Don't Let Cacto Blast Us: Development of a Bi-National Plan to Stop the Spread of the Cactus Moth *Cactoblastis cactorum* in North America

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ABSTRACT The South American cactus moth *Cactoblastis cactorum* (Berg) was first detected in the continental USA on Big Pine Key in southern Florida in 1989. Although it was recognized as a potential threat to *Opuntia*-rich areas in the south-western USA and Mexico, actions were not taken to manage its spread because there are relatively few cactus plants in Florida and the moth was not known to disperse well over long distances. However, the moth has since spread along the coast of the Gulf of Mexico to the State of Alabama. In 2000, an initial meeting of assessment was held in Tampa, Florida, with subsequent planning meetings held in 2002 and 2003 to develop a strategic plan for research, detection, and control. A pheromone-based trapping system has now been developed and an area-wide management approach using the sterile insect technique (SIT) is being tested. In 2006, Mexico will begin contributing funds to help implement a bi-national plan to stop the spread of the cactus moth in North America.

KEY WORDS invasive pest, cactus moth, *Cactoblastis cactorum*, *Opuntia*, Lepidoptera, area-wide, SIT, USA

1. Introduction

Until its appearance in the continental USA as an invasive pest, the South American cactus moth *Cactoblastis cactorum* (Berg), was considered the poster child for biological control of weeds because of its role in reducing large populations of exotic *Opuntia* (prickly pear) cacti in Australia (Dodd 1940) and elsewhere around the world (Julien and Griffiths 1998). Based on this success, *C. cactorum* was intentionally introduced to the Caribbean island of Nevis in 1957 to control an unwanted complex of native *Opuntia* that were replacing grasses in overgrazed rangeland (Simmonds and Bennett 1966). The cactus moth later dispersed or was intentionally introduced to other Caribbean islands where it attacks both weedy and non-weedy native *Opuntia* species. It was reported from Montserrat and Antigua

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in 1960, Grand Cayman in 1970, St. Helena in 1971, and Ascension in 1973. The cactus moth also spread from Nevis to St. Kitts and to the US Virgin Islands (Simmonds and Bennett 1966). It was reported from Puerto Rico in 1963 (García-Tuduri et al. 1971). The cactus moth is currently also present in Haiti, the Dominican Republic, the Bahamas, and Cuba (Zimmerman et al. 2005).

2. Detection in the USA

C. cactorum was first recorded in the continental USA in 1989. Habeck and Bennett (1990) reported the discovery of cactus moth adults in the Florida Keys in October 1989. In addition, Dickle (1991) collected larvae from infested *Opuntia stricta* (Haworth) Haworth in this same area in 1989 and again in May 1990. Between May 1990 and October 1991 collections of cactus moth were made along both Florida coasts up to locations approximately 350 kilometres north of the initial detection site in the Florida Keys. By 1999, the cactus moth was reported from Cumberland Island on the southern coast of the State of Georgia. Hight et al. (2002) found infestations as far north as Folly Island near Charleston, South Carolina, and as far west as St. George Island, Florida. The current (2005) limits of cactus moth distribution along the Atlantic and Gulf coasts are at Bull Island, South Carolina, and Dauphin Island, Alabama, respectively (S. Hight, unpublished) (Fig. 1).

3. Life Cycle

C. cactorum is native to northern Argentina, Uruguay, Paraguay, and southern Brazil (Mann 1969). Larvae are phytophagous and feed on numerous species of prickly pear cacti (*Opuntia* spp.). Adult females lay eggs in a vertical chain containing 50-100 eggs that is glued to a cactus pad or cactus spine. Egg sticks take four to five weeks to develop. Upon eclosion larvae burrow into the cactus pad where they feed gregariously. A cohort of

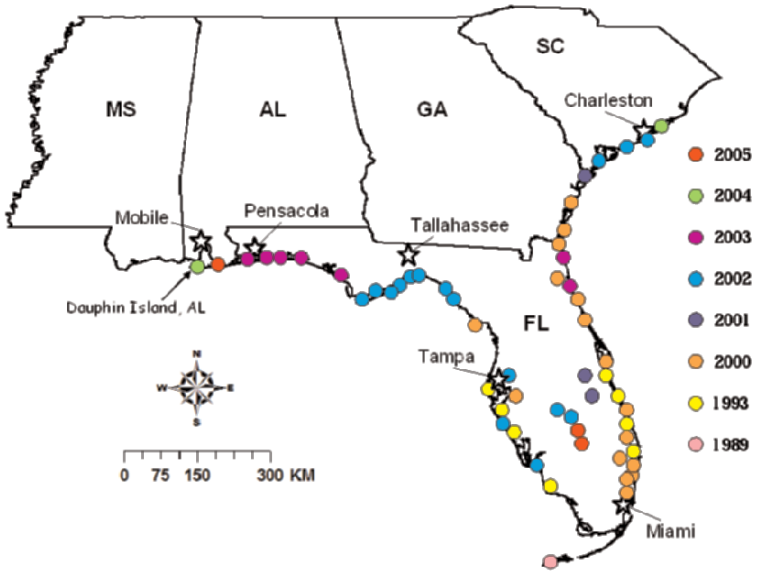

Figure 1. *Detection by year of larval infestations of* Cactoblastis cactorum *in the continental USA. Current efforts to limit the spread of the cactus moth are focused along the Gulf Coast near the western leading edge at Dauphin Island, Alabama.*

larvae typically destroys three to four cactus pads before completing development (Monro 1975). Fully developed larvae spin cocoons in the litter or between collapsed cactus pads (Pettey 1948). The cactus moth completes three generations per year in Florida (Zimmermann et al. 2004).

4. Potential Impacts

Garrett (2004) summarized the potential economic impacts from the spread of the cactus moth in the USA in a white paper for the United States Department of Agriculture-Animal Plant Health Inspection Service (USDA-APHIS). Simonson et al. (2005) prepared a preliminary assessment of impacts and risks associated with the spread of the cactus moth in the USA and Mexico for the International Atomic Energy Agency (IAEA) and the Food and Agriculture Organization of the United Nations (FAO). Currently, prickly pear cactus is of minor importance as a domestically produced food crop in the USA, although demand for both fresh and processed prickly pear pads (nopalitos) and fruit (tunas) has been increasing steadily. Production of prickly pear cactus for edible use in the USA is limited largely to California where 70-80% of the crop is produced from approximately 243 hectares of land.

Most of the commercial value of prickly pear in agriculture is in the ornamental nursery and landscape industries. In the State of Arizona this industry has been estimated to encompass 550 000 plants with a retail value of greater than USD 10 million. Prickly pear cactus is also important in the south-western USA as emergency forage for cattle during periods of drought and is considered integral to maintaining the quality of wildlife habitat for hunting-lease enterprises for animals such as the white-tail deer *Odocoileus virginianus* (Boddaert), javelina *Peccari tajacu* (L.), and bobwhite quail *Colinus virginianus* (L.).

The greatest value of *Opuntia*, however, lies in the ecological roles they play in native desert ecosystems, adding to wildlife habitat, ecosystem structure, and biodiversity in both developed and undeveloped areas. Establishment of the cactus moth in these areas could have effects far beyond a simple decrease in the number of *Opuntia* cacti. For example, in Florida, where cacti are a minor component of the native flora, there are three species of *Opuntia* that are limited to local populations in the Florida Keys and all are being attacked by the cactus moth (Pemberton 1995). These same cactus habitats are also shared by rare and endangered insects such as the Gerstaeckeria cactus weevil *Gerstaeckeria fasciata* Pierce. Other fauna associated with prickly pear cactus and affected by the loss of these host plants include the threatened gopher tortoise *Gopherus polyphemus* (Daudin) along the eastern edge of the Florida Everglades and the endangered San Salvador island rock iguana *Cyclura rileyi rileyi* Stejneger in the Bahamas (Zimmermann et al. 2004). Negative impacts such as these are expected to increase as the range of the cactus moth continues to expand. Additionally, further westward spread could lead the cactus moth into Mexico where prickly pear cactus is a major agricultural commodity and has significantly greater ecological and socio-economic importance (Hernández et al., this volume).

5. Developing an Action Plan

In order to discuss the cactus moth problem in the USA, a first meeting for assessment and planning was held in Tampa, Florida, in September 2000 with scientific experts, regulatory officials, and representatives from the conservation community from the USA, Mexico, and South Africa (Mahr et al. 2001). Meeting participants unanimously agreed that the cactus moth had the potential to be devastating to the fragile arid environments in the USA and Mexico. In July 2002, the FAO and IAEA hosted a cactus moth consultants meeting to review and evaluate the threat of *C. cactorum* to international agriculture and biodiversity (IAEA 2002). The role that the sterile insect technique (SIT) could play in addressing the cactus moth invasion as a model for invasive pests affecting not only

agriculture but the environment also was assessed at these meetings. Furthermore, FAO and IAEA agreed to support research in member states for developing the SIT. Subsequent stakeholder meetings were held in Miami, Florida, in December 2003 (www.invasivespecies.gov/profiles/cactmoth.html) and Mexico City in July 2004 (SAGARPA 2004).

In September 2004, the USDA-APHIS, Plant Protection and Quarantine (PPQ) committed to developing a strategic plan to delimit, monitor, and mitigate the spread of the cactus moth in North America. The strategic plan addresses concerns for: (1) survey and detection of infestations along and in front of the cactus moth's westward expanding range, (2) accurate identification of other Lepidoptera that feed on prickly pear cacti that may be confused with *C. cactorum*, (3) regulation of importation and domestic movement of prickly pear cacti plant material, (4) eradication and containment of known infestations using a combination of mechanical removal of infested plants (sanitation), application of insecticides, and releases of sterile insects, (5) research to refine monitoring and control protocols, (6) outreach activities to increase public awareness, and (7) cooperation with Mexico regarding cost and information sharing.

6. Researching Management Tactics

Scientists from the USDA's Agricultural Research Service (ARS) have now assembled a large body of knowledge about the cactus moths' spread in the south-eastern USA (Hight et al. 2002, Solís et al. 2004), and its behaviour and reproductive biology (Hight et al. 2003). They also have moved quickly to develop trapping protocols and evaluate both natural and synthetic lures (Bloem et al. 2003, 2005a), as well as to evaluate control strategies using different insecticides (Bloem et al. 2005b) and sterile insect releases (Carpenter et al. 2001a,b, Hight et al. 2005).

The SIT could have several applications for suppression of cactus moth populations: (1) it could provide a way to protect rare *Opuntia* cacti (such as those present in the Florida Keys) from attack, (2) it could be available as an eradication tool in new outbreak areas beyond the leading edges of current infestations, and (3) it could be used to erect a barrier to prevent or slow the expansion of the cactus moth's geographical range (Carpenter et al. 2001a). Considering the various control options available for the cactus moth, Stiling (2002) concluded that the use of SIT:

> *...offers perhaps the only realistic chance of drawing a line in the sand, literally, in Florida, and trying to prevent further spread of* C. cactorum *into the USA South-West and Mexico.*

The USDA-APHIS-PPQ, USDA-ARS, and US Geological Survey have also been working with Mississippi State University's GeoResources Institute to set up a web-based monitoring network (www.gri.msstate.edu/research/cmdmn/) for federal- and state-managed lands such as wildlife refuges, national parks and seashores, as well as lands managed by non-governmental organizations. These efforts will complement state departments of agriculture surveys of nurseries and residential properties using APHIS-PPQ's Cooperative Agriculture Pest Survey System, whose public site is at: www.ceris.purdue.edu/ napis/. APHIS-PPQ's Center for Plant Health Science and Technology (CPHST) has been using a risk zone mapping program (www.nappfast.org) to analyse cactus moth phenology data and map larval and adult activity to help predict the most appropriate times to monitor or survey for the moth's various life stages. CPHST has also been developing survey tools using handheld digital data collection systems (personal digital assistants (PDA)) and global positioning system (GPS) units to facilitate accurate data collection and the production of geospatial maps.

In 2005, APHIS initiated a cooperative research effort with ARS to validate the SIT, in combination with sanitation, as a comprehensive area-wide control and risk management strategy against *C. cactorum*, and as a

possible means of establishing a barrier that would stop the cactus moth's westward movement. The SIT evaluation involved three sites. The site along the leading edge (Dauphin Island, Alabama) received sterile insects and a sanitation procedure, a second site was only sanitized (Okaloosa Island, Florida), and a third site was left unchanged (St. George Island, Florida). Sterile cactus moths were released on Dauphin Island two to three times per week (500-5000 moths per release) during April/May, July/August, and October/November. The sanitation procedure involved the removal of cactus pads infested with *C. cactorum* larvae and the removal of all egg sticks and pupae that were encountered on a year-long basis. During this period, all three sites were monitored for adult flight activity (wild and sterile released males) using pheromone-baited sticky traps, as well as for *C. cactorum* infestation on sentinel host plants. The SIT procedure is being evaluated by comparing the magnitude of the change in larval infestations, wild moth captures, and sterile to wild overflooding ratios at each site over the course of the study.

7. Garnering Support for Action

When addressing invasive pest problems, the urgency of response is typically determined by the perceived value of the commodity at risk (i.e. the potential impact of the pest) and the level of outcry by affected stakeholders. Although alarm signals were raised by a number of scientists about the threat that the cactus moth posed to rare *Opuntia* in the Florida Keys and its likely impact should it spread (Habeck and Bennett 1990, Dickle 1991, Pemberton 1995, Johnson and Stiling 1996, 1998), very few people took notice. *Opuntia* cacti are not major components of the Florida landscape, they are of minor agricultural importance throughout the USA, the moth was not historically known to disperse rapidly, and stakeholders in the western USA where cacti are much more common have been largely silent. Not until the biological control community began to raise concerns that the cactus moth might be scrutinized as an example of non-target effects of classical biological control rather than as an invasive pest, and Mexico began to raise concerns about the cactus moth as an invasive threat to its cactus industry and the biodiversity of its desert ecosystems (Hernández et al., this volume), did regulatory officials become engaged.

Once a full assessment of the situation had been made, it became clear that significant knowledge gaps existed regarding the moth's biology and behaviour and very few tools were available to monitor and control its spread, and that these would have to be researched and developed (Mahr et al. 2001).

Rapid progress by ARS scientists in providing some of the necessary technologies has allowed APHIS to proceed with the development of a strategic plan for continued research and programme implementation. Additionally, an agreement between the USDA and Mexico's Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación (SAGARPA) entitled, "Work Programme to Establish Management and a Containment Barrier for the Cactus Moth", through an agreement with the North American Plant Protection Organization (NAPPO), provides joint funding starting in 2006 for a broader binational implementation programme to stop/slow the spread of the cactus moth in North America.

Unfortunately, controlling the cactus moth is now a race against time. From 2001-2004, the moth moved westward along the Gulf Coast of the USA at the rate of 160 kilometres per year, limited largely to *Opuntia*-bearing barrier islands. Dauphin Island, Alabama, is the site of the current western-most infestation and it is the last barrier island with road access until Galveston Island in northern Texas. Although expanded efforts initiated in 2005 may help prevent the moth from moving further west, establishment of a true barrier and emergency response to such movement is still in its infancy. Once the moth reaches the south-western USA, the density and diversity of *Opuntia* cacti increase sharply and *Opuntia*

distribution from the coastline to the interior becomes more contiguous. Therefore, the cost of implementing an abatement programme to stop the spread of the cactus moth would also increase sharply if the infestation is allowed to move westward, and the opportunity to "draw a line in the sand" would quickly diminish.

8. Conclusions

Given the high number of exotic, potentially invasive pests entering the USA each year, and the limitations on funding and other management resources and tools available to address them, assessments of risk must be made and action priorities set. However as the cactus moth story illustrates, the perception of or actual risk may change over time. It also reinforces the fact that the window of opportunity to eradicate or contain a pest is limited. Although the potential impact of *C. cactorum* on *Opuntia* cacti in North America did not become a regulatory concern until 2000, more than ten years after its initial detection, research has since moved very quickly to provide management options. In the span of only five years, the irradiation biology of the moth has been determined, rearing and monitoring methods have been developed, and both field cage and open field trials of the SIT have been conducted. Time will now tell if these efforts and future support prove successful at managing the risk posed by this pest, or whether the line in the sand was drawn too late.

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