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project

Biological control of two major weeds affecting crop and livestock production in East Timor

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1 Acknowledgments

The project team of Charles Darwin University would like to thank our project partners in East Timor for all the hard work and good will that has gone into this project,
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2 Executive summary

Chromolaena odorata has been recognised by the UN Global Invasive Species Program (GISP) as one of the 30 worst invasive weeds worldwide (Baskin 2002). In East Timor, chromolaena is now widespread and has a negative impact on cattle and goat production. It rapidly invades abandoned lands, crowds out other weeds, and replaces grasses and other pasture plants needed for cattle and goats. Chromolaena creates a fire feedback cycle, thereby promoting its own growth and dominance in the landscape. *Mimosa diplotricha* is a serious weed, especially of maize crops in higher rainfall areas of East Timor, reducing productivity and increasing the labour required in maize cropping.

The overall goal of this project was to provide long-term, low cost and low technology control of these two serious weeds (*Chromolaena odorata* and *Mimosa diplotricha*) through the introduction of two main biological control agents, the stem gall fly for chromolaena and a sap-sucking psyllid for *M. diplotricha*.

A key objective was to develop skills in entomology and biological control with staff from the Ministry of Agriculture, Fisheries and Forestry (MAFF) and the Agriculture Faculty of the National University of Timor Lorosae (UNTL), to build knowledge with UNTL students and to raise rural community awareness and understanding of biological control as a pest management option. The project proposed to introduce a wider range of agents for chromolaena and other weeds of significance once the first two agents were established.

The stem gall fly has successfully established throughout East Timor, where it established and spread at a faster rate than initially anticipated. The sap-sucking psyllid was introduced in the final stages of the project and has survived in the nursery sites to date.

After initial community resistance and suspicion, farmers are now asking to be included in the project. We have seen significant change in community attitudes to biological control, from suspicion to outright support and enthusiasm, as evidenced in local farmers protecting release sites from fires. This has been achieved through the extension and socialisation efforts of MAFF and UNTL teams working together to bring these technologies to communities. Local communities in affected areas now have an appreciation of the benefits of biological control, and some people now have a basic understanding of insect life cycles. Farmers themselves are now engaged in collecting and spreading the insects to other areas infested with chromolaena.

Through the project, staff from MAFF and UNTL have developed a good grounding in biological control techniques and have developed the capacity to implement a biological control program with technical support. Students have been actively involved in monitoring and data collection, and this will continue beyond the life of the project as it has been integrated into the curriculum of the agriculture faculty.

The impacts of the project are now evident with galls widespread throughout the Baucau area, and now can be seen at all of the release sites. Further monitoring will be required for the impact on the density and spread of chromolaena infestations to be quantified. Within the next 5-10 years, there should be a noticeable decrease in plant density at release sites, an increase in visibly stressed plants, and a reduction in new satellite infestations. The sap-sucking psyllid has yet to become established in East Timor, although indications are that it will establish at its current release sites. Once this has occurred it can easily be spread by MAFF staff to other suitable sites to accelerate its spread throughout infestations.

More agents need to be introduced to increase the pressure on chromolaena as they become available from researchers in South Africa. Further introductions of the sap-sucking psyllid are needed to ensure establishment of the insects at the nursery sites which would then provide a reservoir of insects to be harvested for release throughout East Timor.

Because the staff of both MAFF and UNTL now have the capacity and skills to maintain insects in a low technology setting and understand the principles of biological control, more work could be done to introduce biological control agents that are readily available and tested to control some of the other serious weeds in East Timor such as Bellyache bush (*Jatropha gossypifolia*), *Prosopis* spp. and *Sida acuta* for example. Much has been achieved on a low budget with long-lasting, sustainable impacts, and much more could be done to improve livelihoods in East Timor.

3 Background

In 2002, the Minister for Agriculture, Forestry and Fisheries of East Timor wrote to ACIAR requesting assistance on the biological control of *Chromolaena*. Dr McFadyen was invited to East Timor in 2003 to present a paper on chromolaena at the workshop on "Agriculture: New Directions for a New Nation", and saw the problem of *Chromolaena* and *Mimosa diplotricha* first hand. She proposed that the psyllid for the biological control of *Mimosa diplotricha* be introduced as well since it has proven to be effective in Queensland and Papua New Guinea. Mr Lourenco Fontes (MAFF) and Mr Acacio Da Costa (UNTL) attended the International Biological Control course held in Brisbane 2003, and the International Workshop on Biological Control and Management of *Chromolaena odorata* held in Cairns during May 2003. Both consider the weed a major pest in East Timor. In development trips, Tania Paul noted problems with the weed at the University farm at Hera and visits to the areas of Manatuto, Liquica, and the areas of Tibar, Gleno and Aileu.

Chromolaena odorata (Asteraceae) is a major invasive weed of pasture, plantation crops, forests and disturbed land in much of the Old World tropics, including western and southern Africa, South and South-East Asia and the Pacific region (McFadyen 1989; McFadyen and Skarratt 1996; Baskin 2002). It is spread by human movement via machinery and packing materials as well as animals and is continuing to increase in East Timor and other countries of South-East Asia. Chromolaena forms dense thickets 2-3 m high and chokes out other vegetation. No vegetation survives beneath the plants, and tree seedlings cannot penetrate the dense growth. Grasslands are rapidly invaded, and the grass is shaded out and completely replaced by chromolaena. All parts of the plant contain high levels of pyrrolizidine alkaloids (Biller et al. 1994) and if cattle or goats eat it the alkaloids progressively destroy their liver, and the animals die (Pancho and Plucknett 1971).

In East Timor, chromolaena is now widespread in most areas below 1,000 m altitude, where it has a negative impact on cattle and goat production and threatens biodiversity and the environment in natural *Eucalyptus alba* savannas and open grasslands of the Los Palos district. It is not found in the very dry areas along the north coast from Dili to Manatuto or in closed forest and coffee plantations, but is found in most other areas. Small farmers may not recognise it as a problem in rice paddies or cultivated fields, as it rapidly invades abandoned lands, crowds out other weeds, and is easier to remove when the land is again cultivated after 3-5 years. However, it replaces grasses and other pasture plants needed for cattle and goats. Chromolaena creates a fire feedback cycle, thereby promoting its own growth and contributing to its dominance in the landscape. In slash-and-burn agriculture it may be of some value as the abundant fallen leaves break down rapidly, thereby maintaining soil fertility. On otherwise denuded slopes it may help reduce soil erosion, although probably less so than the grass cover it replaces. In both situations, use of legumes such as Leucaena is preferable, as these increase soil nitrogen as well as provide fodder for cattle or goats.

It is a major invader of grasslands such as those from Manatuto across the island to the south coast, and in the Los Palos area in the east. It replaces *Imperata cylindrica* (alang-alang or blady grass). This may cause a problem where that grass is used for thatching, or may be seen as beneficial where the grass is a weed of cultivation. In the grasslands visible from the road south of Manatuto through Laklubar to Natar Bora, most of the hillsides are covered with a uniform blanket of chromolaena with little grass left for cattle or goats to graze. The severity of the problem and ecological dominance of this weed therefore creates a great need for control.

The primary long-distance vector responsible for the spread of both chromolaena and *Mimosa diplotricha* is human activity. The barbed seeds of *M. diplotricha* attach to animal fur or human clothing and are transported in this manner. The importance of military vehicles and equipment in spreading seed is confirmed by the Australian Forces

experience with vehicles used in East Timor. There is an increased risk of chromolaena infestations in northern Australia due to ongoing military peacekeeping movements and the increased traffic between Darwin and Dili.

No reliable cost estimates have been made of the impact of chromolaena or *M. diplotricha* in East Timor. Where farmers cannot afford to use herbicides to control *M. diplotricha* it can cause complete crop losses. Chromolaena threatens natural savanna grasslands essential for animal production in subsistence and commercial agriculture. The threat to northern Australia is enormous with over $800,000 already spent in North Queensland on an infestation near Tully. Should chromolaena become established in northern Australian savannas, prime beef cattle and agricultural areas would be under threat from the rapid spread of the weed (McFadyen and Skarratt 1996). Chromolaena would also alter the fire regimes in the tropical north resulting in increased frequency and intensity of bushfires.

In forestry, plantation crops and grazing lands where chromolaena is a serious invasive weed, chemical control using herbicides is possible but not economically or environmentally feasible, as the large seed bank means that repeated treatments are required. In subsistence agriculture, which is the predominant land use, chemical control cannot be afforded and the time required for manual control limits the area of land that can be cultivated. The only permanent and sustainable management method is biological control using insects or pathogens from the countries where the weed is native.

biological control using imported insects and diseases is an established, proven and successful control method for many invasive exotic weeds, especially where they invade land of low economic value such as natural grasslands, or threaten biodiversity in natural ecosystems (McFadyen 1998).

Chromolaena has been recognised by the UN Global Invasive Species Program (GISP) as one of the 30 worst invasive weeds worldwide (Baskin 2002). Biological control was first proposed by the Commonwealth Institute of Biological Control (CIBC) in the mid 1960s (Bennett and Rao 1968). Detailed studies were undertaken in Trinidad and surveys were made in Central and South America. Over 240 phytophagous insects were recorded, several of which were sufficiently host-specific to be potential biological control agents (Cruttwell 1974). Of these, the leaf-feeding moth *Pareuchaetes pseudoinsulata* was the first agent to be deliberately introduced, and was very successful in Guam (Muniappan and Marutani, 1988) and in Sumatra, but has not established in Java or in West Timor. Experience has shown that it requires a long-term and intensive effort with good facilities and experienced staff to achieve establishment and is not recommended in East Timor for the time being. The next insect released was the gall fly *Cecidochares connexa* (Diptera: Tephritidae), first reported from the Americas in 1970 (Cruttwell, 1974) but was not host-tested until 1993 in North Sumatra and released in Indonesia in 1995. It has since been released in all the major Indonesian islands and has also been released and established in Palau, Guam, Papua New Guinea and in Thailand.

Mimosa diplotricha is a serious weed, especially of maize crops in higher rainfall areas of East Timor, has been successfully controlled with releases in Queensland (1988) and Papua New Guinea (1992) of a sap-sucking psyllid from South America, *Heteropsylla spinulosa* after thorough tests in Queensland (Willson and Garcia 1992) found it to be completely host-specific. It is a very small pale green sap-feeding bug about 2.5 mm in length. The psyllids feed on the growing points of the plants, either under the leaves or on the stems. Eggs usually laid on upper leaf surfaces are tiny, oval and yellow, just visible to the naked eye (NRM Facts PP27 2001). High psyllid populations cause growing tip distortion and stunted plants, thereby reducing seed production. Growing tip elongation and seed production can be reduced by 72% and 80% respectively. Once established at initial release sites, the psyllids disperse well, flying or carried on wind currents to new sites. The four-week life cycle of the psyllid and high egg-laying rate allows the insect to rapidly boost its population.

4 Objectives

The overall goal of this project was to provide long-term control of two serious weeds (*Chromolaena odorata* and *Mimosa diplotricha [= M. invisa]*). A key aim was to develop MAFF and UNTL capacity in biological control, build knowledge through students and raise rural community awareness and acceptance of biological control as a pest management option by implementing an efficient, low technology method of collecting and disseminating the stem gall fly for chromolaena and the sap-sucking psyllid for *M. diplotricha* control.

Activity 1 – Training of MAFF and UNTL staff and students in biological control theory and practice

- Train MAFF and UNTL staff in biological control theory, rearing and maintaining insect colonies, release methods and monitoring techniques
- Training of technician and project coordinators in entomological techniques in East Timor and Australia
- Incorporate theory of biological control of weeds (including monitoring practicals) into the UNTL Agronomy curriculum

Activity 2 – Community socialisation/awareness raising of biological control program

- Awareness raising workshops for local communities on weeds and the problems weeds cause
- Train local farmers in the basic concepts of weeds and requirements of biological control
- Distribute posters and leaflets displaying colour pictures of biological control agents and weeds to involved communities and the wider community
- Training of MAFF and UNTL staff in adult education techniques through “train the trainer” workshops

Activity 3 – Introduction of stem gall fly, C. connexa

- Establish populations of the stem gall fly in permanent plots
- Monitor the population of the stem gall fly in permanent plots
- Monitor the stem gall fly impacts on chromolaena in permanent plots
- Release the stem gall fly more widely in chromolaena infestations identified for control by MAFF

Activity 4 – Introduction of sap-sucking psyllid, H.spinulosa

- Establish an irrigated plot of *Mimosa diplotricha* at Hera University farm
- Release and establish psyllid in irrigated plot at Hera University farm
- Release the psyllid in *M. diplotricha* infestations at MAFF identified locations
- Monitor impacts of the psyllid in *M. diplotricha* infestations at above locations

Activity 5 – Introduction of other biological control agents as required

- Determine need for and which other biological agents are required
- Establish rearing facilities for the new agents

- Rear and maintain colonies of the leaf-mining fly, stem-boring weevil and/or the root-feeding flea beetle as appropriate
- Release chosen agent(s) in chromolaena infestations identified by MAFF for control
- Monitor the establishment and spread of the agent(s) at above location
- Monitor the impacts of the agent(s) on the chromolaena infestation

5 Methodology

The methods adopted in the project adhered to the FAO Code of Conduct governing the use of exotic insects and pathogens in the biological control of invasive weeds and pests.

The Code can be summarised as follows:

- Importation must be made only with the consent of the government of the importing country.
- Other countries in the region concerned must be consulted.
- Introductions should only be made when in the public interest.
- Approval for release must be based on information about the agent supplied by the agency proposing the release.
- The host range of any potential agents must be adequately investigated before release.
- Only healthy specimens of the desired species should be released: all other imported material must be completely destroyed.
- To ensure this, the organism should be bred through one or more generations in a secure quarantine in the importing country (not required if importing from the same land area).
- If there is no secure quarantine in the importing country, stocks should be bred through at least one generation in a secure quarantine in another country before shipment to the importing country.
- Records of releases must be kept.
- Evaluations of the impact should be made.

The aim of the Protocol is to ensure the continued safety of biological control and to prevent any undesirable side effects by requiring that the biological control agents have been carefully tested for host-specificity and are imported free from parasites. This project conducted operations in accordance with the FAO guidelines above. The Minister for Agriculture, Forestry and Fisheries agreed to accept testing carried out in Indonesia and Australia for all the biological control agents.

5.1 Chromolaena control using *Cecidochares connexa*

During February 2005, the project team identified sites for monitoring and release of the stem gall fly, *Cecidochares connexa*. There were two types of sites selected. The first is a monitoring site where insects would be released over several seasons. These sites were to be monitored for the life of the project by project team members and UNTL agriculture students, in order to determine the establishment of the insects and to document the impact. These sites were selected based on the abundance and density of chromolaena present, and the willingness of the landholder/s to be involved and protect the site from burning. Sites were selected that were less than one day's travel from Dili as sites further distant would mean greater expense and difficulty for team members and students to access the sites.

The second type of site was a release-only site. Once the stem gall flies were established at the four original sites, galls were collected from the original sites and released at these more remote sites in order to accelerate the establishment, spread and impact of the gall fly over as much of East Timor's chromolaena infested areas as possible. Sites were selected at both ends of East Timor, and on the south coast. These sites were identified

on the basis of density and abundance of chromolaena present and reports from farmers experiencing problems with the weed.

The first four release and monitoring sites were:

- Tibar, Rai Metan
- Maubara – along the roadside near the convent
- Cribas River – an unused piece of land beside the bridge over the Cribas river, directly south from Manatuto
- Baucau airport, opposite barracks.

Site locations were logged using a GPS unit, and these were kept in a database with the numbers of insects released at each site and the dates of release, and place of origin.

Figure 1: Location of chromolaena sites for initial gall fly release throughout East Timor

During an initial survey by the project team, the border areas with West Timor were checked for stem gall flies in the hope that the stem gall flies released in the Atambua area in West Timor had reached the border, and galls could be collected within East Timor. No galls were located, even at the closest point to previous releases in West Timor suggesting that the stem gall fly had not become established from releases conducted near the Atambua area in 1998.

In March 2005, three members of the project team travelled to Lae, Papua New Guinea where, with the assistance of the ACIAR chromolaena project in Papua New Guinea, over 2,000 galls were collected for transport to East Timor. The Papua New Guinea team also demonstrated to MAFF and UNTL staff collection and release methods, and rearing techniques for the stem gall fly and the sap-sucking psyllid for *Mimosa diplotricha* control.

Collected galls were then placed at permanent release sites for the flies to emerge so that successful establishment, spread and impacts could be measured. Initial releases were made where the villagers were in favour of controlling the weed with biological control agents. The collection and release of the gall flies took place during the wet season. At this time of year, galls at the collection sites are plentiful, and emerging flies at release sites can find actively growing plants on which to lay eggs with sufficient time to complete several generations before the plants flower, seed and die back during the dry season.

The gall fly does not lay when the plant is in flower, instead passing the flowering season and the dry season dormant as larvae in the galls. Therefore releases were not made when the plant was about to flower, and in East Timor releases were made during the wet season, prior to the middle of April.

The galls were collected by cutting the stem of the plant about 3 cm below and above the galls. Old galls with an emergence hole in the side are already empty and were not collected. Very young galls that were still soft were not collected either. The galls selected

were green but hard with no emergence hole, but often the emergence “window” was visible on the gall with the plant tissue still intact. These galls can contain 2-4 (up to 8) mature larvae or pupae per gall, and the adult flies emerged within 2-10 days. At least 200 galls were collected for each release. Once collected, galls were kept in cardboard boxes or paper or hessian sacks. After collection, the galls were taken as quickly as possible to the permanent plots. The method developed in Papua New Guinea by Warea Orapa and Ingu Bofeng was also adopted. The gall cuttings were placed in a small plastic cup filled with water in the infestation. This extends the life of the cuttings to about 3 weeks and allows other adults to emerge.

The adult flies emerge from the galls within a week, fly up onto surrounding plants, mate and begin to lay eggs on the young shoots. Swellings on the stems are first visible about 15 days after the eggs are laid, but the gall takes nearly 2 months to develop fully. The next generation of flies begin to emerge and galls became more abundant with each new generation. During the dry season, the fly survives as larvae within the galls in the dry stems, so it was very important that these were not burnt.

Galls collected from Papua New Guinea were then released at the four sites in East Timor, with the release methods being demonstrated to other members of the project team. The team reported sightings of adult insects on the chromolaena plants at the sites only 2 months later. Due to the extended dry season, no galls were expected to form at the release and monitoring sites until the next wet season, November-December 2005.

In late 2005, the south-western coast in Suai district was surveyed for signs of galls crossing from West Timor after reported sighting of gall flies in Same and Ossu, Viqueque. The team conducted surveys in these areas and in collaboration with NAQS officer from Darwin collected samples of insects which were sent to Australia for identification. However it was found to be a species other than *Cecidochares connexa* despite a very similar appearance and behaviour. There were no galls located in any of the areas surveyed at that time.

In February 2006, a team from East Timor travelled to Kupang to collect galls from Nusa Cendana University with Wayan Mudita. The following month Colin Wilson visited East Timor to release gall flies and survey the four initial release sites. Students from the Agriculture Faculty at UNTL were involved in surveying and monitoring the four initial release sites to gather the first data and survey the release sites.

By mid 2007, gall flies had been released in approximately 50 locations in 25 villages throughout 10 districts of East Timor. These were collected from the two release sites where gall flies were released during 2004; at Baucau airport and Rai Metan (near Tibar) in the Liquica district, which was earlier than predicted for establishment and collecting at these sites.

Intensive monitoring was carried out at both of these original release sites, with the project team monitoring these sites whenever possible. Of the four initial release sites establishment of the gall fly failed in two. At Maubara, failure to establish was attributed to the fact that the site was too exposed and dry in the dry season. Establishment at Laclubar south of Manatuto along the Cribas River failed because the site was extensively burnt just 3 months after the initial release. Both of these sites were abandoned. The Cribas River site, although seemingly with excellent conditions and a permanent water source, is located on a well travelled road which is subject to frequent wildfires possibly ignited by cigarette butts etc from passing traffic.

Local farmers from the Cribas site were upset to report that a wildfire had decimated the site within only 2 months of the initial insect release. However, during a routine survey of the site during the following wet season, galls were present on some plants in the area, and several adult flies were observed. The area was too far from other release sites for the insects to have spread independently, therefore there must have been sufficient spread of adults shortly after the release, and sufficient density of chromolaena to allow some adults to survive.

During 2007 and 2008, the project collaborators in East Timor continued to actively progress the project. The detailed monitoring by university students of two *Cecidochares connexa* (gall fly) release sites continued; numerous new release sites were established throughout the country; a nursery at Hera for the rearing of the *Mimosa diplotricha* psyllid was established; and there was a wide-scale release of the psyllid into mimosa infestations.

There were numerous setbacks during the project due to civil unrest, such as the destruction of the original Mimosa diplotricha nursery, looting and loss of project equipment, and subsequent security risks that prevented project staff from travelling outside of Dili for a considerable period of time.

During the project period we were unable to access other biological control agents as hoped due to delays in host testing and availability from the research teams in South Africa. It is hoped that one of the agents which South African researchers believe to be very promising for the long dry season of East Timor will be available before the end of 2009. The leaf miner for chromolaena that had been planned for release was determined to be unsuitable for dry climates after trials in South Africa and Papua New Guinea.

Students from UNTL undertaking weed science studies carried out surveys at the main release and collection and nursery sites as part of their programme of study. The continuing involvement of students in this unit has helped to build the database and will be an ongoing component of the curriculum.

5.2 Control of *Mimosa diplotricha* using the psyllid, *Heteropsylla spinulosa*

The insect chosen for biological control of the weed *Mimosa diplotricha* was the sap-sucking psyllid, *Heteropsylla spinulosa*. It is a very small pale green sap-feeding bug about 2.5 mm in length. The psyllids feed on the growing points of the plants, either under the leaves or on the stems. Eggs are usually laid on the upper leaf surfaces and are tiny oval yellow eggs just visible to the naked eye (NRM Facts PP27 2001). It is in the same group of psyllids as the leucaena psyllid and appears very similar, however *Heteropsylla spinulosa* will not attack any other species including *Mimosa pudica* (R McFadyen pers. comm. 2004). High psyllid populations cause growing tip distortion and stunted plants, thereby reducing seed production. Growing tip elongation and seed production can be reduced by 72% and 80% respectively. Once established at initial release sites, the psyllids disperse well, flying or carried on wind currents to new sites. The psyllids have a short four-week life cycle and high rate of egg production given the correct conditions (NRM Facts PP27, 2001).

Psyllids were collected from populations around the Innisfail area of North Queensland. The psyllid population in North Queensland is free from parasites and therefore does not need to be reared through a generation before releasing onto the permanent plot at Hera, and the Minister for Agriculture, Forestry and Fisheries agreed to waive the requirement for quarantine and rearing a generation prior to release.

The Queensland population levels are at their highest during June/July, which is the ideal time to collect the psyllids. However, the collection time in Queensland correlates with the middle of the dry season in the northern part of East Timor and the psyllids can only survive the dry season in pockets of wet areas where there is fresh new growth to feed on. Therefore an irrigated and fenced plot of *M. diplotricha* was established, irrigated and regularly pruned in readiness to accept the shipments of psyllids from Australia. This irrigated served as a nursery site and the source of psyllids for all releases further afield in East Timor.

In January 2006, ministerial and cabinet papers on psyllids were prepared in order to gain government approval for importation and release of insects. In March, Michael Day from the Department of Natural Resources and Mines Queensland accompanied a shipment of

psyllids to East Timor. There he assisted the team to select suitable *M. diplotricha* infestations as release sites. Timorese partners were also given advice regarding the *M. diplotricha* nursery in the MAFF compound at Comoro and training in rearing and maintenance of psyllids and release methods.

Introductions of the psyllid were planned during 2006 with the collection and preparation of a *M. diplotricha* nursery at the Comoro compound. MAFF staff obtained import permits to allow the transport of the psyllid into East Timor. There were problems, however, in obtaining the psyllid in North Queensland, and then unfortunately the mimosa plants and nursery were destroyed. As the security situation deteriorated and did not improve until 2007, project team members were unable to travel to collect more seeds to establish further plants. No real progress was made on this until 2008 when applications were made for export and import approvals from the relevant authorities in East Timor and Australia. On several occasions in 2008 attempts were made to send psyllids to East Timor, however this proved to be quite difficult and there were several failed attempts at sending live insects.

On the first attempt to send psyllids in 2008, the insects were hand collected from North Queensland and transported to Dili via Darwin. There is a three-day limit from caging to release and the psyllids must be released onto fresh green mimosa. The insects were sent unaccompanied using a courier. Unfortunately, despite all the relevant quarantine certification from both Australia and East Timor, the insects were held up by Timorese customs and the package containing the insects was held in very hot conditions for several hours before being released to the Ministry of Agriculture, Forestry and Fisheries. As a result all insects died before they could be released.

To increase efficiency from the Queensland end, the Queensland Department of Primary Industries decided to rear a population of psyllids at the facilities in Brisbane. This would provide increased flexibility as to when insects could be collected and sent compared to requiring field staff to locate and collect wild populations from North Queensland.

Subsequent attempts to send psyllids have been hindered by problems in sending insects from Brisbane to Darwin – the insects were transported around Darwin in a very hot vehicle for several hours before being delivered to the CDU. The package was very hot when it was received and the majority of insects dead. The few surviving insects were accompanied to Dili and got through customs and quarantine without issue but unfortunately no insects survived.

In December, on the third attempt for the year, insects were hand carried from Brisbane to Darwin and kept in cool conditions until they were taken to Dili. Despite a 48-hour stopover in Darwin due to delays getting certification from AQIS, several hundred insects survived the trip. Unfortunately within half an hour of their release at the Hera research site the area was hit by a monsoonal downpour and it seems that insects were decimated.

Figure 2: Alvaro Alves and Americo Britto releasing psyllids at Hera Research Farm (outside Dili), December 2008

A final attempt to send live psyllids to East Timor from Queensland was made in February 2009. Whilst several hundred live insects were released at two sites (Hera Research Farm and Talitu village), at the time of reporting it was too early to determine whether this was enough to establish a local population.

5.3 Other agents

During 2006, the leaf-miner fly was introduced to Lae, Papua New Guinea with the chromolaena project staff there developing rearing, release and collection methods, and trials have been carried out in South Africa. It was anticipated that once it became established and the results of trials were clearly successful, this project would commence preparations to import this biological control agent. Unfortunately the trials determined that the leaf miner was unsuitable for areas with an extensive dry season, which includes East Timor. It is non-diapausing and therefore unable to withstand the long dry season and has very low impact where it has been established in Papua New Guinea and South Africa.

Other agents that were proposed for release in East Timor once sufficient host testing had been carried out in South Africa were not available during the term of the project despite our best efforts. The root-feeding flea beetle has a long life cycle and the South African researchers experience difficulties in establishing and maintaining colonies. The stem-boring weevil has great potential for East Timor, however there were significant delays in testing and we were not willing to introduce any agents that had not undergone rigorous testing.

5.4 Monitoring

Regular monitoring of the biological control agents determined whether they had established. Monitoring of the agent populations was carried out in the early wet season and the late wet season each year. The monitoring of the weed density was conducted at the same time. Initially, monitoring was carried out by Colin Wilson, CDU and was used as an opportunity to train the East Timorese project participants including the appointed

project coordinator and technician. These collaborators have since trained other MAFF staff members, UNTL staff and students in monitoring techniques with assistance from Australian counterparts where requested.

In April 2008, Colin Wilson visited East Timor to assist MAFF and UNTL staff with monitoring of chromolaena sites where gall flies have been released. This included observing and advising students from UNTL on monitoring techniques.

5.5 Community socialisation and awareness raising

During May 2006, East Timorese partners conducted socialisation activities with communities in new release sites for gall flies and psyllids. Colin Wilson, Tania Paul from CDU and Acacio Da Costa from UNTL and nominated MAFF staff held information workshops for local farmers on the project to raise their awareness of the weed and the biological control agents, and the need to protect the plots from burning and slashing.

The project team developed and distributed brochures on the gall fly and its life cycle. Full colour posters on biological control were translated into Tetum and made available on compact disc. MAFF and UNTL have copies of these posters and these are available to other agencies and the community.

Notice boards were erected at the gall fly release sites in Baucau, Liquica, Manatuto, Maliana, Bobonaro and Covalima districts to inform local communities of importance of allowing the gall flies to become established. The signs inform communities that the area is being used for a government program and should not be burnt.

Evaluation questionnaires were developed for participants in socialisation and training activities and for people who agreed to allow releases to be conducted on their land.

There were long interruptions to community socialisation and awareness-raising activities for the biological control program from 2006 to early 2008 due to the uncertain security situation caused by civil unrest in East Timor and the later assassination attempt on the country's president.

Field days and workshops were held during the dry season with local communities involved in the project to familiarise people with the insects and the project. The main aims of these sessions was to introduce basic biological control concepts, emphasise the importance of protecting the sites from burning and therefore not killing off the insects, and to obtain the goodwill and support of local communities for the project.

In August 2007, MAFF staff conducted extension activities with communities in the vicinity of the permanent plots at Baucau Airport and Raimate. This involved training for local farmers on the control of *C. odorata* using gall flies. Further workshops were conducted in Faturasa village, Remecio subdistrict, Aileu during 2008. This workshop was a result of requests from the community for assistance in controlling chromolaena. Chromolaena stands are very dense in the area and the weed has lead to reduce fodder available to livestock such as water buffalo, cattle and goats. Local land users were also taken to see stands of chromolaena in Liquica where gall flies are already established to allow them to see directly the impact of the flies on chromolaena.

The community in Remexio were always very keen supporters of the project but were not selected for initial releases because the higher elevation of the area, lower day temperatures and relatively low number of clear sunny days in the wet season were not conducive to establishing gall flies in the area. Now that the insect is established more widely in East Timor, this community will be included for releases in the future by MAFF staff. Now that sufficient populations are established elsewhere in the country, effort can be directed to building populations in more difficult to establish areas. It is also of great benefit to foster and include communities that are keen to be involved.

During 2008, MAFF funded the printing of a 22-page bulletin in Tetum regarding the importance of psyllids in the control of *Mimosa diplotricha*.

5.6 Training

MAFF and UNTL staff and students were given training in biological control theory and practice. Four East Timorese staff from the project attended the short course “Biological Control of Tropical Weeds” held at the University of Queensland from 4-15 April 2005. The course was jointly offered by CSIRO Entomology, Queensland Department of Natural Resources and Mines (DNR&M), and the University of Queensland. Participation was funded through this project, and attendance of Mr Americo Brito was funded by ACIAR through DNR&M.

The participants were:

- Mr Americo Brito – MAFF, Chief of Plant Protection
- Mr Alao Alvarez – MAFF Technician
- Mrs Donata De Araujo – UNTL Lecturer Agronomy dept
- Ms Anna Corte e Real – Project Technician

In 2006, project staff from MAFF and UNTL spent two weeks at the biological control section of the Weeds Branch of the Northern Territory Department of Natural Resources, Environment and the Arts. Activities included rearing, maintaining and field releasing biological control agents, surveying and monitoring biological control agents in the field, particularly large pastoral properties outside of Darwin.

Acacio da Costa Gutterres, a senior lecturer from UNTL, received a John Allwright Fellowship jointly supported by this project and another ACIAR Livestock Production Systems project to undertake study at Masters level through Curtin University of Technology, Western Australia and Charles Darwin University, Northern Territory. Acacio undertook and completed a Masters in Agricultural Science. Acacio submitted his thesis on control methods suitable for East Timor of the serious weed *Jatropha gossypifolia*, or Bellyache Bush and successfully submitted his final thesis mid May 2008. Acacio received his award and returned to the Agriculture faculty at UNTL where he has resumed teaching and taken up mentoring other staff and students and become actively involved in other research activities.

Figure 3: (Left to right) Bert Lukitsch, Acacio Guterres, Donata De Araujo Dan Alvaro Alves during training field trip with the Weeds Branch, Northern Territory Department of Natural Resources, Environment and the Arts, Australia

In March 2008, students from the agricultural department of UNTL were given field-based training on collection of galls, gall fly release and methods for monitoring levels of establishment and dispersal of gall flies. Training was conducted at Rai Metan village in Tibar, Liquica district.

Mike Day from the Queensland Department of Primary Industries and Johanna Karam from CDU visited project partners in East Timor in December 2008. Mike Day provided advice on the use of the database and spatial analysis for monitoring chromolaena infestations and distribution of the gall fly.

6 Achievements against activities and outputs/milestones

Objective 1: To train MAFF and UNTL staff and students in biological control theory and practice

no.	activity	outputs/ milestones	status	comments
1.1	Train MAFF and UNTL staff in biological control theory, rearing and maintaining insect colonies, release methods and monitoring techniques	Training conducted and completed	Completed	
1.2	Training of technician and project coordinators in entomological techniques in East Timor and Australia	Training conducted and completed	Completed	
1.3	Incorporate theory of biological control of weeds (including monitoring practicals) into the UNTL Agronomy curriculum	Continuing practical monitoring and surveying with students	Completed and integrated into curriculum	April 2008 – Approximately 40 students participated in monitoring/survey practical as part of UNTL 'Weed Science unit

Objective 2: To raise community socialisation/awareness of biological control program

no.	activity	outputs/ milestones	status	comments
2.1	Awareness raising workshops for local communities on weeds and the problems weeds cause	Workshops held	Completed	August 2007 – Discussions with local communities at Rai Metan (Liquica) and Baucau January 2008 – Discussions with farmers at Remexio regarding weed problems and control
2.2	Train local farmers in the basic concepts of weeds and requirements of biological control	Extension workshops held	Completed	October 2007 – Training with local communities at Rai Metan (Liquica) and Baucau regarding collection and release of gall flies February 2008 – Training for approximately 30 farmers at regarding the use of gall flies for control of chromolaena
2.3	Distribute posters and leaflets displaying colour pictures of biological control agents and weeds to involved communities and the wider community	Posters printed and distributed	Completed	Noticeboards prepared and posted in release sites November 2007 – project team presented information on this project and biosecurity at a national conference
2.4	Training of MAFF and UNTL staff in adult education techniques through “train the trainer” workshops	Formal training to be conducted	Completed	Conducted in 2006-07 over several visits

Objective 3: To introduce stem gall fly, C. connexa

no.	activity	outputs/ milestones	status	comments
3.1	Establish populations of the stem gall fly in permanent plots	Gall flies established in two permanent nursery sites	Completed	Gall flies are well established in the two original release sites at Baucau and Raimate (Tibar)
3.2	Monitor the population of the stem gall fly in permanent plots	Monitoring conducted regularly at permanents sites	Ongoing	Regularly carried out Most recent monitoring February 2009
3.3	Monitor the stem gall fly impacts on chromolaena in permanent plots	Regular visits to permanent field plots to measure chromolaena height, density and gall abundance	Ongoing	Regularly carried out Most recent monitoring February 2009
3.4	Release the stem gall fly more widely in chromolaena infestations identified for control by MAFF	28 new release sites	Ongoing	Regularly carried out

Objective 4: To introduce sap-sucking psyllid, H.spinulosa

no.	activity	outputs/ milestones	status	comments
4.1	Establish an irrigated plot of *Mimosa diplotricha* at Hera University farm	Nursery plot established	Completed	Again in 2007-08 (previous plots destroyed)
4.2	Release and establish psyllid in irrigated plot at Hera University farm	Psyllids released at Hera UNTL farm	Ongoing	Delayed due to difficulty sourcing psyllids. Unsuccessful shipments of psyllids sent in July, September and December 2008. Final shipment sent February 2009 – awaiting results on success of establishment
4.3	Release the psyllid in *M. diplotricha* infestations at MAFF identified locations.	Still awaiting successful establishment at Hera UNTL Farm	Ongoing Need to wait until 2009-10 wet season	Release sites identified along road between Dili and Aileu plus the UNTL farm at Hera
4.4	Monitor impacts of the psyllid in *M. diplotricha* infestations at above locations		Ongoing	Final shipment sent in February 2009. Insects released at Hera research facility and one field location – awaiting results on success of establishment

Objective 5: To introduce other biological control agents as required

no.	activity	outputs/ milestones	status	comments
5.1	Determine need for and which other biological agents are required	Field observations and community consultations to determine need for other biological agents	Incomplete Require more agents for chromolaena, and other weeds	Other control agents are required for more extensive eradication of chromolaena, such as those currently being used in South Africa. Other suggested target weed species are *Jatropha gossypifolia, Sida acuta* and *Prosopis* spp. These all have control agents available in Australia.
5.2	Establish rearing facilities for the new agents		Not completed	Facility identified at Triloka near Baucau that was to be developed

5.3	Rear and maintain colonies of the leaf-mining fly, stem-boring weevil and/or the root-feeding flea beetle as appropriate		Incomplete	Leaf-mining fly has been determined unsuitable through field trials in South Africa and Papua New Guinea Other agents have great potential and listed for future action
5.4	Release chosen agent(s) in chromolaena infestations identified by MAFF for control		Incomplete	For future action
5.5	Monitor the establishment and spread of the agent(s) at above location		Incomplete	For future action

7 Key results and discussion

The current project has created a great deal of enthusiasm, commitment and expertise in biological control in East Timor. As the process of establishing biological control agents and the timeline to see visible impacts are long term, the project has been remarkably successful in generating support and enthusiasm in local communities and amongst agricultural and natural resource management agencies. Biological control projects always take a long time to achieve success. This is especially true in a country such as East Timor where basic facilities are lacking and local collaborators have required extensive training. There have been several setbacks to the project due to security issues and loss of physical assets in civil unrest, which the team have overcome using innovation and teamwork. In short, the team are committed to seeing the project succeed, hope to continue their biological control effort against *Chromolaena odorata* and *Mimosa diplotricha* into the future, and also plan to include other weed species be included to take advantage of biological control agents currently available from Australia.

Acacio da Costa Gutterres, a senior lecturer from UNTL, was the recipient of a John Allwright Fellowship jointly supported by this project and another ACIAR Livestock Production Systems project to undertake study at Masters level through Curtin University of Technology, Western Australia and Charles Darwin University, Northern Territory. Acacio undertook and completed a Masters in Agricultural Science. Acacio submitted his thesis on control methods suitable for East Timor of the serious weed *Jatropha gossypifolia*, or Bellyache Bush, and submitted his final thesis mid May 2008 for assessment.

7.1 Spread of gall flies

By June 2007, gall flies were found to have spread at least 5 km in each direction in the three years since the flies were released.

By April 2008, galls of *C. connexa* were observed 21 km along the road from the Baucau Airport site where gall flies were released in March 2005. Field surveys in the enclave district of Oecusse in July 2007 revealed that galls had become established in all four subdistricts of Oecusse by natural spread from West Timor, Indonesia where gall flies were released approximately ten years earlier. Galls were also observed in Batugade (Bobonaro district), close to the border with Indonesia. Individual plants typically had only a single gall suggesting that the flies have only become established during the most recent wet season. The rapid spread of the gall fly is encouraging in terms of its potential to have nation-wide impacts on chromolaena infestations throughout East Timor.

Whilst it is still too early to see significant social or economic impacts resulting from chromolaena control measures, local communities have reported stunting and a reduction in the health of local stands of chromolaena where *C. connexa* has become established. This has lead to solid community support for biological control of *C. odorata* and requests for further training and extension work to provide farmers with the necessary skills to teach neighbours and friends about using gall flies for chromolaena control.

Students undertaking weed science studies carried out surveys at the main release and collection and nursery sites as part of their programme of study. The continuing involvement of students in this unit has helped to build the database.

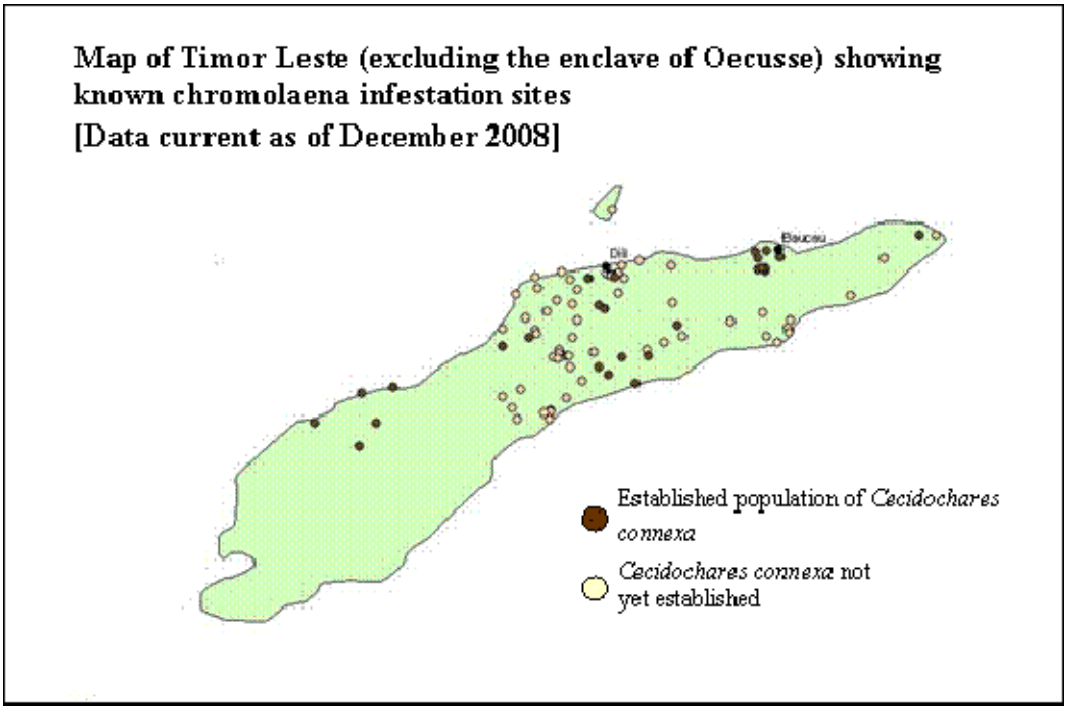

Figure 4: Distribution of chromolaena throughout East Timor showing sites where gall fly populations have been recorded

Figure 5: Example of galls from *Cecidochares connexa on chromolaena, Baucau airstrip, East Timor*

7.2 Extension activities

Partners from MAFF carried out extension activities with local communities from the four initial gall fly release sites, that is; Maubara, Rai Metan (Liquiça), Cribas Village (Manatuto) and Triloka Village (Baucau). This provided an opportunity to discuss the rationale behind the decision to use biological control and to address concerns raised by land holders. Some were concerned that chromolaena would be completely eradicated and that this was not desirable because the weed is also used as traditional medicine for humans and animals as well as an organic pesticide and fertiliser.

There were also concerns raised about the use of gall flies as the means of controlling chromolaena. Some were especially worried that the flies might attack humans and animals or damage their crops.

Figure 6: Community meeting as part of extension activities with local communities to introduce the concept of biological control of weeds (June 2005)

7.3 Incorporation of biological control theory into UNTL Agronomy curriculum

The UNTL Faculty of Agriculture has a unit on Weed Science. A theory component on biological control, specifically using the chromolaena project as an example, has been integrated into the unit. Students are also required to undertake a field activity which is surveying and monitoring for the gall fly. Through this process we plan to establish an ongoing monitoring and surveillance program through the faculty of agriculture, providing a long-term picture through long-term data collection. Student training was disrupted at various times throughout the life of the project due to the high level of risk in taking large groups out of Dili during civil unrest.

The most recent monitoring field visit with students was conducted in late February 2009.

7.4 Difficulties

Several unexpected issues arose throughout which significantly hindered the implementation of this project. Many delays were caused by civil unrest in 2006 and again in early 2008. A database of all releases and of monitoring results has been established, however in 2006 all data was lost along with computers. Fortunately some of the older data survived with project team members residing outside of Dili, so some of the data was recovered. Partners recommenced collection and entry of data in 2007.

New biological control agents for *Chromolaena odorata* that were planned for in the original proposal were altered as the South African researchers determined that the leaf miner is unsuitable as an agent in dry climates. There are promising results from their work on other agents such as *Conotrachelus reticulatus* which is highly host specific. There are several other agents such as *Dichrorampha* sp. that are awaiting the completion of host range testing by the South African researchers, but none of these agents were within the project period as the South Africans experienced delays in carrying out the level of host range testing that would be necessary to allow these agents to be imported for release in East Timor.

Introductions of the psyllid were planned during 2006 with the collection and preparation of a *Mimosa diplotricha* nursery at the Comoro compound and MAFF staff obtained import permits to allow the transport of the psyllid into East Timor. There were problems, however in obtaining the psyllid in North Queensland, and then unfortunately the mimosa plants and nursery were destroyed in the violence. As the security situation deteriorated and did not improve until 2007, project team members were unable to travel to collect more seeds to establish further plants.

This project was extended several times but activities continued to be disrupted due to political unrest in East Timor. Throughout early 2008, staff from the eastern districts of East Timor were unable to visit sites in the western part of the country due to concerns for their safety. This lead to some negotiation of responsibilities between Timorese partners but resulted in minimal disruption to project activities.

The Australian Department of Foreign Affairs and Trade continues to have travel warnings for travel to East Timor at the level of "reconsider your need to travel". This warning remains in place after several years, and has meant that staff from the Weeds Branch, Biological Control Unit of the Northern Territory Government (NTG) were prohibited from travelling to the country. This unfortunately lead to the postponement (and eventual cancellation) of a planned visit of NTG staff to East Timor. However the Biological Control Unit of the Weeds Branch actively participated in the project wherever possible through hosting Timorese project teams for on-the-job training in biological control and entomology, and taking them on lengthy field trips to conduct insect collections and releases in remote pastoral stations in the Northern Territory. This was particularly effective in developing methods for maintaining, caring and transporting insects over long distances to remote areas with minimal to no infrastructure.

A hymenopterous larval parasite of *C. connexa* was found and appears to be relatively abundant. It was present at Baucau Airport in the east of the country and near the border with Indonesia in the west.

Some galls were dissected and a number were found to have hymenopteran parasites. Inside an individual larval chamber in an affected gall was a single small black ‘pellet’ resembling a parasitised aphid ‘mummy’, which could be split open to reveal a wasp pupa. These pupae were only found in relatively young galls and were less than half the size of a *Cecidochares* pupa, so are most likely an internal larval parasite. A number of these were collected in a specimen bottle and some tiny wasps emerged within a couple of days. With the equipment available during the field trip, the species of the wasp could not be determined.

We have asked staff from MAFF to attempt to rear some specimens to send to specialists in Australia for identification. The parasites appeared to be quite common, and the project team will continue to monitor their relative abundance. These parasites are known to be present in chromolaena infestations west of Lombok. All the galls that have been distributed throughout East Timor were collected from West Timor and Papua New Guinea with the intention of avoiding the parasite. Papua New Guinea to date has not reported presence of the parasite, and the presence of the parasite in East Timor suggests that it is also present in West Timor.

8 Impacts

8.1 Scientific impacts – now and in 5 years

The impacts of the project are now evident with galls widespread throughout the Baucau area, and now can be seen at all of the release sites. Further monitoring will be required for the impact on the density and spread of chromolaena infestations to be quantified. Within the next 5-10 years, there should be a noticeable decrease in plant density at release sites, an increase in visibly stressed plants, and a reduction in new satellite infestations. A hymenopterous larval parasite of *C. connexa* was found and appears to be relatively abundant in the western portion of East Timor. This may reduce the effectiveness of *C. connexa* as a biological control agent over time, therefore increasing the need to introduce a more diverse range of biological control agents for chromoleana.

The sap-sucking psyllid has yet to become established in East Timor, although indications are that it will establish at its current release sites. Once this has occurred it can easily be spread by MAFF staff to other suitable sites to accelerate its spread throughout infestations.

More agents need to be introduced to increase the pressure on chromolaena as they become available from researchers in South Africa. Further introductions of the sap-sucking psyllid are needed to ensure establishment of the insects at the nursery sites which would then provide a reservoir of insects to be harvested for release throughout East Timor.

8.2 Capacity impacts – now and in 5 years

Project partners from MAFF and UNTL have become increasingly confident in discussing information regarding the concepts behind biological control of weeds and in particular the use of the gall fly for control of *Chromolaena odorata*. Partners are now confident in methods for releasing gall flies and staff from MAFF plan to continue to distribute the flies to chromolaena infested areas as part of their routine activities beyond the term of the project.

Students from UNTL continue to receive training in monitoring and survey techniques as part of a weed science unit. It is anticipated that this training will continue and increased the overall pool of knowledge regarding biological control theory and practice in East Timor.

Acacio da Costa Gutterres, a senior lecturer from UNTL, received a John Allwright Fellowship jointly supported by this project and another ACIAR Livestock Production Systems project to undertake study at Masters level through Curtin University of Technology, Western Australia and Charles Darwin University, Northern Territory. Acacio undertook and completed a Masters in Agricultural Science. Acacio submitted his thesis on control methods suitable for East Timor of the serious weed *Jatropha gossypifolia*, or Bellyache Bush, and successfully submitted his final thesis mid May 2008. Acacio received his award and returned to the Agriculture faculty at UNTL where he has resumed teaching and taken up mentoring other staff and students and become actively involved in other research activities.

8.3 Community impacts – now and in 5 years

Local partners report that farmers are happy with results of gall fly invasion on stands of chromolaena. Farmers from areas outside the project sites have requested gall flies in areas close to their land.

Results of surveys of farmer and local communities regarding problems with weeds revealed that chromolaena continues to present a major problem for farming communities. Farmers were happy to see that in areas where the gall fly had become established, chromolaena was visibly shorter but recognised the need for further control.

Whilst local communities are very supportive of the project, chromolaena continues to present a major problem affecting agricultural land. Whilst some impact has been observed to the height and density of chromolaena stands the weed is far from being eradicated in any region. Project partners with MAFF are most concerned about the fact that impacts on weed infestations have not met expectations. It is feared that unless some more substantial results can be achieved the community will no longer support their biological control efforts.

8.3.1 Economic impacts

The economic impacts are yet to be determined as the biological control agents are expected to take at least five years to have a detrimental impact on the spread and expansion of *Chromolaena odorata*. Once the insects are established the main effect will be in controlling the expansion of current infestations, and the establishment of new satellite infestations. This in turn means less work in clearing and burning land for pasture for farmers, which decreases the labour requirements in pasture management and crop planting preparations.

8.3.2 Social impacts

Landholders and farmers have taken a keen interest in the biological control agent. From an initially sceptical and resistant point of view in many cases, the project team reports far more requests from farmers for galls to spread on their own lands rather than resistance to the use of biological control agents. The key message has been that these biological control agents will never completely eradicate the plant, but will eventually bring it under control and prevent it spreading into new areas. As some local people use the plant medicinally and believe it has a benefit as a green manure, the message of the socialisation sessions and extension program has been aimed at alleviating this concern in the community. Team members have reported largely positive responses to their activities, an attitude which is also borne out in the protection of the release sites from fire by local communities. Burning of the release sites is a serious concern for the project as any fire in the first year of a release can potentially destroy all the agents released, and we have only experienced the loss of one site due to fires. Local farmers reported that this was due to a wildfire that started some distance away that they could not bring under control before it reached the release sites.

8.3.3 Environmental impacts

Environmental impacts are yet to be determined as the biological control agents are expected to take at least five years to have a detrimental impact on the spread and expansion of *Chromolaena odorata*. Once the insects are established the main effect will be in controlling and suppressing current infestations, and the establishment of new satellite infestations

Gall flies are abundant at, and spreading from, the two initial release sites established early in the project. Galls were found 21 km by road from the Baucau site. They have also arrived in the west of the country by natural spread from West Timor. The impact of galls on the plant is becoming apparent to the extent that farmers are requesting galls for release in their own localities.

At several places e.g. Tibar, gall fly populations were still low and chromolaena was still a major problem, whereas around Baucau, gall fly populations were large and there was noticeable dieback of stems and a reduction in plant height and density.

8.4 Communication and dissemination activities

East Timor Country Report was given at the 7th International Workshop on the Biological Control and Management of *Chromolaena odorata* and *Mikania micrantha*, held at the National Pingtung University in Taiwan, September 2006.

Also during 2006, the project worked with the Australian Cooperative Research Centre for Weed Management to develop a DVD entitled *Siam Weed Threat from the North* published through CSIRO. The project team provided locations, logistics, translations and assistance to the CRC team.

MAFF staff gave a presentation on the issue of biological control at a conference conducted by UNTL in November 2007. This conference focused on current agricultural research in East Timor and was attended by staff and students from the university's Agriculture faculty as well as staff from local and international NGOs. Material presented by staff described the concept of biological control, details of the current project for biological control of chromolaena, including techniques for gall fly introduction and field monitoring techniques.

In December 2008, the Minister of Agriculture, Fisheries and Forestry and several senior members of his department visited Charles Darwin University. During this visit they were presented with updated information regarding this project and were involved in discussions regarding the successes and short-comings of biological control activities in East Timor. The Minister and his staff were very supportive and enthusiastic about the potential for expanding such activities.

9 Conclusions and recommendations

Much ground work has been put into establishing support from local communities for biological control of weeds in East Timor. This support is essential but will only be maintained if clear results of the program can be enjoyed by land users.

Burning is a widespread practice throughout the dry season of East Timor and most of the country is burnt. While it is difficult to stop farmers clearing land for food gardens, there is a need to encourage farmers not to burn chromolaena in areas which are not going to be used for food gardens. Project staff must continue to show farmers the benefits of not undertaking widespread burning in terms of increased galls per plant and subsequent control of chromolaena.

9.1 Conclusions

Whilst more time is required to see the long term impacts of *C. connexa* on chromolaena infestations in East Timor, early indications are that it is affecting the health of the plants. It does seem that a further biological control agent would be required to bring the weed under control.

The impacts of the project are now evident with galls widespread throughout the Baucau area, and now can be seen at all of the release sites. Further monitoring will be required for the impact on the density and spread of chromolaena infestations to be quantified. Within the next 5-10 years, there should be a noticeable decrease in plant density at release sites, an increase in visibly stressed plants, and a reduction in new satellite infestations. The sap-sucking psyllid has yet to become established in East Timor, although indications are that it will establish at its current release sites. Once this has occurred it can easily be spread by MAFF staff to other suitable sites to accelerate its spread throughout infestations.

More agents need to be introduced to increase the pressure on chromolaena as they become available from researchers in South Africa. Further introductions of the sap-sucking psyllid are needed to ensure establishment of the insects at the nursery sites which would then provide a reservoir of insects to be harvested for release throughout East Timor.

Because the staff of both MAFF and UNTL now have the capacity and skills to maintain insects in a low technology setting and understand the principles of biological control, more work could be done to introduce biological control agents that are readily available and tested to control some of the other serious weeds in East Timor such as Bellyache bush (*Jatropha gossypifolia*), *Prosopis* spp. and *Sida acuta* for example. Much has been achieved on a low budget with long lasting, sustainable impacts, and much more could be done to improve livelihoods in East Timor.

9.2 Recommendations

Prior to commencing future biological control activities in East Timor there should be discussions and negotiations with all relevant government agencies regarding the process for importing control agents to the country. This may include workshops with East Timor quarantine staff to discuss the reasons for importing exotic insect species and develop communication strategies around import requirements.

Future collaborations should ensure that the *M. diplotricha* psyllid becomes established and spread throughout the country, and that further *C. odorata* biological control agents that have been rigorously tested and field trialled in sourced from South Africa to complement the impacts that *C. connexa* will begin to have and to further suppress chromolaena. Other possible future biological control collaborations should consider

targeting *Jatropha gossypifolia*, *Sida acuta* and *Prosopis* spp., as all are serious weeds in East Timor and suitable agents for their control are available in Australia.

In December 2008, large patches of lantana were observed on roadsides, which were not present during previous visits in 2006. MAFF staff advised that lantana is rapidly becoming a serious weed and farmers were having trouble clearing it. The agents *Teleonemia scrupulosa, O. lantanae* and *C. lantanae* were found in this area.

Staff or students from UNTL should be encouraged to continue monitoring of chromolaena to capture any benefits of the gall fly. There is evidence that the gall fly is having an impact but there is still insufficient data to quantify the extent of this impact. Any positive impacts documented will support future project proposals.

Michael Day, the entomologist from the Queensland Department of Primary Industries, recommends that further funding should be sought to support continued activities in the area of biological control of weeds in East Timor. He recommended that projects should be small, focused and with clearly achievable objectives. Projects (and therefore the weeds and agents targeted) should consider the logistics with importing insects and that insects need to be hand carried each time without plant material. Michael also recommends that it would be necessary to involve the existing project teams in East Timor and Australia wherever possible as trust and good working relationships have been established over the years, and these can be used as the foundation for further and more technical work in biological control. It would also be worthwhile including senior staff in MAFF and quarantine in East Timor in any new projects to help facilitate the importation of agents, especially where the process is quite complex. Involvement of AQIS staff from Darwin would also be beneficial as they would be involved in issuing certificates when insects are sent from Australia. Staff from UNTL and MAFF will prepare a list of priority weeds. A final list of weeds to be addressed in future projects can be prepared based on what effective agents are available for each weed.

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11 Appendixes

11.1 Appendix 1: Chromolaena infestation database (10 December 2008)

Table of recorded chromolaena infestations noting whether or not the gall fly (*Cecidochares connexa*) has become established at site

Districts	Town/Village	Latitude	Longitude	Altitude (m)	Last Released	Est.	Reported
Baucau	Baucau Airstrip	08° 28.588	126° 23.925	519	01-Mar-05	Yes	
Liquica	Tibar	08° 37.055	125° 28.744	293	01-Mar-05	Yes	
Manatuto	Cribas				01-Mar-05	Yes	
Liquica	Maubara				01-Mar-05	No	
Manufahi	Betano				01-Mar-06	Yes	
Manatuto	Soibada				01-Mar-06	Yes	
Lautem	Mehara				01-Mar-06	Yes	
Ainaro	Hato-udo/Ailoran				01-Mar-06	Yes	
Dili	Pantai Kelapa				Nat. spread	Yes	
Oecussi	Oesilo/Bobometo	09° 21.568	124° 23.445	505	Nat. spread	Yes	17-Jul-07
Oecussi	Passabe/Abani	09° 28.734	124° 18.207	1038	Nat. spread	Yes	18-Jul-07
Oecussi	Nitibe/Bene-ufe	09° 21.605	124° 04.435	14	Nat. spread	Yes	19-Jul-07
Oecussi	Pante Makassar/Nipani	09° 10.542	124° 28.618	3	Nat. spread	Yes	20-Jul-07
Oecussi	Pante Makassar/Lifau	09° 12.402	124° 18.808	90	Nat. spread	Yes	20-Jul-07
Aileu	Liurai				20-Feb-07	Yes	
Aileu	Talitu				20-Feb-07	Yes	
Aileu	Sarin				20-Feb-07	No	
Aileu	Dudato	08° 46.513	125° 33.701	1174	20-Feb-07	Yes	
Viqueque	Ossu/Buanurak				20-Feb-07	Yes	
Viqueque	Ossu Decima				Nat. spread	Yes	
Baucau	Venilale/Bercoli	08° 34.633	126° 23.316	585	20-Feb-07	Yes	
Baucau	Quelicai/Lawaliu				22-Feb-07	Yes	
Baucau	Quelicai/Bualale				22-Feb-07	Yes	
Baucau	Bucoli				09-Mar-07	Yes	
Baucau	Vemasse/Loilubo	08° 34.246	126° 21.123	714	09-Mar-07	Yes	
Baucau	Fatumaca	08° 33.868	126° 23.268	597	17-Mar-07	Yes	
Baucau	Uai-beana	08° 34.049	126° 22.319	690	17-Mar-07	Yes	
Baucau	Darasula	08° 30.991	126° 21.067	643	17-Mar-07	Yes	
Ainaro	Faulata				01-May-07	Yes	
Ainaro	Leolima				01-May-07	Yes	
Manufahi	Babulu				02-May-07	Yes	
Manufahi	Letefoho/Ai Mean laran				02-May-07	Yes	
Liquica	Maubara/Loes	08° 41.903	125° 06.300	33	10-Apr-08		
Bobonaro	Atabae/Migir	08° 52.704	125° 02.240	32	10-Apr-08		
Bobonaro	Balibo/Leolima				15-Apr-08		
Ermera	Hatolia/Alelo	08° 47.503	125° 15.814	138	18-Jun-08		
Bobonaro	Cailaco/Puruboa	08° 40.055	125° 13.482	101	20-Jun-08		

Bobonaro	CailacoMeligo	08° 53.237	125° 12.523	92	20-Jun-08		
Bobonaro	Cailaco/Dereleo	08° 54.196	125° 12.926	92	21-Jun-08		
Bobonaro	Maliana/Korluli	08° 55.172	125° 10.674	123	22-Jun-08	Yes	
Bobonaro	Bobonaro/Wailelo	09° 01.433	125° 17.746	916	23-Jun-08		
Covalima	Zumalai/Lour	09° 04.683	125° 23.199	592	23-Jun-08		
Covalima	Zumalai/Julo	09° 08.672	125° 26.968	127	24-Jun-08		
Covalima	Suai Villa/Beco	09° 14.181	125° 21.962	10	25-Jun-08		
Covalima	Suai Villa/Kamnasa	09° 18.009	125° 17.230	11	26-Jun-08		
Covalima	Suai Villa/Labarai	09° 18.343	125° 17.230	11	27-Jun-08		
Covalima	Suai Villa/Manue	09° 20.603	125° 16.610	0	27-Jun-08		
Viqueque	Watulari/Makadiki	08° 50.114	126° 31.208	36	08-Jul-08		
Viqueque	Watulari/Lugasa	08° 52.289	126° 30.449	12	08-Jul-08		
Viqueque	Viqueque Kota/Fatudere	08° 53.821	126° 30.494	0	09-Jul-08		
Viqueque	Viqueque Kota/Beaco	08° 56.962	126° 27.364	0	10-Jul-08		
Viqueque	Viqueque Kota/Dudukai	08° 55.127	126° 23.837	10	11-Jul-08		
Viqueque	Ossu/Loi-uno	08° 47.731	126° 22.680	716	12-Jul-08		
Dili	Dare						
Dili	Metinaro						
Dili	Balibar						
Dili	Atauro						
Dili	Hera	08° 33.208	125° 39.362	38			
Aileu	Telcom						
Aileu	Remexio/Faturasa						
Aileu	Remexio						
Aileu	Lequidoe						
Aileu	Laulara						
Baucau	Baguia/Lavateri						
Baucau	Baguia/Alawa Atas						
Baucau	Baguia/Alawa Bawah						
Baucau	Baguia/Defawasi						
Baucau	Baguia/Samalari						
Baucau	Baguia/Wakala						
Baucau	Baguia/Afaloicai						
Baucau	Baguia/Oso-una						
Baucau	Baguia/Haekoni						
Baucau	Laga/Samalari						
Baucau	Laga/Saelari						
Baucau	Laga/Sagadate						
Baucau	Laga/Soba						
Baucau	Laga/Atelari						
Baucau	Laga/Libagua						
Baucau	Vemasse/Kairabela				Nat. spread	Yes	
Baucau	Quelicai/Maluro						
Baucau	Quelicai/Laisorolai Leten						
Baucau	Quelicai/Lelalai						
Baucau	Quelicai/Abafala						
Baucau	Quelicai/Afaca						
Baucau	Quelicai/Lacoliu						

Baucau	Quelicai/Laisorolai Kraik						
Baucau	Quelicai/Letemumo						
Baucau	Quelicai/Waitame						
Baucau	Quelica/Abo						
Baucau	Quelicai/Namanei						
Baucau	Quelicai/Macalaco						
Baucau	Quelicai/Guruca						
Baucau	Venilale/Bahamori						
Baucau	Venilale/Daralata						
Baucau	Venilale/Badoho						
Baucau	Gariwai				Nat. spread	Yes	9-Apr-08
Baucau	Wailili				Nat. spread	Yes	9-Apr-08
Baucau	Buibau				Nat. spread	Yes	10-Apr-08
Baucau	Samalari				Nat. spread	Yes	10-Apr-08
Baucau	Caibada				Nat. spread	Yes	11-Apr-08
Baucau	Bucoli				Nat. spread	Yes	17-Mar-07
Baucau	Triloka/Rajawali				Nat. spread	Yes	23-May-08
Baucau	Buruma				Nat. spread	Yes	2-Mar-08
Baucau	Venilale/Waioli						
Covalima	Fohorem						
Covalima	Fatululik						
Covalima	Suai Villa						
Covalima	Fatumean						
Covalima	Tilomar						
Ermera	Ermera Villa						
Ermera	Railaco						
Ermera	Atsabe						
Ermera	Letefoho						
Lautem	Lospalos						
Lautem	Tutuala/Mehara				Nat. spread	Yes	
Lautem	Tutuala						
Lautem	Lour/Baricapa						
Lautem	Lour/Wairoke						
Lautem	Lour/Hafabubu						
Lautem	Lour/Kotamutu						
Lautem	Moro/Eukise						
Lautem	Moro/Ililai						
Lautem	Moro/Com						
Lautem	Moro/Parlamento						
Lautem	Moro/Baduro						
Lautem	Moro/Serelau						
Lautem	Moro/Maina I						
Lautem	Moro/Maina II						
Lautem	Moro/Pairara						
Lautem	Moro/Daudere						
Lautem	Iliomar						
Viqueque	Watucarbau/Afaloicai						
Viqueque	Watucarbau/Loiulu						

Viqueque	Watucarbau/Irabenu Atas						
Viqueque	Watucarbau/Irabenu Bawah						
Viqueque	Watucarbau/Bahatata						
Viqueque	Watucarbau/Waniuma						
Viqueque	Viqueque Villa						
Viqueque	Dilor						
Viqueque	Waimori						
Viqueque	Lacluta						
Viqueque	Liaruka						
Viqueque	Ossu/Lari-gutu						
Viqueque	Waibobo						
Viqueque	Nareca						
Viqueque	Watulari/Waitame						
Manatuto	Laclubar						
Manatuto	Rainbor						
Manatuto	Manehat						
Manatuto	Soibada						
Manatuto	Barique						
Manatuto	Laclo						
Manatuto	Laleia						
Manatuto	Natarbora						
Bobonaro	Atabae/Aidaba leten						
Bobonaro	Atabae/Hataz						
Bobonaro	Atabai						
Bobonaro	Atabae/Rairobu						
Bobonaro	Balibo/Batugade				Nat. spread	Yes	17-Jun-08
Bobonaro	Balibo/Cowa				Nat. spread	Yes	17-Jun-08
Bobonaro	Balibo				Nat. spread	Yes	
Bobonaro	Balibo/Sanirin				Nat. spread	Yes	
Bobonaro	Balibo/Leolitu				Nat. spread	Yes	
Bobonaro	Lolotoe/Lebos				Nat. spread	Yes	
Bobonaro	Lolotoe/Opa				Nat. spread	Yes	
Bobonaro	Lolotoe/Zildapil				Nat. spread	Yes	
Bobonaro	Lolotoe/Contor				Nat. spread	Yes	
Bobonaro	Lolotoe/Cerda				Nat. spread	Yes	
Bobonaro	Lolotoe/Deudet				Nat. spread	Yes	
Bobonaro	Lolotoe/Lopal				Nat. spread	Yes	
Bobonaro	Maliana/Holsa				Nat. spread	Yes	
Bobonaro	Maliana/Odomar						
Bobonaro	Maliana/Saiburai						
Bobonaro	Maliana/Raifu						
Bobonaro	Maliana/Memo				Nat. spread	Yes	
Bobonaro	Maliana/Lahomea						
Bobonaro	Maliana/Ritabou						
Bobonaro	Tapo						
Bobonaro	Malilait						
Bobonaro	Aiasa						

Bobonaro	Molob						
Bobonaro	Oeleo						
Bobonaro	Leber						
Bobonaro	Lour						
Bobonaro	Lourba						
Bobonaro	Hauba						
Bobonaro	Kota Bo'ot						
Bobonaro	Tebabui						
Bobonaro	Carabau						
Bobonaro	Ilatlaun						
Bobonaro	Soilesu						
Bobonaro	Atuaben						
Bobonaro	Bobonaro						
Bobonaro	Cailaco/Mamapu						
Bobonaro	Cailaco/Atudara						
Bobonaro	Cailaco/Gouloco						
Liquica	Bazartete/Ulmera						
Liquica	Liquica Villa						
Manufahi	Simpang Tiga						
Manufahi	Hola Rua				Nat. spread	Yes	
Manufahi	Same Villa				Nat. spread	Yes	
Manufahi	Turiskai						
Manufahi	Alas/Mahakidan						
Manufahi	Fatuberliu/Klakuk						
Manufahi	Fatuberliu/Fatukahi						
Manufahi	Fatuberliu/Caicasa						
Manufahi	Fatuberliu/Fahinean						
Manufahi	Fatuberliu/Bubususu						
Manufahi	Fatuberliu/Welaluhu						
Manufahi	Alas/Dotik						
Manufahi	Fatuberliu						
Manufahi	Maubesi						
Ainaro	Ainaro Villa						
Ainaro	Hatubuilico						
Aileu	Darlau						
Dili	Manleuana				Nat. spread	Yes	

11.2 Appendix 2: Results of chromolaena monitoring field trip with UNTL students

Data shown is for 8 x 1m^2 quadrats randomly selected along a100m transect through dense chromolaena stands.

11.2.1 Results of chromolaena monitoring at the Baucau airstrip and Raimate sites (April 2008)

Site		Number of plants/quadrat	Plant Height (m)	Galls/ Plant	Dry Wt Leaves (g)	Dry Wt Stems (g)
Baucau	Pooled Mean	9	105.45	6.11	5.36	16.13
	Pooled Std Err.	1.06	4.332	0.741	0.559	2.382
Tibar	Pooled Mean	10.62	114.05	3.21	5.27	14.36
	Pooled Std Err.	2.251	4.330	0.465	0.733	2.012