THE STATUS OF *CACTOBLASTIS CACTORUM* (LEPIDOPTERA: PYRALIDAE) IN THE CARIBBEAN AND THE LIKELIHOOD OF ITS SPREAD TO MEXICO

Report* to the International Atomic Energy Agency (IAEA), Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture and the Plant Health General Directorate, Mexico (DGSVB/SAGARPA) as part of the TC Project MEX/5/029

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The islands surveyed during this mission included: Puerto Rico, Dominican Republic, Antigua, Montserrat, St. Kitts, Jamaica and Grand Cayman (funded by the IAEA).

***This report also includes information and conclusions by the second author (Mayra Perez Sandi) who visited and surveyed the following islands in the Lesser Antilles: Guadeloupe, Dominique, Trinidad and Tobago, Chacachacare, Grenada, St. Vicent, Bequia, Barbados, St. Lucia, Martinique and Chevalier. This part of the survey was funded by PRONATURA NORESTE, FMCN Y USAID.**

EXECUTIVE SUMMARY

The cactus moth, *Cactoblastis cactorum* (Berg), which has become the textbook example of successful biological weed control of invasive *Opuntia* species in many countries, including some Caribbean islands, is now threatening not only the lucrative cactus pear industry in Mexico, but also the rich diversity of all *Opuntia* species in most of the North American mainland. Already threatened species in Mexico could go extinct. The moth is now present on most Caribbean islands as a consequence of mostly deliberate or accidental introductions by man, or through natural spread. Although there is convincing evidence that *Cactoblastis* reached Florida inadvertently conveyed by the nursery trade, there also exists the slight possibility of natural spread and by means of cyclonic weather events. The role of the Costa Nursery in the Dominican Republic in facilitating rapid spread of the cactus moth with infested plant material within the Caribbean and to the USA during the seventies to nineties must have been substantial because of the high incidence of *Cactoblastis* presence and because of their ignorance regarding the importance of this insect at that time.

The different pathways that could result in the arrival of the moth to Mexico are analyzed and the most likely route of entry from the Caribbean is probably by means of importation of infested plant material, e.g. through the nursery trade, through local tourism or by plant exchanges. But the chances of its arrival via these pathways are now small, partly because of the overall low *Cactoblastis* populations encountered throughout the Caribbean as a consequence of the diminishing availability of suitable host plants, and because of improved awareness regarding the threat of the insect to mainland America. There is no doubt that *C. cactorum* was highly successful in controlling rampant O*puntia* infestations in many Caribbean islands and that the outcome of this project is praised by retired agricultural officers and land-users affected at that time. The infestations of cacti in the Caribbean resulted from large scale plantings of mainly three species during the first three centuries after colonization, compounded by large scale deforestation and followed by overgrazing.

The long-term impact of the cactus moth on most small *Opuntia* species is severe and the status of several cactus species on the islands may now be regarded as “threatened” (according to the 1994 IUCN categories) , including the species that were originally targeted for biological control, namely, *O. dillenii* and *O. triacantha*. The direct impact of the cactus moth on the larger species, including some of the rare *Consolea* species, is less drastic but the moth is devastating to recruitment, mainly the seedlings of some of the species including *C. rubescens* and *C. spinosissima*. *Nopalea cochenillifera* is the most common species found in the Caribbean and the only species utilized by some of the local people, mainly as an ornamental. It is a suboptimal host for *Cactoblastis* despite the fact that up to 20% of the plants investigated were infected. The plant easily recovers from attacks.

The Caribbean offers unique possibilities for further research on *Cactoblastis* including testing of the Sterile Insect Technique (SIT) and biological control under island situations, host preferences, bio-ecological studies, monitoring techniques and dispersal of the cactus moth. Officials in the Caribbean are willing to assist in this research and to put measures in place to prevent the arrival of *Cactoblastis* in Mexico. It is therefore essential for Mexico to retain the contact and to provide training and information material on a continuous basis to foster and maintain interest. Similar surveys are also recommended for Cuba, Haiti, the Bahamas, Belize and Guatemala that were not included in this survey.

With the exception of Puerto Rico, none of the quarantine and plant health officers on the other islands surveyed were aware of the presence and impact of *Cactoblastis* on their islands prior to this survey. This ignorance can partly be attributed to the general lack of interest in *Opuntia* species and because they are not actively utilized nor cultivated except for some limited use of *Nopalea cochenillifera* as a hair shampoo. The same could apply to Guatemala and Belize where *Opuntia* species are of little or no importance.

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2. INTRODUTION

The Caribbean

The Caribbean comprises more than 1000 islands ranging in size from 114 000 sq. kilometers in the case of Cuba, to small isolated islands covering an area of a few sq. meters. The climate ranges from tropical to semi-desert with rainfalls ranging from 5000 mm to less than 1000 mm with extended dry periods. Altitudes range from more than 3000 m to below sea level. This explains the high diversity of vegetation types ranging from xerophytic cactus-thorn shrub to tropical rain forests with extended marsh, mangrove, beach and riverine plant communities.

More than 13 000 vascular plants have been described from the Caribbean with a high level of endemism of around 6550 species, most of which are confined to Cuba (Areces-Mallea 1997).

Approximately 324 succulent plants are recorded from this region and about 243 (75%) of these are endemic and the rest extend to the nearby American landmasses. There are just over 70 species of Cactaceae recorded from the Caribbean region of which more than 20 species belong to the Genus *Opuntia*. It is widely recognized that the West Indian succulent flora is one of the most endangered plant communities in the world and mention is made specifically to the relict character of some native succulent species. Specific mention is made of the dioecious Antillean group of *Pereskia* and *Dendrocereus*, populations of disjunct distribution of *Dendrocereus nudifloris, Consolea nashii* and *C. millspaughii* and of small remaining populations of *O. hystrix, O. militaris, O. sanguinea. O borinquensis* and *Leptocereus* spp.

Historically the three most abundant *Opuntia* species in the Caribbean are: *O. dillenii, O. triacantha* and *Nopalea cochenillifera.* The latter is an introduced species, widely planted as an ornamental and rarely used as a source of fodder and as a traditional dish in Antigua. The abundance of *O. triacantha* and *O. dillenii* can also be attributed to their use as barrier plants around fortresses and houses in the 16th and 17th centuries and this explains how these two species were deliberately spread to various islands, particularly during the first two centuries after colonization (Howard & Touw 1981). Pinchon (1971) (in Howard & Touw 1981) describes in greater detail how *Opuntia* spp. were used to defend inhabited areas including the fortresses on St. Thomas, St. Lucia, Martinique, Guadeloupe, Antigua and other islands. There was an order given in 1733 that encouraged the reestablishment of *Opuntias* after their use as a “defender of the seashores” had been neglected for some time. The abundance of, primarily, *O. triacantha* and *O. dillenii* and other species was further compounded by large scale deforestation programs followed by overgrazing (G. Proctor and F.D. Bennett, pers. comm.). This provides a convincing explanation of the abundance

of several aggressive opuntias on many Caribbean islands by the turn of the last century.

The taxonomy of the *Opuntia* species in the Caribbean is confusing and is in urgent need of revision. For most cases the classification by Anderson (2001) has been used. For this report the genera *Consolea* and *Nopalea* are recognized as valid genera. **Although the status of the taxa *Platyopuntia* and *Cylindropuntia* are no longer valid, these descriptions are retained to distinguish the *Opuntia* species with flat cladodes from those with cylindrical or round cladodes.** Several *Opuntia* species listed by Anderson (2001) as occurring in the Caribbean are not recognized by local botanists. Some of the rare species have not been seen for many years and it is not known if these species are now accepted as synonyms of other species or if they have become very scarce because of continued attacks by the cactus moth. Taxonomically problematic species include *O. howeyi, O. auberi, O. antillana* and others. *O.pilifera* was mentioned as one of the mayor species cultivated in the Costa Nursery in the Dominican Republic for export but its true identity needs to be confirmed.

Cactoblastis cactorum in the Caribbean

Several *Opuntia* spp. are pre-adapted to exploit disturbances which include clearing, mechanical disturbances and overgrazing. The latter is particularly important because few domesticated animals feed on the spiny opuntias which can become invasive under such conditions. This occurred on several islands where species such as *O. triacantha* and *O. dillenii* have become particularly abundant and troublesome, like in Nevis, Montserrat, St. Kitts, Antigua and Grand Cayman (Simmonds & Bennett 1966), and probably many others. Densifications of these *Opuntia* species were so severe that the then Colonial Development and Welfare Organization of Great Britain requested the Commonwealth Institute of Biological Control (CIBC) in Trinidad and Tobago to consider biological control as an option for control on affected islands under British control.

In 1957 a consignment of *Cactoblastis cactorum,* a pyralid moth native to Argentina, was obtained from South Africa and the first releases were made in Nevis. Control of invasive *Opuntia* species due to the cactus moth was spectacular (Bennett & Habeck 1995). The cactus moth was subsequently taken to Antigua and Montserrat in 1962 where the results were equally impressive. It spread naturally to nearby St. Kitts and was illegally introduced to the US Virgin Islands. The cactus moth then spread to Puerto Rico where it was first recorded on Desecheo Island in 1963 (Garcia-Tuduri 1971). It is not known how the moth reached Puerto Rico. Further spread included Hispaniola (now Haiti and the Dominican Republic), Jamaica and Cuba. The first record from Cuba is from 1980. It was first recorded from Florida in 1989 and the moth arrived there either by natural dispersal or through infested cactus nursery stock originating from the

Dominican Republic (Habeck & Bennett 1990; Johnson & Stiling 1998; Pemberton 1995).

Except for the brief descriptive records by Simmonds & Bennett (1966), Bennett & Habeck (1995) and by Blanco & Vazquez (2001), there are no quantitative records of the impacts of the cactus moth on native or cultivated *Opuntiae* in the Caribbean. Also, there are no official records of the presence of *C. cactorum* on many of the smaller islands, particularly those in the Lesser Antilles. Cacti in general, and *Opuntiae* in particular, play a minor role in the lives and the economy of most Caribbeans and *C. cactorum* would therefore not easily draw attention unless widespread and until causing extensive damage. Some aesthetic value is placed on the impressive cephalium, columnar and candelabra-like cacti and other species in the Tribe Cereeae, some of which have stunning flowers e.g. in the genus *Harrisia*. Within the subfamily Opuntioideae the large tree-like species in the genus *Consolea* draw considerably more attention than the small and inconspicuous species in the genus *Opuntia.* So far *Cactoblastis* has been recorded as feeding mainly on the genus *Opuntia,* but suboptimal feeding has also been recorded from the genera *Nopalea, Consolea* and *Cylindropuntia.*

3. OBJECTIVES OF THIS STUDY, AND STRATEGIC CONSIDERATIONS

The main objectives of this study included the following:

1. Confirm the presence and impact of *C. cactorum* on the islands not yet surveyed, especially those of the Greater and Lesser Antilles. This would also include collating information on the diversity and abundance of some *Opuntia* species recorded from each island visited.

2. It is important to evaluate the perceptions and values assigned to *C. cactorum* in the Caribbean in order to understand the reasons for its introduction and deliberate spread and to consider actions to change these where necessary.

3. Any methods that are in use to minimize damage caused by *C. cactorum* to native and cultivated species should be noted.

4. Interviews with quarantine and plant health inspectors, supported by trade statistics could reveal valuable information to evaluate potential pathways of introduction to Mexico and neighboring countries. Discussions with government officials are necessary to block or restrict any pathways that may exist.

5. Government officials of all the Caribbean islands that have *C. cactorum,* or are likely to be invaded by the cactus moth, must be made aware of the damage to native and cultivated *Opuntia* species in their territories and of

the serious consequences should the insect establish in Mexico. Contacts should be established with key officials and organizations who should receive regular updates on the latest information on the cactus moth and the progress made towards its control and containment. It is important to involve Caribbean countries and to foster a sense of co-ownership of the regional project. This can take the form of establishing screening and alertness programs preceded and supported by training programs. Training materials must be provided by Mexico and USDA/APHIS officials involved in the project.

6. Very limited information exists on the long-term impact of the cactus moth on the native and cultivated *Opuntia* species in the Caribbean. Evaluating this impact on the twenty or more native species of cacti that are found in the Caribbean could provide important information for predicting the effect of *C. cactorum* on the more than 86 native cactus species that are present in Mexico.

4. ITINERARY AND CONTACTS

During the 14th Inter-American Ministerial Meeting on Health and Agriculture held at the headquarters of the Ministry of External Affairs in Mexico City during 21-22 April 2005, the second author introduced the threat to Mexico of the cactus moth for the first time to the representatives from the Caribbean.

The main mission to the Caribbean included surveys on a group of seven islands that were visited between August 8 and 27 August 2005. In addition, the second author had previously visited 11 other islands between July 17 and August 4, 2005. The limited time on each of the islands did not allow for extensive studies on C. *cactorum* and its impact on native *Opuntia* species, and there was not sufficient time to search for the rarer non-target species whose populations may have been severely affected by the moth.

Emphasis was placed on establishing the best possible contacts on each of the islands visited, hence, the visits to several Ministers of Agriculture and/or their Permanent Secretaries. These senior personnel were introduced to, and informed of, the threat of the cactus moth to Mexico. None of them were aware of either the presence of the cactus moth on their territories or of its imminent threat to Mexico. A special effort was also made to identify young and interested entomologists, both at university level as well as within the group of quarantine and plant health officials. These are the persons that could best assist in adding to our knowledge of *Cactoblastis* in the Caribbean region.

On arrival at each island considerable efforts went into arranging the meetings/seminars with the plant health, agricultural and quarantine officials. Each meeting started off with an introduction to the project, the objectives of the mission and the importance of collaboration. This was followed by a DVD

presentation on *Cactoblastis* and a Power Point talk on the importance of cactus pear to Mexico. This set the scene for further discussions on how the Caribbean authorities could assist in preventing the arrival/dispersal of *Cactoblastis* to Mexico. This also included discussion on the potential or existing pathways to Mexico.

These contacts and information sessions were extremely effective and an absolute necessity. The general response was very encouraging as none of the officials and personnel contacted, with the exception of a few inspectors in Puerto Rico, were even aware of the history and impact of *Cactoblastis* on their *Opuntia* flora prior to the information sessions that were arranged and conducted during this visit.

The full itinerary, contact details of the most influential officials and scientists that were contacted during these visits and the program that eventuated on each of the islands are found in Annexure 9.6.

5. RESULTS

5.1 Analyzing the potential pathways to Mexico

The issue of the possible vectoring and the possible pathway for *Cactoblastis* in extending its range from the Caribbean islands to Mexico was discussed at each of the meetings held with agricultural and quarantine officers on all of the islands visited. The following pathways were discussed:

- Natural dispersal and climatic events
- Trade and commerce
- Tourism to and from Mexico
- Research

5.1.1 Natural dispersal

It has been suggested by Johnson & Stiling (1998) that climatic events, including hurricanes and tropical storms could have played a role in the long-distance dispersal of the cactus moth to Florida and along the Florida coast. Zimmermann et al. 2001 are of the strong opinion that the behavior of the adult moth does not support such a theory and they placed more emphasis on long-term dispersal through human activities and interventions. *C. cactorum* has not been able to disperse naturally to some uninhabited off-shore islands in the Caribbean, e.g. Mona, which has large *Opuntia* populations (to be confirmed). The island of Cayman Brac is also still free of Cactoblastis despite its close proximity to Grand Cayman. The closest point from the Caribbean (Cabo San Antonio in Cuba) to the Yucatan peninsula in Mexico is about 240 km. Although this tip of Cuba is open to *Cactoblastis* invasion, the insect has not yet been recorded from this area (Blanco & Vazquez 2001). The closest region where *Cactoblastis* has been recorded is at Pinar del Rio and at Isla de la Juventud, about 380 km from

Yucatan. (Blanco *et al.* 2004) and the likelihood of natural dispersal over the Yucatan channel remains, for the time being, small. Perez Montesbravo (2002) indicated the routes and intensities of hurricanes passing through Cuba between 1844 and 1985 and during this time only one hurricane passed over Cuba directly to Yucatan (1888). Most hurricanes pass over Cuba in a south/north or in a north-westerly direction.

The ability of the cactus moth to disperse over large distances unaided by climatic events is highly questionable (Zimmermann *et al.* 2001). However, it must also be assumed that during the first three years after its establishment on large *Opuntia* infestations in the Caribbean the cactus moth must have at least partly depleted its food supply which must have increased dispersal pressure considerably. *Cactoblastis* populations are presently very low because of an overall shortage of suitable host plants, and this must also reduce the chances for long-distance dispersal.

A more detailed study of population fluctuations of the cactus moth over time and its dispersal patterns throughout the Caribbean since 1960 could reveal important information on the dispersal behavior of the moth and the most likely pathway for its potential, inadvertent introduction into Mexico.

5.1.2 Trade and commerce

There is relatively little direct trade between the Caribbean and Mexico. The islands that may warrant further investigation on trade links with Mexico are Puerto Rico, Cuba and the Dominican Republic. Trade information between Puerto Rico and Mexico will be obtained from Ms. A Llunch (Coordinator of Sampling, Puerto Rico). Trade between Cuba and Mexico is limited to small quantities of seeds. As far as could be ascertained, there is hardly any trade between Mexico and the Dominican Republic or Jamaica (information from the Mexican Embassy, Kingston).

Pemberton (1995) provides evidence of 17 interceptions of cactus nursery plants infested with *Cactoblastis* that were confiscated in Miami between 1981 and 1993. Except for three interceptions from Haiti, all originated from a single nursery (Costa Nursery near La Romana, see figure 9) in the Dominican Republic. A recent visit to this nursery revealed three *Opuntia* species under cultivation for export, namely, *O. pilifera, O. leucotricha* and *N. cochenillifera*. The *O. pilifera* plants were heavily infested with *Cactoblastis* larvae, and egg-sticks were abundant on the plants (see figure 10). The other two species were less infested. All imports reported by Pemberton (1995) were of vegetative material for commercial purposes and all were infested with living larvae. One consignment (August 1981) had 39 adults. Except for the three consignments from Haiti, all were airfreight consignments (Pemberton 1995). The consignments destined for the United States for 1986 alone amounted to more than 350 000 plant specimens in 108 shipments. The chances of the moth reaching Miami

inadvertently and undetected via these nursery consignments must have been very high.

The chances of exporting *Cactoblastis* to Mexico through this means should be a matter of great concern unless a vigorous screening process is put in place. Fortunately there is no evidence of any trade in cactus between the Caribbean and Mexico. Also, nursery personnel at Costa Nursery are now inspecting plants leaving their establishment. This is followed up by another screening process by government plant inspectors of all consignments prior to their export from the Dominican Republic. Plant health personnel were surprised at the high level of *Cactoblastis* infestations and promised to be more vigilant in future, especially after having seen the insect and the damage it causes.

The export of *Opuntia* ornamentals is not only limited to the U.S.A. but also includes Europe and other islands within the Caribbean. Potted plants of *O. pilifera* were found in a nursery in Grand Cayman which originated from the nursery in the Dominican Republic and imported via Miami. This indicates that trade can carry nursery plants to even the remotest corners of the region.

Except for this one case in the Dominican Republic there is no evidence of any other trade in cactus plants between the Caribbean and the U.S.A or Mexico, but this needs confirmation.

The chances are also very small that larvae or pupae of *C. cactorum* may reach Mexico or other uninfested areas in crates or containers unless these are placed directly in the vicinity of infested cactus pear patches (which have become very scarce). The IPPC agreement (FAO Publication 15 of 2002) on the treatment of crates and wood packaging material my also place effective barriers for unwanted contaminants in or on crates. The lack of direct trade with Mexico almost eliminates all these possibilities although this may change in time.

5.1.3 Tourism and Human Movement

Tourism has also been identified as a possible pathway of introduction of *Cactoblastis* to Mexico. For example, in the 1980s, some cactus pear fruit was intercepted in the USA carried by a tourist (Pemberton 1995). The fruit originated from Cancun and were destined for Miami. The risk of introducing *Cactoblastis* through this means is small because cactus moth larvae very seldom attack fruit, and if they do, they only feed on green immature ones. The chances are higher for *Cactoblastis* to be carried by tourists inside infested cladodes destined for planting or cultivation.

Presently, the only direct flights between Mexico and the Caribbean are between Cancun/Mexico D.F. and Havana and it is recommended that a training and awareness program is established with Cuban plant health officials on the threats of *Cactoblastis* to Mexico and that tourists are made aware that no cacti may be

imported from Cuba to Mexico. The other air routes are via Miami and Panama (COPA Airlines) or via cruise ships usually embarking and disembarking in Florida. There are effective control procedures in place at all Florida ports which, however, may not be the case in Panama. This deserves some attention.
In summary, with the exception of Cuba and possibly the Dominican Republic, there is very little tourism between Mexico and the Caribbean islands and thus the risks of Cactoblastis reaching Mexico via this route are small.

N. cochenillifera is a popular garden plant throughout the Caribbean. It has some uses (shampoo, forage, ornament, food) and it is quite feasible that people may transport cladodes between islands. This is the likely pathway which contributed to the very wide distribution of this alien species within the Caribbean today (see 5.2.6).

The unsuspected presence of *O. curassavica* on St. Eustatius, far removed from its main distribution in Bonaire and Curaçao, also suggests that this species could have arrived there by trade within the various Dutch owned group of islands (Howard & Touw 1982).

5.1.4 Research

Research on the Cactaceae of Central America and the Caribbean necessitates the exchange of plant material between countries. Botanical gardens usually have exchange programs in place and authorities issuing permits often rely on the scientific integrity of the researchers involved to prevent the introduction of unwanted plants or contaminants. Even entomologists, who are not necessarily aware of *Cactoblastis,* may overlook the symptoms of infested cladodes as all larvae are strictly endophagous, that is they feed entirely within the cactus joints (cladodes). Stricter control by well trained plant health officers is thus essential to prevent any unwanted introductions through the exchange of botanical specimens earmarked for research.

5.2 Collaboration with Mexico and steps necessary to prevent the introduction of *Cactoblastis* to Mexico

A total of about 102 officers of the various Departments of Agriculture on the Caribbean islands visited, including mainly plant health and quarantine officers, attended the arranged seminars and discussions (see figures 5 & 12). During these discussion the issues concerning collaboration and prevention were discussed. The following provide a summary of these discussions:

1. Contact persons were identified serving each of the islands visited and their names and contact addresses are given in Annexure 9.6. Mexican officials will provide information on the cactus moth to each of these contacts which may include books, videos, brochures, pamphlets, posters etc. All plant health officials on these islands should attend

regular courses as part of their normal training programs and the *Cactoblastis* topic must be included in their curricula with training material provided by Mexico. A special effort should be made to train officials in the Dominican Republic as the export of potentially infected ornamental cactus plants through their nursery trade is particularly high.

2. Further contacts should be maintained with academics at universities, botanical gardens and other similar institutions who should be encouraged to invest in research on *Cactoblastis* in order to fill gaps in our knowledge on the insect. Some projects that could be considered for research are described in Annexure 9.2.

3. Mexico should include the topic of the threat of *Cactoblastis* on the agendas of all meetings pertaining to regional cooperation on agricultural (e.g. IICA and FAO), environmental and quarantine issues. e.g. Phytosanitary Convention on Certification; the FAO (Food and Agricultural Organization of the United Nations, CBD (Convention on Biological Diversity), NAPPO (North American Plant Protection Organization), OIRSA (Organismo Internacional Regional de Sanidad Agropecuaria) and CITES (Convention on International Trade in Endangered Species).

4. The Caribbean provides ideal opportunities to train Mexican scientists and students on *Cactoblastis* and its threat to Mexico. The preferred islands would be the Dominican Republic, Jamaica and Cuba who all have a rich *Opuntia* flora infested with *Cactoblastis* and good universities that can provide the necessary scientific support.

5. Research topics that could be considered for research in the Caribbean are listed in Annexure 9.2.

6. *Nopalea cochenillifera* is the only species that is utilized to some extent in the Caribbean. This is an introduced species from the American mainland. It is common in many gardens and has effectively been spread by human intervention throughout the Caribbean. According to our survey about 20% of all the plants inspected had *Cactoblastis* infested cladodes. Although this is a sub-optimal host for *Cactoblastis* the insect could easily be spread by people through illegal transportation of infested cladodes throughout the Caribbean and elsewhere. Internal feeding by first and second instar larvae will not easily be detected as the cladodes are large, turgid and have a thick epidermis.

5.3 Impact of *Cactoblastis* on native and cultivated *Opuntia* species in the Caribbean

Impact on Native Species

Annexure 9.1 provides updated information on all the *Opuntia* species (including the genera *Nopalea* and *Consolea*) in each of the Caribbean islands, with the exception of the Bahamas and Aruba, Bonaire and Curaçao (ABC). All available literature on the biological control of invasive *Opuntiae* in the Caribbean was consulted and the first author established personal contact with Dr. Fred Bennett, now retired Director of CABI (Trinidad and Tobago) who initiated the *Cactoblastis* project on some of the islands which were under British control in the late 1950s. Contact was also established with three, now retired, agricultural officers who were in charge of the projects on St. Kitts, Antigua and Montserrat, working under the guidance of Dr. Bennett. First hand information could thus be obtained on the exact localities where releases were made, on the severity of the invasions prior to release of *Cactoblastis* and on the events following the releases. These sites were then visited and inspected for the presence of the host plants and *Cactoblastis*.

It was surprising that none of the agricultural plant health and quarantine officers, even up to Director level, knew about *Cactoblastis* and of its impact on *Opuntia* species on those islands where *Cactoblastis* was released. Only some officers in Puerto Rico were aware of *Cactoblastis* through the publicity efforts of the USDA/APHIS. It is thus not surprising that the presentations arranged during this visit on the history and threat of the cactus moth, elicited great interest and astonishment. Some officers did remark having noticed severe damage to cactus pear plants, but because of the low status of these plants they never paid much attention to it. The non-agricultural status and low aesthetic value of opuntiae is the main reason for the general ignorance around cactus pear in the Caribbean. This also explains why the presence of *Cactoblastis* was recorded for the first time on the islands of Guadeloupe and Jamaica during the present survey. There was strong evidence of *Cactoblastis* damage on Dominique, Grenada, St. Lucia and Martinique, but this needs to be confirmed with more intense surveys which will be conducted by officials in each of the islands. These islands had very few *Opuntia* plants.

The species targeted for biological control were *O. triacantha* and *O. dillenii.* The islands where *Cactoblastis* was released (Nevis, Antigua, Montserrat and Grand Cayman) were severely invaded by these two species to the extent that grazing and access was severely impeded by the dense infestations (Henry, Martin & Ryan, pers. comm. 2005; Simmonds & Bennett 1966). Only *O. dillenii* was present on Grand Cayman. Goats and sheep suffered severe injuries caused by spiny cladodes (mainly *O. triacantha)* such that portions of the meat of slaughtered animals had to be discarded because of infections. The impact of *Cactoblastis*, as described by the retired officers, was dramatic and devastating,

but, following the introduction of *Cactoblastis,* all populations of the target species mentioned, but in particular those of *O. triacantha,* declined rapidly to the point where only few plants survived and normal utilization of the pastures could be resumed.

The first effects of continuous *Cactoblastis* attack is the collapse of large flowering and fruiting plants which result in isolated cladodes remaining scattered around the original plant. These take root and develop into new plants which could start flowering within three to four years. *Cactoblastis* usually attacks these young plants before they can fruit again and by doing so, prevent fruit formation entirely. This has serious consequences for the long-term survival of the species. This has been demonstrated in the Kruger National Park with *O. stricta* (Hoffmann *et al*. 1998) (a similar species to *O. dillenii)* and also in Florida (Hight, pers.comm.). The same phenomenon was also observed on *O. triacantha* on Antigua.

No quantitative post-release studies were ever undertaken in the Caribbean and full reliance on the events after the release of *Cactoblastis* depends on anecdotal descriptions and comments. Time constraints prevented a detailed survey of all *Opuntia* species on all the islands. It is anticipated that colleagues and officials on the respective islands will continue with surveys so that a full status report on the impact of *Cactoblastis* on all the species can be obtained.

The following observations were made on the various islands visited:

5.3.1 Montserrat

Despite many hours of searching, (assisted by local plant health officers), *O. triacantha* could not be found on Montserrat. One of the two areas on Montserrat where *O. triacantha* was abundant, namely O'Garra's Estate in the south, could not be accessed because of volcanic activities. A few clumps of *O. dillenii* were eventually found near Jack Boy Hill which were well infested with *Cactoblastis (*see figure 11) . The areas inspected were severely overgrazed which should have favored the proliferation of *O. dillenii.* Also two plants of *N. cochenillifera* were found in gardens and both were infested with *Cactoblastis.*

5.3.2 Nevis

Nevis was not included in this survey because Dr. R.W. (Bob) Pemberton of USDA, Fort Lauderdale, visited this islands during 2002. He found both *O. triacantha* and *O. dillenii,* the former as scattered small, non-flowering plants in the arid eastern and south-eastern areas and on one arid hill on the north-western part of the island. C*actoblastis* often attacked the larger plants of *O. triacantha* and avoid the smaller ones. Seventeen percent of the plants inspected were attacked by *Cactoblastis*. In two areas at Nevis *O. dillenii* grew in large masses or clumps of 10 to 70 m in length, but they were usually found as

separate plants or small clusters. *Cactoblastis* damage was common in the large masses except for the north-western part of the island (see Table 1). *O. dillenii* plants were flowering and fruiting and the same was found in St. Kitts.

O. rubescens was not found in the wild but only as cultivated plants in gardens. No *Cactoblastis* damage was found on this species (unpublished data).

5.3.3 St. Kitts

Pemberton found *O. triacantha* and *O. dillenii* along the coastal stretch on the arid southern part of the island in 2002. Most plant populations of *O. triacantha* were infested with *Cactoblastis* (see Table 1). During the recent survey (2005) no plants were found despite searching in the same area. Only one specimen of *O. dillenii* was found in a garden with *Cactoblastis damage.* A few C. *rubescens* plants were also found growing in a garden with no *Cactoblastis* damage.

5.3.4 Antigua

O. triacantha was found at Shirley Heights and at English Harbour but all plants were non-flowering and small and *Cactoblastis* damage was common. A few *O. dillenii* plants were growing on steep coastal cliffs overlooking Nelson's Dockyard. Some *Cactoblastis* damage was noticed. Overall, both species were scarce. N. *cochenillifera* plants were common in gardens with occasional *Cactoblastis* damage.

5.3.5 Jamaica

There are about seven *Opuntia* and *Consolea* species in Jamaica with the rare *O. sanguinea* and *O. jamaicensis* being endemic. *O. sanguinea* has become very scarce, partly because of the feeding damage of an "unknown insect", probably *Cactoblastis* (Oberli, pers. comm.). *Cactoblastis* was found on *O. tuna, O. dillenii* and on *O. jamaicensis* along the outskirts of Kingston. Damage to C*. spinosissima* was similar to the damage described for *C. rubescens* in Puerto Rico. A high proportion of seedlings and vegetative regrowth was attacked and destroyed by *Cactoblastis* (see figure 4). The large leatherly cladodes on the large 2-4 m high plants were not attacked. Recruitment of this species is definitely affected by the presence of *Cactoblastis.* The fact that no damage on *C. rubescense* in St. Kitts and Nevis was noticed is probably linked to the absence of regrowth and seedlings undernearth the plants in gardens. As in most other islands, *N. cochenillifera,* was confined to gardens with occasional C*actoblastis* damage.

Dr. G. Proctor, a well known botanist in Jamaica, mentioned the sharp decline of several *Opuntia* species over the past 20 years but could not provide a reason for this decline as he was unaware of the history and presence of *Cactoblastis* on Jamaica. The presence of *Cactoblastis* was officially confirmed during this survey

and this provides an explanation for the decline of several species of cacti on Jamaica. This also shows that the cactus moth can go unnoticed for a considerable period despite the work of botanists studying *Opuntiae.* Because *Opuntia* species have no commercial value, agricultural officials and entomologist would not generally pay attention to any damage to these plants. It is not known how the cactus moth arrived in Jamaica.

5.3.6 Grand Cayman

Only two plants of *O. dillenii* could be found, one small plant near a dump and the second one in a garden, despite much effort to locate plants following the advice of farmers who knew the plant well from the time when it was still an invader. *O. dillenii* could certainly be classified as a threatened species on Grand Cayman.

A visit to the nursery of the local botanical garden revealed heavy damage to several *Opuntia* species including *O. dillenii, O. triacantha* and several unknown species. The nursery personnel have great difficulties in cultivating *Opuntia* in their nursery because of continuous *Cactoblastis* damage. They feel that declining or rare species may have to be cultivated for their conservation.

According to a prominent farmer on Cayman Brac, which is a small Island just over 100 km to the East of Grand Cayman, *O. dillenii* is still very common there and he is applying glyphosate to control his infestation. This means that *Cactoblastis* is not present on Cayman Brac and this was confirmed by officials from the Department of Agriculture. This fact also provides further circumstantial but important evidence suggesting that the dispersal powers of *Cactoblastis* are limited, and making it far less plausible that the cactus moth spread through its own powers of natural distribution to Florida in the USA.

5.3.7 Dominican Republic

Cactoblastis was common on *O. taylori* (see figure 3) and on a small patch of *O. ficus-indica* found on an experimental farm, but less common on *Cylindropuntia* (=Opuntia) *caribaea* and *N. cochenillifera*. No damage was found on *C. moniliformis or C. picardae.* No cactus moth damage was found on *O. triacantha* near Azua but this could be because of time constraints. Time constraints also prevented a visit to the dry north-western parts where *O. dillenii* is common. But the second author visited this region in 2003 with two botanist from the local botanical garden (Sesar Rodriguez and Alberto Veloz) and confirmed that *Cactoblastis* was present and abundant on *O. dillenii, O. taylori, N. cochenillifera, Cyl. caribaea* and on *O. antillana.*

Most significantly was the extensive damage to *O. pilifera* and to a lesser extent on *O. leucotricha* in the Costa Nursery (see figures 10 & 13) near La Romana. These are introduced species from the American mainland.

5.3.8 Puerto Rico

A visit to the Guanica Forest Biosphere Reserve showed severe damage by *Cactoblastis* to seedlings and regrowth of *C. rubescens.* Mature cladodes of large plants were very seldom attacked. Unfortunately *O. repens* could not be found but the first author found extensive damage caused by *Cactoblastis* during an earlier visit to Puerto Rico. *Cactoblastis* was also found in small numbers on *N. cochenillifera.*

Mr. Miguel Nieves is the curator of the uninhabited Mona Island between Puerto Rico and the Dominican Republic. This island has large *Opuntia* populations and is, apparently, free of *Cactoblastis.* Mr. Nieves will conduct an in depth survey on the status of the various *Opuntia* species on the island and he will also confirm the absence of the cactus moth.

5.3.9 Cuba

Although Cuba could not be visited during this survey, Dr. Eduardo Perez Montesbravo and Blanco & Vazquez (2001) provide some important information on the presence and impact of *C. cactorum* in Cuba. *Cactoblastis* was first recorded in Cuba in 1980 at Guantanamo where it drastically reduced populations of *O. dillenii* that have invaded more than 31 240 ha of which 23 060 ha were 25% covered and another 534 ha were totally covered by the species. The general perception is that the effect of *Cactoblastis* was most favorable as it would have been unaffordable to control these invasive populations with herbicides. *Cactoblastis* has so far been recorded on *O. dillenii, O. ficus-indica* and *N. cochenillifera* in five regions in Cuba but it is expected that *O. triacantha, O. auberi, O. dejecta. O. vulgaris (*also know as *O. monacantha), O. militaris,* and *O. cubensis* are also likely to be at risk (*O. vulgaris* and *O. triacantha* are known hosts of *C. cactorum* from elsewhere). A detailed survey on the distribution, abundance and host range of *C. cactorum* is thus called for as the above data are probably very conservative.

5.3.10 Guadeloupe

Cactoblastis was first recorded from Guadeloupe by the second author with Eric Francius found the insect feeding on *O. dillenii, O. triacantha* and on some not identified species. Collectively about 70% of the plants were infested with *Cactoblastis.* It is not known when the insect invaded Guadeloupe.

5.3.11 Dominique, Grenada, St. Lucia and Martinique

Opuntia species were very scarce on the islands and it is not known if this can be attributed in any way to the presence of *Cactoblastis.* After an intensive search *Cactoblastis* damage was positively identified but populations were very low. Damage was recorded on *O. dillenii*.

Dominica: Damage was noted on a large plant of *N. cochenillifera* at Dublanc. A local farmer mentioned that the O*puntia* species at Morne Rachette (Rachette in French means raquet, in Spanish raqueta and means "cladode"), have declined drastically over the past 30 years and some damage was noted on *N. cochenillifera, O. dillenii* and other specie*.*

Grenada: Damage was noted on *O. dillenii* at a site near True Blue and near Bedford Pt. Only two populations were encountered, namely at Prickly Point and Lance Aux Epines, names that allude to a time when there were infestations of opuntia present.

St. Lucia: There was damage on *O. dillenii* in the Pigeon Island National Park. Some plants were also found around an old fortress (Fort Vieux) which is an indication that it may have been planted there for protection.

Martinique: Damage was noted on one plant of *O. dillenii* at Sainte-Marie quartier de la Rue Paille and the Bequia island.

Table 1. Percentage damage recorded for various species and localities

Species	Locality	% plants with *Cactoblastis* damage	% cladodes with *Cactoblastis* damage
O. ficus- indica	Las Tablas, Dominican Republic*	31.5%	15.8%
O. taylori	Las Tablas, Dominican Republic	5.2%	3.4%
C. rubenscens	Guanica Puerto Rico	62%	58%
O. dillenii	Montserrat		
Clump 1	Statue Rock	50%	7.5%
Clump 2	Statue Rock	100%	14%
Clump 3	Statue Rock	8.1%	2.1%
Clump 4	Statue Rock	74%	40.4%
Clump 5 (50 sq m)	Statue Rock	34.6%	14.1%
Clump 6	Statue Rock	60%	31.7%
Clump 7	Statue Rock	100%	84.2%
O. tuna	Bull Bay, Jamaica	1.8%	0.9 %
C. spinossisima	Hellshire Hills. Jamaica	>90% of small plants underneath plants	
O. jamaicensis	Hardlands near Spanish Town, Jamaica	< 1%	0.2%
N. cochinillifera	Grand Cayman	19%	1.4%
N. cochinillifera	St. Kitts	8%	2%
O. dillenii	Pointe de l'Anse des Corps Guadeloupe	100%	70%
O. triacantha	Pointe de l'Anse des Corps, Guadeloupe	100%	40%
Opuntia spp.?	Pointe de l'Anse des Corps, Guadaloupe	100%	20%
O. triacantha	Nevis**	3-22%	17%
O. dillenii	Nevis**	10-33%	6-38%
O. triacantha	Shirley heights, Antigua	2.6%	1.6%

*Instituto Dominicano de Investigaciones Agropecuarias y Forestales, campo experimental Las Tablas
** unpublished data from R. W Pemberton

5.4 Impact on Cultivated Species

Nopalea cochenillifera has been introduced to practically all Caribbean islands as an ornamental plant. It is also widely used in Antigua as an ingredient for a

popular food prepared from maize. It is also used as a substitute for shampoo for washing hair. It is common in many gardens but naturalized colonies were not found outside urban areas or outside dumping sites. Although *Cactoblastis* larval colonies could be found on many plants, this is not a preferred host when compared to most of the native species. Damage by *Cactoblastis* on *N. cochenillifera* was never extensive nor frequent. Except for occasional cultivated plants of *N. cochenillifera* in gardens, the cultivation of any of the other commercial *Opuntia* species in the Caribbean islands is unknown. Despite of the importance of *O. ficus-indica* in many countries, this species is not cultivated in the Caribbean and its fruit is largely unknown. One very small experimental cultivation of *O. ficus-indica* was found on an experimental farm near Las Tablas (Peravia Province) in the Dominican Republic with 33 % of the small plants infested with *Cactoblastis*.

The general nuisance value of prickly pears and the absence of *Opuntia* cultivations explains the ignorance and lack of interest in any *Opuntia* insect pest and explains why it has been possible for *Cactoblastis* to go unnoticed for so many years.

5.5 Control of *Cactoblastis*

Information on control and management of the cactus moth on either N*. cochenillifera* or O*. ficus-indica* is not relevant because of the insignificance of cultivations and their limited use. *N. cochenillifera* is not severely affected by the cactus moth and plants easily recover and outgrow the damage caused by the larvae. There was no damage encountered on this species in the Lesser Antilles except for one wild growing plant on Dominica.

Some institutions and botanical gardens in the Caribbean who are concerned with the preservation of threatened *Opuntia* spp. could benefit by having access to effective control methods. The botanical garden in Cayman experienced great difficulties in keeping their nursery free of *Cactoblastis*. Normal sanitation practices would be sufficient to keep damage to a minimum. On the other hand the extensive cultivations of ornamental *Opuntia* species in the Costa Nursery in the Dominican Republic could benefit by using other control methods e.g. sanitation and mechanical control.

5.6 Dispersal of *Cactoblastis* within the Caribbean

Cactoblastis cactorum was first introduced into the Caribbean in 1957 when it was deliberately introduced to Nevis to control invasive *Opuntia* spp. Further releases were then made in Antigua and Montserrat in 1960 with insects originating from Nevis. The insect apparently dispersed naturally from Nevis to St. Kitts which is only 8 km distant from Nevis (Bennett & Habeck 1995). It is on record that the moth was also deliberately and illegally taken by a rancher from Nevis to the US Virgin Islands to control invasive *Opuntiae* (Simmonds &

Bennett 1966) and it is likely that other ranchers from other islands did the same as hardly any regulations on plant movement between islands were in place in the early sixties. There is also good reason to believe that several other nearby islands e.g. St. Thomas, St. John and St. Croix were also severely invaded by *Opuntia* species. Garcia-Tuduri et al.(1971) mentioned the presence of *Cactoblastis* in Puerto Rico by about 1966. The insect was also abundant on the nearby islands of St. Croix, St. Thomas and St. John by 1966, which means that the cactus moth must have arrived there prior to 1966. The insect was also present on most off-shore islands near Puerto Rico shortly after 1966 e.g. Desecheo. Most of the troublesome species like *O. triacantha* and *O. dillenii* were found in abundance on many of these islands. The chances of the cactus moth dispersing naturally over so many islands in such a short time of approximately three to four years is difficult to believe and one must assume that the likelihood of deliberate introductions of the cactus moth to many of these islands must have been high.

Officials in Cuba were contemplating the possible use of *C. cactorum* to control dense infestations of *O. dillenii* at Guantanamo in the late 1970's but decided against it (Perez, pers. comm.). The insect was then discovered at Guantanamo in 1980 where it provided good control of *O. dillenii* to the general satisfaction of local farmers and officials (Blanco & Vazquez 2001). It is not known how the cactus moth spread to Cuba, Puerto Rico or to Hispaniola and it is not known how the cactus moth reached Guadeloupe (see Annexure 9.2 for dates of first records of *C. cactorum)*. Jamaica is relatively isolated and it is hard to believe that *Cactoblastis* dispersed naturally to this remote island. Some other larger and off-shore islands are still free of *Cactoblastis*, including all the islands in the Netherlands Antilles and several in the Lesser Antilles, e.g. Trinidad and Tobago, St. Vincent and Barbados. Dutch officials deliberately kept *Cactoblastis* out of Curaçao despite dense invasions caused by *O. wentiana* and *O. curassavica* and despite pressure from ranchers. The dense cactus stands were seen as a tourist attraction to Dutch visitor and this was regarded as being more important than improving the grazing value of the land. This was confined to the Dutch controlled islands only.

The chances of deliberate, accidental and natural dispersal of *Cactoblastis* to yet uninfested islands within the Caribbean that have *Opuntia* species are now less than they were 20 years ago because of smaller *Cactoblastis* populations, generally (because of so few remaining host plants), and the awareness of plant health and quarantine personnel to the C*actoblastis* issue. It would not have been difficult for a landowner on Cayman Brac to introduce *Cactoblastis* from Grand Cayman to control their invasive *Opuntia* spp. some years ago, but officials will now prevent any such introductions. The same applies to *several* other off-shore islands which are as yet not infested with *Cactoblastis.*

Nopalea cochenillifera is a very common exotic garden plant throughout the Caribbean and it must be assumed that Caribbean people have carried cladodes

of this species to every corner of the region. It is probable that *Cactoblastis* was dispersed through human intervention by means of infested cladodes or plants. The many interceptions of larvae inside cladodes at Miami is testimony of the ease with which the cactus moth can spread unnoticed as larvae inside cladodes. Many cladodes on *N. cochenillifera* have been seen to be infested with Cactoblastis. Except for occasional cultivated plants of N*. cochenillifera* in gardens, the cultivation of any of the other commercial *Opuntia* species in the Caribbean islands is unknown or is unrecorded.

The presence or absence of *C. cactorum* on the major Caribbean islands and on many off-shore islands, could provide some useful information on the ability of the cactus moth to disperse naturally between islands. *C. cactorum* appears to be absent* from the uninhabited Island of Mona, situated between Puerto Rico and the Dominican Republic (* to be confirmed by Miguel Nieves, Manager of the Island of Mona, DRNA, Puerto Rico) which also has a large *Opuntia* presence. But *Cactoblastis* has been recorded from the Island of Desecheo, approximately the same distance from Puerto Rico. Several other islands in the Lesser Antilles also remain uninfested by the cactus moth (see Annexure 9.1).

The absence or presence of *Cactoblastis* from other islands remains to be verified and this can hopefully be done by local plant health officials who are now familiar with the insect and its damage. The contacts that have been established with government representatives, and the interest and awareness raised during this survey, may go a long way in achieving this goal.

5.7 Host preferences of *Cactoblastis cactorum*

C. cactorum shows clear host preferences within the *Opuntia* species that were investigated during this survey. The species most affected are the smaller species which include *O. triacantha, O. repens, O. taylori* followed by *O. dillenii* and *O. antillana.* The species most affected in the Lesser Antilles was *O. dillenii.* No damage was recorded from *C. picardae, C. moniliformis* and *C. millspaughii* during this survey but extensive damage was observed on small plants and isolated cladodes of *C. rubescens* in Puerto Rico and *C. spinosissima* in Jamaica. This damage was so extensive that it may impede on the reproduction and long-term survival of the species. Garcia-Tuduri (1971) recorded Cactoblastis feeding damage on *C. moniliformis* on the island of Desecheo. Although damage to *N. cochenillifera* was common, the damage was limited and confined to only a few terminal or sub-terminal cladodes. Woody stems were not affected and infested plants recovered rapidly. It would appear as if mucilage exudation caused high mortalities in first instars larvae when attempting to penetrate cladodes. Several hatched egg sticks were found with no signs of larval damage. This observation needs to be confirmed experimentally. There is no evidence that the long-term impact of *C. cactorum* on the *Opuntia* species in the Caribbean has resulted in any extinctions but there is no doubt that several of the smaller species survive in very low numbers only and that

some of these may have to be classified as “threatened”. The long-term effect on the recruitment of at least two unique *Consolea* species is also a matter of concern.

5.8 Present and proposed awareness campaigns to inform officials of the dangers of *Cactoblastis* to Mexico

With the exception of Puerto Rico, none of the officials on any of the islands visited in both the Greater and Lesser Antilles were aware of the presence or the threat of the cactus moth, despite the fact that the insect was introduced to control rampant problematic *Opuntia* species in some of the islands. The reason for the ignorance can be attributed to a lack of published post-release information on the cactus moth and the fact that none of the islands are cultivating economic *Opuntia* species, or attribute any significant commercial or ecological value to their native species. Cuba mentions the aesthetic value of some *Opuntia* species but the focus is mainly on the more colorful species in the Tribe Cereeae (candelabra and column-like species).

All officials showed great interest in *Cactoblastis* after they had attended the presentations given by the two main authors during this visit which provided a review of the presence of Cactoblastis in the Caribbean and its dangers to Mexico and having been made aware of the latest information and literature on the cactus moth. The importance of the Caribbean region in providing vital information on the insect and in preventing the introduction of the insect to Mexico, elicited much interest and support. Similar enthusiasm was generated when the second author presented a talk on *Cactoblastis*, written for the first and second authors, titled: “Mitigating the potential impacts and threats of the cactus moth, *Cactoblastis cactorum* (Lepidoptera: Pyralidae), to native and cultivated cactus in the Caribbean and Mexico”. The talk was presented to the Caribbean Food Crop Society congress, held in Gosier, Guadeloupe between 10-16 July 2005 (see the peer reviewed manuscript in Annexure 9.3).

The importance of organizing a regional workshop involving officials from those islands who are affected by *Cactoblastis* should also be considered for the future in order to guarantee their continued participation in the preventative campaign. This would also entice them to obtain more information on the status of *Cactoblastis* and its hosts on their territories.

Contact persons were identified for all the islands visited (see Annexure 9.6) who should receive regular updates on *Cactoblastis*. They should also be presented with posters, pamphlets and training materials on the insect in order to maintain interest, awareness and general alertness to the threat. The threat and control of *Cactoblastis* should be included in the general curriculum for all training programs for plant health inspectors and quarantine officers.

During this survey the first author also had one TV interview (St. Kitts), one radio interview (Montserrat) and one press interview for the Government Information Services Cayman Islands. As has been mentioned, the seven seminars were attended by more than 102 government officials, researchers, NGO's and botanists. Copies of the DVD and the FAO/IAEA publication on *Cactoblastis* and other informational and 'awareness' material (book marks, calendars etc). were widely distributed to participants.

6. CONCLUSIONS

The overall impact of *C. cactorum* on the native *Opuntia* species in the Caribbean is severe and it must be assumed that a similar outcome can be expected in the event that the insect reaches Mexico. Population levels of *Cactoblastis* in general, however, were very low because of the overall scarcety of suitable host plants (although the attack rate for some species was still high). Fortunately the chances for its arrival to Mexico by any means via the Caribbean are thus relatively small provided certain precautionary measures are taken which should include: restricting trade of cactus products between Mexico and the Caribbean, sensitizing Caribbean plant health and quarantine personnel of the threat to Mexico, awareness campaigns and passenger control, and general cooperation with specific countries that have close relations with Mexico, including the Dominican Republic, Cuba and Puerto Rico. Further surveys in Guatemala, Honduras, Belize, Haiti and Cuba are essential as these could be important focal points for possible invasions. A low level monitoring and awareness program for *Cactoblastis* along the east coast of Mexico and along the southern borders with Belize and Guatemala should continue.

From a cost-benefit point of view, however, it is a better proposition to invest more aggressively in effective ways to halt the further westward spread of the cactus moth within the USA. This includes developing highly effective control techniques, e.g. SIT and biological control, and better monitoring tools. The Caribbean could play an important role in this by providing assistance by testing some of these tools on their territories that are already invaded by *Cactoblastis*.

7. RECOMMENDATIONS

The following actions are recommended that may reduce the overall risk of *C. cactorum* reaching Mexico from the Caribbean:

1. Special *Cactoblastis* training material should be provided to selected Agricultural offices that were consulted during these surveys (see Annexure 9.6). The Department of Plant Health and Quarantine in the Dominican Republic involved with plant inspections (about 100 individuals) should receive priority attention. The personnel of the Costa Nursery

should also be included in any training program. Other countries that should be considered for training programs could include Jamaica, Cuba and Puerto Rico.

2. Contact persons were identified for each of the islands visited and their names and contact addresses are given in Annexure 9.6. Mexican officials will provide information on the cactus moth to each of these contact points which may include brochures, pamphlets, posters etc. Further contacts should be maintained with academics at universities, botanical gardens and other similar institutions who should be encouraged to invest in research on *Cactoblastis* in order to fill gaps in our knowledge of the insect. Some projects that could be considered for research are described in Annexure 9.2

3. Mexico should include the *Cactoblastis* threat on the agendas of all meetings pertaining to regional cooperation in agriculture (e.g. IICA and FAO), and on meetings dealing with environmental and quarantine issues. e.g. The Phytosanitary Convention on Certification (FAO), CBD, NAPPO, OIRSA and CITES).

4. The Caribbean provides ideal opportunities to train Mexican scientist and students on *Cactoblastis.* The preferred islands that would qualify for co-operative research programs on *Cactoblastis* would be the Dominican Republic and Cuba. Both these countries have a rich *Opuntia* flora affected by *Cactoblastis*. They also have universities of high standing that can provide the necessary scientific supervisory support. Several islands are now willing to initiate research projects on *Cactoblastis* and these initiatives should be supported with or without financial assistance. These islands (e.g. Grand Cayman and Jamaica) requested a list of possible research topics on *Cactoblastis* (see Annexure 9.3). It would be a good investment to release some funding for support of these projects listed in Annexure 9.2

5. All trade or imports of cactus plants from Jamaica and Guadeloupe to Mexico must be prohibited . It should even be considered to discourage **all** trade in cactus plants with all Caribbean countries because of the uncertainty of the presence of *Cactoblastis* in many of the islands.

6. Continue this survey by adding Cuba, Haiti, Honduras, Guatemala and Belize to the list of countries to be visited. It is important to inform the authorities of these countries of the threat of *Cactoblastis* to Mexico and to solicit their full support for the prevention campaign. Cuba is so far the only country that has invested in preliminary surveys on *Cactoblastis* without any external funding. It would be worth while to invest in a more in-depth research project on the distribution and impact of *Cactoblastis* on their *Opuntia* flora.

7. Albeit small, there remains a risk of direct introduction of *Cactoblastis* to Mexico from the Caribbean. The survey and monitoring program along the most likely points of entry to Mexico should therefore continue in parallel with maintaining the necessary contacts with the key Caribbean countries.

8. Some funding should be released to support some of the research projects listed in Annexure 9.2.The evaluation of a classical biological control approach on some selected islands that wish to control the cactus moth using natural enemies from Argentina, could be a worth while investment and will provide much needed information on the feasibility of starting a biological control program on the American mainland. Some of the islands could also be considered for evaluating the Sterile Insect Technique (Carpenter *et al.* 2001) as a tool to control or eradicate the insect. Promising natural enemies have been identified by Pemberton & Cordo (2001).

9. Creating a Cactoblastis-free barrier on the Florida/Alabama border must continue to receive highest priority.

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ANNEXURE 9.1

The occurrence of *Cactoblastis cactorum* in the Caribbean (from own observations and reliable records from the literature)
I

Country/ Island	Opuntia species recorded on islands	Inspected during various surveys	Cacto Blastis, presence	First year recorded	Key reference and own surveys
Cuba	*O. macrantha*	N	?		
	O. cubensis	N	?		
	O. elata	N	?		
	O. militaris	N	++		
	*O. ficus-indica**	N	?		
	O. dillenii	N	?		
	O. triacantha	N	++		
	O. dejecta	N	+++	±1980	Blanco et al. 2004
	O. auberi	N	++		
	*N. cochenillifera**	N	?		
	*O. streptacantha**	N	?		
	*O. monacantha**	N	++		
	C. nashii	N	?		
	C. monilliformis	N	++		
	C. millspaughii	N			
Dom. Republic	*O. taylori*	Y	++		
	O. dillenii	Y	+++	1987	
	Cyl. caribaea	Y	+		Starmer et al. 1987
	*O. ficus-indica**	Y	+++		Survey by Zimmermann et al. 2005
	O. antillana	Y	0		
	O. triacantha	N	?		
	O. tuna?	N	?		
	*O. pilifera***	Y	+++		
	*O. leucotricha***	Y	+		
	C.moniliformis	Y	0		
	C. picardae	Y	0		
	*N. cochenillifera**	Y	+		
Haiti	*O. acaulis*	N	?		
	O.ekmannii	N	?		
	O.urbaniana	N	?	< 1987	Starmer et al. 1987
	C. falcata	N	?		

	C. moniliformis *C. picardae ?*	N N	? ?		
Jamaica	*O. jamaicensis* *O. tuna* *O. dillenii* *O. sanguinea* *O. ficus-indica** *N.cochenillifera* *C. spinosissima*	Y Y Y ¿ ¿ Y Y	++ +++ ++ ¿ ¿ + ++	2005	Survey by Zimmerman et al. 2005
Grand Cayman	*O. dillenii* *N. cochenillifera**	Y Y	+++ +	1970	Benett & Habeck 1995 Survey by Zimmermann et al. 2005
Puerto Rico and adjacent islands Desecheo island 	*O. borinquensis* *O. brasiliensis* *O. repens* *O. triacantha* *O. dillenii* *O. antillana* *O. ficus-indica** *N. cochenillifera** *C. rubescens* *C. moniliformis* *O. dillenii* *O. triacantha*	N N Y Y Y N N Y Y Y Y Y	¿ ¿ +++ +++ +++ +++ ¿ + ++ +? ++ ++	1963 - 1966 1966 1966 1966	Tuduri et al. 1971 Bennett & Habeck 1995 Survey by Zimmermann et al. 2005 Tuduri et al.1971
Guadeloupe	*O. spinossisima* *O. triacantha* *O. tuna* *O. dillenii* *O. ficus-indica** *O. rubescens* *N. cochenillifera**	N Y Y Y N N Y	¿ ++ ++ ++ ¿ ¿ 0	2005	Fournet 2002 Survey by Pérez Sandi 2005
Virgin Islands	*C. rubescens* *C. spinosissima* *O. dillenii*	N N N	? ? +++	±1965	Bennett & Habeck 1995
St. Kitts	*O. antillana ¿* *O. rubescens* *O. triacantha* *O. dillenii* *N. cochenillifera**	N Y Y Y Y	? 0 +++ +++ ++	 1964	Simmonds &Bennett 1966

ANNEXURE 9.2

Research projects on *Cactoblastis cactorum* that could be considered for financial support in the Caribbean.

1) Host preferences studies on *Cactoblastis cactorum* in some of the larger Caribbean islands

Project outline

There are more than 20 native *Opuntia* species in the Caribbean and little is known of the long-term impact of *Cactoblastis cactorum* on these species other than on the original target species. The main reason for this decline has been attributed to habitat destruction, farming and urbanization and the effect of an "uknown insect", or a combination of these. The islands that should be targeted for such studies are Cuba, Dominican Republic, Jamaica, Guadeloupe and Grand Cayman. The study will include classical oviposition preference tests and subsequent fitness tests as measured by pupal weights, larval development time and fecundity. Such studies could be aimed at Masters or Doctoral levels.

2) Evaluate the reasons for the decline and the conservation status of some scarce *Opuntia* and *Consolea* species in some of the Caribbean islands.

Project outline

This study will include a detailed quantitative survey of *Opuntia* and *Consolea* species on some of the larger islands, their habitats, biologies, abundance, utilization and how they are impacted by *Cactoblastis cactorum* and other factors. The outcome of the study is to evaluate the role that cactus moth has played in the decline of the populations and the measures that should be put in place to secure the long-term survival of the threatened cactus species. The data can be compared with the *Opuntia* populations of yet uninvaded islands, including off-shore islands.

3) The dispersal behaviour of *Cactoblastis cactorum* with relevance to its spread within the Caribbean.

Project outline.

By analizing the absence or presence of *Cactoblastis cactorum* on as many islands as possible, including the small off-shore islands, conclusions can be drawn on the ability of the cactus moth to spread naturally over large distances. This data can be supplemented by using pheromone traps at predetermined intervals to trap marked and unmarked moths. Interviews and questionnaires could also provide valuable data on the role of man in the dispersal of the moth within the Caribbean.

4) DNA studies to determine the genetic variability of *Opuntia dillenii* and *Nopalea cochenillifera* within the Caribbean in order to trace the origin of the species and the extent to which they have been spread by man.

Project outline

There is evidence that *O. dillenii* has been used by British and Spanish colonist to protect their fortresses and dwellings and that the spiny species, in particular *O. dillenii* and *O. triacantha,* has been used for these purposes. This may explain in part why these species have become so abundant in time and why they are found almost throughout the Caribbean. A similar study on *N. cochenillifera* may reveal the origin of this species and its spread within the Caribbean.

5) The susceptibility of species within the genus *Nopalea* to *Cactoblastis cactorum* attack and the resistance mechanisms involved.

Project outline

It was evident from field observations that mature plants in the genus *Consolea* were not readily attacked by *C. cactorum* but that isolated cladodes and seedlings are very vulnerable to larval attack. Some *Consolea* species were not attacked at all (e.g. *C. picardae).* These statements need to be substantiated with experimental data supported with more detailed field observations.

6) Biological studies and number of generations per year in the Caribbean.

Project outline

There are only 2 generations per year in most countries but observations in Florida have shown that the insect has three generations. The number of generations of the insect in the Caribbean may be as high as four. This study can be supplemented by mortality studies (life table studies) to indicate its survival rate under Caribbean conditions.

7) The role of natural enemies in suppressing *Cactoblastis cactorum* populations.

Project outline

There are native phycitids, including cactus-feeding species, in the Caribbean whose populations will be affected by a second trophic level of parasitoids and predators. It must be assumed that some of these natural enemies will, in time, switch to *Cactoblastis cactorum* as an alternative or substitute host. Such host switches may limit the population size of *C. cactorum.* Classical life-table studies may reveal if this is the case and to what extent abiotic factors e.g. extreme temperatures, play a role in population regulations.

8) Survey of cactus-feedings insects on Caribbean Cactaceae.

Project outline

L.F. Hitchcock and J Mann have done limited surveys on cactus-feeding insects in the Caribbean during the 1920's. The phycitids *Amalafrida leithelle* and *Mimorista flavidissimalis* and some unknown *Dactylopius* spp. were mentioned. The weevil *Gerstaeckeria* was also collected. This must be a very small fraction of the cactus-feeding insects associated with the Cactaceae in the Caribbean

and a more thorough survey is long overdue. This information will provide interesting evidence in explaining the success of the introduced *C. cactorum* that was able to have such an impact on the local *Opuntia* species.

9) Evaluating the SIT on selected small islands in the Caribbean.

Project outline

Some small isolated Caribbean islands lend themselves perfectly to evaluate the efficacy of the SIT that has been developed by the USDA/APHIS. Some of these islands will benefit from an eradication program because of some scarce and threatened *Opuntia* species.

10) Evaluating classical biological control against *Cactoblastis cactorum* in the Caribbean.

Project outline

The introduction of key natural enemies from Argentina for a classical biological control program against *C. cactorum* on the American mainland is not supported at this stage because of the danger of non-target effects of these enemies on related cactus-feeding phycitids. However, applying classical biological control on some isolated Caribbean islands that wish to reduce their *C. cactorum* populations can well be implemented and evaluated without much danger of non-target effects because of their depauperate phycitid diversity. Host preference studies of the introduced parasitoids under natural conditions would then indicate the suitability and efficacy of the natural enemy and for its possible use on the American mainland.

11) Survival mechanisms of *Cactoblastis cactorum* on the very small hosts and at very low host plant densities

Project Outline

On some islands e.g. Antigua and Dominican Republic the only remaining preferable hosts are small plants (*O. triacanta* and *O. taylori)* that are unable to sustain the average number of larvae that emerge from a single egg stick. Despite the low host numbers the cactus moth remains present in good numbers. It could be that the insect “ticks-over” on marginal hosts e.g. N. *cochenillifera* and hence the continuous pressure on the preferable hosts. This may lead to near extinction of some of these species.

ANNEXURE 9.3

Proceedings of the Caribbean Food Crops Society. 41(1):___- __. 2005

A PEER REVIEWED PAPER

MITIGATING THE POTENTIAL IMPACTS AND THREATS OF THE CACTUS MOTH, *CACTOBLASTIS CACTORUM* (LEPIDOPTERA: PYRALIDAE), TO NATIVE AND CULTIVATED CACTUS IN THE CARIBBEAN AND MEXICO

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ABSTRACT: The cactus moth, *Cactoblastis cactorum* has become the textbook example of successful biological weed control of invasive *Opuntia* species in many countries, including some Caribbean islands. However it has now turned, and is now threatening not only the lucrative cactus pear industry in Mexico, but also the rich diversity of all *Opuntia* species in most of the North America mainland. The moth is now present on most Caribbean islands as a consequence of either deliberate or accidental introductions by man or by means of natural spread. Although there is convincing evidence that *Cactoblastis* reached Florida through the nursery trade, there also exists the possibility of natural spread by means of cyclonic weather patterns. The different pathways that could result in the arrival of the moth in Mexico are analyzed. With few exceptions, little is known of the impacts of the cactus moth on the native *Opuntia* species in the Caribbean. The main target species, namely *Opuntia triacantha* and *O. dillenii* have become very scarce and may now need protection status. The long-term impact on non-target species is unknown but some species may have been drastically affected. Recently regional and international efforts have been launched to prevent the further spread of *Cactoblastis* to the species rich native *Opuntiae* flora of the southern United States and of Mexico. These include an intensive monitoring program of resident populations at the leading edge near the Florida/Alabama borders and monitoring of large cultivated plantations in Mexico, which are focal points for possible early invasions. An awareness campaign that sensitizes farmers and government officials to the insect and its damage is aimed at interception and early detection to allow eradication in the event of establishment in Mexico. Research also is underway in Florida to develop an SIT (Sterile Insect Technique) program to halt the westward spread of the moth and to create a biological barrier. The involvement and co-operation of plant health and quarantine personnel in these Caribbean islands has become crucial in the campaign to keep *Cactoblastis* out of Mexico.

KEY WORDS: endangered species, awareness campaign, early detection, quarantine, eradication, trade, cyclonic weather patterns, pathways of invasion

RÉSUMÉ. Le papillon de nuit du cactus, *Cactoblastis cactorum* qui est devenu l'exemple du manuel scolaire de contrôle de la mauvaise herbe biologique d'espèce prospère *Opuntia* envahissante dans plusieurs pays, y compris dans quelques îles antillaises, a maintenant apparu, et n'est maintenant pas seulement une menace à l'industrie de la poire du cactus lucrative au Mexique, mais aussi à la diversité riche de toute l'espèce *Opuntia* dans la plupart des terres d'Amérique du nord. Le papillon de nuit est maintenant présent sur la plupart des îles antillaises par suite d'introductions soit délibérées soit accidentelles par homme ou par les moyens de distribution naturelle. Bien qu'il y ait l'évidence persuasive que *Cactoblastis* a atteint la Floride à travers le commerce de la crèche, là aussi existe la possibilité d'étendue naturelle au moyen de modèles du temps cycloniques. Avec peu d'exceptions, on connaît très peu sur des impacts du papillon de nuit du cactus sur l'espèce *Opuntia* autochtone et cultivé dans les Caraïbes. Les efforts régionaux et internationaux ont été lancés récemment pour prévenir l'étendue supplémentaire de C*actoblastis* aux diversités riches d'Opuntiae autochtones du Mexique et de tous les états du sud des États-Unis. Ceux-ci incluent un programme d'écoute intensif de populations résidantes à la pointe près du Florida/Alabama encadre et diriger de grandes plantations cultivées au Mexique qui est des points focaux pour les premières invasions possibles. Une campagne de la conscience qui sensibilise des fermiers et des fonctionnaires du gouvernement sur l'insecte et ses dégâts est visée sur l'interception et la découverte à temps pour autoriser l'éradication dans l'événement d'établissement au Mexique. La recherche va bientôt être en chemin en Floride pour développer un TIS (Technique d'Insecte Stérile) pour faite arrêter l'étendue vers l'ouest, et avec optimisme, pour la pointe à l'est et pour limiter des populations dans la péninsule de la Floride. Cette étendue vers d'évaluer les risques et étudier les voies d'invasion de certaines îles antillaises vers les terres mexicaines. La participation et co-opération du personnel phytosanitaire dans ces îles antillaises sont devenues cruciales dans la campagne pour laisser Cactoblastis hors du Mexique.

RESUMEN. La palomilla del nopal, *Cactoblastis cactorum*, que en cierto momento en los libros de texto se convirtió en el exitoso ejemplo de control biológico de maleza para combatir las especies de *Opuntia* invasoras en muchos países, incluyendo algunas islas del Caribe, en la actualidad se ha convertido en una amenaza no sólo para la lucrativa industria del nopal de México, sino también para la rica diversidad de especies de *Opuntia* en la mayor parte de Norte América. Actualmente, la palomilla está presente en la mayoría de las islas caribeñas como consecuencia tanto de la introducción accidental o deliberada por parte del hombre como por medios de propagación naturales. A pesar de que existe evidencia convincente de que el *Cactoblastis* llegó a la Florida como consecuencia del comercio de plantas de vivero, también existe la posibilidad de la propagación natural inducida por los eventos meteorológicos como los ciclones. Salvo algunas excepciones, se desconoce el daño que la palomilla del nopal causa en las especies de *Opuntia* nativas y cultivadas en el Caribe. Recientemente, se han iniciado acciones regionales e internacionales para

prevenir la propagación del *Cactoblastis* hacia la rica diversidad de las *Opuntia* nativas de México y de los estados del sur de Estados Unidos. Estas acciones incluyen un programa de vigilancia intensiva y permanente de las poblaciones de *Opuntia* cercanas al límite que separa a los estados de Florida y Alabama donde se encuentra el *Cactoblastis,* así como la vigilancia de enormes plantaciones en México que son los puntos focalizados de una posible invasión. Una campaña para que los productores y las autoridades gubernamentales tomen conciencia de la gravedad del problema y sus consecuencias negativas con el objeto de interceptar y detectar tempranamente esta plaga de manera que sea posible su erradicación en caso de que llegue a México. En la Florida está en marcha una investigación para el desarrollo de la TIE (Técnica del Insecto Estéril) para detener la propagación del insecto hacia el oeste y, contenerla en la península de la Florida. Es igualmente importante evaluar los riesgos y estudiar las vías de invasión desde algunas islas caribeñas hacia el territorio mexicano. La participación y cooperación del personal fitosanitario de estas islas del Caribe han sido cruciales en la campaña para mantener al *Cactoblastis* fuera de México.

INTRODUCTION

The cactus moth, *Cactoblastis cactorum* (Berg) (Pyralidae) was effectively used as a biological control agent of invasive *Opuntiae* species in Australia, South Africa and other countries worldwide (Moran and Zimmermann 1984). These successes were the main reasons that lead to subsequent introductions of the cactus moth to the Caribbean in 1957 for the biological control of native invasive *Opuntia* species in Nevis, Antigua, Montserrat and the Cayman Islands (Simmonds and Bennett 1966). These projects were highly successful and heavily invaded areas were converted to productive pastures.

Subsequently the cactus moth also was introduced to other islands, or it has spread naturally on its own (Zimmermann et al. 1999; Zimmermann et al. 2001). It is now widespread in the Caribbean and occurs also in Cuba, Haiti, Dominican Republic, Puerto Rico, Jamaica, Guadeloupe, Virgin Islands, Granada, Dominica and St. Kitts. The cactus moth is still present on all these islands that were originally targeted for biological control despite the fact that the target host weeds, *Opuntia dillenii* Haw and *O. triacantha* (Willdenow), have become scarce. *C. cactorum* also feeds on other non-target *Opuntia* species and on some related *Consolea* species and some of these are severely affected by the insect, e.g. *Consolea* (*Opuntia).rubescens* Lem., *C. (Opuntia) spinosissima* (Mill.) Lemaire, *O. taylori* Britton & Rose, *O. tuna* (Linnaeus) P. Miller, *O. jamaicensis* Britton and *O. sanguinea* Proctor . The cactus moth was first detected in Florida in 1989 (Habeck and Bennett 1990) and has since spread northward and north-westward, crossing the border to Alabama in 2005 (Bloem et al. 2005 (in press); Hight et al. 2002). All six native *Opuntia* spp. in Florida are attacked and the existence of at least one species has been compromised by the insect (Stiling 2002). The drastic impact of the insect on invasive and non-invasive *Opuntia* spp. is an indication of what can be expected should the insect

reach Mexico. This is an account of the impact of *C. cactorum* on the *Opuntia* spp. in the Caribbean, its threat to Mexico and possible action needed to prevent its further spread.

The taxonomy of the genus *Opuntia* in the Caribbean is problematic. In this account the dominant species in the Caribbean, namely, *O. dillenii* is recognized as an independent species following the descriptions by Anderson (2001), Howard and Touw (1982) and Hunt (1999), and supported by own observations. Also, the genera *Consolea* and *Nopalea* are recognized. The former are a unique group of tree-like opuntiae endemic to mainly the Caribbean and Florida.

THE EFFECT OF *CACTOBLASTIS CACTORUM* ON OPUNTIAE IN THE CARIBBEAN

Cactus pear is not commercially cultivated in the Caribbean. The only species that is utilized to some extent is *Nopalea (Opuntia) cochenillifera* (L.) Salm-Dyck which is an exotic species of Central American origin. This species is widely grown as an ornamental in gardens throughout the Caribbean. Young leaf pads of this species also are used in various dishes in some islands e.g. Antigua. At least two *Opuntia* species have become problematic as invaders in many islands, namely *O. triacantha* and *O. dillenii.* Their sudden increase could be attributed to their wide use as live fences and for the protection of fortresses during early colonial times. This went on for many years and the rapid spread was compounded further by large scale deforestation and overgrazing (Howard and Touw 1982). Simmonds and Bennett (1966) described large scale invasions by these two species, impeding access and utilization of the land for grazing. The spines, which become embedded in the flesh causing festering, caused serious injuries to livestock. Also Bennett and Habeck (1995) mention serious invasions on St. Kitts, Nevis, Antigua and Montserrat. Blanco and Vazquez (2001) mention that in Santiago de Cuba and Guantanamo 31,240 ha were invaded of which 23,060 ha had a cover of 25% and 534 ha were fully covered by *O. dillenii.* The remaining species (less than 30) are less common or scarce, and some are even endangered. The genera, *Consolea* and *Nopalea,* previously classified in the genus *Opuntia,* are unique to the Caribbean and each deserves a special status.

The impact of the cactus moth after 30 to 40 years in the Caribbean has never been determined. Only the initial result after its release on invasive *Opuntia* spp. was recorded as highly effective (Simmonds and Bennett 1966; Julien and Griffiths 1999), i.e., to the extent that the target species became scarce. This was confirmed during a survey by the authors in 2005. The outcome of the biological program on the islands targeted for control is still highly praised by all farmers and agricultural officers interviewed during this recent survey. Very few plants of the once abundant *O. triacantha* and *O. dillenii* remain on Grand Cayman, Montserrat, St. Kitts and Antigua, and despite these low numbers the cactus moth is still present. One reason is that it is able to develop on alternative as well as on less suitable hosts which include *N. cochenillifera, Consolea*

rubescens, C. spinosissima O. tuna, O. jamaicensis, O. taylori and *Cylindropuntia caribaea* and probably others. The large and leathery cladodes of *C. rubescens* and *C. spinosissima* are unsuitable for the development of young neonate larva but the small seedlings and young regrowth underneath the large trees are highly susceptible to larval attack. The recruitment of *C. rubescens* and *C. spinosissima* is thus drastically curtailed which must have severe implications for the long-term survival of these species. It is not known what the impact of the cactus moth is on the other tree-like species in the rare genus *Consolea.*

The long-term impact of *C. cactorum* on *O. stricta* (a closely related and similar species to *O. dillenii)* has been well documented in the Kruger National Park in South Africa (Hoffmann et al 1998). Large mature flowering and fruiting plants usually collapse and the scattered isolated cladodes root and form many small plants that need up to three or more years to flower. The cactus moth by continuous attacks usually prevents these plants from reaching the flowering stage. The same was observed in Florida and is probably also true for the Caribbean. This could have severe consequences for the long-term survival of *O. dillenii* and *O. triacantha* in the Caribbean.

Observations on the impact of the cactus moth in the Caribbean also indicate clear host preferences within the genera *Opuntia* and *Consolea* species and that not all species are suitable hosts. Infected cladodes of *N. cochenillifera* are common and approximately 20% of the plants examined in more than 17 islands were infested. This has little impact on the mature plants as it quickly outgrows the damage caused by the feeding larvae. *C. cactorum* is unable to feed on the woody stems and the damage remains confined to the succulent terminal cladodes. Indeed most people are unaware of the damage caused by *C. cactorum* on their garden plants.

The smaller *Opuntia* species are most severely affected, and these include *O. triacantha, O. repens and O. taylori* and possibly others. Further studies are needed to evaluate the risk of the cactus moth to the long-term survival of these species.

Some rare species are particularly threatened by *C. cactorum.* Anecdotal evidence describes the drastic decline of the rare *O. sanguinea* in Jamaica which was caused by the heavy feeding of an unknown insect, presumably *C. cactorum* (Oberli, pers. com.). Some species mentioned in the cactus literature have not recently been found and the cause of this could be either linked to *Cactoblastis* damage, by habitat destruction or to the taxonomic confusion within the *Opuntia* species complex in the Caribbean countries.

Much can be learned from the host-preferences and the impact of this insect on the native opuntiae in the Caribbean and this information can be extrapolated to give some idea on what to expect should it invade Mexico and the southern USA.

THE IMPORTANCE OF CACTUS PEAR TO MEXICO

The first awareness campaign informing the public on the risk of *C. cactorum* reaching Mexico was one of the subjects of a presentation “A New

Insect Pest on Opuntiae Lying in Wait for Mexico" presented during the VIII National Congress and the VI International on knowledge and exploitation of prickly pear by the authors in September, 1999.

The highest diversity of species in the genus *Opuntia* is found in Mexico. In total 55 of the 83 *Opuntia* species recorded for Mexico, or 66%, are endemic. Many of these species are widely utilized by rural people and prickly pear cactus is deeply entrenched in the culture of the Mexican nation. Its national emblem, the flag, depicts an eagle perching on a cactus pear with a snake in its beak, based on a legend dating from the time when the ancient city of Tenochtitlan, now Mexico City, was founded. The site of the capital city's founding, which equates to the foundation of Mexican society, was marked by the first human sacrifice performed in the Valley of Mexico. The emblematic nopal germinated from the first heart torn from an enemy's breast, not that of an outsider, but Huitzilopochtli's own nephew. The divine sacrifice was sublimated in the form of this plant. In a carving of the Teocalli de la Guerra Sagrada, the monument commemorating the founding of Tenochtitlan, the nopal is seen sprouting from Cópil's heart turned to stone, which rises out of the lake. In its claw the eagle is clutching neither snake nor bird, but *nochtli* (tuna), and flowing from its beak atl tlachinolli (burnt water) -the name for war in its sacrificial dimension. The emblematic prickly-pear tree bore firm red fruits which were the hearts of the sacrificed victims. Fray Diego Duran called it the "tree of human hearts" (Dufétel 2002).

Cactus pear is widely used as a source for fodder, fruit, green vegetable and many byproducts are made from this valuable resource including shampoos, soaps, lotions, preserves and medicines. There are more than 20,500 growers that cultivate cactus pear in Mexico. Areas under cultivation include more than 150,000 ha for the exclusive use of cactus pear as fodder, 60,000 ha are cultivated for fruit production and about 10,500 ha are under intensive cultivation for the production of young leaf pads (nopalitos) for human consumption as a green vegetable. The wild growing prickly pears cover more than 3,000,000 ha and these are used mainly by the indigenous people in various ways. The spineless cactus pear, *O. ficus-indica* (L.) Miller, is the most common species cultivated in Mexico and this species has many cultivars, each one with unique characteristics. Prickly pear and its many products is very much part of the everyday diet of the Mexican people.

Of equal importance are the many native wild growing species that are crucial in maintaining ecological function in the various cactus-rich biomes of Mexico. There is no other country where cactus pear plays such an important role in the economy and in the culture of a nation. If the impact of the cactus moth on invading *Opuntia* species in other countries is a reliable indicator, then the effect in Mexico could be disastrous. Studies on climatic matching have indicated that *C. cactorum* is very likely to establish successfully in all cultivated and wild *Opuntia* populations in Mexico (Soberon et al. 2001).

POSSIBLE PATHWAYS OF INTRODUCTION OF *CACTOBLASTIS CACTORUM* INTO MEXICO

The possible pathways of invasion of *C. cactorum* from the Caribbean to Mexico could be the following:

- Natural dispersal and climatic events including tropical storms, trade winds and hurricanes.
- Trade and commerce.
- Tourism.
- Research.

Natural Dispersal. It has been suggested that climatic events and hurricanes could have played a role in the long-distance dispersal of the cactus moth to Florida and along the Florida coast (Johnson and Stiling 1998). Zimmermann et al. 2001 are of the opinion that the behaviour of the adult moth does not support such a theory and they placed more emphasis on long-term dispersal through human activities and interventions. *C. cactorum* has not been able to disperse naturally to some off-shore islands in the Caribbean, e.g. to Cayman Brac from Grand Cayman, which is part of the Cayman group of islands. The closest point from the Caribbean to Yucatan in Mexico is the Pinar del Rio region in Cuba. Fortunately *C. cactorum* is still absent from this region (Blanco et al 2004), and the likelihood of natural dispersal over the Yucatan channel remains, for the time being, small. A detailed study of the dispersal of the cactus moth throughout the Caribbean could reveal important information on the most likely pathway for introduction to Mexico.

Trade and Commerce as a Pathway**.** Pemberton (1995) provides evidence of 17 interceptions based on samples of cactus nursery plants infested with *Cactoblastis* to Miami that have originated from a nursery in the Dominican Republic between 1981 and 1993. Consignments destined for the United States for 1986 alone amounted to more than 350 000 plant specimens in 108 shipments. The chances for the moth to have reached Miami undetected during this period must have been high. A recent visit to this nursery in the Dominican Republic revealed three *Opuntia* species that are cultivated there for export, namely, *O. pilifera* AUTHOR*, O. leucotricha* DC and N. *cochenillifera. O. pilifera* plants were heavily infested with *Cactoblastis* larvae while the other two species were less affected. This nursery also exports cactus ornamentals to Europe. Specimens of *O. pilifera* were found in a nursery in Grand Cayman which originated from the nursery in the Dominican Republic via a wholesaler in Miami. Both the management of the nursery as well as the plant health inspectors in the Dominican Republic are now imposing strict screening procedures to prevent any further exportation of contaminated plants from this source.

Except for the above case, very few or no cactus nursery plants or plant products are exported from the Caribbean to the USA or Europe, and even less so to Mexico. The chances are very small that larvae or pupae of *C. cactorum* could reach *Cactoblastis*-free countries in containers or package material unless the containers have been in the close proximity of infested cactus plants. The almost total lack of trade with Mexico minimized the risk of introduction by means of this pathway.

Tourism as a Pathway**.** *Nopalea cochenillifera* is a popular garden plant with several uses and it is feasible that friends, family members and tourists could transport cladodes between countries. This is the likely pathway which contributed to the very wide distribution of this alien species in the Caribbean. There is, however, very limited tourism between Mexico and the Caribbean and the only direct flights between the Caribbean and Mexico are via Cuba. Effective inspection procedures in Cuba and in Mexico could reduce the risk of introduction of infested cladodes via this pathway to almost zero.

Research as a pathway**.** Research on the Cactaceae of Central America and the Caribbean will necessitate the exchange of plant material between counties. Botanical gardens usually have exchange programs in place and authorities issuing permits often rely on the scientific integrity of the researchers involved to prevent the introduction of unwanted plants, plant products or contaminants. Strict control by well trained plant health officers is nevertheless required to prevent any such unwanted introductions through the exchange of botanical specimens earmarked for research because even scientists might be unaware of infested material and the threat of *Cactoblastis*.

The *Cactoblastis* populations in the Caribbean are considerably smaller compared to thirty years ago because of drastically diminishing host plants. This reduces the overall chances for dispersal by any means.

CONTROL METHODS

Several methods are being considered for the control of *C. cactorum* in Florida or in the event of its naturalization in Mexico. Considerable efforts is focused on developing the Insect Sterile Technique (SIT) for the control or eradication of *Cactoblastis* (Carpenter et al. 2001). All requirements for the implementation of the SIT have been met and the testing of the synthetic pheromone is in its final stages (Bloem et al. 2003). An attempt will be made to establish an insect-free barrier along the leading edge of invasion at the border between Florida and Alabama. A memorandum of understanding between Mexico and the USA has been signed that would provide joint funding of over US $1million for a broader bi-national implementation program to stop the spread of the insect in the USA.

Testing of new generation insecticides for the chemical control of the cactus moth also is in progress as a rapid response approach in the case of its detection in Mexico or elsewhere (Bloem et al. 2005 (in press)). Other control methods for the cactus moth in commercial cactus pear plantations in South Africa include orchard sanitation, as well as chemical and mechanical controls (Zimmermann et al 2004).

PREVENTION

Considerable funds have been allocated for a campaign to prevent the introduction of *C. cactorum* into Mexico. Emphasis is being placed on permanent monitoring and sampling procedures in cultivations that are most likely to receive

the cactus moth in Mexico. More than 7,500 sample points have been monitored in Mexico covering more that 18,000 ha. Early detection is of crucial importance in preventing establishment of the moth beyond the point where eradication is possible. Effective sampling of *Cactoblastis* populations in Florida keep track of the westward and northward spread of the insect. New legislation and regulations in Mexico and the USA have been promulgated that prohibit certain activities, e.g. the import or movement of cactus plant material from countries or states with *Cactoblastis* to yet unaffected areas.

AWARENESS AND TRAINING

Several workshops and meetings have been held to discuss strategies, research, prevention and control programs (Mahr et al. 2001). Special training programs are in place to educate plant health, quarantine and custom officials to identify *Cactoblastis* damage and to learn more about its biology. Mexican officials were trained in Florida and in South Africa on all aspects pertaining to the biology, identification and control of the insect.

Many pamphlets, brochures, posters, and books have been published and many radio interviews and programs on the subject have been broadcast as part of the general awareness campaign, mainly in Mexico. A comprehensive review on *C. cactorum* was recently published by the IAEA and FAO (Zimmermann et al. 2004). Awareness programs aimed at children have been introduced at school level and more than 20 newspaper articles on the threat of *Cactoblastis* to Mexico have been published in local newspapers since 2003. There are several websites where up-to-date information on the latest developments regarding the spread of *Cactoblastis* and research progress can be found, e.g. in www.cactoblastis.org and www.aphis.usda.gov/ppq/ep/emerging_pests/cactoblastis/whitepaper.pdf

RESEARCH

The International Atomic Energy Agency (IAEA) initiated a research program on *Cactoblastis* in 2002 which involved the first studies on evaluating the SIT as a possible control method which included mass-rearing methods, radiation levels and trapping methods (Bloem et al 2005; Bloem et al 2003; Carpenter et al 2001; Hight et al 2005). Further funding was directed at identifying new insecticides for control and research on *Cactoblastis* in its natural habitat in Argentina. Considerable funds have recently been released for a joint Mexico/USA initiative aimed primarily in perfecting the SIT control method.

The Caribbean countries can provide valuable information on long-term impact studies of *Cactoblastis* on *Opuntia* populations, on observations regarding the dispersal of the insect, and host preferences within the more than 30 *Opuntia* spp. native to this region. Research on the biology, and host-preferences of key natural enemies in Argentina also is underway.

Several Caribbean countries with a rich and endangered *Opuntia* flora may wish to control *C. cactorum* to reduce the threat to rare and endangered

species. In this context Jamaica and Puerto Rico may qualify for control programs against *Cactoblastis* which may include biological control. Although this option is not favored for use in the USA because of possible non-target effects of introduced parasitoids, this may not apply to Caribbean islands which have a depauperate cactophagous Lepidopteran fauna, and any potential non-target effects are unlikely to have any effect on the environment. There are promising and relatively host-specific parasitoids available from Argentina (Pemberton and Cordo 2001). Research in biological control in the Caribbean may provide important information on the feasibility of using this method on the American mainland. The risk of possible non-target effects must be weighed against the risk of *Cactoblastis* damage.

CONCLUSIONS

Preventing the introduction or further spread of the cactus moth, *C. cactorum,* into Mexico and the USA is a joint effort of all the countries affected or threatened by the insect. Caribbean countries can provide much needed information that could assist Mexico in its efforts to prevent the introduction of *C. cactorum*. For example, the SIT can be best evaluated in small islands with a known *Cactoblastis* population. Information on the dispersal within the Caribbean and host-preferences of the cactus moth may indicate the chances of natural vs. deliberate introductions and on the expected impact on the native *Opuntia* populations in Mexico and the USA. Also, the potential of classical biological control of *Cactoblastis* can best be tested on some Caribbean islands whose governments desire to have their *Cactoblastis* populations controlled or even eradicated. Any quantitative data on the abundance of existing natural populations of *Cactoblastis* near Pina del Rio in Cuba can be used to calculate the risks of natural dispersal to the Yucatan region. Information on *Cactoblastis* impacts obtained elsewhere can also be used to predict the survival of some *Opuntia spp.* in the Caribbean that are most affected by the moth. The status of these scarce and threatened species also need to be evaluated as it may even become necessary to introduce special efforts to prevent the extinction of some of these species. Recent observations from the Caribbean indicate that the impact of the cactus moth on cultivated and native *Opuntia* spp. in Mexico, and on the cactus-rich biomes of the southern USA could be severe.

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ANNEXURE 9.4.

GPS Coordinates of localities where *Cactoblastis* was found.

Country	Date	Locality	Latitude	Longitude	Observation
Puerto Rico	10/08/2005	Guanica Forest (Road to la Cueva)	N17.95457912	W66.8492766	*Consolea rubescens*, mainly regrowth attacked by Cactoblastis
Puerto Rico	10/08/2005	Guanica Forest (Road to la Cueva)	N17.96457279	W66.84659742	*Consolea rubescens*, mainly regrowth attacked by Cactoblastis
Puerto Rico	10/08/2005	Guanica Forest	N17.94122071	W66.95020334	*Nopalea cochenillifera* with egg stick
Dominican Republic	12/08/2005	Peravia: Las Tablas	N18.26831645	W70.40843067	*Nopalea cochenillifera*, with damage and larvae of Cactoblastis
Dominican Republic	12/08/2005	Peravia: Las Tablas	N18.26907749	W70.40774101	*Opuntia ficus indica* many egg sticks and damage by Cactoblastis
Dominican Republic	12/08/2005	Peravia: Las Tablas	N18.2690496	W70.40913113	*Opuntia tailory* and *O. caribaea*, infested with Cactoblastis
Dominican Republic	12/08/2005	Azua	N18.40855347	W70.58276694	*Opuntia triacantha* y *Opuntia caribaea* with damage.
Dominican Republic	13/08/2005	La Romana: Batey (Costa Nursery)	N18.49472285	W68.99214952	*Opuntia pilifera*, heavy damage by Cactoblastis
Dominican Republic	13/08/2005	La Romana: Batey (Costa Nursery)	N18.49480715	W68.99011472	*Opuntia leucotricha*, some damage by Cactoblastis
Dominican Republic	13/08/2005	La Romana: Altos de Chavon	N18.3935577	W68.83974573	*Consolea picardeae*, No damage found
Dominican Republic	13/08/2005	La Romana: Rumbo a Bayahibe	N18.38828592	W68.83858619	*Consolea moniliformis*, no damage
Antigua	15/08/2005	St. Paul: Sheirly Heights	N17.00838328	W61.754933	Very few plants of *Opuntia triacantha* with damage by Cactoblastis
Antigua	15/08/2005	St. Paul: Look out	N17.00033911	W61.74637238	*Opuntia dillenii*, with Cactoblastis damage
Antigua	15/08/2005	St. Paul: English Harbour	N17.01514512	W61.76819641	*Nopalea cochenillifera*, with damage
Antigua	15/08/2005	St. Paul: Nelson's Dockyard National Park	N17.00481712	W61.76426668	*Opuntia dillenii*, with Cactoblastis damage
St. Kitts	17/08/2005	Conarre Hills	N17.28905219	W62.69267506	*Nopalea cochenillifera*, cladodes with Cactoblastis larvae
St. Kitts	17/08/2005	near Turtle Bay	N17.2789178	W62.67780016	No Opuntia found
St. Kitts	17/08/2005	Banana Bay opposite Nevis	N17.22894947	W62.6395991	No Opuntia found
St. Kitts	17/08/2005	St Kitts Biomedical Research Foundation	N17.37394643	W62.74716616	*Opuntia dillenii*, with Cactoblastis damage
Montserrat	18/08/2005	Olveston	N16.77805883	W62.20491531	*Nopalea cochenillifera*, cladodes with Cactoblastis
Montserrat	19/08/2005	Road to Jack Boy Hill	N16.78066644	W62.17127528	Few plants of *Opuntia dillenii* severely attacked by Cactoblastis
Jamaica	23/08/2005	Bull Bay	N17.94047312	W76.68802793	*Opuntia tuna*, with egg sticks and damage by Cactoblastis
Jamaica	23/08/2005	Palisadoes	N17.94231712	W76.76284689	*Opuntia tuna*, with damage. One moth found
Jamaica	23/08/2005	Hellshire Hills	N17.87655485	W76.90838378	*Consolea spinosissima* regrowth severely affected by Cactoblastis
Jamaica	23/09/2005	Near Spanish Town: Hard Land	N17.94156331	W77.02275472	*Opuntia tuna* , *O. jamaicensis* con and *O. dillenii* with damage
Grand Cayman	24/09/2005	Near Bodden Town	N19.27499619	W81.26786269	One plant of *Opuntia dillenii* with no damage
Grand Cayman	24/09/2005	Queen Elizabeth II Botanical Garden	N19.29900492	W81.2045402	*O. dillenii*, *O. triacantha* and other spp, all with Cactoblastis damage
Guadeloupe	14/07/2005	Pointe de l'Anse des Corps	N16.29859	W61.79891	*O. dillenii, O. triacantha* and other spp. with Cactoblastis larvae, egg sticks, pupae

ANNEXURE 9.5

Photos

Figure 1. Invasion by *Opuntia triacantha* on Nevis in 1952. (Photo: F.D. Bennett)

Figure 2. A site on St. Kitts that was severely invaded by *Opuntia triacantha* (as above) in 1958. Not a single plant was found on 7.8.2005.

Fig. 3 All small Opuntia species are severely affected by Cactoblastis cactorum, e.g. Opuntia taylori in the Dominican Republic.

Figure 4. The extensive damage to seedlings and vegetative regrowth of *Consolea spinosissima* in Jamaica will affect the long-term survival of the species.

Figure 5. Field surveys to search for *Cactoblastis* damage provided excellent training opportunities. (Guanica Forest, Puerto Rico)

Figure 6. All small *Opuntia* species are severely affected by C*actoblastis cactorum* e.g. *Opuntia taylori* in the Dominican Republic.

Figure 7. A conservation garden of native *Opuntia* species in Jamaica was established by an NGO in Kingston which provided useful information.

Figure 8. Remaining clumps of *Opuntia dillenii* were confined to coastal areas of Antigua and Montserrat. All plants were infested with *Cactoblastis*.

Figure 9. Many nursery plants infested with *Cactoblastis cactorum* were intercepted at Miami. They originated mainly from the Costas Nurseries in the Dominican Republic.

Figure 10. *Opuntia pilifera* plants in the Costas Nursery were severey affected by *Cactoblastis cactorum* attacks.

Figure 11. Infestations of *Opuntia dillenii* on Grand Cayman in 1970 prior to the release of *Cactoblastis cactorum.* Only two surviving plants could be found in August 2005 after extensive surveys in the same region (Foto: F.D. Bennett).

Figure 12. More than 102 plant health and quarantine officers and other professionals attended the seminars on *Cactoblastis*.

Figure 13. *Opuntia leucotricha* in the Costas Nursery was less affected by *Cactoblastis*, and could indicate a host preference.

Figure 14. *Consolea spinosissima* (photo) and *C. rubescens* are endemic to the Caribbean and both species (and other species of *Consolea*) could be threatened by continuous attacks of *Cactoblastis* (see text).

ANNEXURE 9.6

THE ITINERARY, CONTACT DETAILS OF KEY PERSONNEL AND SCIENTISTS AND THE ACTIVITIES FOR EACH OF THE ISLANDS VISITED DURING THE MISSIONS.

Date	Island	Contacts	Activities
14.8.05 to 16.8.05 3 days	Antigua	1.Hon. Charlesworth T. Samuel Minister of Agriculture, Lands, Marine Resources and Agro- Industry tel. (268) 5621399 2.Ms. L. Richards, Permanent Secretary of Agriculture, 3. Ms. Jennifer T Maynard, Liaison Officer for International and Regional Organizations and Farmer Groups. Dept. of Agriculture. tel. 12684613233 liaison4@candw.ag maynard4@candw.ag 4.Mr. Joel Matthew, Plant Quarantine Inspector Dept. of Agriculture, Lands, Marine Resources and Agro-Industry joker-boy22@hotmail.com joelmtthw@@yahoo.com 5. Dr. Anthony Richards, Chief Chemist, Dept. of Agriculture, Lands, Marine Resources and Agro-Industry antiguachemist@yahoo.com	1) Meeting with Permanent Secretary of Agriculture and personnel of Plant Health and Quarantine 2) Field survey to evaluate *Cactoblastis* 3) Seminar and PP presentations to 7 field officers of Dept. of Agriculture
26.7.05 to 27.7.05 2 days	Barbados	1.Dr. Vyjayainthi (Vyju) Kamath CAB Internacional Barbados, tel 246/4251722 tel.2696516 v.lopez@cabi.org 2. Mr. Francis Lopez, Research Fellow Sports Agronomy, Univ. of the West Indies cell 2696516 flopez@uwichill.edu.bb 3.Mr. Michael James, Plant Pathologist Ministry of Agriculture and Rural Development Tel: 246-4284150 4.Mr. Louis Chinnery Head: Dept. of Chemical and Biological sciences. tel. 246-417 4361 Univ. of West Indies lchinnery@uwichill.edu.bb 5. Mr.Jeff Chandler Dept. of Chemical and Biological Sciences University of the West Indies UWI, Barbados. Tel 246 4174323 or 246235914 jchandler@uwichill.edu.bb 6. Mr.Ralph Farnum Deputy Chief Agricultural (Crops) Ministry of Agriculture and Rural Development Graeme Hall, Christ Church, Barbados Tel 246-4284160 farnumr@excite.com	1. Meeting in the Ministry of Agriculture 2. Meeting at the University West Indies. Visit the Lepidoptera insectary 3. Travel and survey for *Cactoblastis* on the island with Jeff Chandler 4. Visit the cactus collection and meet with the Barbados Cactus and Succulent Society 5. Travel and survey for *Cactoblastis* with Ralph Farnum and Michael James 6. Meeting with a delegation of the Agriculture
15.7.05 to 18.7.05	Dominica	1. Mr. Ryan Anselm Director Plant Quarantine, Dept. of Agriculture Cell. 6160975. 2. Mr. Albert Bellot	1.Visit the Minister of Agriculture, Dominica Export Import Agency, DEXIA and Botanical Garden 2. Meeting with Director: Plant Health and Plant Quarantine 3. Meeting Mr. Athie Martin, Goldman Prize Awarder for ecology

3 days		gfsgpcompact@cwdom.dm National Coordinator: Global Environment Facility (GEF) cell 6143017 tel. 767- 4404345 3. Mr.Terry Raymond Coordinator: National Youth Environment Service Corps, Youth Development Division, Government of Dominica tor70@cwdom.dm tel 767 4498012 4. Mr.Athie Martin Goldman Award in Ecology exotica@cwdom.dm dhta@cwdom.dm tel 767-4488839 or 767-4488829	4.Travel with Mr. Ryan Anselm from Plant Protection and Quarantine. 5. Meeting with a farmer Mr. Gerry Ben Jamain. 6. Travel with Mr. Albert Bellot and survey for *Cactoblastis.* 7. Consult literature 8. Meeting with Mr. Ferry Raymond and a group of the National Youth Environment Service Corps, Youth Development Division and presentation of Power Point and DVD on C*actoblastis.*
22.7.05 to 23.7.05 2 days	Grenada	1.Dr. Paul Graham paulgraham@caribsurf.com Director: Plant Health, Dept. of Agriculture cell. 4161908 2 Dr. Malachy P. Dottin malachyd@caribsurf.com Biotechnologist Director for Research and Biotechnology Laboratory. Ministry of Agriculture cell 4091219 tel. (473) 440-2708 3. Mr.Curtis Mitchell c/o Pest Management Unit, Dept. of Agriculture tel 444-7690 4. Mr.Thaddeus Peters Carriere Dept. Plant Health, Dept. of Agriculture thadpet@hotmail.com 5. Mr.Daniel Lewis Translator tel. (473) 444-5655 ddclewis@caribsurf.com	1. Meeting with Paul Graham, Director of Plant Health 2. Travel with agronomists Thaddeus Peters Carriere to survey for *Cactoblastis* 3. Discussions and interview with Dr. Malachy P. Dottin 4. Travel and survey for *Cactoblastis* with Paul Graham
24.8.05 to 26.8.05 3 days	Cayman Islands	1. The Hon. D. Kurt Tibbetts, JP Leader of Govermment Business, Minister for District Administration, Planning, Agriculture and Housing tel (345) 9497900 ext 2454 Gay Smith. Secretary gay.smith@gov.ky 2. Dr. Kearney S Gomez, MBE, JP Permanent Secretary, Dept. of Agriculture, Cayman Island. tel. (345) 949 7900 ext 2437 Kearney.Gomez@gov.ky 3. Dr. Alfred Benjamin, BSc., DVM, MS. Chief Agricultural and Veterinary Officer tel. (345) 947 3090 cavo@candw.ky 4.Mr.Adrian R. Estwick, BSc., MSc. Assistant Director (Agriculture) tel. (345) 947 3090 Adrian.estwick@gov.ky 5. Ms. Joan Steer Plant Protection Officer, Dept. of Agriculture. tel. (345) 947 3090 africop@cand.ky 6. Ms. Sasha Frederick Technician: Cayman Dept. of Agriculture, Box 459. Georgetown. tel. (345) 947 3090 sasha.frederick@gov.ky 7. Mr. Brian Crichlow. Marketing Coordinator: Agriculture. tel. (345) 947 3090 / 916 4908 brian.crichlow@gov.ky 8. Ms. Angelique Crowther, Information Officer, Cayman Islands. tel. (345) 244-1773 angelique.crowther@gov.ky	1. Meeting with Permanent Secretary, Director of Agriculture and Chief Plant Quarantine Officer 2. Meet staff at Agricultural Office and plan visit. Visit local nursery and inspect cactus plants on sale. 3. Field survey to evaluate *Cactoblastis*. Visit botanical garden. Interview ex officials and retired farmers. 4. DVD presentation and Power Point presentation with discussions.

		9. Ms. Tytia Habing Horticulturist, Botanical Garden tel. (345) 925 7810 tytiahabing@hotmail.com	
8.7.05 to 15.7.05 7 days	Guadeloupe	1. Ms. Marion Seier, Plant Pathologist CABI Bioscience UK Centre. ASCOT (attending congress) tel. 44(0) 1344 872 999 m.seier@cabi.org 2. Dr. Alain Chidiac Chief Agriculture and Forestry (Chef du Service Direction de l'agriculture et de la Foret alain.chidiac@agriculture.gouv.fr cel 0690352417. 0590820323 3. Mr. Fabrice Guiriaboye Technician, Dept. Agriculture and Forestry fabrice.guiriaboye@wanadoo.fr cell 0590 807612 4.Mr.Eric Francius Plant Health Technician Institute for Agricultural Research (INRA) francius@antilles.inra.fr cell. 0690310167 5. Mr.Jean Etienne jean.etienne2@wanadoo.fr Entomologist tel. 0550 257 505 6.Mr. Marceau Farant farant@gwadloup.antilles.inra.fr Director: Research, INRA Institue for Agricultural Research (INRA) tel. 0590 227 848 cell. 0690 743 204 7. Mr. Didier Robino Director Botanical Garden drobino@jardin-botanique.com tel. 0590284302 8. Mr.Philippe Tormin phtormin@wanadoo.fr cell 0690726998 tel. 0590260532 9. Mr. Herve Mauleon mauleon@antilles.inra.fr Environmental Officer. Institute for Agricultural Research (INRA) tel. 19590-2559 38/00 10. Chelston WD Brathwaite Ph D Director General. Inter-American Institute for Cooperation on Agriculture tel. 506-216 0222 chelston.brathwaite@iica.ac.cr 11. Louis E. Petersen, Ph.D. District Supervisor, University of the Virgin Islands. St. Thomas, U.S. Virgin Islands e-mail: lpeters@uvi.edu Tel: 340-6931071 12. Margaret S. Kalloo Senior Project Officer Agricultural Development Unit. Caribbean Community Secretariat mkalloo@caricom.org Georgetown, Guyana Tel. 592-2269280-9 ext. 2635 13. Waldemar Klassen Program Director, Professor. University of Florida klassen@gnv.ifas.ufl.edu Tel. 305-2467001 ext. 257	1. Survey for *Cactoblastis* and prepare congress presentation 2. Registration for congress and contacts 3. Present the DVD/Video to invasive species group at congress. 4. Meeting with Alain Chidiac, Plant Health Director. 5. Meeting with the director of the Botanical Garden, Mr Didier Robino 6. Meeting also Mr. Herve Mauleon of the National Institute for Agricultural Research, INRA. Study literature 7.Travel with Eric Francius through central part of island and collect *Cactoblastis* at several localities. Deposit collected material at laboratories of Mr. Jean Ettiene 8. Travel with Fabrice Guiriaboye for further surveys.
2.8.05 to 4.8.05	Guadeloupe	1.Dr. Fabrice Guiriaboye Dept. Agriculture and Forestry fabrice.guiriaboye@wanadoo.fr tel. 0590 807612	1. Travel with Fabrice Guiriaboye to survey for *Cactoblastis* 2. Meeting the Director of Plant Health

2 days			
20.8.05 to 24.8.05 3 days	Jamaica	1. Dr. Lisa Myers, Chief Plant Protection Officer Min. of Agriculture. lrmyers@moa.gov.jm tel. 876-983 2267 2.Mr. Denzille Williams, Plant Quarantine, Min. of Agriculture denwill2000@yahoo.com 3. Dr. Jane Cohen, Dept. of Life Science (Botany), UWI tel. (876) 927 1202 jane.cohen@uwimona.edu.jm 4. Mr. Andreas Oberli, NGO Conservation of Threatened Plants. naf-hope@cwjamaica.com tel. (876) 944 8366 5. Dr. Dwight Robinson Entomologist, Univ. West Indies Life Science Dwight.robinson@uwimona.edu.jm 6.Dr. Eric Garraway, Entomologist Dept. life Sciences, Univ. WI eric.garraway@uwimona.edu.jm 7. Dr. George R Proctor Retired Botanist. Former Head: Natural History Division, Institute of Jamaica. C/o Dept. Life Sciences, Univ. West Indies, Kingston	1. Discussions with Mexican Embassy personnel 2. Visit Hope Botanical Garden 3. DVD presentation and discussions with Dept. Agriculture, RADA, NGO's and UWI. 4. Field outing to three sites to evaluate the impact of *Cactoblastis*.
18.8.05 to 19.8.05 2 days	Montserrat	1.Mr. Claude Gerald, Director of Agriculture geraldc@gov.ms tel. 1664-4912600 2. Mr. Claude Browne, Agriculture Development Officer and Radio Program Presenter browneca@gov.ms 3. Mr. James Scriber Daley, Forest Ranger, Dept. of Agriculture scriber14@hotmail.com tel. 664-4913412 4.Mr. Willian P Ryan, retired director of the Dept. of Agriculture. kryan313@yahoo.com tel. 664-491 2653	1) Meeting with Mr. Claude Gerald and Mr. Claude Browne 2) Rent taxi to survey for *Cactoblastis* 3) Give talk and PP presentation to officers of the Dept. of Agriculture (16 attendees) 4) Second field survey to *O. dillenii* site. 5) Meet Mr. William P. Ryan, retired director of agricultural involved in the *Cactoblastis* project of the early sixties.
30.7.05 to 1.8.05 2 days	Martinique	1. Mr. Philippe Terrieux. spv.duf972@agriculture.gouv.fr Area Supervisor, Plant Protection Service tel. 0596-7027 2.Mr. Daniel Alphonse daniel.alphonse@wanadoo.fr tel 0596714298 3. Mr.Christian Lavigne International Cooperative Research Center for Agricultural Development Christian.lavigne@cirad.fr tel. 0596-423078 4. Mr.Clovel Pancarte Research Assistant, International Cooperative Research Center for Agricultural Development (CIRAD) tel. 0596-423077 clovel.pancarte@cirad.fr 5. Ms. Richer Muriel Agronomist. tel 06996256274 6. Regine Coranson Beaudu CIRAD. tel. 699-6256274 cell. 596693668	1. Meeting with Philippe Terreux and obtain localities for *Opuntia* species. 2. Travel with Ms. Richer Muriel 3. Travel to Chevalier island with Ms. Richer Muriel 4. Survey for *Cactoblastis*
9.8.05 to 11.8.05 2 days	Puerto Rico	1. Mr. Albert Roche State Operations Support Officer APHIS. albert.roche@aphis.usda.gov tel. 787-2941645 cell. 787-6729000 2. Ms.Nilda Perez Rousset Director: Plant Health, USDA. San Juan	1. All day meeting and workshop with conservationists, officials of plant health and quarantine services. 2. DVD and PP presentations. Attendees 31 3. Visit Biosphere Guanica and review *Cactoblastis* damage on *Opuntia* spp.

		sanidadvegetal@prtc.net tel. 787-7244627 3. Ms.Aixa Ramirez Lluch Coordinator: State Surveys, Dept. Agriculture prssc@wnetpr.net tel. 787-7237726 cell. 7787 3923264 4.Ms. Mayra E. Colon Alicea State Plant Regulatory Officer Dept. of Agriculture, Puerto Rico regmercado@wnetpr.net tel. 787-723 8537 5. Mr. Miguel Canals Manager: Guánica Forest Reserve menqui@hotmail.com tel. 821-5706 cel (939) 6409848 6. Mr. Norberto Gabriel USDA: Animal and Plant Health Inspection Service norberto.gabriel@usda.gov tel. 787-253 1829 cell. 787-318 0150 7. Mr. Ariel Ramírez arielramirez@uprm.edu ariel_yayo@yahoo.com Dean of the College of Agricultural Science, Extension . tel. 787-553 8737 8. Ms. Carmen Iris Alamo. Agricultural economist. Univ. Puerto Rico cialamo@hotmail.com tel. 787-767 9705 ext. 2178 cell. 7876136498 9. Edwin Abreu Rodríguez M.S. Biologist, University of Puerto Rico tel (809) 8302390 10. Dr. Yasmín Detrés yasmin@cacique.uprm.edu Agricultural Economist. University of Mayaguez, tel. 787-899 2048 ext.248 cell. 787 5538 737 11. Luis R. Pérez-Alegría Ph.,D., P.E. Professor Environmental Engineering Agricultural Engineering. UPR luperez@uprm.edu tel. 787 832 4040 12. Mr. Vivian Carro Figueroa University of Puerto Rico vcarro@uprm.edu tel. 787-767 9705 ext. 2069 13. Ms. Liz M. Pagan Puerto Rico University l.pagan@rumlib.uprn.edu tel. 787-767 9705 14. Ing. Agr. Gabriela Ocampo Plant Propagation, Doña Ines Park Foundation gocampo@parquedonaines.org tel. 787-283 1071 gocampo@parquedonaines.org 15. Mr. Miguel A. Nieves Manager, Natural Forest Reserve, Mona Island tonyamona@yahoo.com tel. 787-981 2229 16. Dr. Alberto Areces Mallea Botanist, Doña Ines Park aareces@parquedonaines.pr	
11.8.05 to 14.8.05	Dominican Republic	1. Ing. Agr. Luis R. Garrido Jansen M. Sc. Director: Department of Plant Health Secretary of Agriculture	1.Presentation of the *Cactoblastis* DVD and PP. 11 Attendees 2. Field survey of *Cactoblastis* on *Opuntia* spp in Azua region

3 days		Santo Domingo. luisgarrido@verizon.net.do tel. 547-3888 ext.2388 cell. 857-8814 2. Ing. Agr. Clara M. Bueno Coronado Division of Plant Quarantine, Dept. of Agriculture bclara18@hotmail.com tel. 809-547 3888 ext. 4101l 3. Ing. Caridad Nolasco Alvarez Department of Plant Health, Quarantine and Post-entry Services caridadnolasco@hotmail.com cell. 519 9594 4. Ing. Agrónomo José Manuel Asiático Dept. of Agriculture, Plant Health joseasiatico@yahoo.com joseasiatico@hotmail.com Tel. 809-549 0901 cell. 809 886 4827 5. Ms. Rosina Taveras Macarrulla Biological Control , Univ. Autónoma de Santo Domingo. franco.ornes@verizon.net.do Tel. 809-537 9465 6. Ms. Quisqueya Perez Univ. Autónoma de Santo Domingo, Faculty of Agricultural and Vetenary Science . u.decanato@codetel.net.do 7.Mr. Tony Costa Costa Nursery tcosta@costanursery.com tel. (809) 685 9975/76/77 cell. 809 284 9300 8. Mr. Roberto Montalvo General Manager, Costa Nursery montalvo@costanurserydr.com tel. (809) 687 0666 9. Mr. José Santana Nursery supervisor Costa Nursery Farms, Inc. (C.N.F.) jsantana@costanurserydr.com costanursery@veriozn.net.do tel. 284 9332 10.Mr. Ricardo García Deputy Director, Botanical Garden jardin.botanico@verizon.net.do acacia_rg@hotmail.com tel. 809-385 2611/13 cell. 804 3460 11.Mr. Sesar Rodriguez Researcher: Botanical Garden sesarrodriguez@hotmail.com 12.Mr Russell A. Duncan Caribbean Area Director APHIS attaché Russell.A.Duncan@aphis.usda.gov tel. 809- 227 0111 13.Mr. Ramón Arbona Research Director Dominican Institute for Forest and Agricultural Research (IDIAF) rarbona@idiaf.org.do 14. Ms. Isabel B. Téllez de Ortega Embassador of México Cel. 2586316 15. Ms. Patricia Herrerías Ortega Mexican Embassy lacalle@codetel.net.do 16. Dr. Colmar A. Serra National Plant Protection Program (IDIAF) Cell. 809 8444 820 colmar.serra@gmx.net 17. Ms. Concepción Sánchez	3. Field survey to Costa Nursery near Romana-Guaymate. Survey on *Opuntia* species 4. Visit Botanical Garden and the University

		Entomologist, Dept. of Agriculture, Plant Health cuarantenaveg7@hotmail.com tel. 37 210 05 18. Ing. Enrique Elías Comprés Jorge Pest Risk Analysis , Dept. of Agriculture tel 547 3888 Ext. 2391 cell. 860 8927 enriquecompres16@yahoo.com ecompres16@yahoo.com	
24.7.05 to 25.7.05 2 days	St. Vincent Bequia	1. Mr. Phillmore Isaacs Chief Agricultural Officer, Ministry of Agriculture and Fisheries agrimin@caribsurf.com tel.1-784 4561410 1-7844561021 2. Mr.Marcus Richards mlrids@yahoo.com Plant Protection and Quarantine Unit. cell 784 5307297 4. Mr.Winston George Agricultural Officer Communications Unit, Ministry of Agriculture georgewinston@hotmail.com citumaf@hotmail.com tel. 784 4571283 1. Ms. Cassile Walsh wcassile@hotmail.com 2. Mr. Nolly Simmons Retired Officer Box 23-Bequia	1. Rent taxi to survey for *Cactoblastis.* Travel with Mr. Marcus Richard to survey for *Cactoblastis* 2. Meeting with Mr.Phillmore Isaacs, Chief Agricultural Officer, Ministry of Agriculture 3. Visit the off-shore island Bequia and check for the presence of *Cactoblastis*
16.8.0 to 17.8.05 2 days	St. Kitts	1. Hon. Cedric R. Liburd Minister of Housing, Agriculture, Fisheries and Consumer Affairs minhafca@caribsurf.com crilburd@hotmail.com cell. 869 6622450 fax. 869 4652635 2.Dr. Jerome C. Thomas Director of Agriculture doastk@caribsurf.com tel. (869) 465 2335 Fax. (869) 465 2928 3.Mr. Llewellyn Rhodes CARDI Representative, St. Kitts and Nevis. Entomologist. cardiskn@caribsurf.com tel. (869) 465 2335/2928 4. Mr. Melvin James Plant protection officer CARDI tel (869) 465 1498 Cardiskn@caribsurf.com 5. Mr. Kenneth Martin Retired, Director Department Agriculture 6. Ms. Irene Laurence Director: Ministry of Housing, Agriculture, Fisheries and Environment antheacleo@hotmail.com 7. Mr. Godwin Francis TV representative for Ministry of Housing, Agriculture, Fisheries and Environment godozz51@hotmail.com tel. 1869 4052335	1) Visit CARDI office and discuss program 2) Give DVD presentation and discuss *Cactoblastis* (8 attended). TV interview on *Cactoblastis*. 2) Visit Minister of Agriculture and discuss Cactoblastis. 3) Visit Mr. Kenneth Martin (retired officer) and discuss the project of the 1960's. 4) Field survey to south-east peninsula and Medical Research Centre near Nicola Town.
28.7.05 to 29.7.05 2 days	St. Lucia	1.Mr. Armando M. Esparza Charge d'affaires, Embasy of Mexico aesparza@sre.gob.mx tel. 285 2970 2. Mr. Peter Darius Gabriel Director: Ministry of Agriculture, Forestry and	1. Meeting by Embassy personnel 2. Meeting with Ministry Agriculture and with government officials to discuss *Cactoblastis* 3. Survey for the presence of *Cactoblastis* 4. Travel with Armando M. Esparza 5. Travel with Gregory Squires and Stephen Romain

		Fisheries ddas@slumaffe.org tel (758) 468 4125 3. Mr.Gregory Squires Crop Protection Officer Agricultural Union tel. 1758 4502375 Fax 1758 450 1185 pegsqu@yahoo.com 4. Mr. Dunley Auguste Deputy Permanent Secretary Ministry of Agriculture, Forestry and Fisheries tel. 758-4689 4121 5. Mr. Stephen Romain Translator and Agronomist steveromain@hotmail.com	
19.7.05 to 21.7.05 3 days	Trinidad and Tobago	1. Mrs. Luz Elena Ines Bueno Zirion Mexican Ambassador luzelen@carib-link.net cell. 8687359625 2. Ms. Claudia E. Cabrera Vazquez claudiac@carib-link.net Mexican Embassy, Dept. Political Affairs and Cooperation tel 868 6221422 3. Mr.Jorge L Guadarrama jguadarrama@carib-link.net Embassy of Mexico, Consular and Administration tel. 868-627 7047/6988 jguadarrama@carib-link.net 4. Mr. Winston J. Gibson Permanent Secretary Ministry of Agriculture,Land and Marine Resources psmalmr@tstt.net.tt tel 868 6225596 cell. 868 7358498 5.Ms. Cynthra Persad Director for Research, Ministry of Agriculture, Soils and Marine Resources minalmrdirresearch@tstt.net.tt tel. 1 868 6467657 6.Mr. Perry Polar Insect Pathologist Caribbean and Latin America Regional Centre CAB International p.polar@cabi.org tel 868 6624173 www.cabi.org 7. Mr. Alta Garcia Trace Agricultural officer, Agronomist tel. 648-2384 8. Ms. Monica Lessey Agricultural officer, Ministry of Agriculture, Soils and Marine Resources monicalessey@yahoo.com tel. 6482384 9. Mr. Winston Johnson Librarian tel 8686453509 Library University of the West Indies	1. Meeting with Ambassador Mrs. Luz Elena Inès Bueno. 2. Meeting with Mr. Winston J. Gibson, Permanent Secretary and officers of the Ministry of Agriculture, Land and Marine Resources and Director for research and Ms. Cynthra Persad. 3. Meeting with Ms. Monica Lessey and field survey with Ms. Alta Garcia Trace. 4.Visit CABI research facilities at Curepe and Mr. Perry Polar, CABI. Study herbarium material of Dr. F D Bennett 5.Travel island of Chacachacare with Mr. Perry Polar 6. Visit the University West Indies Trinidad Campus: Visit Library and National Herbarium of Trinidad and Tobago, Department of Plant Science. 7. Work with Ms. Claudia Cabrera and prepare for visits to other islands.