This competition is likely to affect all major vegetable crops grown in Florida, like tomatoes, peppers, eggplants, cucumbers, muskmelons, and to some degree, watermelons. For instance, U. S. imports of greenhouse tomatoes have grown rapidly, from 43.9 million pounds in 1994 to 395.5 million pounds in 2000, including 224 million from Canada, 76.5 million from the EU, and 96 million from Mexico (Cook 2002). As imports increase, fresh tomato acreage declines in both Florida and California. Concern is growing about the impacts of importing greenhouse tomatoes on U. S. vegetable industry.

Along these lines, an economic evaluation of the potential damage to the Florida fruit and vegetable sector from a Medfly infestation must be approached within a framework of growing competition among the different economic agents from both within and outside the United States. In addition to the potential losses associated with yield reduction and increases in pre- and postharvest costs, Florida growers' competitive position would be further weakened through price adjustments due to losses in export markets and shipment restrictions to other states. APHIS (1993, 1999) predicts that countries would react according to their Medfly status and their regulations. While some countries like Mexico, Argentina, and Chile would require treatment of Medfly hosts from Florida, others like China, Japan, and the Caribbean nations would prohibit the importation of all Medlfy hosts, including marginal hosts for a number of years. It is estimated that Florida would lose over 50% of its export markets if Medfly became established in Florida.

APHIS and FAO/IAEA have carried out many studies to assess the economic impact of the potential Medfly damage on fruit and vegetable production, using a partial budget approach (APHIS 1993, 1999; FAO 1995; IAEA 1995; Enkerlin and Mumford 1996). Losses in producers' revenues are estimated, but none of these studies have given consideration to price changes related to changes in output and export markets. All changes in production are measured at current prices and costs to customers are completely ignored.

Furthermore, findings from risk assessment studies carried out by APHIS (1995b) are not incorporated into the economic analysis, which could have better supported and shaped regulatory policy options. Losses in the value of production are grossly estimated at 5% (APHIS 1993, 1999), under the questionable assumption that eradication, regarded as a proven technology, can be achieved with complete certainty. The State of Florida would incur an expected eradication[9] cost of $4.8 million each year if eradication were successful. Costs to producers would range from $32 million to $300 million, depending on whether eradication is successful.

However, Farnsworth (1985) argued that eradication is a two-event combination (eradication feasible and eradication not feasible) with a range of probabilities summing to one. Other studies emphasize the uncertainty of prevention and control program effectiveness and recommend the use of partial equilibrium models to estimate the

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[9] The expected cost of eradication per year is calculated by multiplying the probability of an outbreak per year by an average eradication cost. The calculation of this probability is based upon the history of Medfly outbreaks in Florida. It is predicted that, given no major changes in APHIS' exclusion activities, this probability is about 0.2 per year (or once every 5 years).

economic effects of this program under different outbreak scenarios (Regev et al. 1976; Rendelman and Spinelli 1999; Brown et al. 2002). Approaches taken in these studies allow for price changes in the commodities concerned under the assumption that linkages with other similar commodities are small.

Summary

Medfly is one of the most destructive agricultural pests in the world. It has been introduced 18 times in Florida, leading to 9 infestations. Five of these infestations occurred in or around Miami Springs, a small upper income housing area located on the northern edge of the Miami International Airport. Without control measures, much of Florida would maintain high Medfly populations because of both favorable climate and availability of preferred host materials throughout the year. Various observations strongly suggest that Latin American countries could be a high-risk source of Medfly infestations in Florida.

Florida is a managed Medfly-free area in which the pest has been intermittently eradicated. Millions of dollars are spent annually on exclusion and detection activities to prevent Medfly establishment in Florida or at least provide early detection of its introductions. Such investments are justified because of the importance of the fruit and vegetable industry in Florida. The State leads the nation in the production of a wide range of fresh fruit and vegetable crops, thereby responding to an increased consumer demand driven by population growth and growing concern over a healthy diet. An economic evaluation of the potential damage from Medfly on the Florida fruit and vegetable sector must be approached within a framework of growing competition among the different economic agents from both within and outside the United States. Partial equilibrium models can be designed to allow for potential price changes in the commodities concerned and take into account the uncertainty of the detection and eradication program effectiveness.

Figure 2-1 Female Mediterranean fruit fly

Table 2-1 Major fruit and vegetable crops grown in Florida according to their importance as Medfly hosts

Heavily infested	Occasionally infested	Unknown	Lab infestations
Grapefruit, tangelo, tangerine, lime, bell peppers, lemon, mango	Avocado, eggplants, ripe tomatoes, strawberries	Watermelons, snap beans, squash	Cucumbers, eggplants

Sources: Liquido et al. 1991


Figure 2-2 Male Mediterranean fruit fly

Table 2-2 Costs of Medfly infestations in Florida

Year	Area of detection	Counties affected	Costs ($ millions) Nominal	1990
1929	Orlando	20	7.5	56.5
1956	North Miami	28	11	50.6
1962	Miami	3	1	4.1
1963	Miami	1	0.3	1.2
1981	Tampa	1	1	1.4
1984	Miami	1	1	1.2
1985	Miami	1	2.2	2.6
1987	Miami	1	1.3	1.5
1990	Miami	1	1.8	1.8
1997	Tampa	5	24	20

Source: Clark et al. (1992)

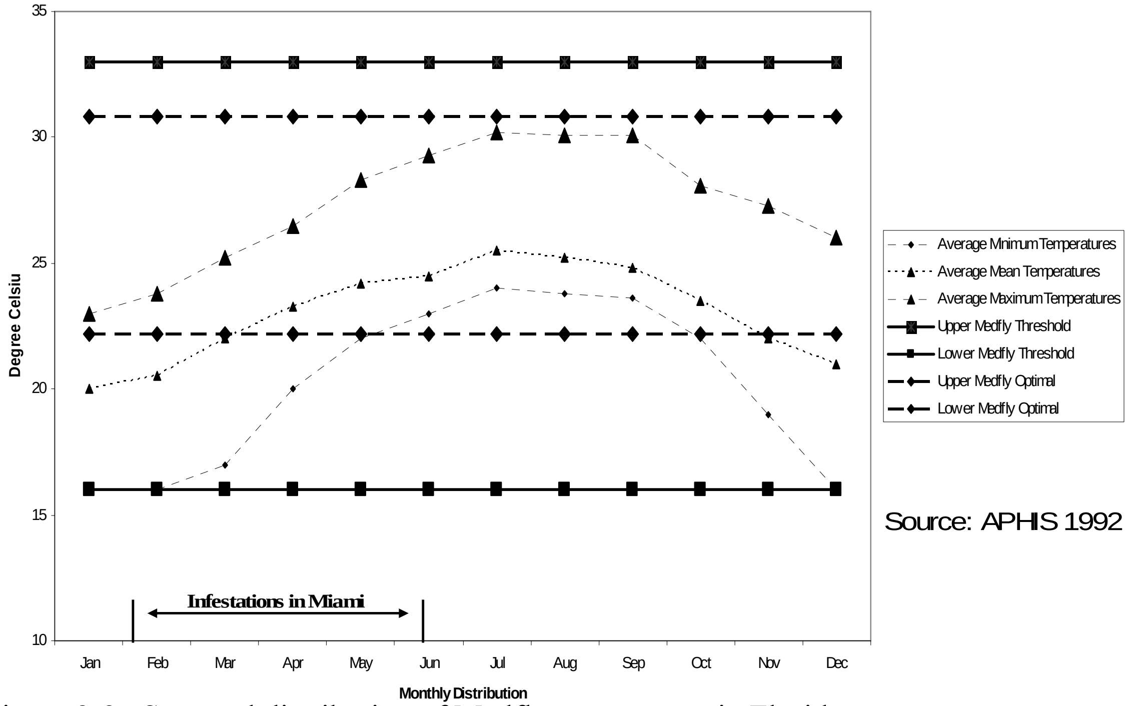

Figure 2-3 Seasonal distribution of Medfly occurrences in Florida

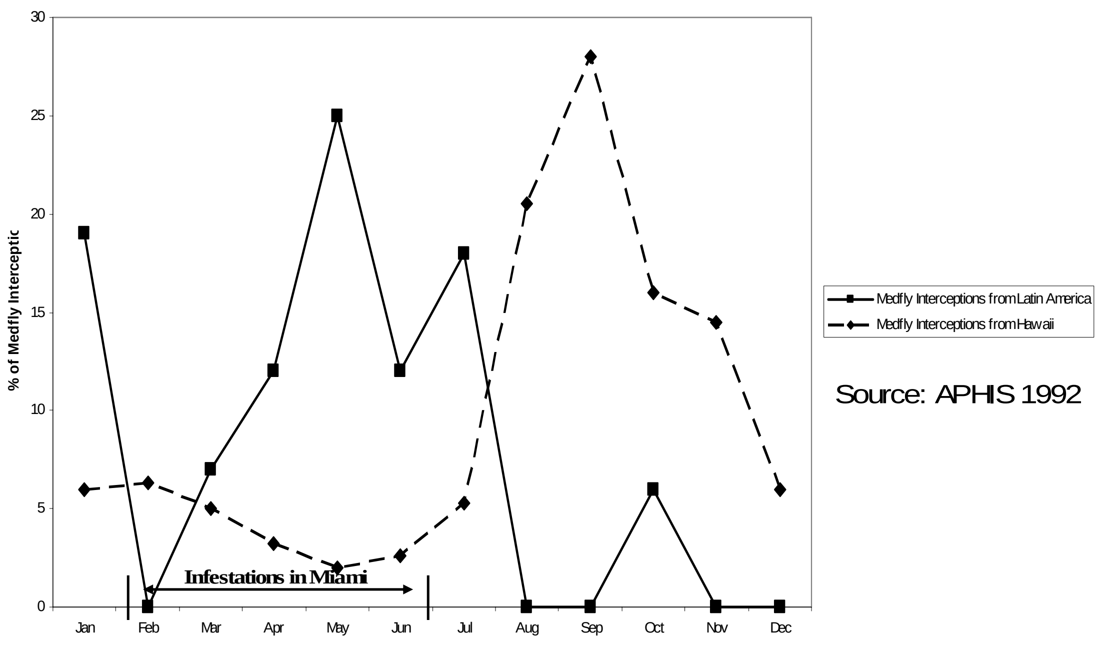

Figure 2-4 Distribution of Medfly interceptions in Florida

Table 2-3 Baseline and emergency budgets for the Medfly prevention and detection program

	Preventive release program		Detection program	
	Baseline annual budget ($)	Emergency budget [a] ($)	Baseline annual budget ($)	Emergency budget [b] ($)
Salaries, benefits & overtime	931,402	5,000	5,090,988	112,000
Travel expenses	27,300	2,000	56,625	105,000
Transportation & shipping	168,000	9,600	14,500	30,500
Rents, utilities & communication	250,376		362,149	9,000
Services & repairs	1,006,544	10,120	180,000	116,000
Supplies	892,000	55,000	989,000	21,000
Equipment	67,000		241,000	5,000
Total	3,342,622	81,720	6,934,262	398,500

[a] These costs are estimated for each additional production and release of 400,000 flies per week and per block of 100 square miles. [b] These costs are estimated for each month of emergency.
Source: APHIS 2002

Table 2-4 Important fruits: acreage, yield, and use (by crop), 2001-02

Crop	Bearing acreage (1,000 acres)	Yield per acre (boxes)	Use		
			Fresh	Processed (1,000 boxes)	Total
All oranges	586.9	392	9,524	220,476	230,000
All grapefruit	101,3	461	17,380	29,320	46,700
All tangerines	24	275	4,204	2,396	6,600
Tangelos	9.7	222	696	1,454	2,150
Limes	0.8	188	125	25	150
Lemons	0.9	94			85
Avocados	5.9	156	920		920

Source: Florida Agricultural Statistics Service (2003).

Table 2-5 Important vegetables: acreage, yield, and utilization, by crop, 2001-02

Crops	Planted Acreage	Harvested Acreage	Yield per Acre	Production	Total Value
	(acres)		cwt	(1,000 cwt)	($ 1,000)
Tomatoes	43,500	43,500	338	14,688	474,284
Cucumbers	7,500	7,500	386	2,893	56,012
Bell Peppers	17,250	17,100	320	5,469	170,340
Squash	12,000	11,700	135	1,578	44,543
Eggplants	1,800	1,800	257	463	12,501
Watermelons	25,000	23,000	330	7,590	62,238
Strawberries	6,900	6,900	255	1,760	153,472

Source: Florida Agricultural Statistics Service (2003).

CHAPTER 3
POLICY FRAMEWORK OF THE SANITARY AND PHYTOSANITARY (SPS) AGREEMENT

The World Trade Organization Agreement on the Application of Sanitary and Phytosanitary Measures

Sanitary and phytosanitary (SPS) restrictions are characterized as a subset of trade-related policies known as technical barriers to trade (TBT[10]). They include all measures adopted by a country to protect human, animal, or plant life and health from risks related to diseases, pests, and disease-carrying or –causing organisms, as well as additives, contaminants, toxins or disease-causing organisms in food, beverages, or feedstuffs. Primary method of protection has been the development of quarantine protocols exhibiting differing degrees of trade restrictions like complete bans, seasonal and/or geographical bans, postharvest disinfestations procedures (fumigation, cold storage or others), inspection at points of export and import, and even information remedies (Paul and Armstrong 1994; Roberts 1998). Unlike most non-tariff barriers, SPS measures are potentially welfare-increasing, for they may correct market failures resulting from externalities associated with the movement of agricultural products across national borders (Roberts et al. 1999; Spreen et al. 2002).

The World Trade Organization (WTO) Agreement on the Application of SPS measures recognizes all nations' sovereign rights to enforce health standards on imports, as agricultural trade facilitates the transportation of potentially harmful pests (which can

[10] The Technical Trade Barriers (TBT) are in turn characterized as a subset of social regulations, encompassing all measures adopted by a country to achieve health, safety, quality, and environmental objectives (Roberts et al. 1999)

cause widespread destruction when carried into a country). Increasing use of SPS standards and regulations reflects in many cases increased concern for public health and the environment. However, it is generally acknowledged that SPS measures can also be used as disguised protection for domestic agriculture. Domestic producer groups with a vested interest in a particular regulatory outcome are likely to lobby for overly restrictive measures that limit competition from imports, by exaggerating either the probability of infestation or the cost impact of infestation (Spreen et al. 2002).

One objective of the Uruguay Round of multilateral trade negotiations, as set out in the Punta del Este Declaration, is to minimize the adverse effects that SPS regulations and barriers can have on trade in agriculture. Indeed, government size and power facilitate the enactment and enforcement of regulatory barriers to trade for producer protectionism and/or consumer welfare purposes (Thilmany and Barrett 1996). The Standards Code defined in the Tokyo Round failed to stem disruptions of trade in agriculture caused by the misuse of technical restrictions (Stanton 1977). The challenge before the negotiators of the new WTO Agreement on the Application of SPS measures was to create a set of rules that would strike the proper balance between allowing health and environmental protection and disallowing mercantilist regulatory protectionism (Roberts 1998).

Toward this end, new substantive and procedural disciplines were established to facilitate the decentralized policing of SPS measures. WTO country members are required (1) to apply the same rules to domestic and imported products and (2) to notify their trading partners of proposed SPS measures that might affect trade. Trading partners are therefore given opportunities to comment on a measure before it is adopted. The SPS

Agreement also establishes a dispute-settlement procedure involving several levels of consultation, such as informal consultations, bilateral negotiations, recourse to the Committee on Technical Trade Barriers, and convocation before a panel of government officials.

The cornerstone of the SPS Agreement is found in its Article 5 (which deals with the issues of risk and level of protection) [Federal Register 2004a]. Countries are granted the rights to choose their appropriate level of protection (ALP) against imported pests and diseases, but their regulations must be demonstrably based on an assessment of risk and clearly related to the control of the risk. Risk assessment typically involves the identification of the hazard, appraisal of the likelihood and consequences of the hazardous situation, and specification of the way in which SPS measures would reduce those consequences (Caswell 2000). The SPS Agreement recommends that risk analysts develop a strong understanding of the pest biology and potential pathways leading to its introduction in a new environment (Gray et al. 1998). They often have to make use of value judgments, while struggling with data gaps, large uncertainties and the need to extrapolate. In sum, the analysis results in an assessment of the probability of introduction of a pest or disease (a likelihood model). The different disease outcomes are treated as inputs into the economic model to estimate.

Net social welfare is the yardstick used by economists to capture the trade and welfare effects of a regulatory protection model under pest control situations involving either probabilities of infestation or certainties (Roberts et al. 1999; Roberts 2000). From the perspective of the importing country, changes in net social welfare resulting from the imposition of a phytosanitary barrier (Spreen et al. 2002) can be expressed as follows:

$$\Delta W = \Delta CS \frac{\Delta W}{\Delta CS} + \Delta PS \frac{\Delta W}{\Delta PS} + \Delta EC \frac{\Delta W}{\Delta EC} + \Delta H \frac{\Delta W}{\Delta H} \tag{3-1}$$

where W is aggregate social welfare, PS and CS denote producer surplus and consumer surplus respectively, EC accounts for the enforcement costs associated with the imposition of the phytosanitary barrier, and H is some index of human health.

Figure 3-1 examines more closely changes in producer surplus resulting from the reduction in the aggregate supply (AS) due to a shift of the excess supply (ES) in the exporting country and an increase in the production costs associated with the use of the additional technology required by the SPS barrier. As a result, domestic prices increase, and consequently, domestic production (DS) also increases. The model could also accommodate the prevention program costs and the expected value of government pest eradication expenditures. These economic considerations allow risk managers to identify the most effective pest management strategies and to gauge whether a proposed measure meets the criterion of the SPS Agreement that it be the least trade restrictive (Caswell 2000).

However, the SPS Agreement, as a trade facilitator, does not endorse an explicit account of the costs and benefits of a policy's effects on producers and consumers. Rather, it encourages a myopic focus on direct risk-related costs of import protocols (Roberts 1998). Consideration of producer surplus losses (gains) resulting from lower (higher) prices would likely be seen to be in violation of the spirit of the SPS Agreement, because they are costs related to commercial activity, but unrelated to health or environmental protection (Roberts 2000). Thus, under the SPS Agreement, commercial considerations might be appropriately factored into a country's choice of its single ALP

(Appropriate Level of Protection), but they should not be used as decision criteria for individual risk mitigation measures.

Such an approach stands in contrast to the economic paradigm of the U.S. Executive Branch directives requiring agencies to base their SPS measures on cost-benefit analysis (CBA) [USDA 1993]. Under the risk assessment paradigm, the role of economics is relegated to the calculation of quantities of imports to help risk assessors with their job of calculating the likelihood and consequences of disease or pest introduction. Primary intent is to reduce the opportunities of practicing mercantilist regulatory protectionism in favor of domestic producer groups. Therefore, the application of the SPS Agreement calls for the development of international standards for the monitoring of CBA-based regulatory policies.

Along these lines, the SPS Agreement seeks primarily to harmonize analytical frameworks for addressing risk. International standards for phytosanitary measures — such as the use of a systems approach, the establishment of pest free areas — are designed to achieve international harmonization of SPS measures. The former standard provides guidelines for the development and evaluation of integrated measures for pest risk management, while the latter describes the requirements for the establishment and use of pest-free areas (PFA) as a risk management option for phytosanitary certification of plants and plant products (FAO 1996, 2002). Assignment of a PFA status is normally based on verification from specific trapping surveys and, subsequently, appropriate phytosanitary measures are required to maintain freedom. A more effective pest management can be achieved by combining two or more independent phytosanitary measures[11], like cultural practices, field treatment, post-harvest disinfestations, inspection, or other procedures.

The development of these internationally-accepted standards would contribute to facilitating trade by limiting the use of unjustifiable SPS measures. Recognizing that the international guidelines may not reflect the preferences and/or needs for externality mitigation of every nation, the WTO Agreement also allows country members to set a higher level of protection, which must be based on available scientific evidence. Thus opportunities are given for the expression of political and cultural differences among the country members for evaluating threats to people and the environment. A number of situations are enumerated where national standards may differ from and/or exceed international standards (Article 2 of the SPS Agreement). Wide discretion is also afforded to national governments in the determination of situations where international standards might be inappropriate (Bredahl and Forsythe 1989).

The first two years of implementation of the SPS Agreement saw a broad-based regulatory review among some WTO members. High-income countries started to question whether the regulatory measures imposed by their major trading partners were in compliance with the new Uruguay Round disciplines. The United States, for instance, identified over 300 questionable market restrictions imposed by 62 countries, which threatened, constrained, or blocked an estimated $ 5.0 billion of US exports (Roberts 1999). One illustration of these market restrictions, dating back to 1988, relates to the European Union (EU) ban on the importation of beef from cattle treated with growth-

[11] The characteristic of a systems approach is that it requires at least two or more phytosanitary measures that are independent of each other. With independent measures, the probability of failure is the product of the probabilities of all the independent measures. A systems approach may also include any number of measures that are dependent on each other. With dependent measures, the probability of failure is approximately additive, implying that all dependent measures must fail for the system to fail (FAO 2002).

enhancing hormones. The United States questioned the scientific basis of this regulatory measure, thereby arguing that the ban had been primarily motivated by the desire of the EU officials to impose a disguised restriction on the productivity in the beef sector and on imports from the most competitive beef exporters. In return, the EU rejected these claims, arguing that the ban addressed public anxieties vis-à-vis the consumption of hormone-treated beef and that the SPS Agreement contained no disciplines restricting the absolute level of protection that a member may choose.

The USA/EU dispute exemplifies a very difficult case to resolve, where culture and consumer preferences affect risk assessment. Citizen and consumers from country members show different perceptions towards risk associated with SPS issues (Bureau and Marette 2000; Caswell 2000; Schuh 2000). For instance, the U.S. beef exporters have been less willing to accept the fact that a large percentage of European consumers may have a cultural aversion to eating beef produced with growth-enhancing hormones or antibiotic drugs. The issue is whether international trade regulations should take into account cultural differences among countries and how to establish a clear dividing line between what is perceived as a food safety issue and what could be a mere subterfuge for plain old economic protectionism.

The SPS Agreement provides no guidance and offers little scope for incorporating cultural analysis into SPS trade issues (Caswell 2000). While recognizing the EU rights to adopt a precautionary approach on a temporary basis, the Panel argued that the ban per se was not in conformity with the SPS Agreement and that there was no sufficient scientific evidence of dangerous effects on human health associated with the consumption of meat products treated with hormones. The hormone case provides some preliminary indication that the WTO Dispute Settlement Body is more likely to base its verdicts on a rational relationship between objective scientific assessments and the policy choices made by governments.

Another interesting case was the Mexico complaint about the U. S. ban imposed since 1914 on the importation of Mexican Hass avocados, on the grounds that the fruit was a host of various fruit flies and that its importation could also lead to the importation of quarantine pests of concern. Mexico conducted in situ experiments to demonstrate that the Hass avocado fruits attached to the tree are biochemically and ecologically resistant to infestations[12] with A. serpentina, A. ludens, and A. striata under natural field conditions and there was only a minimal risk associated with importing this crop (Hoeflich 2000). While scientific arguments and evidence may have been a necessary condition for trade liberalization, they were certainly not a sufficient condition. For over 80 years, no trade protocol could be reached prior to NAFTA between Mexico and the United States. The policy process was captured by Californian producers benefiting from the monopoly over the U. S. avocado market. However, the approval of NAFTA contributed to the end of this monopoly situation, providing space for negotiations and an opportunity for science to take part in the decision-making process (USDA 2001, Federal Register 2004b; Hoeflich 2000).

The above cases show the complexity of the issues involved in the application of the SPS Agreement. Politics, economics and culture often play prominent roles in the choices of regulatory measures to address risk management problems (Caswell 2000). In particular, economics may play a strong role in measuring costs and benefits of SPS

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[12] It is important to underline that, under laboratory and field force conditions, Hass avocado fruits are a good host of A. ludens, an average host of A. serpentina, and a poor host of A. striata.

measures and ranking them on the basis of how much they will improve (or undermine) the social well-being. Ultimately, policy choices emerge from the interaction of the demand for measures by various domestic interest groups (including producers, consumers, and processing industries) and the supply of barriers available to policymakers.

Few people disagree that the SPS Agreement has contributed to improve international trading relationships among country members and to restore the rule of law in this fractious area (Thornsbury 2002). Transparency of the WTO members has been enhanced. Procedures and rules for dispute settlement have been established and followed by WTO members. More importantly, regionalization efforts have fostered the alignment of national regulations with international standards for phytosanitary measures and the compliance with the obligations of the SPS Agreement. The risk paradigm of the SPS Agreement has also reduced the degrees of freedom for the disingenuous use of SPS measures to restrict imports in response to narrow interest group pressures (Roberts 2000). However, the SPS Agreement still faces the ongoing challenge of how to lay the foundations of the SPS measures on scientific restrictions, while allowing for more flexibility in the use of economic and cultural considerations. Empirical evidence concerning the extent of questionable technical measures in international agricultural trade is very difficult to assess, because of unavailability of comprehensive data sources (Thornsbury 2002). Furthermore, despite several attempts over the years to resolve the USA/EU dispute over the hormone-treated beef, the ban is still in effect (Pantin et al. 2004), leaving substantial room for questioning the capacity of the SPS Committee and the Appellate Body of the SPS Agreement to enforce authorized sanctions.

Phytosanitary Protocols for the International Movement of Fresh Fruits and Vegetables in Fruit Fly Free Areas

Tephritid fruit flies are among the most destructive agricultural pests threatening the sustainability of fruit and vegetable industries in many parts of the world. Millions of dollars are spent annually in fly-free countries to enforce quarantine restrictions with a view to preventing the introduction of exotic fruit fly pests and maintaining their fly-free area status. On the other hand, fruit producers in fly-infested countries invest in expensive post-harvest facilities and treatments in return for gaining and/or maintaining access to export markets. The application of the SPS Agreement has materialized essentially into the establishment of phytosanitary protocols serving as mechanisms for facilitating trade and transferring the cost of enforcement of the SPS restrictions onto the exporting countries (Spreen et al. 2002).

The agreed-upon phytosanitary protocols between importing and exporting countries are inspired by the fly-free production model that often uses the concept of the systems approach. A fly-free field may refer to small areas such as a farm, an orchard, or a group of properties. Its delimitation requires a thorough knowledge of the biological profile of the pest concerned (FAO 1996) and a risk management strategy aimed at maintaining pest freedom from specific parcels and production areas (Malavasi et al. 1994).

However, attention is now moving from a fly-free field to fly-free zone approach (Vijaysegaran 1994; IAEA 1995). The fly-free zone concept encompasses an entire geographic or political entity in which permanent eradication efforts – such as intensive use of inspection sites at ports / airports and road stations, massive sterile fly barrier, trapping surveys, and regular sprays against fruit flies – result in freedom of all fruit fly species of quarantine importance (Hendrichs et al. 1983; Hendrichs 1996). Pest population suppression over large geographical areas would undoubtedly provide better control and benefit a large number of growers. Apart from the success of an eradication project in Japan, eradication of a fruit fly species by sterile insect technique (SIT) and/or other means has not been reported in other Asian countries (Kawasaki 1991). Major concerns would be the cost of the sterile insect technique and the increasing risk of re-infestation.

Table 3-1 presents three different formats of phytosanitary protocols agreed upon between importing and exporting countries. Phytosanitary requirements for international movement of fresh fruits and vegetables vary according to pest status and distribution, number of other key pests, isolation, geographical location, technical level of fruit production, economic value of the crop, and changes in target markets (Hendrichs 1996). Format I (see column 1of Table 3-1) accounts for the basic phytosanitary protocol providing for detection surveys in and around the designated production areas to assure pest freedom against fruit flies of quarantine importance in the field. This quarantine restriction is the centerpiece of the phytosanitary protocols governing (1) the shipment of fresh citrus fruit from the United States (Florida, California, Arizona and Texas) to some specific ports of entry in China and (2) the importation of watermelon, squash, cucumber, and oriental melon from the Republic of Korea to the United States between December 1st and April 30 (Federal Register 2003a). Minimum trap densities based on research findings are specified in these protocols, as are the frequency of trap servicing and the suitable trap locations for the surveillance of flies of quarantine importance. The National

Plant Protection Organization (NPPO[13]) of the exporting country must provide monitoring reports on trap surveys and relevant information on groves, shippers/packers, and storage facilities for annual review of the protocol. Pre-inspection visits by the NPPO of the importing country to the exporting country are provided for to conduct a review of the certification procedures. Travel expenses (i.e. transportation, lodging, and a per diem allowance) for all trips during the first two years of the agreement to designated groves, shippers/packers, and storage facilities are borne by the exporting country.

Certification procedures are based on negative trapping, providing scientific evidence that the concerned pests do not occur in designated areas and that this condition has been officially maintained. Exported fresh commodities must be transported under closed conveyance and kept separated from packed commodities from non-designated areas. The NPPO of the exporting country shall perform a strict inspection of export shipments and ensure that exported products are free of quarantine pests. No post-harvest treatment is required in the protocol. In the event of detection of a live fly on arrival, the importing country shall immediately notify the exporting country about suspending the importation of fresh commodities from the designated grower or grove, shipper/packer and storage facility, and the shipment shall be returned, re-exported or destroyed. The suspension of the phytosanitary certificate shall be maintained until the relevant cause is identified and appropriate corrective actions are taken.

Format II (see column 2 of Table 3-1) differs from Format I in that the former involves a more stringent and complex certification process, reflecting the dominant

[13] Each member country is required to form a National Plan Protection Organization (NPPO), which accounts for the government's official service to discharge the functions specified by the International Plant Protection Convention (IPPC), deposited in 1951 with FAO in Rome, and subsequently amended (NAPPO 1998; Federal Register 2002).

position of countries like Japan and South Korea (which are regarded as lucrative markets for fresh products) [Vijaysegaran 1994; Simpson 1993; Reiherd 1992]. Cases of this format are exemplified in the phytosanitary protocols for the shipment of Florida citrus fruit to Japan and South Korea (APHIS 2003b). The cornerstone of this protocol format is the requirement that the designated production area be surrounded by a buffer zone of 1.5 mile, which should not contain any preferred host plants of the pest concerned. Where a preferred host plant does occur in the buffer zone, ground or aerial bait spray shall be applied at 7 to 10-day intervals beginning 7 days prior to harvest and continuing until the end of harvest. Also, the minimum size of the designated area is required to be 300 acres. Such a phytosanitary restriction is designed to stimulate the development, among fruit growers, of a concerted fly population management strategy over a significantly large area, so that the potential number of flies moving into orchards from neighboring orchards is largely reduced. (Hendrichs 1996).

Early season certification criteria for grapefruit shipped during August 1st to December 20 are less restrictive. Such procedures are based on the proven resistance of early season citrus fruit to Caribfly infestation, which is regarded as a fly-free period (Simpson 1993). Nonetheless, the standard certification procedures appear to be very stringent, requiring an early surveillance of the Caribbean flies (trap servicing beginning 30 days prior to harvest) and a high trap density (15 traps per square mile).

Format II also allows for a second certification procedure referred to as “bait spray” with the following requirements: 1) the minimum size of the designated area must be 40 acres (16 hectares) surrounded by a 300-foot wide buffer zone, 2) the buffer zone must be free of preferred host plants, 3) the designated area must be at least ½ mile from areas where numerous host plants are present, 4) traps are located in the designated area and 300 feet buffer zone at the density of 15 traps per square mile with trap servicing beginning 30 days prior to harvest, and 5) aerial bait sprays are applied at the beginning of the harvest period, consisting of a mixture of 2.4 ounces of 91 percent malathion and 9.6 ounces of protein hydrolyzate bait per acre. Where the designated area is located within ½ mile of numerous preferred hosts, aerial bait sprays shall be applied earlier, beginning 28 days before harvest at 7 to 10-day intervals until the end of harvest.

In the event of a Medfly outbreak, countries like Japan, South Korea, and South Africa take a more drastic approach by prohibiting the importation of all Medfly hosts including marginal hosts for a number of years (USDA1999). Japan, in particular, will not issue any phytosanitary certificate for any Medfly host commodity from the infested country, even if a quarantine treatment approved by the country of origin is applied. Such phytosanitary restrictions are justified by the seriousness of the Medfly attacking over 300 fruit and vegetable commodities. Nevertheless, other countries like Mexico, Argentina, and New Zealand adopt a more flexible approach based on the fly-free production model. The phytosanitary regulations include the establishment of a quarantine area around a radius of 17 miles from the epicenter of the outbreak, intensive trapping surveys, and the treatment of Medfly hosts according to agreed-upon treatment schedules.

The third and last protocol format (column 3 of Table 1) provides an illustration of the peculiar use of a systems approach based on the notion of low pest prevalence. This strategy reflects the delicate position of the United States — as both net exporter of some fresh agricultural commodities and net importer of others — switching from its longstanding practice of only recognizing entire countries as "free" or "not free" of a particular disease to a "regionalization regulation" (Ahl and Acree 1993; Federal Register 2003a). Another significant factor is the fact that the U.S. territory is not free of fruit flies. By allowing the importation of fresh fruit commodities in the mainland from Hawaii where the Mediterranean fruit fly has been established, APHIS finds itself forced to abide by the principle of national treatment and, therefore, to apply the same rules to imported products. These considerations support the tendency towards the adoption of risk management strategies combining various pre- and post-harvest actions and treatments sequentially so that they can provide acceptable statistical probabilities of quarantine security (Armstrong 1991). Two cases fall within this "systems approach" framework:

- the importation of clementines, mandarins, and tangerines from Chile (where the Mediterranean fruit fly and other quarantine pests of concern are known to occur) under a series of complementary phytosanitary measures. The requirements include a test program of certification of low prevalence, a post-harvest processing, and phytosanitary inspection (Federal Register 2004a)
- the importation of fresh Hass variety avocados from Mexico into the United States, using pest risk mitigation strategies combining two major tactics: (1) limiting the geographical distribution of avocados to 19 States and the District of Columbia within the Unites States and (2) allowing a 4-month shipping season each year (Federal Register 2004b).

The efficacy of the systems approach is based on the combination of complementary measures acting independently to ensure an appropriate level of phytosanitary protection (FAO 2002). For instance, the phytosanitary restrictions act in a fail-safe manner, so that redundant safeguards are built into the process. If one mitigation measure is not completely successful, the other will ensure that the risk of pest introduction is insignificant. Furthermore, any pest detection or irregularity would result in immediate actions to eliminate the pest risk, including partial cancellation of phytosanitary certificates or total prohibition of imports.

It is worth noting that the phytosanitary protocols between exporting and importing countries have been products of continuous and intense negotiations. Disputes over SPS standards go beyond the evidence of scientific phytosanitary restrictions. The most important issue is often examination of the implications these scientific protocols would have on the “safety” of domestic producers. In fact, policymakers tend to place greater weight on producer rather than consumer welfare. Cases dealing with food safety issues are even much more difficult to resolve as producer groups could easily mobilize consumers to back their claims for more regulatory protectionism. What really makes possible the establishment of these phytosanitary protocols is the opportunity provided by the SPS Committee to air grievances over unjustified measures when bilateral technical exchanges reach an impasse. Despite fierce opposition from domestic interest groups, regulatory agencies are often forced to arrive at some acceptable arrangement with their trading partners by fear of retaliatory measures and / or unnecessary reciprocal phytosanitary barriers on domestic exports.

Regulated Post-harvest Treatments and Procedures for the Quarantine Control of Fruit Flies

This section turns to the analysis of the regulated postharvest treatments that are often required for allowing unrestricted movement of tephritid fruit fly host commodities in domestic or international commerce. No quarantine treatment is universally applicable to all products or all quarantine pests (Mitchell and Kader 1985). Each treatment has some inherent problems and limitations. Agricultural research and regulatory agencies have developed various tests to evaluate potential quarantine treatments against fresh commodities infested with different fruit fly life stages. Two major tests — confirmatory test for quarantine security and small test for efficacy —are commonly used for the approval of a postharvest treatment schedule. Quarantine security refers to the level of confidence that the quarantine treatment will disinfect quarantine pests from the host commodities (Armstrong and Couey 1989). Specifically, it involves compliance with the phytosanitary requirements defined by the NPPO of the importing country to ensure that the quarantine pest of concern cannot become established in any geographical area where it does not already exist.

One problem in quarantine treatment development is the lack of availability of appropriate statistical criteria that can guarantee quarantine security (Couey 1983). Although the probit 9[14] mortality at the 95% confidence level remains the quarantine security statistics most commonly used in the post-harvest technology literature, it does not properly indicate the risk of a pest species spreading into non-infested areas (Landolt et al. 1984). Alternatives to the use of probit 9 mortality have been proposed, but not fully developed, such as the probability of mated pairs of quarantine pests in a shipment of a host commodity (Landolt et al. 1984), the host/pest relationships and natural infestation rates (Couey and Chew 1986).

Commercially applied treatments are also monitored for efficacy. The term "efficacy" describes a quarantine treatment that adequately disinfests pest organisms at the required level of quarantine security without adversely affecting the commodity

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[14] The probit 9 statistics at the 95% confidence infers that no more than 3 individuals from a population of 100,000 will survive a quarantine treatment, which is a mortality rate of 99,997%. The treated population must equal 100,000 or more target organisms in three or more tests with no survivors. So, the treated populations are derived for the survivors of the control population by the formula: (A/B)C= estimated treated population, where A = the population of survivors from the controls, B=the control weight (untreated commodity), and C= the treated commodity weight (Spitler and Couey 1983; Armstrong et al. 1984).

(Armstrong and Couey 1989). While APHIS as the regulatory agency is not liable for damages caused by the quarantine treatment, other Federal and State agencies like the Food and Drug Administration (FDA), the Environmental Protection Agency have primary responsibility for ensuring that approved control treatments are not harmful to the commodity, workers, the consumer, or the environment (Federal Register 2002).

The number of approved fumigants and fumigation schedules has drastically diminished over the last two decades, due to environmental problems, health concerns, and lack of research. Following the cancellation of ethylene dibromide's registration by the U.S. Environmental Protection Agency (Federal Register 1984), the methyl bromide (MB) has remained the most widely used fumigant for horticultural commodities because of low cost, ease of application, relative safe usage, rapid dispersion throughout the fumigation chambers, and rapid penetration into the commodity (Mitchell and Kader 1985; Armstrong and Couey 1989).

Approved MB concentrations, durations, and temperatures depend upon the commodity and the fruit fly species to be controlled. Strawberries infested with Ceratitis *capitata* can be safely transported from the quarantine area after MB fumigation schedules at 15^{o}C or above with 48 g/m^3 for 3 h (Armstrong et al. 1984). MB dosages required to achieve 99.9968% kill (probit 9) of Anastrepha suspensa infestations of grapefruits at 21^{o}-24^{o}C are proven to be 40 mg/liter for a 3-carton load and 56 mg/liter for a 12-carton load fumigated in 0.8 m^3 chambers (Table 3-2, column 1). However, final acceptance requires tolerance and residue tests under the variety of conditions encountered in processing and shipment (Benschoter 1979). Following successful cucumber fumigation schedules at 19^{o}C or above with 32 g/m^3 for 4 h, the results of phytotoxicity tests revealed very minor phytotoxic effects that cannot affect the marketability of the product (Armstrong and Garcia 1985).

However, the safety of MB fumigation has been called into question because of reports of carcinogenicity on laboratory animals. MB residue levels in papaya, tomatoes, bell peppers, bananas, and eggplants treated against Ceratitis capitata are showed to range from 1.7 to 42 ppm, depending on the method of fumigation, the commodity, and the method of storage (Baker 1939; Seo et al, 1970, 1971). Therefore, alternate treatments may be needed if agriculture and food supplies are to be protected. One potential candidate fumigant that is receiving attention is phosphine, which offers some advantages in terms of rapid diffusion throughout the load without a re-circulating system, rapid dissipation of very low residues, and tolerance to fumigation by avocados, bananas, tomatoes, and bell peppers (which are injured by fumigation with methyl bromide) [Seo et al. 1979]. The main disadvantage of phosphine fumigation is, however, the long treatment time (2 to 4 days instead of 2 hours), which makes it less promising for perishable commodities. Intensive refrigerated fumigation facilities would be needed at a very high cost to keep perishable commodities under refrigeration during that long exposure time and, consequently, avoid unacceptable deterioration (Mitchell and Kader 1985).

A combination of MB fumigation and cold treatment seems to be a more economically feasible alternative. This technique was used in California to disinfect fresh stone fruits during a Medfly outbreak. Treatment schedules listed in APHIS' quarantine treatment manual specify fumigation with 32 g/m^3 for 2, 2.5, or 3 h, followed by cold storage for a minimum of 3 days to a maximum of 11 days at temperatures ranging from a low of $0.55^{o}C$ to $13.33^{o}C$ (Code of Federal Regulations 2003; Spitler and Couey 1983). The cold portion of the treatment is often conducted aboard ship, while in transit from infested areas. Shipments of cold treated fruits are certified upon compliance with strict requirements for temperature monitoring in cold storage facilities.

Cold treatments alone have been accepted by USDA–APHIS as quarantine treatments for 14 fruits and vegetables from 48 countries subject to infestations by Ceratitis *capitata*, Anastrepha *ludens*, and other species of Anastrepha (APHIS 1976). Treatment schedules are very severe (Table 3-2, column 3), involving fruit exposure to temperatures below $5^{o}C$ for extended durations (from 10 to 16 days). The highest temperature listed in the Plant Protection Quarantine Manual (APHIS 1976) is $2.2^{o}C$. Probit analyses also predicted that 16-20 days would be required for fruit held at temperatures ranging from 2.8 to $6.6^{o}C$ (Burditt and Balock 1985). Such quarantine requirements severely limit the use of cold treatments, since most tropical fruits are damaged by extended storage below $10^{o}C$. Under cold treatment conditions, a certain percentage of fruit always exhibits chilling injury symptoms. In particular, susceptibility of grapefruit to low temperatures is proved to vary with season and fruit location on the tree. Fruit on the outer canopy are more susceptible to chilling injury than those harvested from the interior of the tree. Reducing losses in grapefruit shipments involves strict compliance with a series of basic requirements such as: avoiding prolonged degreening, ensuring proper application of fungicides, using stable water wax, and providing proper warming before fumigation and after completion of cold treatment (Ismail et al. 1986).

Recent studies also show that preconditioning at warm temperatures increase fruit tolerance to cold treatments (Mitchell and Kader 1985). For instance, papayas infested with eggs and larvae of D. *dorsalis*, D. *cucurbitae*, and C. *capitata* are successfully treated after immersion in 49°C water and exposure to 8° or 9°C for 10 days (Couey et al. 1984). Nevertheless, the use of combined heat and cold treatments requires knowledge of the biological profile of the insect, the lethal effects of the standard heat treatment for decay control, cold treatment, and appropriate quality control procedures. Papaya fruits are required to be picked between colorbreak and one-quarter ripe. Unripe papayas are unlikely to be infested with fruit flies, as containing sufficient quantities of benzyl-isothiocyanate to deter oviposition and to reduce survival of eggs and larvae whenever ovipostion occurs (Seo et al. 1982; Seo and Tang 1982).

Hot-water treatment also may be used alone to disinfect fruit. Exposure to hot water at 45°C for 20 min or at 55°C for less than one min would destroy all immature stages of D. *dorsalis*, D. *cucurbitae* or C. *capitata* (Armstrong 1982), but it would easily damage many fresh commodities (Table 3-2, column 2). Sinclair and Lingren (1955) found that navel oranges, lemons, and avocados were very easily damaged by the standard vapor heat treatment. One in six unripe papayas is damaged after exposure to microwave until a central temperature of 45°C, followed by a double-dip in 48.7°C and 24°C during 20 min respectively (Hayes et al. 1984).

Cases of tolerance to heat treatments are reported to very few commodities. Damage to valencia oranges and grapefruit treated with standard heat vapor[15] or the quick run-up can be avoided (or reduced) if the fruits are hydrocooled after treatment. Satisfactory results have also been obtained with mangoes immersed in 50°-55° C water

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[15] The vapor heat treatment consists of gradually warming infested fruit for several hours (approach time), then increasing the fruit temperature to 43°C and holding that temperature for 8 h (holding time). The quick run-up requires a short pre-heat period to a specified temperature, then a gradual warming to 47°C, similar to the approach time in the standard vapor heat treatment (Baker 1952; Balock and Kozuma 1954).

for 15 minutes (Sharp and Spalding 1984) or vapor heated at 46°C for 160, 220 and 280 minutes (Mitcham and McDonald 1993). Concern is, however, growing about the feasibility of heat treatment due to the relatively high cost of application. Vapor heat cost per kg of fruit is estimated at \$ 0.35 against \$ 0.027 and 0.26 for methyl bromide fumigation and irradiation respectively (Federal Register 2002, 2003b; Pszczola 1992).

Other alternatives to fumigation for insect quarantine treatments have also been explored, such as the controlled atmosphere and irradiation treatments. Forced air treatments (Table 3-2, column 4) consist of exposing fresh horticultural commodities to moderately low levels of O_2 (≤ 2%) and /or high levels of CO_2 (≥ 50%). Although modified atmosphere is cost competitive to chemical fumigation (Soderstorm et al. 1984) and leaves no chemical residues on the fruit, the possibilities for commercial use are much less certain. Most fresh fruits and vegetables cannot tolerate such extreme atmospheres for prolonged storage periods (Armstrong and Couey 1989; Smilanick and Fouse 1989; Yahia et al. 1991; Ke and Kader 1992). Keitt mango is, however, reported to be very tolerant to insecticidal O_2 and/or CO_2 atmospheres for up to 5 days (Yahia 1993). Further research work is needed to determine the level of tolerance of other mango cultivars and the level of mortality of important quarantine insects.

Radiation is by far the most publicized quarantine treatment, mainly because of renewed interest in this treatment as a potential alternative to the use of chemicals. Treatment schedules (Table3-2, column 5) involve exposing the product to a radiation source for a time period sufficient for it to absorb a required dose level of gamma or X rays. Successful use of this procedure is based on the determination that an undesirable organism will be inactivated at a dose level that is tolerated by the host commodity

(Mitchell and Kader 1985). For safety concerns, the Food and Drug Administration (FDA) establishes a dose limit of one kilogray (Federal Register 2002), which is by far less than all irradiation doses contained in APHIS's rule. This quarantine policy is consistent with study findings indicating that most insects are sterilized by doses below 0.75 kGy.

Unlike the heat, cold, and fumigation treatments that generally kill the pest, what really matters in irradiation is the treatment dose required to break the life cycle of the insect, so that it cannot become established in a new uninfested area (Rigney 1989; Baker 1939). Treatment efficacy is based on prevention of adult emergence. The killing of fruits flies in order to minimize fruit damage from feeding insects is of secondary importance. While the criterion of quarantine security may be fully achieved with a low irradiation dose, the marketability of the fruit is likely to decrease, due to the potential presence of large numbers of fruit fly eggs and/or larvae in the fruit. Achieving a lethal effect on fruit fly eggs or larvae would require doses in excess of 1 kGy, which would be damaging to many fruits.

Research findings indicate that irradiation provides acceptable quarantine treatment for various fresh commodities infested with fruit flies. For instance, probit 9 quarantine security is reached with doses below 150 Gy for grapefruit and mangoes infested with Caribbean fruit flies, causing acceptable levels of phytotoxicity to the fruit (von Windeguth 1986, 1987). Phytotoxicity tests at doses ranging from 50 to 1500 Gy indicated that no observable damage occurred at levels between 50 and 500 Gy when Arkin carambolas were irradiated at 25^{o}C and then held for 9 days at the same temperature (Gould and von Winderguth 1991). Furthermore, irradiation of foods offers consumers many advantages the most important of which could be safe transport of produce from insect quarantine areas and replacement of less safe chemical fumigants (Bruhn et al. 1987; Schutz et al. 1989).

However, there are a number of considerations that dictate extreme caution in projecting radiation as an alternative to fumigation for insect quarantine treatment. First, consumer acceptance is critical to the application of irradiation and the realization of the advantages it offers. Consumers have expressed growing concerns about the safety of irradiated foods, due to negative advertisements sponsored by opposition groups. Although consumers show a higher level of concern for chemical sprays and pesticide residues than for food irradiation, it is still hard to sell irradiation to the American public (Schutz et al. 1989; Bruhn et al. 1986). Secondly, most fresh fruits offer no promise for commercial irradiation because either alternative procedures are cheaper and more effective or radiation injury is excessive. Irradiation is unlikely to compete at present cost with chemical inhibitors or to substitute for refrigeration. In the future, feasibility of irradiation will depend on whether the phase-out of methyl bromide as a soil fumigant results in an increase in its unit cost of production (Federal Register 2002).

Concluding Remarks

This literature review on the SPS Agreement emphasized the new substantive and procedural disciplines established to achieve harmonization of SPS regulations and minimize their adverse effects on agricultural trade. Countries are granted the rights to choose their appropriate level of protection (ALP) against imported pests and diseases, but their regulations must be supported by scientific criteria. Thus, the SPS Agreement encourages the use of the least trade restrictive measures, thereby making provision for the inclusion of the costs of prevention and control programs as the major factor in regulatory decisions.

The application of the SPS Agreement has materialized essentially into the establishment of agreed-upon phytosanitary protocols between exporting/importing countries. These protocols serve primarily as mechanisms for facilitating trade and transferring the cost of enforcement of SPS restrictions to the exporting countries. In the event of a Medfly outbreak in Florida, it is anticipated that the reactions of export markets vis-à-vis Florida fresh fruit and vegetable commodities would greatly differ, ranging from additional certification, quarantine treatment, to prohibition. Florida growers would be unlikely to reach a trading arrangement with countries like Japan and South Korea, which are regarded as lucrative markets for fresh citrus. Negotiations would be very tense as to whether their total prohibition would affect Florida's total fruit and vegetable production or the portion of production localized in the quarantine area.

Other countries would allow for the importation of fresh fruit and vegetables from Florida under very strict phytosanitary restrictions. Given the seriousness of the Medfly attacking over 200 species of fruits and vegetables, the phytosanitary restrictions are expected to be more stringent that those contained in the Caribbean fruit fly-zone certification protocol, including intensive trapping surveys, establishment of quarantine areas around 17 miles from the outbreak epicenter, and regulated postharvest treatments. Treatment schedules would vary across commodities, including fumigation (strawberries and cucumbers), cold storage (fresh citrus), combination fumigation and refrigeration treatments (avocados), and vapor heat treatment (mangoes). Florida growers would be reluctant to applied some of APHIS-approved quarantine treatments to commodities —

such as bell peppers, eggplants, tomatoes — because either they are uneconomical or cause excessive fruit injury. More research work needs to be done on the technical and economic feasibility of the regulated postharvest treatments.

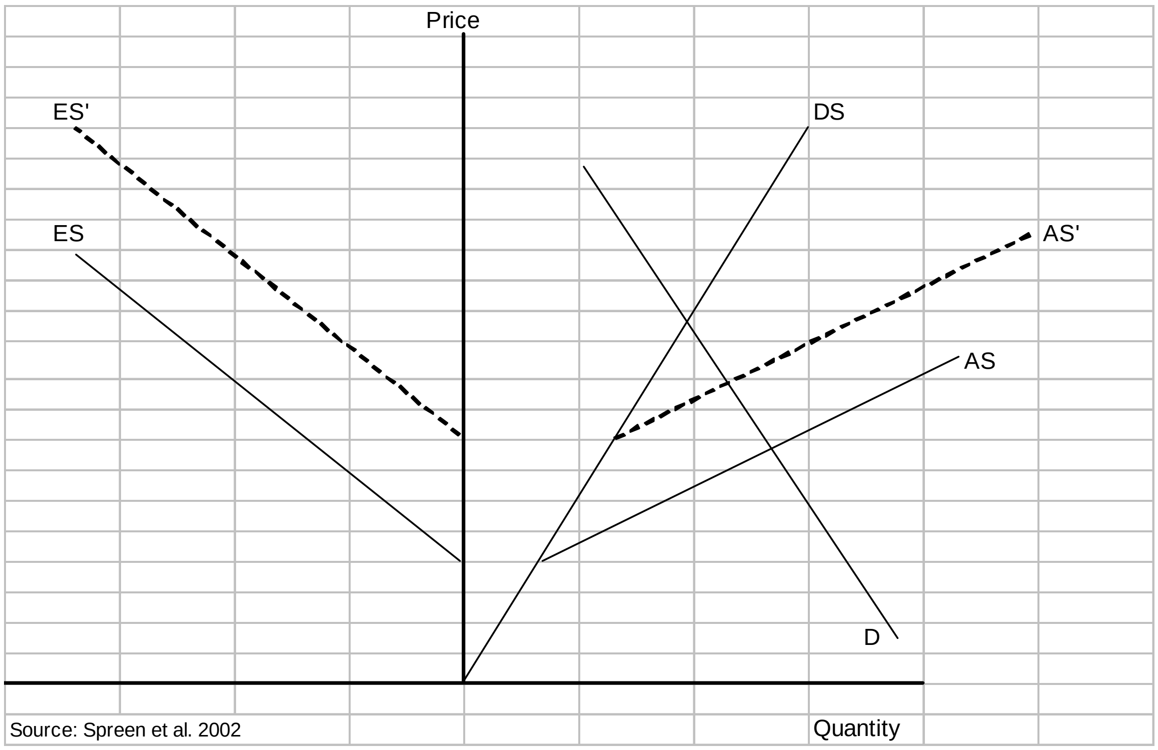

Figure 3-1 Inward shift in import supply resulting from the imposition of an SPS barrier

Table 3-1 Formats for phytosanitary protocols for the international movement of fresh fruit and vegetable commodities

Format I (column 1)	Format II (column 2)	Format III (column 3)
1. Properties Sites *Must be free of fruit fly, monitored by MCPhail traps. Groves, packing houses, and storage facilities must also be certified 2. Certification Procedures *Based on negative trapping -Annual notifications of the exporting country to the importing about the trapping surveys in the areas of production *Phytosanitary inspection -Pre-inspection visits (one per year) by the authorities of the importing country to supervise the process of certification at the expense of the exporting country. -Citrus fruit must be free of live insects and mites of quarantine concern and identified with labels indicating place of production, grower, shipper, and storage facility -Citrus must be transported in sealed container and kept separated from unapproved shipments -Exports restricted to specific ports of entry in the importing country	1. Production Sites *Must be free of fruit fly, located at specific distances from preferred hosts and surrounded by a buffer zone ≥ 1.15 mile. Packing facilities must be located ≥ 3 mile from infested area 2. Certification Procedures *Based on negative trapping -For early season, minimum size of production area is 300 acres. Trap surveys with 2 traps per sq. mile. If buffer zone has preferred hosts, ground or aerial applications at 7-10 day intervals, beginning 7 days prior to harvest -For standard season, minimum size of prod. Area is 300 acres. Trap surveys with 15 traps per sq. mile. If buffer zone has preferred hosts, ground or aerial applications at 7-10 day intervals, beginning 7 days prior to harvest *Based on bait spray procedures -For early season, minimum size of production area is 40 acres. Trap surveys with 15 traps per sq. mile. If buffer zone, has preferred hosts, ground or aerial applications at 7-10 day intervals beginning 7 days prior to harvest. -For standard season, minimum size of prod. Area is 40 acres, must be at least ½ mile from preferred host. Trap surveys with 15 traps per sq. mile. Aerial applications at 7-10 day intervals, beginning 28-30 days prior to harvest	1. Productions sites *May be a pest free area or low prevalence area 2. Certification Procedures *Based on the use of systems approach combining two or several independent phytosanitary measures *Case 1 combining three sequential measures -Low prevalence Certification Test of low prevalence based on a random sample of fruit undergoing a washing process. If no pests are found along the process, the production site is certified -Post-harvest treatment Products treated in accordance with the agreed treatment manual. Shipments must be accompanied by documentation indicating the type of treatment adopted -Phytosanitary Inspection Based on biometric sampling with an acceptance level of zeros infested units. *Case 2 combining two major tactics -A geographical ban: limiting the importation to some specific geographic areas -A seasonal ban: limiting the importation during some specific periods of the year

Table 3-1 Continued

Format I (column 1)	Format II (column 2)	Format III (column 3)
3. Measures to be taken if detection is found *Immediate notification to the exporting country and establishment of a regulated quarantine area with a radius of 17 miles from the center of the pest outbreak *If a Mexican fly is found, the shipment must be treated but no citrus fruit from the affected grove will be exported 4. Exceptional measures in case of a Medfly infestation *Increase the trapping density to one trap per square km and immediate suspension of citrus fruit from the regulated quarantine area with a radius of 17 miles from the center of the outbreak. Shipment of fruit transited through this quarantine area must be in sealed container	3. Measures to be taken if detection is found during inspection *Immediate notification to the importing country if one fly is found as a result of the trap survey *Withdrawal of the production area from the protocol season if three files are found. Reinstatement is conditioned to intense spraying after investigation 4. Exceptional measures in case of a Medfly infestation *Fruit & vegetables considered to be hosts of Medfly fly are prohibited entry from countries to be infested with this pest. Such commodities remain prohibited regardless of whether they have met the entry requirements of any other country	3. Measure to be taken if detection is found *If one live fruit fly is intercepted along the inspection process, the consignment will be reshipped or destroyed and a prohibition will be placed on further imports of the host material until corrective action is undertaken 4. Exceptional measures in case of a Medfly infestation * Increase the trapping density to one trap per square km; establishment of a quarantine area found a radius of 17 miles from the center of the outbreak; treatment of all regulated articles according to approved schedules. Shipment of fruit transited through this quarantine area must be in sealed container

Source: http://excerpt.ceris.purdue.edu/doc/ctrylist.html

Table 3-2 Regulated postharvest treatments, advantages, limitations, and alternatives under consideration

	Fumigation	Heat Treatment	Cold Treatment	Controlled Atmospheres	Irradiation
Regulated schedules	*MB fumigation at 21° C or above at NAP with 32-48g/cubic meter MB for two to four hours. *MB fumigation at NAP with 32g/cubic metric MB for 3 hours at 21°C for citrus infested with Medfly. *MB fumigation at 27°C and NAP for 2 hours for citrus infested with Caribfly and Mexican fruit fly.	*Vapor-heat treatment of citrus at 43°C for 8 hrs. *Hot-water preheat im - mersion of papayas, bananas, & mangoes at 42°C for 20 min to di-sinfect against Medfly, Melon, Oriental & Caribflies.	*Cold treatments at temperatures ranging from 0°C to 2.2°C for a minimum of 10 days and a maximum of 16 days respectively. Such treatments are used against Medly, Caribfly and other quarantine fruit flies	*Exposure of fresh commodities to low levels of oxygen and high levels of carbon during some period of time	*Limit dose of one KGy established by Food and Drug administration for disinfestations *Approved doses varies between 150-250 Gy across different fruit fly species *Dose varying between 50-150 Gy to achieve probit for grapefruit and mango infested with Caribflies
Advantages	*MB is the preferred fumigant for horticultural commodities be-cause of low cost, ease of application, and relative safe usage.	*Papayas & mangoes are resistant to heat damage. *Heat treatments have the merit of effective fungicidal & insecticidal action and no chemical residue.	*Cold treatments are very practical when used during transit from producing areas to distant markets	*Cost competitive to chemicals *Fruit treated with forced air are free of chemical residue	*Provides quarantine security by prevention of adult emergence *Strawberries and pa-payas show high poten - tial for commercial irradiation because they tolerate high doses without excessive ham

Table 3-2 Continued

	Fumigation	Heat Treatment	Cold Treatment	Controlled Atmospheres	Irradiation
Limitations	*Growing health & safety concerns about the use of MB	*Valencia oranges & grapefruits are resistant to vapor heat injury but other citrus are easily damaged. *Hot water treatment kills fruit fly eggs but a low percentage of larvae can survive if fruits begin to ripen. *High potential fruit damage and relative high cost of application	*Use of cold treatments is limited because most fresh commodities are damaged by extended storage below 10°C	*Very few fresh fruits can tolerate extreme atmosphere for extended storage periods	*Consumer reluctance about the safety of irradiated foods. Hard to sell to the American public *Limited economic feasibility of irradiation while requiring high capital investments *Irradiation shows little promise for perishable commodities because of excessive injury
Alternatives under investiga-tion	* Fumigation at 30°C, with decreased fumiga-tion time and MB concentration is very promising due to losses in MB phytotoxicity and reduction in inorganic residues *Research on potential candidates for MB re-placement	*Satisfactory results are obtained through com-bining heat treatment with MB fumigation of stone fruits and papayas *Need further research word on the economic feasibility of combined heat and fumigation treatments	*Preconditioning at warm temperatures reduce cold storage injury on some citrus like grapefruit *Proven technical feasi-bility of combined heat and cold treatments to disinfect papayas of Medfly and other fruit flies	*Keitt mango is very tolerant to insecticidal atmospheres for up to 5 days. Further research work is needed to test other mango varieties and level of pest mortality	*Need further research work on consumer acceptance of irradiated food *Need further research work on the economic feasibility of combined cold and irradiation treatments

CHAPTER 4
COST ANALYSIS OF THE MEDFLY DETECTION AND ERADICATION PROGRAM

Specification of the Bayesian Modeling Framework

Overview of the Bayesian Decision Process

This sub-section discusses the basic principles behind Bayesian statistical inference. The problem is to use historical information about Medfly interceptions and trap sensitivity with a view to (1) computing the probability of detecting a Medfly infestation into Florida at a given time and (2) determining the optimal trap density that minimizes the expected cost of APHIS's prevention, detection, and eradication program. Such an approach to statistical inference is called Bayes' theorem, which combines some prior distribution and available data to form a posterior or revised distribution. The underlying principle of this theory is that all uncertainties are described by probabilities: unknown parameters have probability distribution both before the data are available and after the data have been obtained (Cox and Hinkley 1974). While the theory does not offer a formal guarantee of objective truth about the system under study, it does at least ensure some kind of internal consistency among related decisions by the same individual. The decision is called a Bayesian decision (or the optimal decision) if the action chosen minimizes average (expected) loss that is associated with the costs of a wrong decision (Wonnacott & Wonnacott 1977)

Let $X_1, \ldots\ldots, X_n$ denote a sample distribution indexed by a continuous parameter θ. While, in classical statistical estimation, it is appropriate to treat the parameter θ as a single fixed value, the Bayesian theory allows for treating it as a random variable to account for our knowledge and uncertainty regarding the parameter's value (Press 1989; Morgan and Henrion 1990). The function g (θ) is called prior probability mass function, since it is determined before observing X in the current experiment; that is, θ is based on previous practical experience and understanding. The posterior or revised distribution of θ for X_1,,….., X_n is given by:

$$h(\theta|\chi_1,\ldots\ldots,\chi_N) = \frac{L(\chi_1,\ldots\ldots,\chi_N|\theta)g(\theta)}{\int L(\chi_1,\ldots\ldots,\chi_N|\theta)g(\theta)d\theta} \tag{4-1}$$

where the first term in the numerator $L(x_1,\ldots\ldots,x_N|\theta)$ is a likelihood function indexed by the parameter θ. The conditional probability h $(\theta|x_1,\ldots.,x_N)$ is called posterior probability mass function, given the current data, since it is determined after observing the current data set. The prior distribution provides additional information into the analysis and allows for a gain in logical clarity.

Figure 4-1 summarizes the logic of a Bayesian decision. The framework analyzes the trade-off between early versus late detection in terms of costs of the Florida Medfly prevention, detection and eradication program. Early detection costs are high for trapping, but low for eradication (with a low probability of establishment). Late detection costs for eradication are high (with a high probability of establishment). The major components of the framework — past data on Medfly interceptions, single trap sensitivity, prior probability of infestation, multiple trap sensitivity — are supportive of the optimal decision relative to the trapping strategy. The probability of detection f $(x_1|$ x_2, z) is a posterior probability, as its computation revises the prior probabilities to reflect the observational information available on trap density and sensitivity. If the objective is to minimize the expected cost of eradication, then this cost has to be computed for each possible trap density per location and season of the year. The optimal (or Bayesian) decision is to select the trapping strategy associated with the lowest expected prevention and eradication costs.

Definition of the Variables

We assumed the introduction, into Florida, of a small lot of mangos originating from a hypothetical Latin American country and containing approximately 1,000 Medfly eggs. We considered two correlated non-normal variables $X_{1,t}$ and $X_{2,t}$:

1. $X_{1,t}$ stands for the total Medfly population present at a given time and some location in Florida

2. $X_{2,t}$ accounts for the number of Medflies captured in the trapping system put in place by APHIS. The amount of information provided by trapping reflects both the density of traps and the single trap sensitivity.

The objective of this model was to build a spatially and temporally demographic picture of a hypothetical Medfly infestation in Tampa and Miami. Spatial distribution of Medfly host plants was assumed to be uniform throughout the regions of interest. The mate-finding process was also considered a crucial determinant of the potential for pest colonization in natural settings (Allee 1931; Prokopy and Hendrichs 1979). Along these lines, the infestation model was initialized with a cohort of 50 ovipositing females resulting from a twenty-percent survival of pre-adult Medflies with a sex ratio of 1:1 (i.e. 100 female adults and 100 male adults). Egg production covered a 10-day period at a fixed rate of 11 eggs /female /day. Survival rates varied across stages; egg survival is 0.4, larval survival is 0.5, pupal survival is 1. Only 20% of the newborn Medflies survived to adulthood.

Temporal dimension

The infestation model is inspired by the time-specific life-table approach to population growth, which is grounded on the assumptions of constant recruitment rate and steady mortality rate (Southwood and Henderson 2000). The rate of insect population growth is basically dependent on temperature and is predicted with time. Physiological time is commonly expressed in terms of day-degrees (D^o) or hour-degrees (h^o), being the cumulative product of total time x temperature (above the threshold) [Hughes 1962; Hardman 1976; Atkinson 1977]. A minimum temperature exists below which no measurable development takes place. The developmental zero for Medfly was found to be ≈ 54.3°F (Shoukry and Hafez 1979). Thus, the number of day degrees, D^o, accumulated above the developmental threshold for a life stage is computed as follows:

$$D^o(^oF) = AV(^oF) - TH(^oF) \tag{4-2}$$

where AV stands for the average daily temperature in Fahrenheit and TH is the developmental threshold for Medfly in Fahrenheit.

This temperature model is also used by APHIS to predict the entire life cycle of a Medfly population and to guide program actions (eradication treatments, length of trapping activities, and regulatory functions). About 328° C-day degrees (590.4° F-days degrees) must be accumulated before one life cycle has been completed (APHIS 2002). Table 4-1 shows the number of day-degrees required by one bug to transition from one stage to the next stage. Temperature data (minimum and maximum daily average temperature) used to simulate the growth development process are collected from the National Oceanic and Atmospheric Administration, United States Department of Commerce.

The model design includes two locations (Miami or Tampa) at three different months of the year (February, June, or October) to allow for both regional and seasonal differences in the State. The analysis is carried out over a 200-day period, using an Excel spreadsheet that provides information on the structure and the size of the pest population over time. Under each scenario, the instantaneous rate of population change, r, and the doubling time, DT[16], are computed, using the following equations (Carey 1982b):

$$1 = \sum_{t=0}^{\infty} e^{-rt} l_t m_t \tag{4-3}$$

$$DT = {(\log_e 2)}/{r} \tag{4-4}$$

where t is the age in days, l_t is the probability of surviving to age t, m_t is the number of female offspring produced at age t. The parameter, r, is key to predict the size of the Medfly infestation at different points of time, using the finite version of the Malthusian equation:

$$N_t = N_0 e^{rt} \tag{4-5}$$

where N_t and N_0 stand for the size at time t and the initial size of the population, respectively.

Spatial dimension

Spatial dispersion and movement is as important as birth and death rates for the population dynamics of insects and is a major determinant of the boundaries of the infested region (Papadopoulos et al. 2002, 2003). The underlying assumptions for modeling spatial distribution of the infestation are that (1) the Medflies are considered

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[16] The parameter, DT, designates the time (in number of days) needed for the pest population to double.

relatively weak dispersers and (2) the vast majority of the population does not disperse very far (Soria and Cline 1962; Katiyar and Valerio 1963; Nadel and Guerrieri 1969; Serghiou and Symmons 1974; Wakid and Shoukry 1976; Plant and Cunningham 1991; Katsoyannos et al. 1998; Papadopoulos et al. 2000; Papadopoulos et al. 2001). Table 4-2 gives the proportion of pre-adult and/or adult Medflies dispersed to different distances from the epicenter. Random dispersal is the dominant strategy of spread, occurring over an expected radius of 0.113 mile per month and thereby resulting in the scattering of ≈ 29% of the original population and the expansion of the infested area. Cases of long distance flights in search for food and/or oviposition sites (Bateman 1972; Harris and Olalquiaga 1991) and of human conveyance over distances ranging from 24 to 100 miles (Williamson 1983) are also incorporated into the model, as leading to potential outbreaks in new areas. Nevertheless, the probabilities of facing new Medfly outbreaks away from the initial epicenter are subject to the so-called Allee-effect, that is, the opportunity of finding a mate. If the number of adult females moving away from the epicenter is less than one, the outbreak potential is considered insignificant. This restriction is based on the assumption that the chances for the males to attract the females would be very low when the size of the lek formed by the males is too small (Carey 1982b).

The model implies that the density of pests is highest at the epicenter and decreases in space as small portions of the pest population move away from the epicenter. The notion of the epicenter of a pest infestation suggests that there is a point from which the pest infestation originates (Mangel et al. 1984). Figure 4-2 illustrates the spatial dispersion pattern of a hypothetical pest infestation occurring in Miami during the month of October at Day 50. Each 1-by-1-mile square parcel[17] accounts for the infested unit area, while the number inside each square parcel stands for the number of pre-adult and/or adult females present in the square parcel. The size of infestation is the sum of the 1-by-1-mile square parcels and the quarantine area can be derived through delineating a 5-mi-wide buffer perimeter around all infested core areas.

Cost Function

The optimal decision (or Bayesian decision) was made on the basis of the optimal trap density that minimizes the expected cost of the Medfly prevention, detection, and eradication program. We assumed that the cost function of the emergency program was approximated by the log functional form:

$$\ln(C) = \alpha_0 + (\alpha_1 - 1)\ln A + \alpha_1 \ln x_{1,t} + \alpha_{11}(\ln A + \ln x_{1,t})^2 \qquad (4\text{-}6)$$

where C stands for the emergency program cost per ha, A is the infested area in ha units, and $X_{1,t}$ is the pest population density per ha. The size of infestation and the quarantine area are the key parameters used to calculate the total emergency program costs by summing (1) the cost of the emergency detection cost (DC), (2) the cost of the curative release of sterile flies around all buffer perimeters (RC), and (3) the costs of weekly malathion applications (AC) over the infested area under scenarios of low, moderate, and high pesticide efficacy.[18] The total emergency program cost (TC) under each scenario is computed, using the following equations:

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[17] Each 1-by-1-mile square parcel can be associated with what is called a section in the Township and Range system developed by the Federal government. Each township comprises 36 sections.

[18] Pesticide efficacy is defined here as the proportion of bugs that will not survive the weekly spray treatment. Thus, low, moderate, and high pesticide efficacies correspond to 70%, 80%, and 90% of bugs killed during the spraying operation, respectively.

DC=WEEKLY EMERGENCY DETECTION COST * (# SPRAYING WEEKS +THREE LIFE CYCLES) (4-7)

RC= (QUARANTINE AREA/100) * STERILE RELEASE COST * (# SPRAYING WEEKS +THREE LIFE CYCLES) (4-8)

AC = AREA INFESTED * APPLICATION COST UNIT * # SPRAYING WEEKS (4-9)

TC = DC + RC + AC (4-10)

The spreadsheet models used to compute the number of spraying weeks required to eradicate the pest population take into account both the proportion of individuals surviving a spray treatment and the new adult females emerging during eradication operations. The infestation rates applied under spraying conditions are extremely low, ranging from 3 to 6 eggs per female over a three-day oviposition period. The Medfly population is considered totally eradicated in the model when the sum total of ovipositing females is less than 1.

We computed the OLS estimates of the parameters for the cost function under each outbreak scenario (Miami or Tampa, February, June, or October). These estimates are shown in Table 4-3. The F statistic was used to test whether the regression coefficients are different in the different periods (February, June, and October) or it is appropriate to pool the data and estimate a single equation for the entire period from February to October. The resulting F ratios are highly significant, with calculated values for F [6,204] approximating 390.5533 and 440.2952 for Miami and Tampa respectively. So, consistent with our expectations, these results reject the null hypothesis that the coefficient vectors are the same for the three periods in each location.

Future cost of eradication

As stated above, there is a trade off between early versus late detection. Maintaining high trap densities over a wide area to discover low, patchy populations of wild flies is extremely costly. On the other hand, if the trapping system is ineffective and fails to detect the pest population at early stages, APHIS managers would have to face the weighted values of the future cost of eradicating a growing pest population. Therefore, the future cost of eradicating the pest at time t, $FU(X_{1,t})$, can be expressed as follows:

$$FU(x_{1,t}) = \sum_{t=1}^{T} \int_{x_{1,0}}^{x_{1,50}} \int_{x_{1,50}}^{x_{1,98}} \int_{x_{1,98}}^{x_{1,119}} \left(\prod_{s=0}^{t-1} f(x_{1,s}, x_2 = 0 | z) * f(x_{1,s}, x_2 = 1 | z) C(x_{1,t}) d\, x_{1,t} \ldots d\, x_{1,s} \right. \tag{4-11}$$

where $F(X_{1,s},X_{2,s}=0|z)$ and $F(X_{1,s},X_{2,s}=1|z)$ are the multiple trap sensitivities for $X_{2,s}=0$ and $X_{2,s}=1$, respectively. $C(X_{1,t},A)$ stands for the cost function of the emergency program.

Optimization model

To find the optimal trap density, the minimization problem can be defined as follows:

$$\underset{Z}{Min} \ldots\ldots\ldots PZ + FU(x_{1,t}) + C(x_{1,t}) f(x_2 = 1, x_1 | z) \tag{4-12}$$

where Z is the variable accounting for the trap density and P is the detection program cost per trap unit. The calculation of P is based on the assumption that 47,404 traps are placed in Florida over 4,490 square miles. The average annual price of a trap is roughly $168.22. The value of the objective function is computed under all outbreak scenarios for the values of Z lying between 1 and 500. The optimal trapping density for each scenario is the one that minimizes the objective function.

Probabilistic Models

Probability of Detection: F ($X_{1,t}$ | $X_{2,t}$, Z)

The purpose is to calculate the probability of detecting the presence of a Medfly infestation at a given point of time, on the basis of prior information available (probability of infestation, single trap sensitivity of the trapping system, and number of traps). As shown in Figure 4-1, the probability of detection, F($X_{1,t}$ | $X_{2,t}$, Z) is defined as follows:

- F ($x_{1,t}$| x_2, Z) = Probability of detecting a Medfly population in Florida at a given time t, given the number of traps (Z) and trap sensitivity

$$= \frac{F(\chi_{1,t}, \chi_2 \ |Z)}{F(\chi_2 \ |Z)} \tag{4-13}$$

- The term F($X_{1,t}$, $X_{2,t}$ | Z) in the numerator is a joint density function and, therefore, is the product of the multiple trap sensitivity [F ($X_{2,t}$ | $X_{1,t}$, Z)] and of the probability of infestation at t = 0, [F ($X_{1,0}$)]. It can be calculated as follows:

$$F(\chi_{1,t}, \chi_2 \ |Z) = F(\chi_2 \ |\chi_{1,t}, Z) F(\chi_{1,0}) \tag{4-14}$$

- The term F(X_2 | Z) in the denominator is a summation that encompasses all possible outcomes of the trapping system, including the probabilities that the pest is present but not trapped, and the probabilities that the presence of pest is detected with different numbers of Medfly adults captured in the trapping system.

$$F(\chi_2 \ |z) = \int_0^{\alpha} F(\chi_{1,t}, \chi_2 \ |Z) d\,\chi_{1,t} \tag{4-15}$$

Probability of Infestation: F(X1,0)

This model of probability examines routes of Medfly introduction and uncertainties regarding fly survival and effectiveness of exclusion activities. It is assumed that opportunities of Medfly introduction into Florida are continuously increased through high volume of international travel, agricultural industry demands, and international trade agreements (USDA 1999). International air passenger baggage is considered the highest risk pathway for Medfly into Florida. About 8.8 million air passengers arrive in Florida per year, of which 5 million originate from Medfly infested countries (APHIS 1999). Weighted passenger with Medfly infested materials to Florida is estimated in 1995 at 6.6 x 10^{-10}, based on baggage surveys carried out by Plant Protection and Quarantine from July, 1993 through September 1994 **(**APHIS 1994**)**.

Using the general framework developed by Baker et al. (1993), the probability of a Medfly infestation in Florida can be calculated as follows:

$$F(X_{1,0}) = 1 - (1 - p\Phi)^{N} \tag{4-16}$$

where N stands for the number of passengers per year arriving from countries where Medfly occurs, p is the proportion of weighted passengers with high risk materials, and Φ is the probability that a single infested unit leads to an establishment. The parameter, p, is considered the infestation level associated with air passenger baggage clearance. To be 95% confident that the infestation level is no more than p, the number of passengers (n) to inspect can be calculated (Couey and Chew 1986) as:

$$n = \frac{\log(1-0.95)}{\log(1-p)} \tag{4-17}$$

Under the assumption that the number of survivors per infested unit follows a Poisson distribution, the parameter Φ is defined (Whyte et al. 1996) as follows:

$$\Phi = \Psi(1 + e^{-\mu\phi} - 2e^{-\mu\phi/2}) \tag{4-18}$$

where μ is the average number of pests present per infested unit, ϕ is the proportion of individuals surviving to reproduce, and Ψ is the suitability of conditions for the pest. Thus, the probability of a Medfly infestation is written as

$$F(X_{1,0}) = 1 - (1 - p\Psi[1 + e^{-X1,0} - 2e^{-X1,0/2}])^{N} \qquad (4\text{-}19)$$

where $X_{(1,0)}$ ($X=\mu\phi$) stands for the number of ovipositing females per infested unit. As stated above, all outbreak scenarios are built up under the assumption that the infestation is initialized with a small lot of mangos containing 1000 eggs. The number of eggs per infested mango is assumed to be 100 with a ten-percent probability of surviving to adulthood and a 1:1 sex ratio.

Multiple Trap Sensitivity of McPhail traps: F(X_2,t | X_1,t , Z)

The multiple trap sensitivity, $F(X_{2,t} | X_{1,t}, Z)$, stands for the probability of capturing one or several flies by trapping, given the occurrence of an infestation at a given time and some location in Florida. It is a function of the size of the adult population and the number of traps. Our study used data on different population levels of a uniform distribution and age class with various numbers of McPhail traps per unit area (Calkins et al. 1984). The conditional probability of detecting low to moderate populations of Anastrepha *suspensa* in citrus groves in Central Florida was described by a polynomial approximation of the cumulative distribution function (cdf), which was constrained to the zero-one range by a hyperbolic tangent function (Taylor 1984, 1990). The functional form of the conditional cdf is written as:

$$F(\chi_2 | \chi_{1,t}, Z) = 0.5 + 0.5 * \tanh(H(\chi_{1,t}, \chi_2, Z)) \qquad (4\text{-}20)$$

and the associated conditional probability density function (pdf) is computed by taking the derivative of Equation 4-20. Thus, the conditional pdf is:

$$f(\chi_2 | \chi_{1,t}, Z) = 0.5 * H^{j}(\chi_{1,t}, \chi_2, Z) * \sec h^{2}(H(\chi_{1,t}, \chi_2, Z) \qquad (4\text{-}21)$$

where H(.) is a polynomial function, H^j is the partial derivative of H(.) with respect to x_2, tanh(.) is the hyperbolic tangent, and sech(.) is the hyperbolic secant. By restricting the polynomial approximation to a quadratic function, Equation 4-21 can be extended as follows:

$$\begin{aligned} & f(x_2 | x_{1,t}, Z) = 0.5 * (a_2 + a_{12} x_{1,t} + a_{23} Z + 2 a_{22} x_2) \\ & * \sec h^2 (a_0 + a_1 x_{1,t} + a_2 x_2 + a_3 Z + a_{12} x_{1,t} x_2 + a_{13} x_{1,t} Z \\ & + a_{23} x_2 Z + a_{11} x_{1,t}^2 + a_{22} x_2^2 + a_{33} Z^2) \end{aligned} \tag{4-22}$$

The parameters characterizing the polynomial approximation are estimated by least-square error method. The minimization problem is expressed as follows:

$$Min.....\sum_{i=1}^{N} \left[(f(x_2 = 0, x_{1,T} | Z) - (1 - T_i))^2 + (f(x_2 = 1, x_{1,t} Z) - T_i)^2 \right] \tag{4-23}$$

subject to:

$$f(x_2 = 0, x_{1,t} | z) \geq 0.......\forall x_{1t}, ...34 \leq x_{1,t} \leq 10{,}000 \tag{4-24}$$

$$f(x_2 = 1, x_{1,t} | z) \geq 0.......\forall x_{1,t} .....34 \leq x_{1,t} \leq 10{,}000 \tag{4-25}$$

$$\frac{\partial H}{\partial x_{1,t}} = a_1 + a_{12} x_2 + a_{13} z + 2 a_{11} x_{1,t} \succ 0 \tag{4-26}$$

$$\frac{\partial H}{\partial z} = a_3 + a_{13} x_{1,t} + a_{23} x_2 + 2 a_{33} z \succ 0 \tag{4-27}$$

where $f(x_2=0, x_1|z)$ and $f(x_2=1,x_1|z)$ are the respective theoretical values of the probability derived from the hyperbolic tangent function, T_i are the probabilities provided in the dataset, and $\partial H/\partial X_1$,t and $\partial H/\partial Z$ are the partial derivatives of H with respect to $X_{1,t}$ and Z. The last two constraints (Equations 4-26 and 4-27) are imposed to satisfy the requirements that the probability density function be monotonic and increasing over the range of values of $X_{(1,t)}$ lying between 34 and 10,000 and Z varying between 1 and 500. All correspondent probabilities are also constrained to be positive (Equations 4-24 & 4-25).

The least-square error estimates provided by the Excel solver are given in Table 4-4. All constraints and optimality conditions are satisfied. The value of the standard error of the estimate accounts for the measure of the “goodness of fit” of the estimated regression line. Also, the Kolmogorov-Smirnov test statistics do not reject the null hypothesis that the theoretical values of the probability density functions (derived from the hyperbolic tangent function) and the values of probability provided in the dataset follow the same distribution.

Comparative Sensitivity of McPhail versus Jackson Traps

Results obtained in experiments with McPhail traps can be properly extrapolated, using estimates of comparative trap sensitivity. Literature reported significant differences between McPhail and Jackson traps in their performance of capturing Ceratitis *capitata* in terms of probability of detecting small populations, number of flies captured, and proportion of females (females/[males + females]) captured (Heath et al. 1997; Katsoyannos 1994; Katsoyannos et al. 1999a, 1999b; Papadopoulos et al. 2001). McPhail traps (ML traps) are baited with a dry synthetic multilure/liquid protein and, such as, are used to capture both females and males of a number of pest tephritid species (Newell 1936; IAEA 2003). On the other hand, trimedlure compounds are typically placed in Jackson traps (TML traps) that are effective in attracting males, but they are weakly attractive to females (Beroza et al. 1961; Nakagawa et al. 1970; Harris et al. 1971). Casana-Giner et al. (2001) argued that no attractant for female C. *capitata* was comparable to the male C. *capitata* captures of TML traps, which may be due to a higher response to odor-attraction of the males than females in C. *capitata*. Development of trimedlure compounds would contribute to enhance the probability of Medfly control, improve trapping strategies, and reduce costs of trapping systems.

We used capture data from experiments of sterile insect releases conducted by APHIS in Tampa to develop estimates of comparative sensitivity of ML and TML traps by making the assumption that the experimental conditions (type of crop, density of crop, tree fruit distribution, trap location or position) were the same (Drummond et al. 1984). The full dataset covers 1700 observations of daily captures from 2nd to 27 February (20 counts), from 31 May to June 30 (23 counts), and from 1st to 30 October (22 counts). Trap counts were expressed as the mean number of flies caught per trap per day and transformed to [ln(catches +1)] to stabilize their variances before analysis (Katsoyannos et al. 1999a; Cohen and Yuval 2000; Papadopoulos et al. 2001). Using the data for the entire sample, February, June, and October, we obtained four estimated OLS regressions, postulated as follows:

$$\ln(catchesTML + 1) = \beta \ln(catchesML + 1) + u \qquad (4.28)$$

where β stands for the coefficient of comparative trap sensitivity. We used the F statistic for testing whether the unrestricted regressions (as opposed to the restricted or pooled regression) for the three periods were systematically different. A probability level of 0.05 was used for all statistical tests.

Results of the regression model (Table 4-5) show variations in mean daily captures and coefficient of relative sensitivity across seasons and types of traps. Both TML and ML traps were more effective in February, when the life cycle of the pest is longer and fly dispersal ion is restricted. Nevertheless, TML traps outperformed ML traps in total captures of male C. *capitata* during all periods. Mean daily captures in TML traps are 5.80 times greater than in February, 9.84 times greater than in October, and 7.65 times greater in June.

The t-test statistic supported the hypothesis that the coefficients of comparative sensitivity estimated in the OLS regressions are statistically different from zero. Confidence intervals for the estimated coefficients are shown in Table 4.5. On the basis of the F test, we strongly rejected the null hypothesis of homogenous slope coefficients. The test sequence is naturally halted, as the regression models (Equation 4.28) postulated do not contain any intercept. These findings are supportive of the conclusion that the coefficients of relative sensitivity vary systematically across seasons and types of traps. These coefficients are incorporated into the hyperbolic tangent function as augmentation factors (Moss et al. 2004) to investigate the effects of trap sensitivity improvement on probability of detection and optimal trap density.

Consider $\Upsilon(\psi)$, the augmentation factor, ψ being the technological change. The multiple trap sensitivity of TML trap can be expressed as follows:

$$F_{TML}(X_{2,t} \mid X_{1,t}, Z) = \psi F_{ML}(X_{2,t} \mid X_{1,t}, Z) \tag{4-29}$$

Results

The findings from the Bayesian modeling framework are outlined in this section. Our study provides estimates of the colonization potential of Medfly populations in Florida, probabilities of detecting low populations at early stages, expected costs of the prevention and eradication program, and optimal trapping densities across different locations and seasons.

Pest Population Projection

Results of the temporal model of infestation (Tables 4-6 and 4-7) show variations in generation time across locations (Miami or Tampa) and seasons (February, June, and October). In the event of a February infestation in Miami or Tampa, the expected time for F_1 generation to reach the ovipositional stage is 44 and 64 days, respectively. At 50 days of the infestation, for instance, the projected size of the pest population is 860 and 200 Medflies, respectively. The instantaneous rate of change in population size is 0.0812 and 0.0587 for Miami and Tampa, respectively, implying that the pest population will double approximately every 8.53 and 11.80 days, respectively (Table 4-7). These results follow from the fact that average mean monthly temperatures in both Miami and Tampa are below optimal levels for Medfly development during the months of February and March. However, as the temperature increases during the months of April and May, the length of the life cycle will be drastically reduced to 22 or 23 days for the fourth generation. The instantaneous rate of population change in population will also increase to 0.1005 and 0.0988 in Miami and Tampa, respectively. As a result, the colonization potential at 119 days will increase with a population size approximating 38,781 and 22,990 Medflies, respectively.

As expected, the colonization potential of a Medfly population is much higher during the summer months, when average mean monthly temperatures for Miami and Tampa are in the optimal range for Medfly development. The time to the ovipositional stage averages 21 days and the projected doubling time is 4.65 days and 4.83 days for Tampa and Miami, respectively. For instance, at 98 days of the infestation, the pest population size in Miami and Tampa is expected to be 363,390 bugs and 532,267 bugs, respectively. Differences in population size and structure between Tampa and Miami

(Appendix A) spell the sensitivity of the Medfly development to changes in weather conditions.

As opposed to a February infestation, the October infestation starts under more favorable weather conditions, and, therefore, with a moderate colonization potential. At 50 days of the infestation, initial pest populations in Miami and Tampa are expected to attain a size of 1960 bugs and 1300 bugs, respectively. The first two generations will increase on average by approximately 11.06% and 9.33% each day, respectively. However, the duration of the egg, larval, and pupal stages will be considerably increased by lower temperatures during the months of December and January, causing a significant reduction in the colonization potential of the pest population. In Miami, generation times increase from 29 days for the second generation to 52 days for the fourth generation, while the intrinsic rate of population increase decreases up to 0.0777. In Tampa, the drop in the intrinsic rate of population increase is even more severe. The development of larval and pupal stages is expected to be almost stopping, thereby causing a sort of stagnation in the pest population size.

Size and Cost of the Infestation

The results of the spatial model of the infestation (Table 4-8) show variations in infested areas, quarantine areas, and total eradication costs under different outbreak scenarios. Note that the eradication cost is hereby estimated under the assumption of a ninety-percent pesticide efficacy.

None of the outbreak scenarios simulated in the spatial-temporal model can be considered early-detected infestations (which, according to the APHIS criteria, are supposed to spread over a quarantine area equal to or less than 110 square mile). Maintaining such a target involves detecting the pest population and starting to spray it at less than 44 days. The reason for this is that, at 50 days, the initial parent cohort under all outbreak scenarios (including both seasonal and geographical variations) is expected to start ovipositing, implying that the eradication will not be completed around the time required for all F_2 eggs to emerge as adults. By this time, the infested area averages 22 square miles large with a quarantine area ranging from 121 to 421 square miles. The February infestation in Tampa is expected to be confined to a two-square-mile area, while the June infestation in Miami or Tampa will spread over a 32 square mile area and the total regulated area will encompass a 421-square-mile area.

Nevertheless, any infestation detected at 50 days can be considered a moderate outbreak as the maximum distances flown by the flies are expected to be less than 4 linear miles and the expected proportion of adults moving away from the epicenter is low (< 10%). Total cost of eradication of a 50-day old infestation is expected to vary across locations and seasons, from \$ 2.06 million for a February infestation in Tampa, \$ 6.1 million for an October infestation, to \$ 26.3 million for a June infestation in Miami.

When spraying starts three weeks later (i.e., at 77 days of the infestation), the cost of eradication of a February or October infestation in Miami will approximately quadruple compared to the costs of the 50-day old infestation in the same location and season. The 77-day old pest population in Miami is expected to spread over a 21 and 24 square-mile area for the February and October infestations, respectively. However, the rate of increase in eradication cost is much less in Tampa, approximating 48% and 110% for a 77-day-old infestation occurring in October and February, respectively. The Tampa infestation is expected to spread over a 12-square-mile area and less than 250 square miles will be placed under strict regulation. Theses results reflect well the sub-optimal weather conditions prevailing in Tampa for the Medfly development, especially during the winter months.

A 77-day-old infestation must be considered a serious outbreak when it occurs during the summer months either in Miami or Tampa. Average distances flown by the flies are expected to be greater than 12 linear miles and the projected proportion of adults moving away from the epicenter will be around 12%. Such an infestation is very likely to spread over two to four counties. The expected treatment area covers 115 square miles large and 1,055 square miles are expected to be under strict regulation. The Tampa infestation will be more costly than the Miami one. The reason for this relative difference is based entirely on the size and the structure of the F_1 generation in the two locations. The highest proportion of the pest population in egg, larval, and pupal stages in Tampa spells the difference in eradication costs.

As shown in Table 4-8, it will cost twice or three times more to eradicate the F_1 and F_2 generations of an October infestation than those of a February infestation. The reversal of this situation is observed for the F_3 and F_4 generations. At 98 days and more, whilst eradication costs of an October infestation in either Miami or Tampa increase at a decreasing rate, those of a February infestation tend to increase at an increasing rate. In Miami, the projected eradication cost of a 98-day or 119-day old infestation will be approximately \$ 147 million and \$ 1.9 billion, respectively. At 119 days, for instance, the February infestation will spread over a 300-square mile area with high risks of facing additional outbreaks in remote areas during eradication operations.

A 98 or 119-day old infestation is even more serious when it occurs during the summer months in either Tampa or Miami. The expected quarantine area encompasses approximately 6,800 and 8,000 square miles respectively. Eradication costs are expected to be extremely expensive, approximating \$ 2.9 billion and \$ 7.7 billion in Miami and Tampa, respectively. It is likely that such infestations become out of control.

Multiple Trap Sensitivities for ML Traps

The estimates of multiple trap sensitivity for the ML trap (Table 4-9) are extremely low, thereby confirming how difficult it could be to detect low Medfly populations at early stages. As expected, the highest trap sensitivities are reported for the pest population during the summer months. For instance, the sensitivity of a trapping system to a 50-day-old infestation varies across trap densities from 4.95×10^{-6} for a density of one trap per square mile in Miami to 5.84×10^{-4} for a density of 21 traps per square mile in Tampa. The chances of detecting a 119-day old infestation are higher, with trap sensitivities lying between 1.35×10^{-4} and 1.11×10^{-2}. On the other hand, the lowest trap sensitivities are found for a 50-day old infestation during the months of February and October. For instance, the chances of detecting a 50-day old infestation in Tampa are ten times lower in February than in June.

The marginal values of trap sensitivity (Table 4-10) are all positive within the interval ranges of our dataset, varying from 7.08×10^{-7} to 6.31×10^{-4} with a clear tendency to increase with trap density. The higher the trap density, the higher will be the marginal trap sensitivity. For instance, for a given pest population in Miami (October), the marginal trap sensitivity to a 50-day old infestation varies from 3.88×10^{-6} to 2.74×10^{-5} for trap densities of 2 and 21 traps per square mile, respectively. The direction of changes in marginal trap sensitivity is also the same with changes in pest population size. For a given trap density in Tampa (June), the marginal trap sensitivity varies from 5.7 x

10^{-6} for a 50-day old infestation to 1.59 x 10^{-4} for a 119-day old infestation. These results strongly suggest that there is a positive gain in increasing trap density.

Probabilities of Detection for ML Traps

The computed values for the probability of detection (Table 4-11) differ from the trap sensitivities in that the former are conditional to (1) the probability of infestation, $F(X_1)$, estimated at 0.005371 for the State of Florida and (2) to all possible outcomes in the trapping system, ranging from X_2=0 to $X_2 \rightarrow \infty$. Nevertheless, the results relative to the probability of detection follow the same pattern as those for the multiple trap sensitivity. The reported probabilities vary across trap densities from 3.23 x 10^{-6} to 2.24 x 10^{-4}. The highest probabilities of detection are found for the pest infestation occurring during the summer months, while the chances of detecting a pest infestation during the month of February are extremely low. Furthermore, all marginal values of probability of detection are positive, ranging from 4.77 x 10^{-7} to 2.11 x 10-4. Like for the marginal trap sensitivity, the general tendency is for the marginal values of the probability of detection to increase with trap density and pest population size. Nevertheless, at some trap densities, i.e. at a density of 12 traps per square mile, the marginal values of probability of detection show a slight decrease with an increase in trap density.

Optimal Trap Densities

The optimal solutions regarding trapping density are presented in Table 4-13. The lowest optimal trap density for ML traps is 82 traps per ha and is reported for a June infestation occurring in Tampa. A total of 184 traps per ha are to be placed in Miami during the month of February to achieve the optimal solution. The highest optimal trap density for ML traps (465 traps per ha) is found for a Tampa infestation starting in

October. These results are supportive of the hypothesis that the optimal trapping density varies across locations and seasons.

The optimal solutions for ML traps greatly differ from those for TML traps that are found to be more effective for capture of male C. *capitata*. Optimal trapping densities for TML traps range from 9 to 80 traps per ha, with the highest optimal trap density being reported for a February infestation occurring in Tampa. A total of 25 traps per ha are to be placed in Tampa during the month of October to achieve the optimal solution. The lowest trap density (9 traps per ha) is found for a June infestation in Tampa. These results highly suggest that emphasis should be placed more on improving trap sensitivity rather than on increasing trap density.

Conclusions

The objectives of this chapter were to (1) compute the multiple trap sensitivities for ML and TML traps and the probabilities of detecting a Medfly infestation in Florida at its early stages and (2) determine the optimal trapping density that can minimize the total expected cost of the Medfly prevention, detection and eradication program. Our study shows that the colonization potential greatly varies across seasons and locations and that none of the outbreak scenarios simulated in the spatial-temporal model can be considered early-detected infestations. The chances of detecting Medfly populations at early stages are extremely low. Sensitivity of ML traps to a 50-day-old infestation varies across trap densities from 4.95×10^{-6} for a density of one trap per square mile in Miami to 5.84×10^{-4} for a density of 21 traps per square mile in Tampa. Because of significant progress made in developing more potent lures for male *C. capitata*, TML traps are expected to be on average 7.76 times more sensitive than ML traps.

The results relative to the probability of detection follow the same pattern as those for the multiple trap sensitivity. The reported probabilities vary across trap densities from 3.23×10^{-6} to 2.24×10^{-4}. The highest probabilities of detection are found for the pest infestation occurring during the summer months, while the chances of detecting a pest infestation during the month of February are extremely low.

Optimal trapping densities also vary across locations and seasons, ranging from 82 to 465 traps per ha for ML traps and from 9 to 80 traps per ha for TML traps. These results strongly suggest that emphasis should be placed on improving the multiple trap sensitivity, which is, reportedly, increasing with trap density and population size.

Table 4-1 Distribution of day degrees required by stage

Transitional Phase	Day Degrees Required to Transition (^{o}F)		
	Minimum	Maximum	Average
Egg / Larvae	33.8	47.9	40.85
Larvae / Pupae	153.9	219.45	186.67
Pupae / Pre-adults	308.6	436.8	372.7
Pre-adults / Adults	596	608.3	603.1

Source: APHIS 2002

Table 4.2 Average monthly distances flown by different fractions of Medfly population

Means of spread	Fraction of population moving away from the epicenter	Average distances flown (linear mile)
	0.15	0.125
Random	0.06	0.435
dispersal	0.042	0.75
	0.027	1.25
	0.018	1.75
Long	0.0015	12
distance	0.0006	24
flight &	0.00042	48
human	0.00030	96
conveyance	0.00018	108

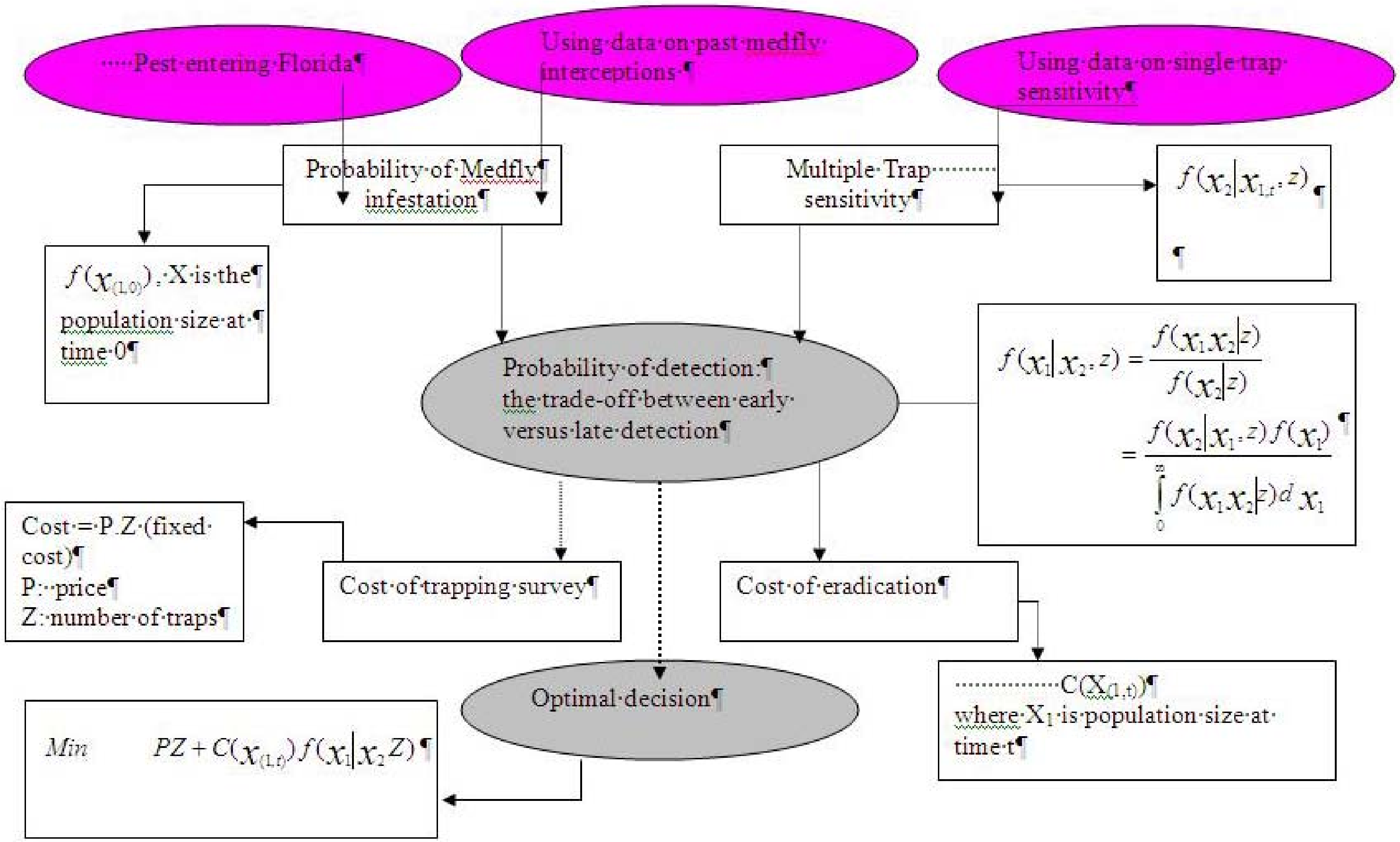

Figure 4-1. Bayesian decision process

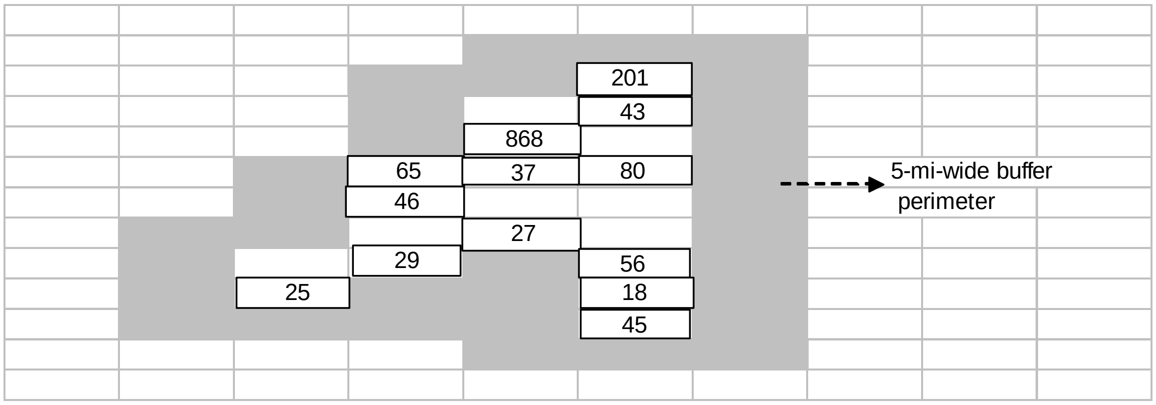

Figure 4-2 Treatment and quarantine areas of an infestation scenario in Miami (October)

Table 4-3 Eradication cost equations

Coefficients	Tampa				Miami			
	Pooled data	February	June	October	Pooled data	February	June	October
A_0 (se)	9.8013 (0.456)	10.32897 (0.0015)	7.072238 (0.0164)	8.774308 (0.0000)	9.6896 (0.440)	9.626233 (0.0108)	8.802522 (0.0002)	8.234525 (0.001)
A_1 (se)[a]	0.3409 (0.032)	0.917753 (0.0137)	1.52183 (0.0118)	0.702589 (0.0114)	0.5854 (0.029)	0.85166 (0.0187)	1.061598 (0.0052)	0.822641 (0.0193)
A_{11} (se)	0.0634 (0.075)	0.011916 (0.0298)	-0.04039 (0.0279)	-0.04655 ((0.0345)	0.0241 (0.072)	0.046724 (0.0548)	-0.02198 (0.012)	-0.00538 (0.0377)
Residual sums of square	196.983	3.77434	9.76437	0.58212	181.18	9.770366	1.40914	3.330146
F[6,204]	440.2952				390.5533			

[a] se=standard error of the parameter

Table 4-4 Hyperbolic tangent approximation of marginal probability function for multiple trapping sensitivity of McPhail traps

Coefficients [a]	a_0= -3.74367 ; a_1= 0.25243; a_2= 1.053351; a_3 = 0.68775; a_{12}= -0.04322; a_{13}= -0.02082; a_{23}= -0.07316; a_{11}=0.0114269; a_{22}=0.69595; a_{33}=-0.01823
Standard error of the estimate	Residual sum of squares = 0.00024037 Standard error = 0.0000160247
Kolmogorov-Smirnov test [b]	D value = 0.08 P-value = 1.00

[a] These coefficients refer to the conditional probability density function described in Equations 4.21 & 4.22, which is approximated by a quadratic function. The size of the adult population, X, and the number of traps, Z, are the two major variables of this function. [b] Kolmogorov Smirnov test determines if two datasets differ significantly by using the maximum vertical deviation between their curves. The maximum difference in cumulative fraction is D=.45. With a D value estimated at 0.08 for a p-value =1.00, the KS test supports the hypothesis that the values of the probabilities in the dataset and the theoretical values of the probability density functions follow the same distribution.

Table 4-5 Coefficients of comparative sensitivity and mean daily captures by period

	Pooled Data	February	June	October
Trap counts	65	20	23	22
Untransformed means of daily captures				
TML trap	43.4	84.4	21.5	29.0
ML trap	5.9	11.6	3.5	3.3
Coefficient of comparative sensitivity of TML to ML traps (in log space)	1.928979	1.75722	2.034088	2.286278
confidence intervals	1.62≤ β ≤2.23	1.01≤β≤ 2.77	1.20≤β≤2.86	1.48≤β ≤3.09
standard error	0.152154	0.354838	0.400214	0.387087
t value	12.67778	3.451957	2.936439	3.211114
Residual sum of squares	36.17546	4.92351	10.55651	10.6455
Calculated F[2,64] value		12.30973		

Table 4-6 Distribution of the expected population size and generation time per location and per season at 50, 77, 98, and 119 days [a] of the infestation

Month	Day	Miami		Tampa	
		Expected [b] population size (Medflies)	Generation [c] time (Days)	Expected population size (Medflies)	Generation time (Days)
	50	860	44	200	64
Feb.	77	2,211	33	1,420	33
	98	20,570	27	1,584	25
	119	38,781	23	22,990	22
	50	4,741	24	5,588	23
June	77	75,044	21	91,948	21
	98	363,390	21	532,267	21
	119	1,448,303	21	2,206,223	21
	50	1,960	26	1,300	29
Oct	77	14,300	29	2,200	52
	98	25,531	41	14,179	91
	119	138,243	52	14,300	39

[a] Medfly populations at 50, 77, 98, and 119 days roughly correspond to the first (F1), second (F2), third (F3), and fourth (F4) generations, respectively. [b] Population size is expressed in terms of numbers of female pre-adults or adults and its calculation takes into account the survival probabilities at all stages. [c] Generation time refers to the time required for one generation of eggs to reach the ovipositional age.

Table 4-7 Distribution of the intrinsic rates of increase and doubling times of the pest population per location and per season

Month	Day [a]	Miami		Tampa	
		Intrinsic rate of increase	Doubling time (days)	Intrinsic rate of increase	Doubling time (days)
	50	0.0812	8.53	0.0587	11.81
Feb.	77	0.0812	8.53	0.0587	11.81
	98	0.1005	6.89	0.0813	8.53
	119	0.0805	8.61	0.0989	7.01
	50	0.1484	4.67	0.1490	4.67
June	77	0.1249	5.55	0.1263	5.49
	98	0.1108	6.26	0.1144	6.06
	119	0.1008	6.87	0.1042	6.65
	50	0.1240	5.59	0.1222	5.67
Oct	77	0.0974	7.12	0.0644	10.76
	98	0.0769	6.36	0.0718	9.65
	119	0.0777	7.96	0.0551	12.57

[a] Medfly populations at 50, 77, 98, and 119 days roughly correspond to the first (F1), second (F2), third (F3), and fourth (F4) generations, respectively.

Table 4-8 Distribution of the infested area, quarantine area, and eradication cost per location and per season at 50, 77, 98, and 119 days [a] of the infestation

Month	Day	Miami			Tampa		
		Infested area	Quarantine area	Eradication cost	Infested area	Quarantine area	Eradication cost [b]
		(square mile)		($1,000)	(square mile)		($1,000)
	50	4	182	2,327	2	121	2,066
	77	21	327	10,325	11	208	4,345
Feb	98	81	860	146,824	39	504	27,991
	119	299	1,943	1,960,186	140	936	373,674
	50	32	421	26,265	32	421	24,825
	77	115	1,055	289,511	115	1,055	315,602
June	98	250	4,276	1,574,211	445	5,714	5,355,057
	119	365	6,764	2,907,668	554	8,228	7,702,316
	50	12	252	6,091	6	192	4,913
Oct	77	24	360	22,453	13	240	7,281
	98	48	740	61,384	13	240	7,281
	119	49	758	99,271	15	263	15,882

[a] Medfly populations at 50, 77, 98, and 119 days roughly correspond to first (F1), second (F2), third (F3), and fourth (F4) generations, respectively. [b] The costs for pesticide applications are part of the total eradication cost and are estimated under the assumption of 90-percent pesticide efficacy

Table 4-9 Distribution of multiple trap sensitivities for ML traps under all outbreak scenarios for different trap densities

Trap density (per mi ^{2})	50	77	98	119	50	77	98	119
	Tampa February				Miami February			
1	0.000000584	0.000000877	0.00000184	0.00000871	0.000001	0.00000192	0.00000949	0.000012
2	0.000002	0.00000294	0.00000594	0.0000262	0.00000334	0.00000618	0.0000285	0.0000355
5	0.00000966	0.0000138	0.0000265	0.000107	0.0000155	0.0000275	0.000115	0.000142
10	0.0000305	0.0000425	0.0000787	0.000296	0.0000475	0.0000814	0.000318	0.000388
12	0.000041	0.0000568	0.000104	0.000384	0.0000634	0.000108	0.000413	0.000503
16	0.0000652	0.0000894	0.000161	0.000578	0.0000995	0.000167	0.000621	0.000753
21	0.0001	0.000137	0.000243	0.000846	0.000152	0.000251	0.000907	0.001097
	Tampa June				Miami June			
1	0.00000553	0.0000287	0.0000732	0.000188	0.00000495	0.0000265	0.0000599	0.000135
2	0.000017	0.0000823	0.000203	0.000506	0.0000153	0.0000763	0.000168	0.000367
5	0.0000707	0.000315	0.000742	0.001771	0.000064	0.000293	0.000618	0.001305
10	0.0002	0.000832	0.001897	0.004382	0.000182	0.000776	0.00159	0.003265
12	0.000261	0.001068	0.002414	0.005526	0.000238	0.000998	0.002027	0.004131
16	0.000396	0.001577	0.003512	0.00793	0.000361	0.001474	0.002959	0.005956
21	0.000584	0.002266	0.004977	0.011088	0.000534	0.00212	0.004205	0.008368
	Tampa October				Miami October			
1	0.00000332	0.00000401	0.0000132	0.0000129	0.00000365	0.0000104	0.0000117	0.0000421
2	0.0000104	0.0000125	0.000053	0.000039	0.0000383	0.0000114	0.0000311	0.000119
5	0.0000448	0.000053	0.000155	0.000153	0.0000487	0.000125	0.000139	0.000447
10	0.000129	0.000152	0.000423	0.000416	0.00014	0.000345	0.00038	0.001166
12	0.00017	0.000199	0.000547	0.000539	0.000184	0.000447	0.000492	0.001491
16	0.000261	0.000304	0.000817	0.000805	0.000281	0.000671	0.000737	0.002188
21	0.0003888	0.000451	0.001188	0.001171	0.000418	0.000979	0.001074	0.003126

Table 4.10 Marginal trap sensitivities for ML traps under different outbreak scenarios

Trap density (per mi ^{2})	50	77	98	119	50	77	98	119
	Tampa February				Miami February			
2	0.000000708	0.000001032	0.00000205	0.00000874	0.00000117	0.00000213	0.00000951	0.00001175
5	0.00000255	0.00000362	0.00000685	0.0000269	0.00000405	0.00000711	0.0000288	0.0000355
10	0.000004168	0.00000574	0.0000104	0.0000378	0.0000064	0.00000108	0.0000406	0.0000492
12	0.00000525	0.00000715	0.00001265	0.000044	0.00000195	0.0000133	0.0000475	0.0000575
16	0.00000605	0.00000815	0.00001425	0.0000485	0.00000903	0.0000148	0.000052	0.0000625
21	0.00000696	0.00000952	0.0000164	0.0000536	0.0000105	0.0000168	0.0000572	0.0000688
	Tampa June				Miami June			
2	0.000005735	0.0000268	0.0000649	0.000159	0.00000518	0.0000249	0.00005405	0.000116
5	0.0000179	0.0000775	0.0001797	0.000422	0.0000162	0.0000722	0.00015	0.0003127
10	0.00002586	0.0001034	0.000231	0.000522	0.0000236	0.0000966	0.0001944	0.000392
12	0.0000305	0.000118	0.0002585	0.000572	0.000028	0.000111	0.0002185	0.000433
16	0.00003375	0.000127	0.0002745	0.000060	0.0000308	0.000119	0.000233	0.000456
21	0.0000376	0.000378	0.000293	0.000632	0.0000346	0.000129	0.0002492	0.0004824
	Tampa October				Miami October			
2	0.00000354	0.000004324	0.0000129	0.0000127	0.00000388	0.0000104	0.0000115	0.0000384
5	0.0000115	0.0000135	0.0000386	0.0000382	0.0000124	0.0000313	0.0000348	0.0001093
10	0.00001684	0.0000198	0.0000536	0.0000526	0.0000183	0.000044	0.0000482	0.0001438
12	0.0000205	0.0000235	0.000062	0.0000615	0.000022	0.000051	0.000056	0.0001625
16	0.00002275	0.00002625	0.0000675	0.0000665	0.0000243	0.000056	0.00006125	0.0001743
21	0.0000254	0.0000294	0.0000742	0.0000732	0.0000274	0.0000616	0.0000674	0.0001876

Table 4-11 Distribution of probabilities of detection for ML traps under all outbreak scenarios for different trap densities

Trap density (per mi ^{2})	50	77	98	119	50	77	98	119
	Tampa February				Miami February			
1	0.00000329	0.00000484	0.0000107	0.0000481	0.00000552	0.0000106	0.0000525	0.0000663
2	0.00000418	0.00000615	0.0000124	0.0000548	0.00000698	0.0000129	0.0000596	0.0000742
5	0.00000635	0.00000907	0.0000174	0.0000703	0.00001018	0.0000181	0.0000755	0.0000933
10	0.00000992	0.00001382	0.0000256	0.0000962	0.00001545	0.0000265	0.0001034	0.0001262
12	0.00001151	0.00001595	0.0000292	0.0001078	0.00001781	0.0000303	0.0001159	0.0001413
16	0.00001513	0.00002074	0.0000374	0.0001341	0.00002309	0.0000387	0.0001441	0.0001748
21	0.00002041	0.00002796	0.0000496	0.0001726	0.00003102	0.0000512	0.0001851	0.0002239
	Tampa June				Miami June			
1	0.00003057	0.0001586	0.000405	0.001039	0.00002736	0.0001465	0.0003311	0.0007463
2	0.00003555	0.0001721	0.000425	0.001058	0.000032	0.0001596	0.0003513	0.0007676
5	0.00004645	0.0002069	0.000487	0.001163	0.00004204	0.0001925	0.0004060	0.0008574
10	0.00006505	0.0002706	0.000617	0.001425	0.00005919	0.0002524	0.0005172	0.001062
12	0.00007329	0.0002999	0.000678	0.001552	0.00006684	0.0002803	0.0005692	0.001160
16	0.00009190	0.0003659	0.000815	0.001840	0.00008378	0.0003421	0.0006867	0.001382
21	0.0001192	0.000462	0.001015	0.002263	0.0001089	0.0004327	0.0008581	0.001708
	Tampa October				Miami October			
1	0.00008354	0.00002217	0.0000729	0.0000713	0.00002018	0.0000575	0.0000647	0.0002327
2	0.00002175	0.00002614	0.0000815	0.0000801	0.00002384	0.0000650	0.0000726	0.0002489
5	0.00002943	0.00003482	0.0001018	0.0001005	0.00003199	0.0000821	0.0000913	0.0002937
10	0.00004195	0.00004943	0.0001376	0.0001353	0.00004553	0.0001122	0.0001236	0.0003793
12	0.00004774	0.00005588	0.0001536	0.0001513	0.00005167	0.0001255	0.0001318	0.0004187
16	0.00006057	0.00007055	0.0001896	0.0001868	0.00006521	0.0001557	0.0001710	0.0005078
21	0.00007985	0.00009204	0.0002425	0.0002389	0.00008531	0.0001998	0.0002192	0.0006380

Table 4-12 Marginal values of probability of detection for ML traps densities under different outbreak scenarios

Trap density (per mi ^{2})	50	77	98	119	50	77	98	119
	Tampa February				Miami February			
2	0.000000477	0.00000065	0.00000113	0.00000332	0.000000729	0.000001156	0.000003572	0.00000395
5	0.000000721	0.000001458	0.000002494	0.00000775	0.00000107	0.000002571	0.000007974	0.00000952
10	0.000000714	0.000002378	0.00000409	0.00000129	0.000000105	0.000000420	0.00001394	0.00001645
12	0.000000797	0.000001064	0.000001805	0.00000578	0.00000118	0.00000192	0.000006276	0.00000753
16	0.000000904	0.00000239	0.000004079	0.00001314	0.00000132	0.000004213	0.00001406	0.00001675
21	0.000001055	0.00000361	0.000006114	0.00001926	0.00000159	0.00000623	0.00002049	0.0000245
	Tampa June				Miami June			
2	0.00000249	0.00000673	0.00000995	0.00000949	0.00000232	0.00000654	0.00001011	0.0000106
5	0.00000363	0.00001741	0.00003146	0.0000526	0.00000335	0.0000164	0.00002733	0.0000449
10	0.00000372	0.00000318	0.0000648	0.000131	0.00000343	0.0000299	0.0000555	0.0001023
12	0.00000412	0.00001465	0.0000304	0.0000633	0.00000382	0.00000139	0.00002604	0.0000490
16	0.00000465	0.00003302	0.0000685	0.000144	0.00000424	0.0000309	0.0000587	0.000111
21	0.00000545	0.0000482	0.0001003	0.0002112	0.00000504	0.0000452	0.0000857	0.0001628
	Tampa October				Miami October			
2	0.00000170	0.00000198	0.00000429	0.00000439	0.00000183	0.00000377	0.00000394	0.00000807
5	0.00000256	0.00000434	0.00001013	0.00001021	0.00000272	0.00000569	0.00000725	0.00001493
10	0.000002505	0.00000731	0.0000178	0.00000173	0.00000271	0.00000602	0.00000645	0.00001711
12	0.0000289	0.00000322	0.00000801	0.00000803	0.00000307	0.00000666	0.00000728	0.00001974
16	0.00000321	0.00000733	0.00001800	0.00001772	0.00000338	0.00000754	0.00000821	0.00002226
21	0.00000372	0.00001074	0.0000264	0.00002608	0.0000402	0.00000881	0.00000963	0.00002604

Table 4-13 Optimal trapping density per type of trap, location and month

Month	Optimal trap density (# traps per ha)			
	Miami		Tampa	
	ML trap	TML trap	ML trap	TML trap
February	322	55	465	80
June	92	12	82	9
October	184	19	248	25

CHAPTER 5
WELFARE ANALYSIS OF A MEDFLY OUTBREAK IN FLORIDA

Fundamentals of the Partial Equilibrium Model

Theoretically, partial equilibrium models deal with a competitive economy where consumers and producers are considered price takers (Mass-Colell 2000). Adam Smith's invisible hand acts to bring the market to the point where the two curves cross, i.e., supply equals demand. The key feature of these models is that they do not include all production and consumption accounts in an economy, nor do they attempt to capture all changes in the global economy. It is assumed that consumers' expenditures on the goods included in the model account for a small portion of their total expenditures.

Three conditions are essential for a competitive equilibrium, corresponding to the requirements that producers optimize, consumers optimize, and that markets clear at the equilibrium prices. The equilibrium will then consist of a production plan y^{j*} for each firm, a consumption vector x^{i*} for each consumer, and a price vector p^{*}. Below are the mathematical expressions of the requirements:

3. Profit maximization . Given the equilibrium price p*, firm j's equilibrium output q* must maximize

$$\max_{q} \ldots\ldots\ldots pq_j - c_j(q)_j \tag{5-1}$$

$$subject..to.....q_j \in Y_j \tag{5-2}$$

where Y_j is the technology set, c_j (q_j) is a cost of producing q units, with c'(q) > 0 and c"(q) >0. Because each competitive firm takes prices as given, the first order condition

$$p - c'(q) = 0 \tag{5-3}$$

defines the supply function and the inverse supply function can be written as

$$p = Q^{-1}(q) \tag{5-4}$$

4. Utility maximization. Given the equilibrium price p*, consumer i's equilibrium vector (x_i) must maximize

$$\max_x .....U_i(X_i) \tag{5-5}$$

$$subject..to.....\textstyle\sum_i px_i = m_i \tag{5-6}$$

where m is the budget share. The first order condition is

$$U'(x_i) = p^* \tag{5-7}$$

The aggregate demand for consumption good under consideration is the sum of the corresponding individual demands across consumers:

$$x(p) = \textstyle\sum_i x_i(p) \tag{5-8}$$

The inverse demand function can be expressed as:

$$p(x) = X^{-1}(x) \tag{5-9}$$

5. Market clearing. Figure 5-1 represents the price vector such that aggregate demand for x equals aggregate supply. The equilibrium solutions p*, qj*, and xj* must solve the system of equations:

$$p^* = c'_j(q_j(p))..for..all..j \tag{5-10}$$

$$p^* = U'_i(x_i(p)...for...all..i \tag{5-11}$$

$$\sum_i x_i(p^*) = \sum_j q_j(p^*) \tag{5-12}$$

6. Welfare analysis. Economic welfare analysis specifically involves assessing how the equilibrium outcome (p*, q*, and x*) of a competitive market adjusts to changes in the environment. Consumer surplus is, by definition, the amount of extra utility consumers enjoy at price p and is represented by the area below the demand curve and above the price equilibrium. Likewise, producer surplus is the extra revenue received by producers at p and is represented by the area below the price equilibrium and above the supply curve. The effects on consumers are measured in terms of changes in the consumer surplus (CS), which is expressed as

$$CS_i = U_i(x_i) - p\,x_i \tag{5-13}$$

A differential change in CS is given by

$$dCS(\hat{p}) = (p(x) - \hat{p})dx \tag{5-14}$$

since consumers face new effective price $(\hat{p})$ and U'(x) = p(x) for all goods. Likewise, the effects on producers are captured as follows:

$$PS_j = p\,x_j - c_j(q_j) \tag{5-15}$$

$$dPS(\hat{p}) = (\hat{p}) - c'(q)dq \tag{5-16}$$

where PS stands for the producer surplus. The net social welfare (or aggregate social surplus) is the summation of the change in aggregate consumer surplus and the change in aggregate producer surplus. Let S (x, q) be the net social welfare formally defined as follows:

$$dS = dCS(\hat{p}) + dPS(\hat{p}) \tag{5-17}$$

$$dS = (p(x) - c'(q))dx \tag{5-18}$$

Integrating the equation 5-18 from 0 to x yields to the total value of the net social welfare:

$$S(x) = \int_0^x (p(s) - c'(s))ds \tag{5-19}$$

7. Impact of a Medfly infestation. In the event of a medfly introduction and/or colonization into Florida, the changes in net social welfare are likely to be associated with a decline in export markets. This would follow from the imposition of phytosanitary restrictions on traded goods by importing countries (Figure 5-2). These phytosanitary regulations would increase the cost of exporting, thus shifting the excess supply schedule to the left (from ES to ES'). Prices would rise from P1 to P2, leading to a decreasing demand of traded goods in importing countries. Aggregate welfare is likely to decline in importing countries. The underlying assumption is that there are no demand-stimulus effects from the phytosanitary restrictions.

Effects of a medfly infestation on net social welfare will vary across commodities, depending upon the Florida's initial market share for each commodity and the geographic and temporal dynamics of the pest population. Define $x_i^*(m)$, $q_j^*(m)$, and $p^*(m)$, respectively, to be the consumption, production, and price paid by consumers during the quarantine period. Letting $S^*(0)$ and $S^*(m)$, be the levels of net social welfare before and during the quarantine period. The change in S is given by:

$$S^{*}(x^{*}(m)) - S^{*}(x^{*}(0)) = \int_{x^{*}(0)}^{x^{*}(m)} (p(s) - c'(s))ds \qquad (5\text{-}20)$$

Adaptation of the Spatial Equilibrium Model to the Fruit and Vegetable Industry

Grapefruit Model

The grapefruit model used was originally developed at the University of Florida in 1991 (Pana) and later modified in 1995 (Spreen et al. 1995). Basically, the model consists of supply and demand components combined in an optimization problem to generate market-clearing prices for a given period. The supply component is represented by an implicit supply function for Florida, which is the unique supply region included in the model. In fact, Florida is the world's dominant grapefruit supplier, producing nearly 47% of total production for the 2000-2001season. Two commodities, red seedless and white seedless grapefruit are produced and total production for each commodity is computed, based on the inventory of bearing and non-bearing trees, the number of trees by age, and a vector of yields. The model allows for an endogenous allocation between fresh and processed utilization.

The demand side of the model includes consumption in the United States, European Union, Canada, and Japan. White seedless and red seedless grapefruit varieties are treated separately in the fresh market. A single market for grapefruit juice is also considered. In sum, the model consists of nine inverse demand equations, eight for the fresh market and one for the processed market. Simple linear own-price demand equations were estimated for each market (Pana 1991). Quality standards greatly vary across fresh markets and such differences are reflected through variations in packout rates and market prices.

The methodology and mathematical representation of the spatial equilibrium model are outlined in Appendix B. The model uses the profit-maximizing problem to find the optimal shipments for each commodity (red seedless versus white seedless) in each market and the equilibrium prices as well. Then, harvesting and marketing costs are deducted from these equilibrium prices to estimate the fresh and processed on-tree prices.

Vegetable Model

We hereby used a monthly partial equilibrium model initially developed by Spreen et al. (1995) and, later extended by VanSickle et al. (2000). Vegetable crops are allocated in the model across four demand regions of the United States, including the Northeast, Southeast, Midwest, and West. These regions are represented by the New York City, Atlanta, Chicago, and Los Angeles wholesale markets, respectively. Transportation costs were included for delivering shipments to each of the regional markets based on mileages determined by the Automap software. Average transportation cost of a fully loaded refrigerated truck carrying is estimated at $1.3072 per mile (VanSickle et al., 1994).

The model includes the following vegetable crops: tomatoes, peppers, cucumbers, squash, eggplants, watermelons, and strawberries. All of these crops are listed as preferred or marginal hosts for Ceratitis *capitata* (Liquido et al. 1991) and, therefore, are regarded by APHIS as regulated articles (Federal Register 2003a). Cropping systems used in each producing area differ in harvesting date, crop planted and crop association. Double cropping involves the use of the same unit of land for a secondary crop after the primary crop is harvested. Such a practice allows growers to save inputs used in the first crop. Pre-harvest and post-harvest production costs were estimated for each production system and area by Smith and Taylor (2003).

Monthly wholesale prices and unloads data collected by U.S. Department of Agriculture, Agricultural Marketing Service, Fruit and Vegetable Division, and Market News Branch were used to estimate the parameters of the market demand equations, using the inverse Rotterdam system. Intercepts of the demand equations were adjusted to reflect aggregate demand (Spreen et al. 1995). The model assumes that the commodities produced in the different production points are perfect substitutes. Slopes of the demand functions are also assumed to be constant over all quantities.

The supply side of the model incorporates an implicit supply function under the assumption of a fixed proportion technology. The upward sloping supply curve results, in part, from the increasing transportation costs as the demand region grows out from a particular supply region (McCarl and Spreen 1980; Peters and Spreen 1989). The methodology and mathematical representation of the model are outlined in Appendix C. Optimal dual solution to this spatial equilibrium model provides market prices in each demand area by month and commodity.

Specialty Model

The specialty model is developed to analyze the allocation of the specialty citrus crops (k- early, temples, early tangerines, honey tangerines, and tangelos) in the U. S. market. The supply side of the model is domestically represented by the production of specialty crops from Florida, which is by far the predominant supplier in the U.S. market. Florida production accounts for over 70% of the U.S. production and is determined in the model through multiplying for each specialty crop bearing acreage by average yield per acre. Domestic production is supplemented by imports mainly from Mexico and Spain. The model assumes that Florida fresh early tangerines compete with imports of Mexican tangerines and Spanish clementines in the U.S. market. The imposition of a fixed per-unit tariff is included in the model. It is also assumed that they are perfect substitutes and the U.S. consumption of these varieties is driven by the same demand curve.

Simple linear own-price own demand equations are calculated for the fresh utilization of each specialty crop in the U. S. market. Price and quantity effects obtained from the model are assumed to be the average of effects across different market locations within the U.S. market. The processed market is a residual market for the fruit that are damaged or too small to be sold in the fresh market (USDA 2003). A fixed-price model is included for the specialty juice used by the Florida juice processing industry to blend with orange or grapefruit juice for coloring and sweetening. The model allows an endogenous allocation to the fresh and processed market.

The specialty model can be characterized as a spatial equilibrium problem with an implicit supply. Supplies and demand of specialty crops are equated in an optimization problem to generate market-clearing prices for the 2000-2001season. The demand side of the model is delineated by defining:

$$P_v = a_v - b_v Z_v \qquad (5\text{-}21)$$

as the inverse demand for commodity v in the U.S. market. Z_v is the quantity of commodity v consumed in the U. S. market. If the subscript v refers to early tangerines, Z_v includes both domestic production and imports from Spain and Mexico. The parameters a_v and b_v account for the intercept and the slope of the inverse demand equation, respectively, and are both assumed to be non-negative. Consider:

1.	Q_v	Thousand cartons of commodity v sent to packing house
2.	λ_v	Packout rates for commodity v
3.	E_v	Quantity of commodity v eliminated in fresh market and sent to processing market: $E_v = (1-\lambda_v)Q_v$
4.	PR	Processing costs in dollars per sse (Single Strength Equivalent) gallons of juice
5.	PJ	Fixed price of juice produced for blending purposes
6.	JU_v	Quantity of juice of commodity v sold for blending purposes

7.	UJ_v	Juice yield for commodity v in sse gallons per box
8.	TP_v	Total production of commodity v from Florida
9.	PK	Packing costs incurred in Florida
10.	MXEAT	Imports of Mexican tangerines
11.	CLEM	Imports of clementines from Spain
12.	TARS	Per-unit tariff imposed on clementines imported from Spain
13.	TARM	Per-unit tariff imposed on Mexican tangerines

With these definitions, the quadratic programming model can be written as:

$$Max.....\sum_v (a_v Z_v - ½ b_v Z_v^2) + (PJ - PR)\, JU_v - PK_v Q_v -$$
$$(MXEAT - TARM + CLEM * TARS) \qquad (5\text{-}22)$$

$$subject..to$$
$$0.5 Q_v \le TP_v \qquad (5\text{-}23)$$
$$Z_v \le \lambda_v Q_v + MXEAT + CLEM \qquad (5\text{-}24)$$
$$JU_v \le \sum_v UJ_v (1 - \lambda_v) Q_v \qquad (5\text{-}25)$$
$$Q_v, Z_v, JU_v .... \ge 0.... for...all..v \qquad (5\text{-}26)$$

The optimal solution to this quadratic programming model provides the equilibrium FOB prices for each commodity in the U.S. market and the optimal allocation between the fresh and processed markets.

Cost Impact of a Medfly Quarantine Restriction on Florida

The baseline models described above were modified under outbreak scenarios with three-month, six-month, and one-year quarantine periods. A characterization of these scenarios is presented in Table 5-1. Scenario I assumes a three-month quarantine period with a 11% reduction in yields over the area affected. About 30% of total fruit and vegetable production area in Florida is assumed to be marked out within the core area infested. A higher yield reduction (30%) is associated with a six-month quarantine period (Scenario II) and the size of the production area affected is assumed to be 50%. The worst case scenario (Scenario III) is associated with a situation where APHIS has little control over the eradication process. The quarantine period spreads over one year: the entire fruit and vegetable production area is affected with a 50% yield reduction.

Given the seriousness of the Mediterranean fruit fly, the alternative models assume that all shipments of fresh fruits and vegetables from Florida would be subject to a stringent and complex certification process similar to the Caribbean Fruit Fly protocol. Quarantine regulations imposed in the Medfly model are guided by the principles of the systems approach, comprising several complementary measures: intense trapping servicing, field treatment, and postharvest treatments. Trap servicing costs vary with trap density from \$10.8 for the low-prevalence case (three-month quarantine period) to \$72 for the high prevalence case (one-year quarantine period). It is the same for the costs associated with field treatment for the control of the infestation. It is assumed that malathion will be applied once a week during the time the fruit is susceptible to attack. The number of malathion applications is assumed to double in an Medfly endemic situation in Florida.

The Medfly models only incorporate the recurrent costs that are, by definition, incurred annually in the postharvest processes. Compliance treatments used in the models vary from crop to crop, depending on government regulations, the level of quarantine security offered by the treatment, and its efficacy. For those commodities with more than one treatment available, the model uses the least costly treatment. This accounts generally for the treatment that causes the least damage to the commodity. For instance, methyl bromide fumigation schedules are adopted as quarantine treatments for strawberries, cucumbers and watermelons infested with Ceratitis *capitata*. Citrus fruits are cold treated with treatment damage varying from 5% to 15% across commodities (grapefruit, tangerines, tangelo, and oranges).

The Medfly models assumed that vapor heat treatment would be used for the certification of peppers, eggplants, and squash infested with Ceratitis *capitata*. While this treatment has not proven economical in the past (APHIS 1993), our study offered an opportunity of assessing its economic feasibility as a quarantine treatment. Nevertheless, it is assumed that tomato growers would prefer paying the cost of removing and dumping ripe tomatoes from the field rather than the cost of treating them by vapor heat. Tomato fruits would be harvested earlier than usual (i.e., with less color) at the cost of a reduced yield so as to reduce the portion of ripe tomatoes.

Empirical Results

The baseline model for each category of crops was solved using GAMS programming software. The first simulation was made for the 2000-01 crop year under the assumption that Florida is a Medfly-free area. Then, the baseline model was adjusted to reflect decline in yields, increase in preharvest, and postharvest production costs associated with a Medfly outbreak/infestation in Florida. Simulation of Medfly models was made under scenarios of three-month, six-month, and one-year quarantine periods. In particular, the Medfly grapefruit model was also solved under two different options. The first option assumed the best alternative, that is, Florida growers would manage to negotiate with Japan and agree on a Medfly fly-free zone certification protocol. Thus, the Medfly grapefruit model includes the market of Japan. The second option (the Medfly model without the market of Japan) was then solved where domestic supplies were increased to reflect the decrease in export markets. The results of the baseline and Medfly models are outlined in the following sections.

Solutions of the Grapefruit Model under a Medfly Quarantine

The optimal solution to the baseline model provides the equilibrium fresh and processed utilization for each variety (red seedless and white seedless), the equilibrium consumption of fresh grapefruit in both domestic and export markets, and the equilibrium market prices as well. The baseline solution performed reasonably well in replicating the observed pattern of prices and consumption for the 2000/2001 production season. Results of the baseline model (Table 5-2) show variations in the optimal allocation between fresh and processed utilization for the baseline model. While the utilization of red varieties is almost split into half between the fresh and processed markets, approximately 80% of the white grapefruit production goes to the processed market. Roughly 80% and 51% of white seedless and red seedless grapefruit shipments, respectively, are exported (Table 5-3 and 5-4). Exports of white seedless grapefruit to Japan are extremely crucial for Florida growers, accounting for over 70% of the total production. FOB fresh prices for exports to the European Union and Japan markets tend to be higher than domestic prices, underlying the lower pack-out rates for higher quality fresh fruit intended for the export markets. It is the same for FOB prices of fresh red seedless grapefruit, which are higher than FOB prices of white seedless grapefruit.

Option I (with the market of Japan)

We consider first the results of the Medfly model that includes the market of Japan, under the assumption that a phytosanitary protocol is reached between APHIS and Japan for the certification of shipments of fresh citrus. Under the scenario of a three-month quarantine period, average fresh on-tree prices are expected to fall by approximately 2.90% and fresh utilization of red seedless and white seedless varieties is projected to increase by 47,000 and 17,000 boxes, respectively (Table 5-2). These results follow from a reduction in the volume of fruit abandoned (which compensates for the decline in yields).

Processed utilization of red seedless grapefruit is projected to decline by approximately 16,000 boxes, whereas projected processed utilization of white seedless grapefruit increases by 15,000 boxes. Total losses in overall on-tree revenues for white seedless and red seedless grapefruit are estimated at $4 million, with a loss of $3.1 million for red seedless grapefruit and $930,000 for white seedless grapefruit. A portion of the loss in the overall on-tree revenue for white seedless grapefruit is offset by the gain in the processed on-tree revenue for this variety. FOB revenues are projected to decline in both domestic and export markets, with total losses approximating $ 1.0 million and $2.7 million for white seedless and red seedless grapefruit, respectively (Tables 5-3 & 5-4). Fall in FOB prices results in an increase in the marketings of fresh red seedless and white seedless grapefruit in the United States, European Union, and Canada. The situation is different in the market of Japan where the increase in the FOB prices of fresh red seedless and white seedless grapefruit leads to a reduction in the level of consumption.

Patterns of change differ under a six-month quarantine scenario. Average on-tree prices for the fresh market of red seedless and white seedless grapefruit are expected to increase approximately 8% and 68%, respectively. Fresh on-tree revenues for red seedless grapefruit also increase by approximately $3 million, offsetting the reduction in fresh utilization of this variety (Table 5-2). However, fresh on-tree revenues for white seedless grapefruit decline by approximately $10 million, as a result of a significant decline in fresh utilization of this variety.

Average processed on-tree prices of red seedless and white seedless grapefruit are projected to increase approximately 137% and 130%. Processed utilization of both varieties will decline by approximately 97,000 boxes and 3 million boxes respectively. For both, the processed on-tree revenues are expected to increase, offsetting the decline in processed utilization. Overall on-tree revenues of red seedless and white seedless grapefruit are projected to increase by approximately \$23 million and \$3 million, respectively.

World FOB revenues for red seedless and white seedless grapefruit in the six-month quarantine model are expected to experience a reduction of approximately \$3 million and \$33 million, respectively (Tables 5-3 & 5-4). Nevertheless, the impact on FOB revenues will differ across the different markets. In the United States and European Union, the FOB revenues for red seedless and white seedless grapefruit will increase as a result of an increase in FOB prices, which will offset the reduction in the marketings of fresh grapefruit. In Japan, the reduction in the marketings of fresh red seedless and white seedless grapefruit by 523,000 boxes and 3.8 million boxes, respectively, will more than offset the potential gain from the rise in FOB prices. As a result, the FOB revenues for red seedless and white seedless grapefruit are expected to decline 7.5% and 54.8% respectively.

In Canada, FOB revenue for white seedless grapefruit is expected to increase by \$203,000, as a result of a 34-percent increase in FOB price. However, FOB revenues for red seedless grapefruit will experience a reduction by approximately \$1 million: the increase in the marketings of red seedless grapefruit will not offset the loss from the fall in FOB prices.

Results of the one-year quarantine model (Scenario III) give a picture of a general collapse of the Florida grapefruit industry. The marketings of fresh grapefruit are systematically blocked in the United States, European Union and Japan. Only the market of Canada will survive, with significant reduction in total fresh sales of red seedless and white seedless grapefruit by approximately 713,000 boxes and 104,000 boxes, respectively (Table 5-2). FOB prices of red seedless and white seedless grapefruit in this market will rise to $15.78 and $18.78 per carton, respectively (Tables 5-3 & 5-4). World FOB revenues will be drastically reduced.

The significant reduction in fresh utilization will more than offset the potential gain from the rise in average fresh on-tree prices. Fresh on-tree revenues for red seedless and white seedless grapefruit are projected to decline 94% and 99%, respectively, compared to their levels in the baseline model. In the processed market, on-tree revenues for red seedless and white seedless grapefruit will increase 197% and 307%, respectively. Overall on-tree revenue for red seedless grapefruit will decline by approximately $ 80,000, whereas total on-tree revenues for white seedless grapefruit will increase by approximately $ 10,000.

Option II (without the market of Japan)

We now turn to the analysis of the results of the Medfly grapefruit model without the market of Japan (Tables 5-5 to 5-7). Under a three-month quarantine scenario, the pattern of changes in fresh on-tree prices is the same as in the previous case (Medfly model with the market of Japan), but the magnitude of the fall in on-tree prices is bigger in the Medfly model without the market of Japan. An average 40-percent decrease in fresh on-tree prices (Table 5-5) is reported in the Medfly model without the market of Japan, as opposed to a 3-percent decrease in the Medfly model with the market of Japan.

This result reflects the loss of Japanese export markets and a glut on the domestic market. Unlike the previous case, fresh utilization of red and white grapefruit is expected to decline, as a result of a large increase in the volume of fruit abandoned. As a result, fresh on-tree revenues of red seedless and white seedless grapefruit decline 45% and 84%, respectively. Overall on-tree revenues for red seedless and white seedless grapefruit also decrease by approximately $ 23 million and $ 11 million, respectively, in spite of significant gains in processed on-tree revenues.

The direction of the change in FOB prices and revenues for red seedless grapefruit is the same as in the previous case. FOB prices per carton in the United States, Canada, and European Union decrease to $ 7.85, $ 7.62, and $ 8.96, respectively, leading to an increase in the marketings of red seedless grapefruit (Table 5-6). Losses in FOB revenues for this variety are estimated at $ 5.8 million, $ 2.1 million, and $ 2.8 million in the United States, Canada, and European Union, respectively. World revenues for white seedless grapefruit also decline 79%, from $ 80 million to $ 17 million (Table 5-7). However, FOB revenue for white seedless grapefruit in each individual market is projected to increase, as a result of a significant increase in FOB prices, which will more than offset the reduction in fresh utilization.

In the six-month quarantine model (Scenario II), FOB prices of white seedless grapefruit in the United States, Canada, and European Union increase to $ 9.24, $ 8.28, and $ 10.21, respectively, leading to an average 12-percent increase in FOB revenues in comparison with the baseline solution. FOB prices of the red seedless grapefruit also increase in comparison with their low levels in the three-month quarantine model, but still remain below the optimal solution in the baseline model. As a result, FOB revenues for red grapefruit in the United States and Canada decline by approximately by $ 0.5 million and $ 1.9 million, respectively. European Union is the only market where FOB revenue for red seedless grapefruit is not expected to change in spite of the increase in FOB prices.

Fresh on-tree prices per box of red and white seedless grapefruit increase to $ 8.21 and $ 8.46, respectively (Table 5-5), in comparison to the optimal solution in the three-month quarantine model. This increase is not enough to offset the reduction in the marketings of fresh grapefruit. Fresh on-tree revenues for red seedless and white seedless grapefruit decline by approximately $ 38 million and $ 31 million, respectively. In the processed market, average on-tree prices of red seedless and white seedless grapefruit continue to increase by approximately 291% and 272%, respectively, leading to significant gains in the processed on-tree revenues. The overall on-tree revenues of red and white seedless grapefruit are expected to decline by $ 4.3 million and $ 7.1 million, respectively.

Under a one-year quarantine scenario, results of the Medfly model without the market of Japan are identical to those of the Medfly model with the market of Japan. World FOB revenues for red seedless and white seedless grapefruit are expected to decline by approximately $ 223 million and $ 79 million, respectively (Tables 5-6 & 5-7). Only the marketings of fresh grapefruit in Canada will survive, with significant reductions in total fresh sales.

Solutions of the Vegetable Model under a Medfly Quarantine

The baseline solution to this model provides the equilibrium consumption of each commodity in every month in each demand region, the optimal level of shipments from each supply point, the optimal production of each cropping system by production area, and the quantity of each commodity produced in each supply by month. The baseline solution performed reasonably well in replicating the observed pattern of shipments and acres planted for the 2000/2001 season.

Results of the baseline model (Table 5-8) show the distribution of acreage planted by cropping system in each producing area. Acreage planted in Florida is 104,863 acres, accounting for approximately 40% of total acreage planted in all producing areas included in the model. Approximately 35% of total vegetable production is produced in the State of Florida. Florida is the second major producer of tomatoes after Mexico, with a production of 56.5 million cartons (Table 5-9). Florida is the only watermelon producing area in the model and is also the leader in the production of peppers, squash, and eggplants. Results of the Medfly model are outlined in the following sections. The analysis is made on the assumption of an infestation starting in Palm Beach and Southwest (three-month quarantine scenario), then spreading over the West Central and the Dade County (six-month quarantine scenario), and leading to a Medfly endemic situation over the whole State of Florida.

Tomatoes

Under a scenario of a three-month quarantine period in Palm Beach and in Southwest Florida, acreage planted to tomatoes in Florida is expected to increase as a result of a significant increase in the acreage planted in Dade County by 20,452 acres (Table 5-8). Palm Beach County will stop producing commercial quantities of tomatoes and total acreage of tomatoes in all producing areas is also expected to decline. Tomato production in Florida will increase 20% (Table 5-9) and Florida growers will increase their shipping point revenues by approximately $ 100 million (Table 5-10) as a result of an increase in their market share. These results reflect the competitive advantage held by Florida in tomato production, which is due to higher yields per acre and lower marketing costs in all producing areas. Mexican growers will suffer the greatest loss in tomato shipping point revenues with a loss of $52.4 million. The overall tomato production will increase by 0.1%, but average wholesale prices in demand markets will increase approximately 1%, from $8.64 to $8.72 per carton (Table 5-12). Quantities of tomatoes consumed will only decline in the area of Los Angeles (Table 5-11).

A six-month quarantine period is considered a serious blow to tomato production in Florida. Total acreage of tomatoes in Florida is expected to decline by approximately 22,000 acres (Table 5-8), compared to the total acreage in the baseline model. Most of Florida production will concentrate in West Central Florida. Dade County will stop producing commercial quantities of tomatoes and total acreage in the Southwest and Palm Beach will decline by approximately 20,000 acres and 1,000 acres, respectively. As a result, total tomato production in Florida will decline 76% (Table 5-9), and Florida growers will suffer a loss in their shipping point revenues estimated at $293 million (Table 5-10). Alabama will stop producing commercial quantities of tomatoes and Virginia will suffer a loss of $5.7 million in their shipping point revenues. All other producing areas will increase their tomato production and shipping point revenues. Increase in production will be small in California and South Carolina, estimated at 3.2% and 4.9%, respectively (Table 5-9). Mexico will experience the greatest benefit with an expansion of its acreage of tomatoes and an increase in production by 37%. Mexican growers will gain market share and shipping point revenues. Nevertheless, overall tomato production will decrease by 9.1%, leading to an increase in average wholesale prices by

9.2% (Table 5-12). Quantities of tomatoes consumed will decrease in all demand markets.

In a Medfly endemic situation (one-year quarantine period), the economic impacts on Florida tomato production will be much greater. Dade County, Palm Beach and Southwest Florida will stop producing commercial tomatoes. West Central Florida will be the only producing point in Florida with 10,846 acres. Florida growers will lose 90% of their market share and suffer a loss of $377 million in their shipping point revenues. On the contrary, Mexico will increase further its production and market share. The total revenues that Mexican growers receive for tomatoes are expected to increase by $225 million. Nevertheless, average wholesale price is expected to increase by approximately 13% as a result of a significant decline in overall tomato production. The level of tomato consumption in demand markets will decrease by an average 10% (Table 5-11).

Peppers

Under a three-month quarantine scenario, acreage of peppers will increase by 43 acres in West Central Florida, while acreage of peppers in Palm Beach will decline by 1971 acres (Table 5-8). Total production in Florida will decline 16.3% as a result of a reduction in total acreage planted to peppers by 1928 acres. Texas is also expected to decrease acres of peppers from 12,680 acres to 9,962 acres. Mexico will increase acreage by 1908 acres. Overall pepper acreage and production are expected to decline 6.16% and 8.8%, respectively (Table 5-9), while the average wholesale price is projected to increase 5.93%.

The impacts of a six-month quarantine scenario are even bigger for Florida. West Central Florida will stop producing commercial quantities of pepper and Palm Beach will decrease acres of peppers from 7,715 acres to 1,756 acres. As a result, pepper production in Florida will decline 91.8% (Table 5-9) and growers will suffer a loss of $151 million in their shipping point revenues (Table 5-10). Mexico and Texas will increase their production of peppers by 28% and 54%, respectively, and will gain significant market share. Like in the previous case, overall pepper production will decline by approximately 25%, leading to a 12-percent increase in average wholesale price. Quantities of peppers consumed in Atlanta, Los Angeles, Chicago, and New York will decrease 36.1%, 9.4%, 21.9%, and 41.7%, respectively (Table 5-11).

Under a one-year quarantine scenario, commercial production of peppers will be completely blocked in Florida. Texas and Mexico will be the only producing points in the one-year quarantine model. This shift accounts for a loss of $171million in shipping point revenues for Florida, while Texas and Mexico increase their shipping point revenues by $17.4 million and $71.2 million, respectively. Average wholesale price increases 12.8%, leading to an average 23-percent decline in the equilibrium consumption in demand markets.

Cucumbers

Cucumber production in Florida is expected to decline under all scenarios. The rate of decline varies with the temporal dynamics of the pest population, from 31.6% in the three-month quarantine model to 92.6% in the one-year quarantine model. It is the same for the losses in Florida's shipping point revenues, approximating $5 million, $12 million, and $23 million in the three-month, six-month, and one-year quarantine models, respectively. As cucumber production decreases, Mexico gains more market share and shipping point revenues. Shipping point revenues for Mexico increase by $120,000, $990,000 and $4.1 million under scenarios of a three-month, six-month, and one-year quarantine periods, respectively (Table 5-10). Total shipping point revenues in the

Medfly model are expected to decline under all scenarios, as a result of a decline in the quantities of cucumbers consumed in all demand markets. Average wholesale prices increase 5.6% in the one-year quarantine model.

Squash

In the event of a three-month quarantine period in Palm Beach and Southwest Florida, squash production will be completely blocked in Southwest Florida. Double cropping of squash increases in West Central Florida and single cropping increases in Dade County. Total squash acreage in Florida is expected to increase (Table 5-8), but total production will decline 4% (Table 5-9). Loss of squash production in Florida is not offset with increased production in Mexico. Overall squash production in the three-month quarantine model declines 1.94%, leading to a 0.8-percent increase in average wholesale prices (Table 5-12). Equilibrium consumption in demand markets declines by an average 1.8-percent (Table 5-11). Florida growers suffer a loss of $2.9 million in their shipping point revenues, while Mexico increases their shipping point revenues by 1.01 million.

The six-month quarantine will be disastrous for Florida, where squash production will be completed blocked in all producing areas. Mexico is expected to increase squash production from 1518 units to 3335 units. Overall production in the six-month quarantine model declines 43.6%. The average wholesale price increases 9.6%, leading to a reduction in consumption levels by 43.6% in demand markets. Mexico will gain market share and shipping point revenues, while Florida will lose $51 million in shipping point revenues.

Mexico is expected to decrease their acreage from 15,959 acres in the one-year quarantine model to 10,886 acres in the one-year quarantine model. Overall production in the one-year quarantine model increases by 587 units, compared to the optimal solution in the six-month quarantine model. Average wholesale prices per carton decline from $15.17 to $14.90, leading to some improvement in the level of squash consumption in all demand markets.

Eggplants

The impacts are particularly disastrous for Florida. Commercial eggplant production will be completely eliminated in Florida. This accounts for a loss of $56 million for Florida growers. Mexico production increases by approximately 130%, which is largely insufficient to offset the total loss of Florida production. Overall eggplant production will decline 28.6%, leading to an increase in average wholesale price by 7.86%. The level of eggplant consumption in demand markets will decline 71.4%.

Watermelons

Florida is the only watermelon producing area in the model. Watermelon is grown as a second crop following pepper in West Central Florida and tomatoes in Southwest Florida. Acreages of watermelon are expected to decline under all scenarios, as a result of the loss in profitability of the first crop. In the six-month and one-year quarantine models, production of watermelon as a second crop following pepper will be completely eliminated. Furthermore, Southwest Florida will stop producing commercial watermelon in the one-year quarantine model. This shift results in a decline in watermelon production, ranging from 12% in the three-month quarantine model to 58% in the one-year quarantine model. Average wholesale prices are expected to increase 5.9%, 17.3%, and 33.5% in the three-month, six-month, and one-year quarantine models, respectively. Florida growers will lose shipping point revenues as a result of significant reduction in the level of consumption in the demand markets. For instance, in the one-year quarantine model, quantities of watermelons consumed will decline by 57.9%, causing a loss of $22.3 million in shipping point revenues.

Strawberries

Total impacts are not really significant for strawberries under a three-month quarantine scenario. Acreages of strawberry planted in West Central Florida will decrease by 26 acres, while California will increase production acreage by 14 acres. Overall strawberry production in the three-month quarantine model will decline 0.01%, but the average wholesale price remains the same. Neither will there be a change in the level of consumption in the demand markets.

However, commercial strawberry production in Florida will be completely eliminated in the six-month and one-year quarantine models. California is expected to increase production by 20.6%, which is not enough to offset the loss of Florida production. Overall production in these models will decline 2.6%, causing an increase in the average wholesale price by 4.5%. The level of consumption in demand markets will decrease by 1.82%. California will increase their shipping point revenues by $81 million, but Florida will lose $94 million.

Solutions of the Specialty Model under a Medfly Quarantine

Over two thirds of total production of k-early, temples, and tangelos are shipped to the processing plant, with the highest percentage (95%) of processed allocation reported for k-early (Table 5-13). On the contrary, fresh allocation is predominant for early and honey tangerines, accounting for 70% and 57% respectively.

In the event of a three-month quarantine period, utilization of all specialty crops is expected to decline, resulting in an increase in prices. The decline in the fresh utilization will be highly significant for k-early, temples and tangelos, approximating 49%, 81%, and 97%, respectively. Average on-tree prices of these specialty crops will increase by 161%, 408%, and 407%, respectively. Nevertheless, average fresh on-tree prices of early tangerines and honey tangerines are expected to decline 28% and 45%, respectively. In particular, the decline in the average on-tree price of early tangerines is due in part to the competition with imports of early tangerines and clementines from Mexico and Spain, respectively.

Fresh on-tree revenues for temples, tangelos, early tangerines, and honey tangerines are projected to decline by approximately $9000, $363,000, $3.6 million, and $4.4 million, respectively. Regarding the k-early, the increase in the average on-tree price will more than offset the decline in fresh utilization, leading to an increase in fresh on-tree revenue by approximately $5.3 million.

In the processed market, the pattern of change is roughly similar for all specialty crops. Processed on-tree revenues in the three-month quarantine model will decline as a result of a reduction in processed utilization. Average processed on-tree prices of early tangerines and honey tangerines will remain unchanged, but those of tangelos, temples, and k-early will increase by 11%, 5.9%, and 1.2%, respectively. Total on-tree revenues for all specialty crops are expected to decline by approximately $18.5 million.

Revenues for k-early, tangelos, early tangerines, and temples are projected to decline by approximately $ 7.8 million, $5.1 million, $4.5 million, and $1.8 million, respectively (Table 5-14). Price increase for honey tangerines will more than offset the decline in the marketings of this commodity. As a result, projected FOB revenues for honey tangerines will increase by $353,000.

The economic impacts of a six-month quarantine period are even bigger. Marketings of fresh temples and tangelos will completely cease, as total production of these specialty crops is expected to be sent directly to the processing plant. Fresh utilization of k-early, early tangerines, and honey tangerines will decline 80%, 72%, and 15%, respectively (Table 5-13). Fresh on-tree revenues will also decline by approximately $4 million, $4.5 million, and $619,000 respectively, as the decline in fresh utilization offset the increase in fresh on-tree prices. Processed on-tree revenues are expected to decline as a result of the reduction in processed utilization. The projected overall on-tree revenue loss is approximately $67 million, with losses for k-early and early tangerine accounting for $57.8 million and $5.8 million, respectively.

Adjusted FOB revenues for k-early and early tangerines are projected to decline by approximately $41 million and $15 million, respectively, in spite of significant increase in average FOB prices (Table 5-14). Regarding honey tangerine, the increase in prices will more than offset the decline in total fresh sales. As a result, FOB revenue for honey tangerine will increase by $1.25 million.

The results of the one-year quarantine model (Scenario III) give a picture of a general collapse of the specialty citrus industry. Fresh marketings of all specialty crops but honey tangerines will be completely eliminated. The processed market will survive with significant reductions in total processed utilization. Processed revenue losses are estimated at $168 million, with losses for k-early accounting for $162 million. Overall on-tree revenues for all specialty crops will decline by approximately $195 million.

Aggregate Impacts

A Medfly outbreak in Florida is expected to have significant aggregate impacts (Tables 5-15 to 5-17) on producer revenues and consumer surplus. In the event of a three-month quarantine period in Florida, aggregate revenues in the whole fruit and vegetable sector are expected to decline approximately \$9 million or \$39 million (Table 5-15), depending upon whether Florida growers could negotiate a certification protocol for the exports of fresh grapefruit to Japan. Nevertheless, projected shipping point revenues increase \$13.7 million for the Florida vegetable sector (Table 5-16). Vegetable production in all producing areas but Virginia/Maryland is projected to decrease, with production losses in Alabama/Tennessee and South Carolina accounting for 46.6% and 32.6%, respectively (Table 5-17). Shipping point revenues for these vegetable producing areas will decline \$9.5 million and \$23.2 million respectively.

These results follow from the fact that much of the potential revenue loss associated with yield reduction and pre- and postharvest production cost increase will be offset by the rise in average wholesale prices and FOB prices. Consumers' surplus is expected to decline \$237.6 million (in the Medfly model with the market of Japan) or \$343.4 million (in the Medfly model without the market of Japan). Consumers' surplus losses are due to both a decline in the quantities of products consumed and an increase in the prices paid for those products consumed.

Impacts of a six-month quarantine period in Florida are more significant for both consumers and producers. Consumer surplus losses increase to \$821.3 million (Option I) or \$1.25 billion (Option II) as the general price levels for fresh commodities increase and the consumption levels decrease. Florida shippers stand to lose \$705.7 million (Option I) or \$742.2 million (Option II) in shipping point revenues, as a result of severe production losses and significant increases in pre- and postharvest production costs. However, California, Texas, and Mexico are expected to increase their vegetable production by

13.3%, 28.1%, and 41.4%, respectively. In particular, Mexico growers will increase their shipping point revenues by \$ 294.3 million in the vegetable sector. They will also gain additional revenues from increasing their exports of tangerines to the U.S. market.

An endemic Medfly situation (Scenario III) is considered a coup de grace to the whole fresh fruit and vegetable industry in Florida. Vegetable production is expected to decline 91.4%. The grapefruit and specialty citrus industry is unlikely to survive without the fresh market. This scenario will result in a \$ 1.03 billion decline in Florida shipping point revenues. Total consumer surplus loss will amount to \$ 1.75 billion.

Alabama will also stop producing commercial quantities of vegetables and Virginia will suffer some production loss estimated at 8%. However, California, Texas and Mexico will further increase their production, market share, and shipping point revenues. The overall production level will decline, as total fruit and vegetable production loss in Florida from an endemic Medfly situation cannot be completely offset in the short term.

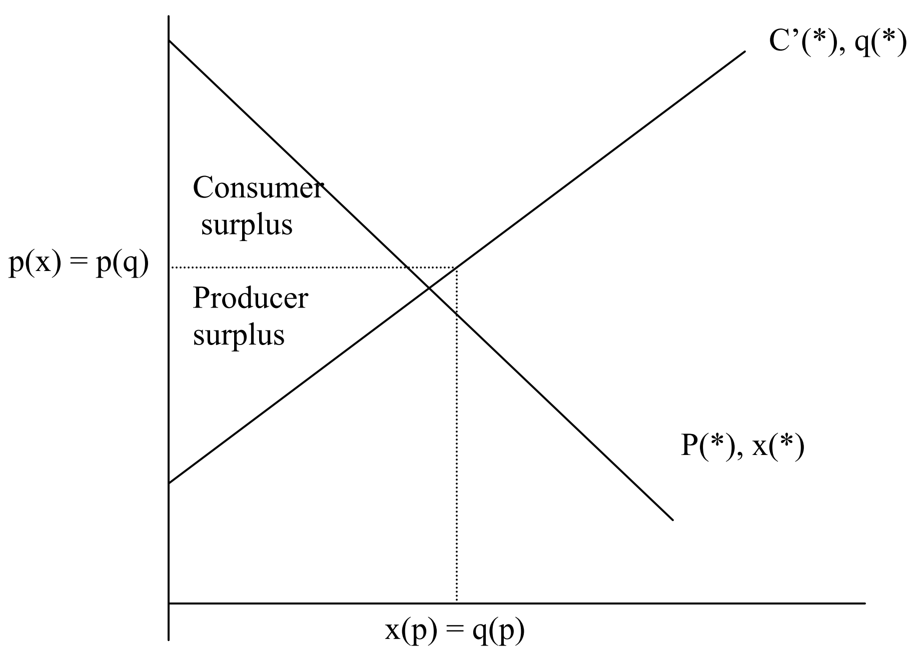

Figure 5.1 Price equilibrium, aggregate demand and supply

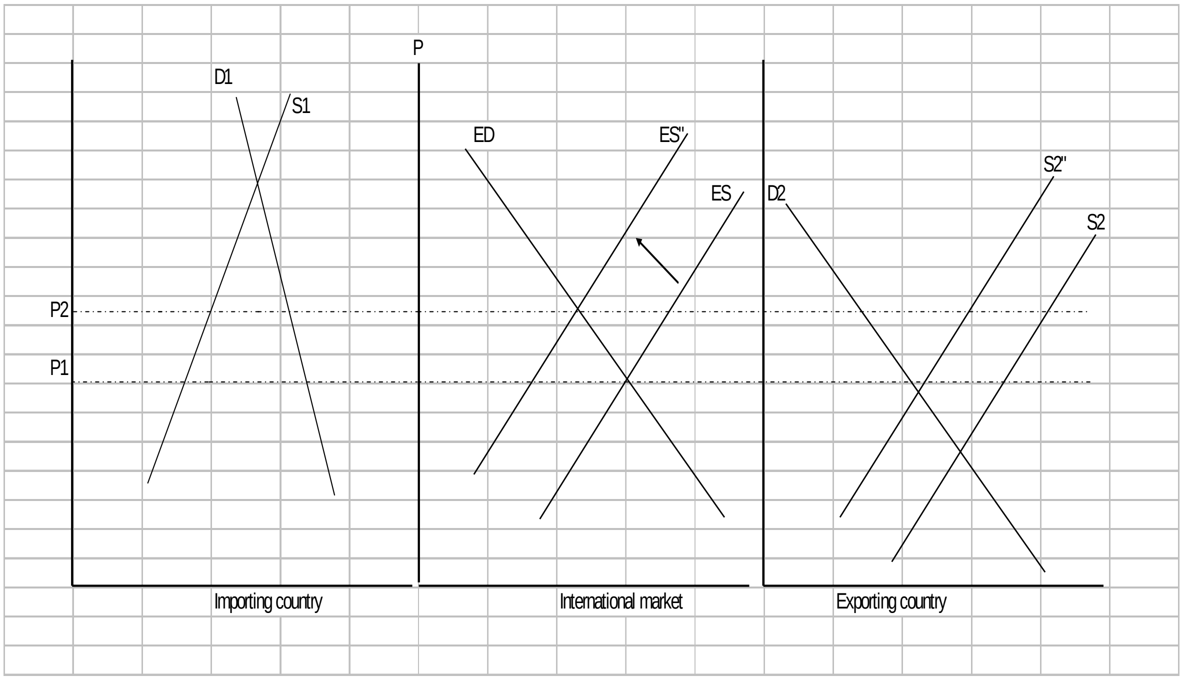

Figure 5-2 Effects of phytosanitary regulations

Table 5.1 Outbreak scenarios and cost implications of a Medfly infestation on the Florida fruit and vegetable industry

	Outbreak Scenarios		
	Scenario I	Scenario II	Scenario III
Characterization			
Quarantine Period	3 months	6 months	One year
Production area Affected	30%	50%	100%
Yield reduction	11%	30%	50%
Quarantine Control		($ per 1,000 cartons)	
Trapping Servicing	10.8	36	72
Field Treatment	560	560	1120
Cold storage Treatments	1900	1900	1900
Transport ripe Tomatoes	4250	4250	4250
		$ / per 1000 kg	
MB fumigation	27	27	27
Vapor heat	200	200	200

Table 5-2 Baseline annual returns of fresh and processed Florida grapefruit for the 2000-01 season and changes in the medfly model including the market of Japan

Grapefruit Variety	Fresh Fruit			Processed Fruit			Total On-tree Revenue
	Utilization	On-tree Price	On-tree Revenue	Utilization	On-tree Price	On-tree Revenue	
	(1,000 boxes)	($ per box)	($ 1,000)	(1,000 boxes)	($ per box)	($ 1,000)	($ 1,000
Baseline Solution							
Red	11,886	10.27	122,069	14,891	0.98	14.593	136,662
White	3,851	10.02	38,587	14,325	1.09	15,614	54,201
Scenario I [a]							
Red	11,933	9.97	118,972	14,875	0.98	14,577	133,549
	(0.4)[d]	(-2.92)	(-2.54)	(-0.10)	(0.00)	(-0.10)	(-2.27)
White	3,868	9.73	37,640	14,340	1.09	15,631	53,271
	(0.4)	(-2.90)	(-2.45)	(0.10)	(0.00)	(-0.10)	(-1.71)
Scenario II [b]							
Red	11,297	11.07	125,103	14,797	2.32	34,314	159,417
	(-4.95)	(7.82)	(2.48)	(-0.63)	(136.63)	(135.14)	(16.65)
White	1,711	16.78	28,717	11,169	2.52	28,112	56,829
	(-55.56)	(67.50)	(-25.57)	(-22.03)	(130.91)	(80.04)	(4.84)
Scenario III [c]							
Red	715	21.58	15,429	6,211	6.97	43,303	58,732
	(-93.98)	(110.11)	(-87.36)	(-58.29)	(611.40)	(196.73)	(-57.02)
White	31	27.55	854	9,058	7.00	63,469	64,323
	(-99.19)	(174.9)	(-97.78)	(-36.76)	(542.84)	(306.48)	(18.67)

[a] Scenario I: three-month quarantine period. [b] Scenario II: six-month quarantine period. [c] Scenario III: one-year quarantine period. [d] The numbers in parentheses refer to percent changes in the parameters; they can be positive or negative.

Table 5-3. Baseline world FOB revenue for red grapefruit for the 2000-01 season and changes in the Medfly model including the market of Japan

	Baseline Solution			Scenario I [a]			Scenario II [b]			Scenario III [c]		
	FOB Price	Fresh Sales	FOB Revenue	FOB Price	Fresh Sales	FOB Revenue	FOB Price	Fresh Sales	FOB Revenue	FOB Price	Fresh Sales	FOB Revenue
	$ per carton	1,000 cartons	$ 1,000	$ per carton	1,000 cartons	$ 1,000	$ per carton	1,000 cartons	$ 1,000	$ per carton	1,000 cartons	$ 1,000
USA	9.22	11,784	108,601	9.03	11,958	107,981	9.73	11,294	109,891	0	0	0
				(-1.98)[d]	(1.47)	(-0.57)	(5.6)	(-4.16)	(1.19)			
Canada	9.22	2,142	19,741	8.81	2,186	19,259	8.44	2,226	18,787	15.78	1,429	22,542
				(-4.4)	(2.05)	(-2.44)	(-8.5)	(3.92)	(-4.83)	(71.2)	(-33.3)	(14.2)
European Union	10.42	6,050	63,605	10.28	6,118	62,893	10.97	5,800	63,626	0	0	0
				(-1.43)	(1.12)	(-0.27)	(5.21)	(-4.13)	(0.88)			
Japan	14.36	3,796	54,526	14.75	3,603	53,114	15.41	3,273	50,436	0	0	0
				(2.7)	(-5.1)	(-2.53)	(7.3)	(-13.8)	(-7.50)			
World FOB Revenue			245,933			243,277			242,740			22,542
						(-1.1)			(-1.3)			(-90.8)

[a] Scenario I: three-month quarantine period. [b] Scenario II: six-month quarantine period. [c] Scenario II: one-year quarantine period. [d] The numbers in parentheses refer to percent changes in the parameters; they can be positive or negative.

Table 5-4 Baseline world FOB revenue for white grapefruit for the 2000-01 season and changes in the Medfly model including the market of Japan

	Baseline Solution			Scenario I [a]			Scenario II [b]			Scenario III [c]		
	FOB Price	Fresh Sales	FOB Revenue	FOB Price	Fresh Sales	FOB Revenue	FOB Price	Fresh Sales	FOB Revenue	FOB Price	Fresh Sales	FOB Revenue
	$ per carton	1,000 cartons	$ 1,000	$ per carton	1,000 cartons	$ 1,000	$ per carton	1,000 cartons	$ 1,000	$ per carton	1,000 cartons	$ 1,000
USA	6.71	1,816	12,189	6,22	1,881	11,700	9.92	1,394	13,828	0	0	0
				(-7.4)[d]	(3.6)	(-4.01)	(47.8)	(-23.2)	(13.44)			
Canada	6.71	166	1,114	6.05	172	1,041	8.96	147	1,317	18.76	62	1,163
				(-9.9)	(3.6)	(-6.6)	(33.5)	(-11.4)	(18.22)	(179.47)	(-62.65)	(4.4)
European Union	7.83	283	2,217	7.32	292	2,137	10.95	227	2,486	0	0	0
				(-6.5)	(3.18)	(-3.6)	(39.8)	(-19.8)	(12.13)			
Japan	11.90	5,437	64,619	11.96	5,390	64,464	17.64	1,654	29,177	0	0	0
				(0.6)	(-0.9)	(-0.24)	(48.43)	(-69.6)	(-54.8)			
World FOB Revenue			80,139			79,342			46,808			1,163
						(-1.0)			(-41.6)			(-98.5)

[a] Scenario I: three-month quarantine period. [b] Scenario II: six-month quarantine period. [c] Scenario II: one-year quarantine period. [d] The numbers in parentheses refer to percent changes in the parameters; they can be positive or negative.

Table 5-5 Baseline annual returns of fresh and processed Florida grapefruit for the 2000-01 season and changes in the Medfly model excluding the market of Japan

Grapefruit Variety	Fresh Fruit			Processed Fruit			Total
	Utilization	On-tree Price	On-tree Revenue	Utilization	On-tree Price	On-tree Revenue	on-tree Revenue
	(1,000 boxes)	($ per box)	($ 1,000)	(1,000 boxes)	($ per box)	($ 1,000)	($ 1,000)
Baseline solution							
Red	11,886	10.27	122,069	14,891	0.98	14,593	136,662
White	3,851	10.02	38,587	14,325	1.09	15,614	54,201
Scenario I [a]							
Red	11,064	6.02	66,605	13,304	3.54	47,096	113,701
	(-6.9)[d]	(-41.38)	(-45.43)	(-10.70)	(261.22)	(222.73)	(16.80)
White	1,041	5.90	6,142	9,739	3.78	36,813	42,955
	(-72.96)	(-41.12)	(-84.1)	(-32.01)	(246.8)	(135.8)	(-20.74)
Scenario II [b]							
Red	10,192	8.21	83,676	12,706	3.83	48,664	132,340
	(-14,25)	(-20.1)	(-31.45)	(-14.70)	(290.8)	(233.47)	(-3.16)
White	939	8.46	7,944	9,670	4.05	39,164	47,108
	(-75.61)	(-15.60)	(-79.41)	(-32.50)	(271.60)	(150.82)	(-13.10)
Scenario III [c]							
Red	715	21.58	15,429	6,211	6.97	43,303	58,732
	(-93.98)	(110.11)	(-87.36)	(-58.29)	(611.40)	(196.73)	(-57.02)
White	31	27.55	854	9,058	7.00	63,469	64,323
	(-99.19)	(174.9)	(-97.78)	(-36.76)	(542.84)	(306.48)	(18.67)

a Scenario I: three-month quarantine period. b Scenario II: six-month quarantine period. c Scenario III: one-year quarantine period. d The numbers in parentheses refer to percent changes in the parameters; they can be positive or negative.

Table 5-6 Baseline world FOB revenue for red grapefruit for the 2000-01 season and changes in the Medfly model excluding the market of Japan

	Baseline Solution			Scenario I [a]			Scenario II [b]			Scenario III [c]		
	FOB Price	Fresh Sales	FOB Revenue	FOB Price	Fresh Sales	FOB Revenue	FOB Price	Fresh Sales	FOB Revenue	FOB Price	Fresh Sales	FOB Revenue
	($ per carton)	(1,000 cartons)	($1,000)	($ per carton)	(1,000 cartons)	($1,000)	($ per carton)	(1,000 cartons)	($1,000)	($ per carton)	(1,000 cartons)	($1,000)
USA	9.22	11,784	108,601	7.85 (-14.9)[d]	13,087 (11.10)	102,733 (-5.4)	9.05 (-1.8)	11,942 (1.34)	108,075 (-0.48)			
Canada	9.22	2,142	19,741	7.62 (-17.35)	2,315 (8.10)	17,640 (-10.64)	7.75 (-15.95)	2,300 (7.37)	17,825 (-9.70)	15.78 (71.2)	1,429 (-33.3)	22,542 (14.2)
European Union	10.42	6,050	63,065	8.96 (-14.01)	6,726 (11.17)	60,265 (-4.44)	10.27 (-1.43)	6,141 (-1.5)	63,068 (0.00)			
Japan	14.36	3,796	54,526									
World FOB revenue			245,933			180,638 (-26.55)			188,968 (-23.2)			22,542 (-90.8)

[a] Scenario I: three-month quarantine period. [b] Scenario II: six-month quarantine period. [c] Scenario II: one-year quarantine period. [d] The numbers in parentheses refer to percent changes in the parameters; they can be positive or negative.

Table 5-7 Baseline world FOB revenue for white grapefruit for the 2000-01 season and changes in the Medfly model excluding the market of Japan

	Baseline Solution			Scenario I [a]			Scenario II [b]			Scenario III [c]		
	FOB Price	Fresh Sales	FOB Revenue	FOB Price	Fresh Sales	FOB Revenue	FOB Price	Fresh Sales	FOB Revenue	FOB Price	Fresh Sales	FOB Revenue
	($ per carton)	(1,000 cartons)	($1,000)	($ per carton)	(1,000 cartons)	($1,000)	($ per carton)	(1,000 cartons)	($1,000)	($ per carton)	(1,000 cartons)	($1,000)
USA	6.71	1,816	12,189	7.88 (17.43)[d]	1,662 (-8.48)	13,097 (7.45)	9.24 (37.7)	1,484 (-18.28)	13,712 (12.50)			
Canada	6.71	166	1,114	7.71 (14.9)	157 (-5.42)	1,210 (8.62)	8.28 (23.4)	153 (-7.8)	1,267 (13.73)	18.76 (179.47)	62 (-62.65)	1,163 (4.4)
European Union	7.83	283	2,217	8.96 (14.4)	263 (-7.06)	2,356 (6.27)	10.21 (30.4)	240 (-15.2)	2,450 (10.5)			
Japan	11.90	5,437	64,619									
World FOB Revenue			80,139			16,663 (-79.2)			17,429 (-78.25)			1,163 (-98.5)

[a] Scenario I: three-month quarantine period. [b] Scenario II: six-month quarantine period. [c] Scenario II: one-year quarantine period. [d] The numbers in parentheses refer to percent changes in the parameters; they can be positive or negative.

Table 5-8 Planted acreage in the baseline and Medfly models by crop and area

Crop / Area		Acreage (acres)			
		Baseline	Scenario I [a]	Scenario II [b]	Scenario III [c]
Tomato					
Florida	Dade	4,408	24,860	0	0
	Palm Beach	2,798	0	1,653	0
	West Central	11,077	6,211	14,230	10,846
	Southwest	20,975	16,425	1,006	0
California		36,408	35,729	37,583	37,252
Alabama / Tennessee		3,448	1,842	0	0
South Carolina		6,923	4,665	7,266	6,960
Virginia / Maryland		6,282	7,758	5,449	5,781
Mexico	Sinaloa	34,951	29,298	49,265	53,185
	Baja	5,369	6,556	5,972	5,732
Total		132,639	133,344	122,424	119,756
Bell Peppers					
Florida	Palm Beach	7,175	5,204	1,756	0
	West Central	10,997	11,040	0	0
	South west	0	0	360	0
Texas		12,680	9,962	16,249	16,445
Mexico	Sinaloa	13,600	15,508	20,917	23,058
Total		44,452	41,714	39,282	39,503
Cucumbers					
Florida	Palm Beach	6,693	5,204	3,409	0
	West Central	0	0	0	705
Mexico	Sinaloa	10,076	10,095	10,231	10,724
Total		16,769	15,299	13,640	11,429
Squash					
Florida	Dade	8,081	9,369	0	5,408
	Southwest	3,637	0	0	0
	West Central	0	2,493	0	0
Mexico	Sinaloa	7,265	7,650	15,959	10,886
Total		18,983	19,512	15,959	16,294
Eggplants					
Florida	Palm Beach	5,327	0	0	0
Mexico	Sinaloa	2,734	6,294	6,294	6,294
Total		8,060	6,294	6,924	6,294
Watermelons					
Florida	West Central	1,812	1,630	14,230	10,140
	Southwest	17,338	16,425	1,006	0
Total		19,150	18,055	15,236	10,140
Strawberries					
Florida	West Central	4,545	4,519	0	0
California	South	10,518	10,543	14,470	14,470
	North	9,217	9,206	8,029	8,029
Total		24,280	24,268	22,499	22,499

[a] Scenario I: three-month quarantine period. [b] Scenario II: six-month quarantine period. [c] Scenario III: one-year quarantine period.

Table 5-9 Baseline production for the 2000-01 season and percentage changes in production in the Medfly model by crop and area

Crop / Area	Production			
	Baseline	Scenario I [a]	Scenario II [b]	Scenario III [c]
Tomato	(Units)	(	% changes	)
Florida	56,506	20.0	(75.9)[d]	(91.6)
California	39,321	(1.9)	3.2	2.3
Virginia / Maryland	4,272	23.5	(13.3)	(8.0)
South Carolina	6,853	(32.6)	5.0	0.55
Alabama / Tennessee	2,138	(46.6)	(100.0)	(100.0)
United States	109,090	7.7	(40.3)	(49.8)
Mexico	73,786	(11.1)	37.0	46.1
Total	182,876	0.1	(9.1)	(10.5)
Bell Peppers				
Florida	18,172	(16.3)	(91.8)	(100.0)
Texas	7,735	(21.4)	28.1	29.7
United States	25,907	(17.9)	(56.0)	(61.3)
Mexico	10,282	14.0	53.8	69.5
Total	36,189	(8.8)	(24.8)	(24.1)
Cucumbers				
Florida	4,016	(31.6)	(58.2)	(92.6)
Mexico	5,572	0.2	1.5	6.4
Total	9,588	(13.1)	(23.5)	(35.1)
Squash				
Florida	4,395	(4.5)	(100.0)	(62.5)
Mexico	1,518	5.3	119.7	49.8
Total	5,913	(1.9)	(43.6)	(33.7)
Eggplants				
Florida	7,457	(100.0)	(100.0)	(100.0)
Mexico	3,352	130.2	130.2	130.2
Total	10,809	(28.6)	(28.6)	(28.6)
Watermelons				
Florida	6,475	(12.1)	(31.7)	(57.9)
Strawberries				
Florida	12,725	(0.6)	(100.0)	(100.0)
California	53,354	0.1	20.6	20.6
Total	66,069	(0.01)	(2.6)	(2.6)

[a] Scenario I: three-month quarantine period. [b] Scenario II: six-month quarantine period. [c] Scenario III: one-year quarantine period. [d] The numbers in parentheses refer to negative percent changes.

Table 5-10 Baseline revenue for the 2000-01 season and changes in revenues in the Medfly model by crop and area

Crop / Area	Revenues ($)			
	Baseline	Scenario I [a]	Scenario II [b]	Scenario III [c]
Tomato		(	changes in revenues	)
Florida	448,227,870	99,845,370	(292,344,865)[d]	(376,920,890)
California	286,004,000	(5,335,300)	9,228,300	6,628,900
Virginia / Maryland	42,736,960	10,039,420	(5,666,830)	(3,412,580)
South Carolina	71,270,170	(23,244,210)	3,528,690	385,930
Alabama / Tennessee	20,477,170	(9,540,260)	(20,477,170)	(20,477,170)
United States	868,716,950	71,764,240	(305,732,655)	(393,796,590)
Mexico	496,178,430	(52,445,250)	181,606,640	225,859,660
Total	1,364,895,380	19,318,990	(124,126,015)	(167,936,930)
Bell Peppers				
Florida	171,026,490	(18,248,230)	(150,679,366)	(171,026,490)
Texas	58,828,370	(12,608,780)	16,556,590	17,469,280
United States	229,854,860	(30,857,010)	(134,122,776)	(153,557,210)
Mexico	102,449,600	14,372,700	55,118,400	71,243,500
Total	332,304,460	(16,484,310)	(79,004,376)	(82,313,710)
Cucumbers				
Florida	26,579,760	(4,770,520)	(11,132,500)	(23,121,807)
Mexico	64,228,410	120,240	987,010	4,133,530
Total	90,808,170	(4,650,280)	(10,145,490)	(18,988,277)
Squash				
Florida	51,107,510	(2,797,163)	(51,107,510)	(29,234,740)
Mexico	19,105,090	1,012,360	22,862,580	9,523,530
Total	70,212,600	(1,784,803)	(28,244,930)	(19,711,210)
Eggplants				
Florida	56,568,750	(56,568,750)	(56,568,750)	(56,568,750)
Mexico	25,895,360	33,727,530	33,727,530	33,727,530
Total	82,464,110	(22,841,220)	(22,841,220)	(22,841,220)
Watermelons				
Florida	65,883,680	(3,321,801)	(8,497,300)	(22,345,670)
Strawberries				
Florida	93,912,080	(431,710)	(93,912,080)	(93,912,710)
California	466,867,600	450,500	80,500,700	80,500,700
Total	560,779,680	18,790	(13,411,380)	(13,411,380)

[a] Scenario I: three-month quarantine period. [b] Scenario II: six-month quarantine period. [c] Scenario III: one-year quarantine period. [d] The numbers in parentheses refer to negative changes in revenues.

Table 5-11 Baseline demand for the 2000-01 season and percentage changes in demand in the Medfly model by crop and market

Crop /.Demand Areas	Demand			
	Baseline	Scenario I [a]	Scenario II [b]	Scenario III [c]
	($ / Unit)	(	% changes	)
Tomatoes				
Atlanta	41,080	0.6	(9.2)	(9.7)
Los Angeles	33,871	(0.8)	(5.5)	(5.8)
Chicago	38,744	(0.14)	(10.7)	(11.8)
New York	66,763	(0.06)	(10.6)	(13.2)
Bell Peppers				
Atlanta	9,955	(7.8)	(36.1)	(20.5)
Los Angeles	5,529	(2.4)	(9.4)	(7.9)
Chicago	11,399	(7.1)	(21.9)	(21.3)
New York	9,305	(15.8)	(41.7)	(41.1)
Cucumbers				
Atlanta	2,077	(20.4)	(36.3)	(50.9)
Los Angeles	1,988	(1.70)	(7.0)	(12.8)
Chicago	2,943	(14.7)	(22.3)	(28.2)
New York	2,580	(14.2)	(27.4)	(47.3)
Squash				
Atlanta	1,808	(2.1)	(61.3)	(38.2)
Los Angeles	1,690	(1.5)	(1.4)	(0.9)
Chicago	1,686	(2.3)	(48.0)	(42.1)
New York	728	(1.8)	(93.3)	(82.9)
Eggplants				
Atlanta	1,673	(67.2)	(67.2)	(67.2)
Los Angeles	2,991	(5.5)	(5.5)	(5.5)
Chicago	3,983	(19.1)	(19.1)	(19.1)
New York	2,162	(48.2)	(48.2)	(48.2)
Watermelons				
Atlanta	468	(68.6)	(100)	(100)
Los Angeles	1,348	(7.2)	(24.7)	(51.2)
Chicago	1,484	(13.3)	(45.8)	(95.0)
New York	3,174	(5.2)	(17.9)	(37.1)
Strawberries				
Atlanta	11,088	(0.0)	(3.0)	(3.0)
Los Angeles	16,215	(0.0)	(0.7)	(0.7)
Chicago	17,554	(0.0)	(1.6)	(1.6)
New York	20,649	(0.0)	(2.0)	(2.0)

[a] Scenario I: three-month quarantine period. [b] Scenario II: six-month quarantine period. [c] Scenario III: one-year quarantine period. [d] The numbers in parentheses refer to negative percent changes in demand.

Table 5-12 Baseline average prices for the 2000-01 season and percentage changes in prices in the Medfly model by crop

Crop	Average Price			
	Baseline	Scenario I [a]	Scenario II [b]	Scenario III [c]
	($ / Unit)	(	% changes	)
Tomatoes	8.64	0.92	9.72	13.42
Bell Peppers	10.28	5.93	12.54	12.84
Cucumbers	13.21	2.20	3.93	5.60
Squash	13.91	0.80	9.06	7.11
Eggplants	8.55	7.86	7.86	7.86
Watermelons	13.84	5.85	17.27	33.53
Strawberries	11.77	0.00	4.50	4.50

[a] Scenario I: three-month quarantine period. [b] Scenario II: six-month quarantine period. [c] Scenario III: one-year quarantine period.

Table 5-13.Baseline annual returns of fresh and processed specialty citrus for the 2000-01 season and changes in the Medfly model

Specialty crops	Fresh Fruit			Processed Fruit			Total on-tree Revenue
	Utilization	On-tree Price	On-tree Revenue	Utilization	On-tree Price	On-tree Revenue	
	(1,000 boxes)	($ per box)	($ 1,000)	(1,000 boxes)	($ per box)	($ 1,000)	($ 1,000)
Baseline solution							
K-Early	6,405	2,47	15,820	121,686	2.58	313,950	329,770
Temples	287	0.74	212	865	2.53	2,188	2,400
Early Tangerines	2,480	2.64	6,547	1,063	1.83	1,945	8,492
Honey Tangerines	1,165	8.12	9,460	883	2.28	2,013	11,473
Tangelos	563	0.74	416	1,234	2.46	3,036	3,452
Scenario I [a]							
K-Early	3,269 (-49)[d]	6.45 (161)	(21,085 (33.3)	115,092 (-5.4)	2,61 (1.2)	300,390 (-4.3)	321,475 (-2.5)
Temples	54 (-81)	3.76 (408)	203 (-4.2)	689 (-20.3)	2.68 (5.9)	1,847 (-15.6)	2,050 (-14.6)
Early Tangerines	1,571 (-36.7)	1.90 (-28)	2,985 (-54)	673 (-36.7)	1.83 (0.0)	1,232 (-36.7)	4,217 (-50.3)
Honey Tangerines	1,130 (-3)	4.46 (-45)	5,040 (-46.7)	856 (-3)	2.28 (0.0)	1,952 (-3)	6,992 (-39)
Tangelos	14 (-97)	3.75 (407)	53 (-87.3)	843 (-31.7)	2.73 (11)	2,301 (-24)	2,354 (-32)

Table 5-13 Continued

Specialty crops	Fresh Fruit			Processed Fruit			Total
	Utilization	On-tree Price	On-tree Revenue	Utilization	On-tree Price	On-tree Revenue	on-tree Revenue
	(1,000 boxes)	($ per box)	($ 1,000)	(1,000 boxes)	($ per box)	($ 1,000)	($ 1,000)
Scenario II [b]							
K-Early	1,269	9.35	11,865	99,258	2.62	260,056	271,921
	(-80)	(279)	(-25)	(-18.4)	(1.6)	(-17.2)	(-17.54)
Temples	0	0	0	573	2.73	1,564	1,564
	(-100)	(-100)	(-100)	(-33.8)	(7.9)	(-28.5)	(-34.8)
Early	705	2.98	2,101	302	1.83	553	2,654
Tangerines	(-71.6)	(12.9)	(-67.9)	(-71.6)	(0.0)	(-71.6)	(-68.7)
Honey	990	8.93	8,841	750	2.28	1,710	10,551
Tangerines	(-15)	(9.9)	(-6.5)	(-15.1)	(0.0)	(-15.1)	(-8.0)
Tangelos	0	0	0	731	2.74	2,003	2,004
	(-100.0)	(-100.0	(-100.0)	(-40.7)	(11.4)	(-34)	(-42)
Scenario III [c]							
K-Early	0	0	0	57,641	2.63	151,596	151,596
	(-100)	(-100.0)	(-100.0)	(-52.6)	(1.9)	(-51.7)	(-54)
Temples	0	0	0	337	2.73	920	920
	(-100)	(-100.0)	(-100.0)	(-61)	(7.9)	(-58)	(-61.7)
Early	0	0	0	0	0	0	0
Tangerines	(-100)	(-100.0)	(-100.0)	(-100)	(-100.0)	(-100.0)	(-100)
Honey	582	25.32	14,736	441	2.28	1,005	15,741
Tangerines	(-50)	(212)	(-55.7)	(-50)	(0.0)	(-50)	(-37.2)
Tangelos	0	0	0	430	2.74	1,178	1,178
	(-100)	(-100.0)	(-100.0)	(-65.1)	(11.4)	(-61.2)	(-65.9)

[a] Scenario I: three-month quarantine period. [b] Scenario II: six-month quarantine period. [c] Scenario III: one-year quarantine period. [d] The numbers in parentheses refer to percent changes in the parameters; they can be positive or negative.

Table 5-14.Baseline FOB revenues for specialty citrus for the 2000-01 season and changes in the Medfly model

	Baseline Solution			Scenario I [a]			Scenario II [b]			Scenario III [c]		
	FOB Price	Fresh Sales	FOB Revenue	FOB Price	Fresh Sales	FOB Revenue	FOB Price	Fresh Sales	FOB Revenue	FOB Price	Fresh Sales	FOB Revenue
	($ per carton)	(1,000 cartons)	($1,000)	($ per carton)	(1,000 cartons)	($1,000)	($ per carton)	(1,000 cartons)	($1,000)	($ per carton)	(1,000 cartons)	($1,000)
K-Early	5.67	12,809	72,627	9.91	6,537	64,782	12.62	2,537	32,017	0	0	0
				(74.8)	(-49)	(-10.8)	(123.5)	(-80.2)	(-55.9)	(-100)	(-100.0)	(-100.0)
Temples	4.80	573	2,750	8.56	108	924	0	0	0	0	0	0
				(78.3)	(-81.2)	(-66.4)	(-100)	(-100.0)	(-100.0)	(-100)	(-100.0)	(-100.0)
Early	5.75	4,959	28,514	7.63	3,142	23,973	9.44	1,410	13,310	0	0	0
Tangerines				(32.7)	(-36.6)	(-15.9)	(64.2)	(-71.6)	(-53.3)	(-100)	(-100.0)	(-100.0)
Honey	8.50	2,329	19,797	8.92	2,259	20,150	10.63	1,980	21,047	15.63	1,165	18,209
Tangerines				(4.9)	(-3.0)	(1.8)	(25.1)	(-15.0)	(6.3)	(83.8)	(-99.91)	(-8.02)
Tangelos	4.80	1,126	5,405	8.56	28	240	0	0	0	0	0	0
				(78.3)	(-97.5)	(-95.6)	(-100)	(-100.0)	(-100.0)	(-100)	(-100.0)	(-100.0)

[a] Scenario I: three-month quarantine period. [b] Scenario II: six-month quarantine period. [c] Scenario II: one-year quarantine period. [d] The numbers in parentheses refer to percent changes in the parameters; they can be positive or negative.

Table 5-15 Aggregate impacts of a Medfly outbreak in Florida with scenarios of three-month, six-month, and one-year quarantine periods

	Aggregate Impacts ($)			
	Consumer Surplus Loss		Revenue Loss	
	Option 1 [d]	Option 2 [e]	Option 1	Option 2
Scenario I [a]	237,672,602	343,475,606	8,834,760	38,998,760
Scenario II [b]	821,344,300	1,248,580,549	705,753,280	742,181,280
Scenario III [c]	1,748,625,935	1,748,625,935	1,027,090,400	1,027,090,400

[a] Scenario I: three-month quarantine period. [b] Scenario II: six-month quarantine period. [c]Scenario II: one-year quarantine period. [d] Option 1: Medfly model with the export market of Japan. [e] Option 2: Medfly model without the export market of Japan.

Table 5-16.Baseline production and percentage changes in crop production in the Medfly model by area

Areas	Production			
	Baseline	Scenario I [a]	Scenario II [b]	Scenario III [c]
	(Unit)	(	% changes	)
Florida	109,746	(1.3)[d]	(80.7)	(91.4)
California	92,674	(0.7)	13.3	12.9
Texas	7,735	(21.4)	28.1	29.7
Virginia/Maryland	4,272	23.5	(13.2)	(8.0)
South Carolina	6,854	(32.6)	4.9	(0.5)
Alabama/Tennessee	2,139	(46.6)	(100.0)	(100.0)
United States	223,420	(2.7)	(34.2)	(39.6)
Mexico	94,509	(2.4)	41.4	49.4
Total	317,929	(2.6)	(11.8)	(13.2)

[a] Scenario I: three-month quarantine period. [b] Scenario II: six-month quarantine period. [c]Scenario II: one-year quarantine period. [d] The numbers in parentheses indicate negative changes in production.

Table 5-17 Baseline revenues by area for the 2000-01 season and changes in revenue in the Medfly model

Areas		Change in revenue ($1,000)		
	Baseline ($1,000)	Scenario I [a]	Scenario II [b]	Scenario III [c]
Florida	913,306,070	13,707,240	(664,242,280)[d]	(773,130,400)
California	752,871,600	(4,884,800)	89,729,000	87,129,500
Texas	58,828,370	(12,608,780)	16,556,590	17,469,280
Virginia/Maryland	42,736,960	10,039,420	(5,666,830)	(3,412,580)
South Carolina	71,270,950	(23,244,990)	3,527,910	385,150
Alabama/Tennessee	20,477,170	(9,540,260)	(20,477,170)	(20,477,170)
United States	1,859,491,120	(26,532,170)	(580,572,780)	(692,036,220)
Mexico	707,856,930	(3,212,550)	294,302,140	344,487,660
Total	2,567,348,050	(29,744,720)	(286,270,640)	(347,548,560)

[a] Scenario I: three-month quarantine period. [b] Scenario II: six-month quarantine period. [c]Scenario II: one-year quarantine period. [d] The numbers in parentheses indicate negative changes in revenue

CHAPTER 6
POLICY RECOMMENDATIONS AND CONCLUSIONS

Areas for Alternative Policy Measures

Assessing the level of Medfly Risk in Florida

Table 6-1 provides an estimate of the level of Medfly risk in Florida, which is defined as the cumulative expected value of the consequences associated with a Medfly outbreak and/or infestation in Florida. As stated in Chapter 3, Medfly risk encompasses two major cost components: prevention and eradication expenditures and producer revenue losses. Expected value of Medfly prevention and eradication expenditures varies across locations and seasons. An October infestation in Tampa accounts for the lowest risk case scenario, while the June infestation in this same location stands for the highest risk case scenario with an expected cost approximating $ 4 million. Whereas the summer months are considered the highest risk period for an infestation in Florida, the risk-related costs associated with producer revenue losses are very likely to be insignificant, because very few shipments of fresh commodities occur in summer.

Expected revenue losses shown in the below part of Table 6-1 vary with the duration of the quarantine period. The three-month, six-month, and one-year quarantine scenarios are associated with 77-day, 98-day, and 119-day old infestation, respectively. Expected revenue losses for Option I (including the market of Japan) are $ 39,612, $ 80,240, and $ 655,918 for a three-month, six-month, and one-year quarantine period respectively. The expected revenue losses for Option 2 are higher than those for Option I, reflecting the importance of Japanese export markets for the survival of the Florida grapefruit industry. These results suggest the need for Florida growers to negotiate with Japan and agree on a Medfly fly-free zone certification protocol.

It is noteworthy to recall here that the SPS Agreement encourages a myopic focus on risk-related costs of import protocols and eradication expenditures. Consideration of producer revenue losses in the definition of the Acceptable Level Risk (ALR) is likely to be seen as a violation of the spirit of the SPS Agreement. Our research findings show that the producer revenue losses cannot be ignored, because any Medfly infestation in Florida will further undermine the competitive position of Florida growers in the world's sectors of fresh commodities. The probabilities of a Medfly endemic situation in Florida are low, but the consequences of such an event are very high, threatening the survival of the production of fresh commodities in Florida. This issue emphasizes the debate regarding the incongruence of the SPS Agreement with the cost-benefit-analysis approach advocated by the U.S. Executive Branch directives.

Assessing the effects of entry conditions on the level of risk

Table 6-2 gives a summary of the effects of entry conditions on the level of Medfly risk in Florida. These effects are the same on both expected costs of prevention and eradication and producer revenue losses. One-percent increase in the average number of bugs present per infested unit leads to approximately 0.42-percent increase in the level of Medfly risk. On the other hand, the ratio of change between the level of risk and the number of passengers (N) or the level of infestation (p) is roughly 1:1: one-percent increase in N or p will result in one-percent increase in the level of risk. Therefore, the increasing number of international passengers entering Florida can be considered the driving parameter that will impact on the likelihood of a Medfly introduction and establishment in Florida.

Our study also investigated the relationships between the parameters N and p. As the number of international passengers, N, tends to increase over time, APHIS managers are expected to increase the staffing level at the inspection points with a view to reducing the level of infestation, p, and, at least, keeping constant the level of Medfly risk in Florida. When N increases by 5%, 4.45 additional staff years are needed to keep constant the level of Medfly risk in Florida. The level of infestation, p, will be reduced by 4.76% and the passenger baggage clearance costs to achieve this target are estimated at $ 213,274. By the same token, the projected additional clearance cost is $ 426,563, when N increases by 10%. These results suggest that APHIS would have to maintain significant increases in inspection technologies and staffing to keep pace with a continuous and increasing movement of potentially infested host material.

Improving the single trap sensitivity

Table 6-4 presents a summary of the potential gains of a technological change in the trap design. Improving the attractiveness of female attractants in the field would contribute to increase the single trap sensitivity (ψ) and reduce the optimal trapping density. When, for instance, the single trap sensitivity doubles, the probability of detecting low populations will increase by 201.66% and the optimal trap density will decrease by 50.19%. Another important finding is that the rate of change in the probability of detection increases as the single trap sensitivity increases. When ψ is multiplied by 5, the probability of detection will increase by more than ten times, leading to a reduction in the optimal trapping density by approximately 80%.

Improving the pesticide efficacy

Another important area of concern is to check on the effect of pesticide efficacy on the level of risk. The computations of the multiple trap sensitivities, probabilities of detection, and optimal trap densities in Chapter 4 are made under the assumption of 90-percent pesticide efficacy, meaning that 90% of pests are killed during each spraying operation. Figure 6-2 shows the shifting out of the curve of the eradication cost function with an increase in pesticide efficacy, indicating a decline in total eradication cost. Nevertheless, a decline in the pesticide efficacy will lead to a higher eradication cost and, in some circumstances, to higher probability of Medfly establishment in Florida.

Table 6-5 shows the impact of a change in pesticide efficacy on the level of Medfly risk in Florida. When the pesticide efficacy decreases from 90% to 80%, the level of Medfly risk in Tampa (October) increases by 23.31%. The rate of change in the level of Medfly risk varies across locations and seasons. With the same 80-percent pesticide efficacy, the level of Medfly risk increases by 28.13% and 22.33% in Tampa during the months of June and February, respectively. Furthermore, the lower the pesticide efficacy, the higher will be the level of Medfly risk. When the pesticide efficacy drops to 70%, for instance, the level of risk in Tampa during the months of June and February will increase by 61.25% and 40.91%, respectively.

Summary and Conclusions

The overall objective of this study was to analyze the cost implications of a Medfly outbreak and/or infestation for APHIS and the State of Florida in general, and for Florida producers and consumers in particular. In Chapter 2, we reviewed literature on Medfly introductions and infestations in Florida. In Chapter 3, we discussed the issues regarding the application of Sanitary and Phytosanitay (SPS) Agreement and the major rules and quarantine regulations that affect the fruit and vegetable sector in the event of a Medfly outbreak in Florida. In Chapter 4, we developed a Bayesian modeling framework to examine the trade-off between early and late detection in terms of expected costs of APHIS's prevention, detection, and eradication program. Finally, the results of welfare models are presented in Chapter 5.

Our Bayesian modeling framework provides support for the hypothesis that there exists an optimal trapping density that varies across locations and seasons. Because the computed values of probability of detection of low Medfly populations are very low, the corresponding optimal trapping densities are very high, ranging from 82 to 465 traps per ha for ML traps and from 9 to 80 traps for TML traps. It would be infeasible and extremely costly to maintain such high trap densities over a wide area. Alternative solutions lie in the search for an increase in pesticide efficacy and an improvement of the performance of the trapping system. Potential gains from improving the trap technology would include increasing the sensitivity of the trapping system in detecting small populations of C. *capitata* and lowering optimal trap densities. Emphasis should be placed on developing potent synthetic attractants for female C. *capitata*. Such a development will provide a new dimension to the detection survey.

Our spatial equilibrium models provide estimates of potential welfare changes from a Medfly infestation under scenarios of three-month, six-month, and one-year quarantine periods. A Medfly outbreak in Florida is expected to have significant aggregate impacts on producer revenues and consumer surplus. In the event of a three-month quarantine period in Florida (Scenario I), aggregate revenues in the whole fruit and vegetable sector are expected to decline approximately $9 million or $39 million, depending upon whether

Florida growers could negotiate a certification protocol for the exports of fresh grapefruit to Japan. Consumers' surplus is expected to decline \$237.6 million (in the Medfly model with the market of Japan – Option I) or \$343.4 million (in the Medfly model without the market of Japan – Option II).

Impacts of a six-month quarantine period (Scenario II) in Florida are more significant for both consumers and producers. Consumer surplus losses increase to \$821.3 million (Option I) or \$1.25 billion (Option II), while Florida shippers stand to lose \$705.7 million (Option I) or \$742.2 million (Option II) in shipping point revenues, as a result of severe production losses and significant increases in pre- and postharvest production costs. An endemic Medfly situation (Scenario III) is considered a coup de grace to the whole fresh fruit and vegetable industry in Florida. Vegetable production is expected to decline 91.4%. The grapefruit and specialty citrus industry is unlikely to survive without the fresh market. This scenario will result in a \$ 1.03 billion decline in Florida shipping point revenues. Total consumer surplus loss will amount to \$ 1.75 billion.

In addition to the producer revenue losses, the levels of Medfly risk are also associated with prevention and eradication expenditures whose expected values vary across locations and seasons. An October infestation in Tampa accounts for the lowest risk case scenario, while the June infestation in this same location stands for the highest risk case scenario with an expected cost approximating \$ 4 million. The expected prevention and eradication cost for a June infestation in Miami is about \$ 1 million.

Our study also investigated the effects of improved trap sensitivity, change in pesticide efficacy, and entry conditions on the levels of Medfly risk in Florida. When, for instance, the single trap sensitivity doubles, the probability of detecting low populations will increase by 201.66% and the optimal trap density will decrease by 50.19%. The rate of change in the level of Medfly risk resulting from a change in pesticide efficacy is expected to vary across locations and seasons. When the pesticide efficacy decreases from 90% to 80%, the level of Medfly risk is expected to increase by 28.13% and 22.33% in Tampa or by 25.31% and 31.65% in Miami during the months of June and February, respectively.

The number of international passengers, N, entering Florida can be considered the driving parameter that will impact on the likelihood of a Medfly introduction and establishment in Florida. When N increases by 5%, 4.45 additional staff years are needed to keep constant the level of Medfly risk in Florida. Additional passenger baggage clearance costs would also be needed to keep pace with an increasing number of international passengers entering Florida and to prevent a resulting increase in the level of Medfly risk. Alternative ways of mitigating the risk of Medfly introduction into Florida are to encourage and support suppression and eradication activities against fruit fly populations Caribbean Basin's countries. Emphasis can also be placed on implementing educational programs aimed at raising public awareness of the threat of exotic pests, like the Mediterranean fruit fly.

Limitations of the Study and Suggestions for Further Research

Our study provides estimates of the direction and magnitude of the potential impact of a Medfly outbreak and/or infestation in Florida. The quantitative results of this study may not be taken literally, but they are consistent with the biological profile of the pest under consideration and with historical data on past interceptions and trap sensitivity. Its primary limitation is the lack of extensive data on different aspects covered in this study.

We often had to make judgment calls to cope with the risk assessment on the Medfly case. Further research should focus on the improvement of the trapping technology. Field studies can also be done in Medfly-infested countries to test the sensitivity of different traps to low populations.

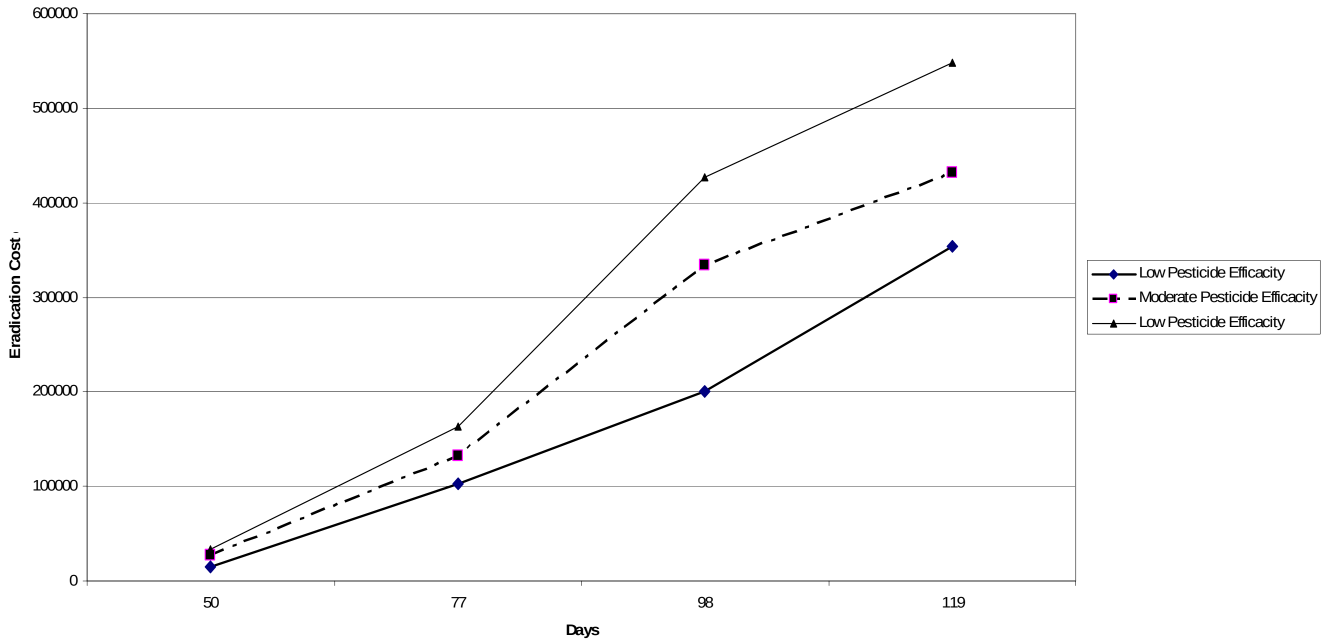

Figure 6-1 Shifting of the eradication cost curve with change in the pesticide efficacy

Table 6-1 Medfly risk levels in Florida

	Medfly risk ($)	
Expected prevention and eradication cost		
Month	Tampa	Miami
October	946	12,281
February	9,333	66,944
June	3,910,186	1,026,099
Expected revenue losses		
Scenarios	Option 1[a]	Option 2[b]
Three-month quarantine	39,612	40,069
Six-month quarantine	80,240	82,444
One-year quarantine	655,918	666,405

[a]Option 1: Medfly model with the export market of Japan. [b]Option 2: Medfly model without the export market of Japan.

Table 6-2 Effects of entry conditions on the risk level

Change in parameters	Number of passengers (N)	Number of bugs per infested unit ($X_{(1,0)}$)	Level of infestation (p)
	(% change in risk level)		
5%	4.98	2.11	5.01
6%	5.98	2.50	5.98
7%	6.98	2.88	6.98
8%	7.97	3.26	7.99
9%	8.97	3.64	8.97
10%	9.99	3.98	9.96

Table 6-3 Air passenger baggage clearance cost implications of changes in the number of passengers

Change in # of passengers (N)	Percent change in level of infestation [a] needed (%)	Additional staff years needed	Additional clearance costs ($)
5%	4.76	4.45	213,274
6%	5.66	5.34	255,922
7%	6.54	6.23	298,572
8%	7.41	7.12	341,224
9%	8.23	8.01	383,872
10%	9.09	8.90	426,563

a) This is the percent change in the level of infestation required to keep constant the level of Medfly risk as N increases over time

Table 6-4 Impact of an improvement in single trap sensitivity on the optimal trapping density

Technological change (ψ)	Probability of detection	Optimal trap density
	(% change)	
$\psi = 2$	201.66	(50.19)
$\psi = 3$	466.80	(66.48)
$\psi = 4$	781.31	(74.85)
$\psi = 5$	1138.43	(79.66)

Table 6-5 Impact of pesticide efficacy on the level of Medfly risk

Month	Expected Prevention / Eradication Cost ($)	
	Tampa	Miami
High Pesticide Efficacy (90%)		
October	946	12,281
February	9,333	66,944
June	3,910,186	1,026,099
Moderate Pesticide Efficacy (80%)		
October	1,166	14,614
% increase	*23.31*	*18.99*
February	11,416	83,892
% increase	*22.33*	*25.31*
June	5,010,254	1,350,899
% increase	*28.13*	*31.65*
Low Pesticide Efficacy (70%)		
October	1,333	17,033
% increase	40.91	*38.69*
February	13,759	102,654
% increase	*47.43*	*53.34*
June	6,305,054	1,748,090
% increase	*61.25*	*70.36*

APPENDIX A
PEST POPULATION STRUCRURE IN MIAMI AND TAMPA

Table A-1. Distribution of pest population structure in Miami per season at 50, 77, 98, and 119 days of the infestation

		Population Structure				
Month	Day	OF	Eggs	Larvae	Pupae	AF
	50	100	2,200	1,760	----	100
February	77	110	1,210	-----	----	1,980
	98	---	-----	-----	33,880	3,630
	119	11,374	97,163	39,930	11,979	1,719
	50	660	7,260	7,260	-----	1,540
June	77	6,292	69,212	116,063	29,814	17,908
	98	42,060	462,656	535,275	73,791	104,351
	119	143,921	1,583,131	36,076	81,170	1,096,465
	50	200	----	----	440	1,540
October	77	2,200	----	13,552	17,424	----
	98	726	13,310	----	----	23,474
	119	1,815	192,995	423,791	22,361	----

OF = Ovipositing females   PAF = Pre-adult females

Table A-2. Distribution of the pest population structure in Tampa per season at 50, 77, 98, and 119 days of the infestation

		Population Structure				
Month	Day	OF	Eggs	Larvae	Pupae	PAF
	50	---	---	----	----	200
February	77	100	---	3,520	880	----
	98	1,100	3,630	484	----	----
	119	---	----	4,840	30,008	6,776
	50	770	8,470	9,680	242	1,430
June	77	8,833	97,163	142,683	44,721	15,367
	98	55,237	607,601	664,702	122,985	188,603
	119	196,190	2,158,083	36,076	81,170	1,744,622
	50	200	----	440	1,980	----
October	77	2,200	----	----	----	----
	98	220	32,670	34,848	----	1,980
	119	2,200	----	30,976	8,712	----

OF = Ovipositing females; PAF = Pre-adult females

APPENDIX B
GRAPEFRUIT MODEL

Consider

Q_v^F	boxes of grapefruit of variety v grown for the fresh market
Q_v^P	boxes of variety v grown for the processed market
TP_v	total production of variety v in boxes
PF_v	growing and harvesting cost for fresh market
PR_v	growing and harvesting cost for processing market
$P_{vj}^F = a_{vj} - b_{vj} Z_{vj}$	inverse demand for variety v in fresh market j
P_{vj}^F	price of variety v shipped to destination j
Z_{vj}	cartons of variety v consumed in market j
λ_{vj}	packout rate for variety v in market j
E_{vj}	quantity of variety v eliminated for fruit packed in market j
Q_{vj}^F	cartons of variety v intended to be sold in market j

$$\sum_j Q_{vj}^F = Q_v^F$$

$$Z_{vj} = \lambda_{vj} Q_{vj}^F$$

$$E_{vj} = (1-\lambda_{vj}) Q_{vj}^F$$

$P^P = \alpha - \beta Y$ inverse demand for processing market

$$Y = \sum_v JU_v * \sum_j E_{vj} + \sum_v JU_v Q_v^P$$

P^P	price of one gallon of juice in processing market
PK_{vj}	packing costs per carton
PE_{vj}	eliminating charge per carton
PP	processing cost per box

$$\text{Max} \quad \sum_v \sum_j (a_{vj} Z_{vj} - \tfrac{1}{2} b_{vj} Z_{vj}^2) + (\alpha Y - \tfrac{1}{2} \beta Y^2) - \sum_v PF_v Q_v^F - \sum_v PR_v Q_v^P$$
$$- \sum_v \sum_j PK_{vj} Q_{vj}^F - \sum_v \sum_j (PE_{vj} + \tfrac{1}{2} PP) E_{vj} - \sum_v PP\, Q_v^P$$

st

$$.5 \sum_j Q_{vj}^F \leq Q_v^F$$
$$Q_v^F + Q_v^P \leq TP_v$$
$$Z_{vj} \leq \lambda_{vj} Q_{vj}^F$$
$$E_{vj} \leq (1- \lambda_{vj}) Q_{vj}^F$$

$$Y \leq .5 \sum_{V}\sum_{J} JU_v E_{vj} + 5 \sum_{V}\sum_{J} JU_v E_{vj}$$

All variables non-negative

The Lagrangian function associated with the quadratic programming model is:

$$L = \sum_{v}\sum_{j} (a_{vj} Z_{vj} - ½ b_{vj} Z_{vj}^2) + (\alpha Y - ½ \beta Y^2) - \sum_{v} PF_v Q_v^F - \sum_{v} PR_v Q_v^P$$
$$- \sum_{v}\sum_{j} PK_{vj} Q_{vj}^F - \sum_{v}\sum_{j} (PE_{vj} + ½ PP) E_{vj} - \sum_{v} PP Q_v^P +$$
$$\mu_v [Q_v^F - .5 \sum_{j} Q_{vj}^F] + w_v [TP_v - Q_v^F - Q_v^P] +$$
$$\sigma_{vj} [\lambda_{vj} Q_{vj}^F - Z_{vj}] + \eta_{vj} [(1- \lambda_{vj}) Q_{vj}^F - E_{vj}] +\gamma [5 \sum_{V}\sum_{J} JU_v E_{vj} +$$
$$\sum_{v} JU_v Q_v^P - Y]$$

The first order conditions associated with the Lagrangian function are:

(1a) $\partial L / \partial Z_{vj} = a_{vj} - b_{vj} Z_{vj} - \sigma_{vj} \leq 0$ **(1b)** $(\partial L/\partial Z_{vj}) . Z_{vj} = 0$ **(1c)** $Z_{vj} \geq 0$

(2a) $\partial L / \partial Y = \alpha Y - \beta Y - \gamma \leq 0$ **(2b)** $(\partial L/\partial Y) . Y = 0$ **(2c)** $Y \geq 0$

(3a) $\partial L / \partial Q_v^F = - PF_v + \mu_v - w_v \leq 0$ **(3b)** $(\partial L/\partial Q_v^F) . Q_v^F = 0$ **(3c)** $Q_v^F \geq 0$

(4a) $\partial L/ \partial Q_v^P = - PR_v + \gamma JU_v - w_v - PP \leq 0$ **(4b)** $(\partial L/\partial Q_v^P) . Q_v^P = 0$ **(4c)** $Q_v^P \geq 0$

(5a) $\partial L/ \partial Q_{vj}^F =- PK_{vj} - ½ \mu_v +\sigma_{vj} \lambda_{vj} + \eta_{vj} [(1- \lambda_{vj}) \leq 0$ **(5b)** $(\partial L/\partial Q_{vj}^F) . Q_{vj}^F = 0$
(5c) $Q_{vj}^F \geq 0$

(6a) $\partial L/ \partial E_{vj} = - PE_{vj} + ½ \gamma JU_v - ½ PP \leq 0$ **(4b)** $(\partial L/\partial E_{vj}) . E_{vj} = 0$ **(4c)** $E_{vj} \geq 0$

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BIOGRAPHICAL SKETCH

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