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1999 Annual Report

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January 1 - December 31, 1999

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CAUTION: The results in this report are preliminary and tentative. In order to prevent the spread of out-of-date or inaccurate information, this report should not be quoted or cited without verifying accuracy with the USDA-ARS Australian Biological Control Laboratory.

This report was originally prepared with embedded digital images cited as figures. Images were removed due to size limitations. For full report with pictures contact Dr. J.A. Goolsby (ABCL).

Table 1. List of acronyms used in this report

ABCL	- (USDA-ARS) Australian Biological Control Laboratory
ANIC	- Australian National Insect Collection
APHIS-	- (USDA) Animal and Plant Health Inspection Service
ARS	- (USDA) Agricultural Research Service
CSIRO	- Commonwealth Scientific and Industrial Research Organization
NQ	- North Queensland, north of the Tropic of Capricorn
nNSW	- Northern New South Wales, north of Coffs Harbour
NSW	- New South Wales
QLD	- Queensland
sNSW	- Southern New South Wales, south of Coffs Harbour
SQ	- South Queensland, south of the Tropic of Capricorn
SEL	- (USDA-ARS) Systematic Entomology Laboratory
TAG	- (USDA-APHIS) Technical Advisory Group on the Biological Control of Weeds
USDA	- United States Department of Agriculture

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Summary

Our research focus is on exploration for natural enemies of target insects and weeds, insect and plant ecology, field host-range surveys, and host-range testing. The goal of the research is to gain a better understanding of the insect or weed and of the full array of potential biological control agents within their native range. Ultimately, a greater diversity of agents can be discovered and investigated, thus increasing the potential for success in the biological control programs we support.

In 1999, a team of researchers from USDA, CSIRO, the Univ. of Florida and the Univ. of Adelaide came together to undertake an intensive study of the *Fergusonina/Fergusobia* gall-making fly/nematode complex attacking *Melaleuca quinquenervia*. The research group combined expertise in the fields of nematology, ecology, entomology, and biological control to complete this complex task in a remarkably short period of time. The research effort discovered and described the biology of *Fergusonina/Fergusobia* spp. and clearly demonstrated host-specificity for *M. quinquenervia*. Based on this information we intend to petition TAG in FY-2000 to release *Fergusonina/Fergusobia* in Florida against *M. quinquenervia*.

Field evaluation of *Fergusonina* sp. shows it to be closely synchronized with the phenology of *M. quinquenervia*, in direct correlation with the presence of new growth and the formation of buds. Data from this study indicates that *Fergusonina* sp. does respond well to increasing bud density, therefore it should be able to fully exploit the high bud densities found in the dense monocultures of South Florida.

Field and laboratory evaluation has continued with other high priority insects including, *Poliopaschia lithochlora, Lophodiplosis indentata,* and *Careades plana.* The gall-making cecid, *L. indentata* appears to be highly host specific and could be sent to Gainesville for final quarantine screening at any time. While *P. lithochlora* shows high levels of specificity it has proven difficult to rear. Additional research is planned to improve rearing techniques before this insect is sent to Florida for final screening. Recent collections of *C. plana* in Thailand from *M. cajuputi* have generated considerable excitement in this insect as a potential defoliator of *M. quinquenervia*. Intensive collections are planned to establish *C. plana* in culture for screening.

Collaboration has been initiated between researchers at ABCL and ARS-Ft. Lauderdale to compare ecology and pathology of *M. quinquenervia* between Australia and Florida. Comparisons of biomass distribution, seed production, and stand density identified many of the factors that limit the regenerative potential of *M. quinquenervia* in Australia.

Exploration for biological control agents for *Lygodium microphyllum* was conducted in Australia, Indonesia, Malaysia, Thailand and Singapore. Fourteen insects and one mite species have been recovered from *L. microphyllum* and related species. Three pyralid moths, *Cataclysta camptozonale, Neomusotima sp.* and *Musotima* sp. show good promise as biological control agents. No-choice host-range testing is underway with the first two species. Preliminary host-range testing for *C. camptozonale* will be completed in early 2000. Shipment of the agent to quarantine facilities in Gainesville is expected in May 2000.

Eriophyid mites have been collected from *L. microphyllum* across Australia and Southeast Asia. Mites collected from Queensland have been identified as *Floracarus* sp. These mites cause leaf-galling which often leads to leaf necrosis. Field studies in Sumatra show a strong correlation between increasing mite density and disease expression. Studies are underway to explore the potential of *Floracarus* sp. as a biological control agent.

Overview

Administration and Support

The USDA-ARS South Atlantic Area in Athens, Georgia and Aquatic Weed Control in Ft. Lauderdale, jointly administered ABCL for the first half of 1999. In August of 1999, ABCL was incorporated into the newly redesigned USDA-ARS, Office of International Research Programs under the direction of Dr. Darwin Murrell (Assistant Administrator) and Arlyne Meyer (Deputy Director). The personnel and facilities of the ABCL in Australia are provided through a cooperative agreement with CSIRO Entomology. The United States Embassy in Canberra provides the administrative support.

A coalition of federal, state and local agencies fund the overseas research on biological control of *Melaleuca quinquenervia, Lygodium microphyllum,* and *Maconellicoccus hirsutus*. South Florida Water Management District, Jacksonville District of United States Army Corps of Engineers, Florida Department of Environmental Protection, and USDA-APHIS National Biological Control Institute contributed substantially to the research during 1999.

ABCL works closely with the following project leaders to coordinate the research, Dr. Ted Center (Melaleuca & Hydrilla); Dr. Bob Pemberton (Lygodium & Paederia), and Dr. Alan Kirk (Pink Hibiscus Mealybug). ARS National Program leaders are Dr. Ernest Delfosse (Weeds) and Dr. Kevin Hackett (Biological Control).

Staff and Facilities

Dr. John Goolsby, the new Laboratory Director and Research Entomologist arrived at the ABCL on February 1, 1999. Ms. Kylie Galway departed ABCL in December to begin her doctoral studies at Lincoln University, in Canterbury, New Zealand. Mr. Ryan Zonneveld joins the program in February 2000. Ryan has ten years experience in host testing of weed biological control agents with CSIRO.

Travel and Visitors

In July, John Goolsby, Tony Wright and Matthew Purcell attended the International Symposium on Biological Control of Weeds in Bozeman, Montana. Three posters were presented on biological control of *M. quinquenervia* and *L. microphyllum*, Old World climbing fern.

Dr. Robin Giblin-Davis, a nematologist with the University of Florida, Ft. Lauderdale was on sabbatical at ABCL from March through August. Rob's research focused on the biology and evolutionary ecology of the gall fly *Fergusonina* sp. and its obligate nematode, *Fergusobia* sp. Drs. Kerrie Davies and Gary Taylor, nematologist and entomologist respectively, from the University of Adelaide in South Australia, joined the *Fergusonina* research group at ABCL for the month of June.

In November, Tony Wright, Matthew Purcell, and John Goolsby visited Singapore, Malaysia and Thailand to collect biological control agents for *L. microphyllum*, Old World climbing fern; *M. quinquenervia*, broadleaf paperbark tree; and *Paederia foetida*, skunkvine. Several new agents were collected for the target weeds. While in Southeast Asia, Tony Wright organized a meeting with collaborators from Indonesia, Malaysia and Thailand to discuss our joint research findings.

Thai Van, Min Rayachhetry, and Alex Racelis, from ARS Ft. Lauderdale, Florida, visited ABCL in November-December to conduct field studies on the ecology and pathology of *M. quinquenervia*. Field studies, in collaboration with Margaret Greenway (Griffith University, Brisbane), are underway to quantify seed rain and biomass production of *M. quinquenervia* in its native habitat.

Biological Control of Melaleuca

The Australian broadleaf paperbark tree, *M. quinquenervia*, was introduced into Florida as an ornamental at the beginning of this century. There has been a rapid expansion of this pest's range in southern Florida over the past 30 to 40 years. It now infests half a million acres, resulting in extensive environmental and economic damage.

There are up to 250 species in the genus *Melaleuca* in Australia, though most are shrubs with needle-like leaves and do not resemble *M. quinquenervia*. *Melaleuca quinquenervia* is placed with 10 other closely related *Melaleuca* species in the *M. leucadendra* complex. These 11 species have different habitat requirements, and can be distinguished by differences in fruits, flowers, and leaf proportions. Saplings, as well as sterile material from older trees, can be taxonomically difficult even for botanists familiar with the group.

Melaleuca quinquenervia is widespread along the eastern coast of Australia, usually occurring in swamps and other wetlands. The Australian range is roughly from Sydney to the tip of Cape York Peninsula. The most extensive stands are located in southeast Queensland and northern New South Wales near the border with QLD. In Australia, *M. quinquenervia* is also sold as an ornamental by commercial nurseries.

Gall Fly/Nematode Complex – *Fergusonina/Fergusobia* sp.

The gall-making fly *Fergusonina* sp. Malloch (Diptera: Fergusoninidae) is under study as a potential biological control agent for *M. quinquenervia. Fergusonina* sp. and its obligate nematode, *Fergusobia* sp. Currie (Nematoda: Tylenchida: Sphaerulariidae), form galls in the leaf and flower bud tissue of *M. quinquenervia*. Preliminary data indicates the nematode initiates gall formation (Giblin-Davis unpublished data). Galls stop the terminal growth of the stem and prevent the formation of flowers. Reducing seed production could be important in the management of *M. quinquenervia* in Florida.

Field Survey of *Fergusonina* spp. from the *Melaleuca leucadendra* complex. In order to determine if each *Melaleuca* spp. in the *leucadendr*a complex has its own co-evolved *Fergusonina/Fergusobia* sp., numerous field excursions were undertaken to collect galls from as many locations as possible. Galls on *M. quinquenervia* were collected mainly from SQ and nNSW, though a small number of specimens were collected in NQ and sNSW. Galls were collected south of Sydney on ornamental plants growing outside the native range of *M. quinquenervia*. This indicates that the flies/nematodes can tolerate climates from cool temperate to tropical conditions. During three trips to NQ during 1999, galls were collected from *M. dealbata* and *M. leucadendra* and for the first time on *M. cajuputi*, *M. fluviatilis*, *M. nervosa* and *M. stenostachya*. Two collecting trips were also conducted in Darwin in the Northern Territory where galls were collected from *M. viridiflora* and for the first time on *M. argentea*. Galls on *M. viridiflora* were found in small numbers at only one site near Darwin, and in QLD at Poona National Park, 212 km NNW of Brisbane. Both molecular genetics and classical taxonomy was used to analyze the diversity of the gall-making flies and nematodes. The evidence shows clear distinctions between *Fergusonina/Fergusobia* for each of the *Melaleuca* spp. in the *leucadendra* complex.

Host Specificity Evaluations. Host specificity evaluations began in September, towards the end of the field season. In a preliminary trial, seven females and three male flies reared from *M. quinquenervia* galls were released into a gauze sleeve enclosing several buds of a potted *M. dealbata* plant. After 5 days, the buds were examined and five scars were detected on one bud, though no subsequent gall development occurred. Two no-choice oviposition tests were conducted for *Fergusonina* sp collected from *M. quinquenervia*. In the first test, two test plant species, *Callistemon viminalis* and *M. viridiflora* and a *M. quinquenervia* control were each replicated three times (Table 2). Two pairs of flies were introduced into a gauze sleeve enclosing a single bud on each plant. After six days, the adults were removed and the buds were dissected. The number of eggs in each bud, and oviposition scars on leaves were recorded. An average of 58 eggs/bud and 37 oviposition scars/bud were counted on the *M. quinquenervia* controls, while no eggs or scars were found on any of the test plants. The second test was aborted when the flies died prematurely. The laboratory host specificity evaluations confirmed the field host specificity tests conducted in 1997 and 1998.

Table 2. Results of a no-choice oviposition host-range test where two *Fergusonina* sp. pairs were released into a gauze sleeve enclosing a single bud of each plant species for six days.

Plant Species	No. Replicates	Average No. Eggs/Bud	Average No. Scars/Bud
Callistemon viminalis	3	0	0
Melaleuca quinquenervia	3	58	37
Melaleuca viridiflora	3	0	0

Phenology of *Fergusonina*. To study the seasonal phenology of *Fergusonina* sp. on its host, *M. quinquenervia*, three study sites were selected in QLD and NSW. The three study sites are typical of stands within the native range of both *M. quinquenervia* and *Fergusonina* sp. in subtropical, eastern Australia. Peregian and Woodburn are seasonally inundated sites, with standing water common during the summer months. Morayfield remains free from standing water year-round. Monthly surveys were conducted at each site from July 1997 to September 1999. At each site, fifty trees were selected and the total numbers of galls on each of the sample trees were counted. Buds were categorized by stage and relative abundance each month. Only stage two and three buds were used to rate density because it was observed that *Fergusonina* sp. flies only oviposit into buds within these two size classes. Thirty galls adjacent to the study areas were collected monthly and held for emergence of *Fergusonina* sp., inquilines and parasitoids. Rainfall and temperature records for all three sites was provided by the Queensland Department of Natural Resources using the Data Drill program. CLIMEX was used for comparing the climate of southeast QLD with that of south Florida. CLIMEX uses long-term meteorological data from the target locations to make comparisons. The match index indicates the level of similarity in maximum temperature, minimum temperature, total rainfall, relative humidity, and rainfall pattern.

Fergusonina sp. appears to be closely synchronized with the phenology of *M. quinquenervia*, in direct correlation with the presence of new growth and the formation of buds. Formation and growth of *M. quinquenervia* second and third stage buds was seasonal, with the highest density occurring during Austral winter from May to September. Peak bud density occurred during July/August at all three of the study sites. Sharp peaks in gall density typically followed previous periods of high bud density. This indicates that *Fergusonina* sp. is able to quickly respond to localized increases in bud density. Gall density was strongly correlated with bud density and temperature, but not rainfall.

Comparison of climates between Brisbane and Miami using CLIMEX shows only a 59% match. The greatest differences between the two climates are in minimum temperatures and RH. Winter temperatures in Miami are consistently warmer and with higher RH than Brisbane. Cairns, QLD represents the more northern part of the range of *M. quinquenervia* and *Fergusonina* sp. in Australia. Cairns and Miami have nearly identical year-round average temperatures. However, South Florida, including Miami, can experience short bursts of cold weather which makes exact comparisons of climate difficult. In our comparison using CLIMEX we do not foresee the climate of South Florida to be a limiting factor for *Fergusonina* sp. *Fergusonina* sp. is found on *M. quinquenervia* throughout a range of climates in Australia, from tropical northern Queensland to Wollongong in the temperate climate of southern NSW. The climate of Florida falls within the range of temperatures, humidities, and rainfall patterns found in the native distribution of *Fergusonina* sp.

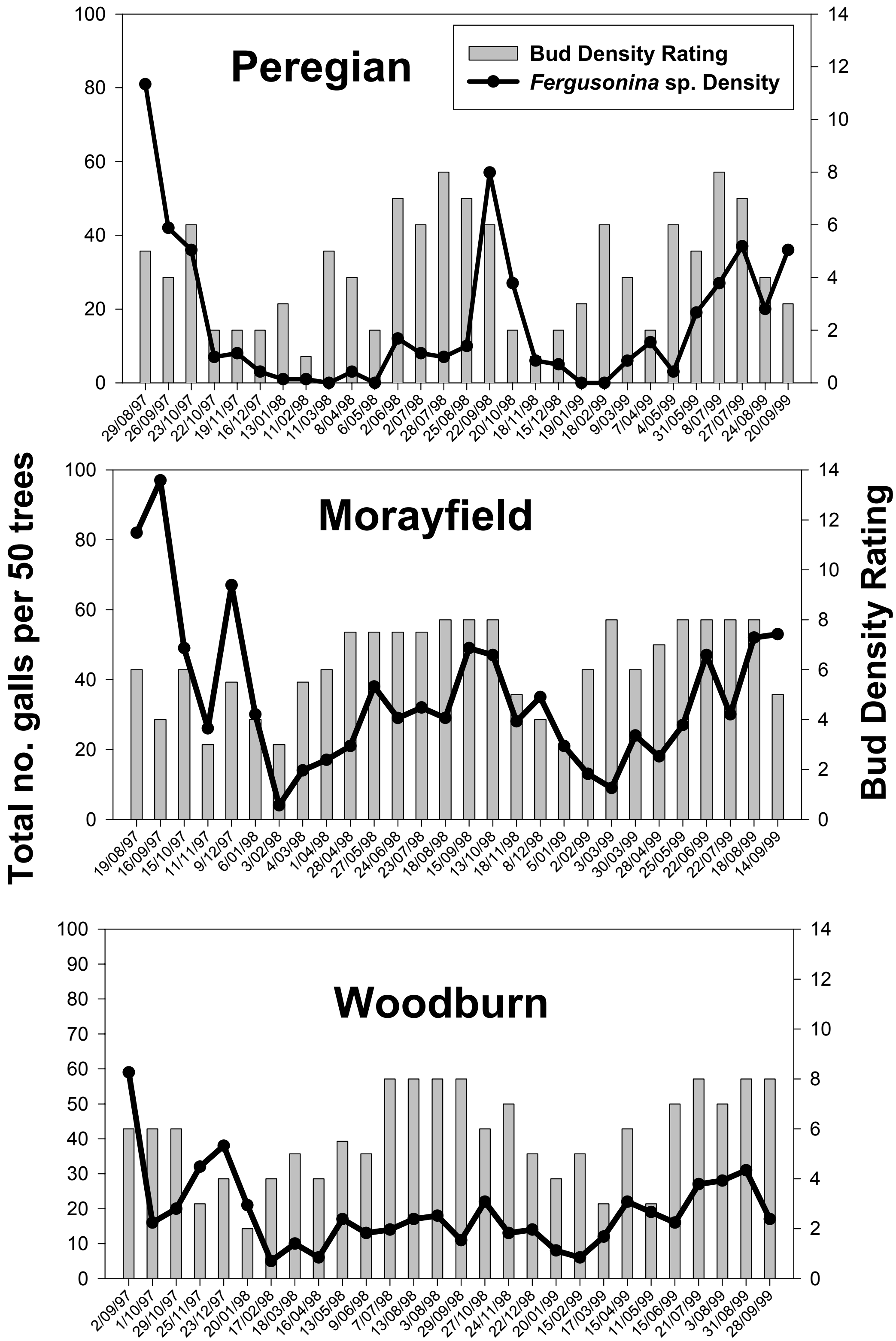

Fig. 3 Seasonal population levels of *Fergusonina* sp. compared with *M. quinquenervia* bud density

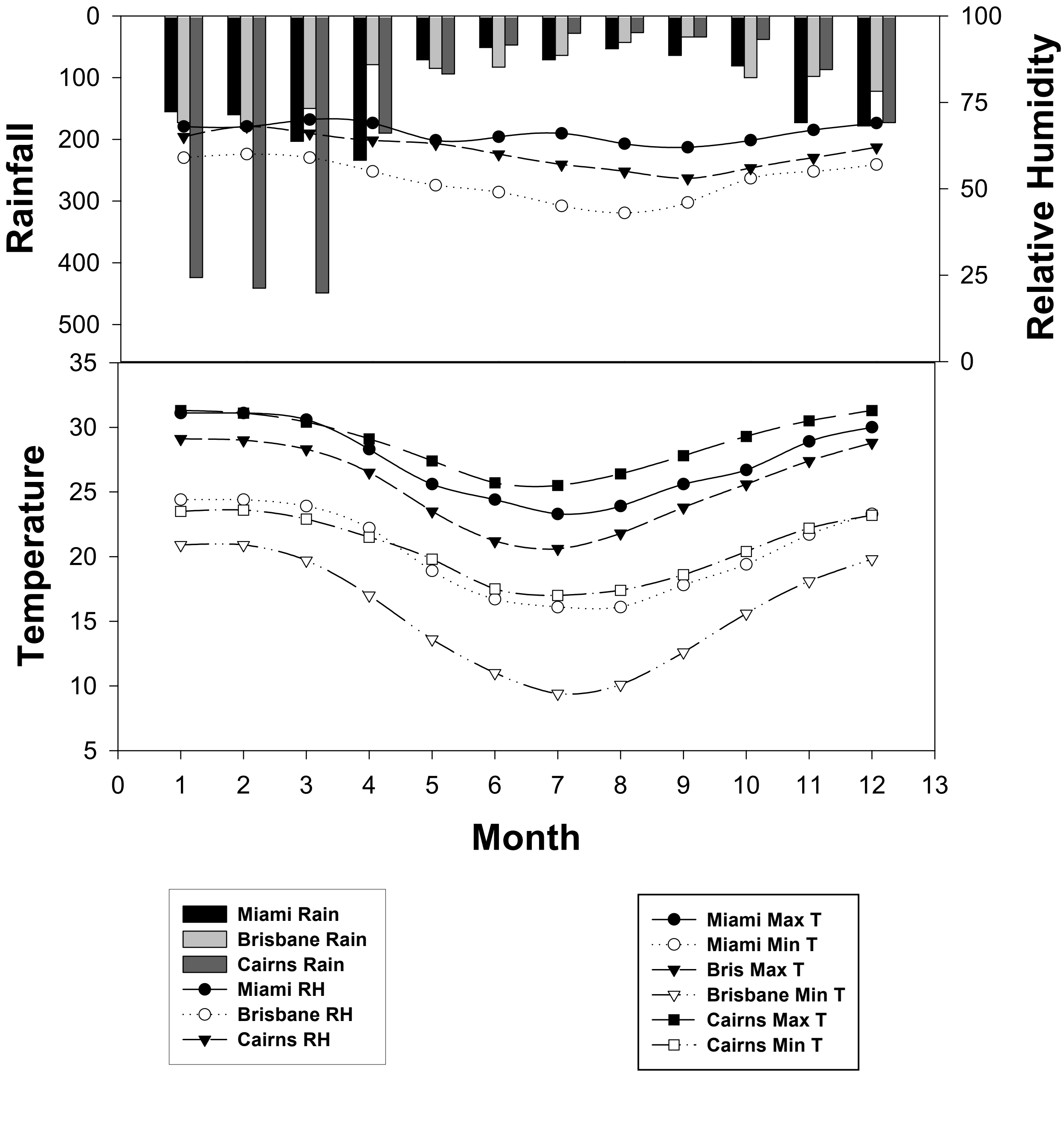

Fig. 4 Comparison of climates between Cairns and Brisbane Queensland with Miami, Florida

Parasitism of *Fergusonina* in Australia. In conjunction with the study of *Fergusonina* gall phenology, we also investigated the effect of parasitism on the bud gall fly populations. We now have a better understanding of why *Fergusonina* populations in Australia never reach high population levels. We also used this information to predict levels of parasitism in Florida. In the study, we examined lab emergence from galls collected in the vicinity of the three survey sites (Peregian, Morayfield, and Woodburn). 1122 galls were collected in 82 surveys conducted over the three sites; overall there was 63% emergence of non-*Fergusonina* insects. Another aspect of this study was to elucidate the biology and habits of the range of insects reared from these galls, enabled by a combination of gall dissections, juvenile rearing and DNA analysis.

At Morayfield and Peregian parasitism was around 70% (493 galls at 67.0% and 366 galls at 70.7% respectively) but dropped to 40% (from 263 galls) at Woodburn due to the virtual absence of *Eurytoma*, the most common parasitoid of the twelve wasp species that emerged. *Eurytoma* was determined to be a primary ecto- and endo-parasitoid of *Fergusonina* larvae and pupae. The next most common wasps, *Coelocyba* and *Neanastatus,* (and *Megastigmus* appearing in smaller numbers at all sites), have also been confirmed as primary parasitoids, but unlike *Eurytoma* they seem to develop upon a single *Fergusonina* larva. Like *Eurytoma, Pycnobracon* is a voracious feeder, parasitizing multiple *Fergusonina* larvae and pupae, but it also appears capable of acting as a hyperparasite. *Eupelmus* (Macroneura) and *Chromeurytoma* appear to be exclusively hyperparasitic, from the small numbers of specimens we have examined.

As yet we have been unable to confirm the life-history of *Cirrospilus*, *Eupelmus* (Eupelmus), and *Euderus*. *Poecilocryptus* is parasitic upon Lepidopteran larvae, and *Neomegastigmus* appears to be parasitic upon cecids, of which a few have been reared from these galls. We hope that DNA sequencing of larvae dissected from galls will fill in missing life-histories. All of these wasps, except *Cirrospilus,* were rare in this study. As well as the wasps reared from these galls 151 Lepidopteran larvae were recorded. While they were feeding purely on gall tissue they possess the destructive ability to hollow out complete galls, and as a result kill developing insects reliant upon that tissue. They must also be considered as having a major impact upon *Fergusonina* development.

In summary, parasitism of *Fergusonina* sp. is very high throughout the year. A complex of native parasitoids exerts a strong regulatory influence on *Fergusonina* sp. populations. We predict that levels of parasitism in Florida will be much lower due to the absence of specialized, co-evolved parasitoids. Furthermore, *Fergusonina* sp. populations could reach levels necessary to have a significant impact upon *M. quinquenervia.*

Potential Impact of the *Fergusonina/Fergusobia* Gall on *Melaleuca* in Florida. Several authors have reviewed the traits of gall-making insects and described what appear to be traits, which increase their effectiveness (Dennill 1988, Harris & Shorthouse 1996). The most effective gall-makers were powerful metabolic sinks, diverting substantial amounts of nutrient away from plant reproduction. The most effective galls either sever the vascular connection and persist over the entire growing season, or develop a vascular system with a heavily lignified shell. Using the attributes listed above, *Fergusonina/Fergusobia* galls have many of the elements that make them effective metabolic sinks. *Fergusonina/Fergusobia* galls do not completely sever the vascular connection. Galls are weakly vascularized and are comprised of parynchemal tissue with pockets of hypertrophied cells around developing fly and nematodes. It does appear that *Fergusonina/Fergusobia* forms a lignified gall. *Fergusonina/Fergusobia* have the potential to divert a considerable amount of plant nutrients into gall tissue. If gall numbers reached a high density on the plant their impact could be substantial, especially considering that the galls persist throughout the growing season.

Field data from this study indicates that *Fergusonina* sp. does respond well to increasing bud density, therefore it should be able to fully exploit the resources of the target plant in its new environment. The high bud densities found in the dense monocultures of the Everglades (Rayachhetry *et al.* 1998) may provide the ideal habitat for the gall fly. Parasitism of the galls is extremely high in Australia throughout the year. If parasitism in the introduced environment was significantly lower, population levels of *Fergusonina* sp. could increase dramatically. Because the *Fergusonina/Fergusobia* gall has many of the attributes necessary to be an effective metabolic sink, high densities could potentially suppress seed production and reduce vigor of the tree. Based on all these factors, *Fergusonina* sp. is good candidate biological control agent of *M. quinquenervia*

Tube-dwelling Moth - *Poliopaschia lithochlora*

The larvae of *P. lithochlora* feed on the leaves of *M. quinquenervia*, forming retreats made of frass webbed together into convoluted tubes. Leaves surrounding the tubes are also webbed together forming a small shelter. The eggs are laid in batches on the surface of leaves. Larvae initially form small colonies of at least half a dozen individuals, with tubes lined side by side on the leaf surface, on which they feed. In later instars, larvae separate, though at least 2-3 immatures can be found in a single, webbed shelter. These immatures leave their tubes to feed on surrounding leaves or to construct tubes. In the final instar, larvae form sealed bulbs within which they pupate. Development from egg to adult takes approximately 72 days. Adults are active at dusk and most oviposition occurs at night. Longevity for adult males and females is approximately 7 days.

Feeding by *P. lithochlora* larvae can occasionally kill small saplings of *M. quinquenervia*, probably due to repeated defoliation. High populations have been observed on small saplings/suckers at several sites in SQ, though they can also be found on older trees. Larvae and pupae are parasitised by *Carcelia* sp (Diptera: Tachinidae) and one Ichneumonidae (Hymenoptera) species.

In 1999, studies of *P. lithochlora* focused on establishing a laboratory colony to (1.) provide insects for shipment to quarantine facilities in Florida when required (2.) prepare for releases into the experimental field plot and (3.) provide adults to conduct preliminary laboratory host-range testing. In May we commenced weekly collections of larvae and pupae from field sites in SQ and nNSW to supplement laboratory rearing. Due to the distinctive form of the tubes, *P. lithochlora* are easily detected in the field. The laboratory colony peaked at almost 400 immatures, though these numbers could not be sustained due to high mortality levels. Mortality probably relates to a combination of disease and handling. The rearing process is labor intensive as larvae are reared in individual containers that must be cleaned weekly and resupplied with food biweekly. The average weekly mortality from May through December was 21%. In 2000 we plan to introduce new techniques to substantially reduce mortality.

For the third consecutive year we conducted field host-range studies of *P. lithochlora* at two sites in SQ, Caloundra (69 km N of Brisbane) and Morayfield (39 km NNW of Brisbane.) At each site, all plants along a transect were searched for the presence of *P. lithochlora* colonies. The plant species and the number of colonies per tree were recorded. The results are given in Table 3. The transects included 117 plants from eight species at Caloundra, and 162 plants from eight species at Morayfield. As in previous years, all *P. lithochlora* colonies were found on *M. quinquenervia*. Another tube-dwelling moth species was collected from *M. linariifolia*. Tube-dwelling moths collected in supplementary surveys of *Acacia hubbardiana*, *Callistemon viminalis*, *Leptospermum polygalifolium*, an undetermined *Leptospermum* sp., an undetermined *Melaleuca* sp., and further larvae from two unknown plant species were not *P. lithochlora*.

Table 3. Results of *Poliopaschia lithochlora* field surveys conducted at Caloundra and Morayfield (March 1999) in SQ.

Family	Plant Species	Caloundra		Morayfield	
		No. Trees	No. Colonies	No. Trees	No. Colonies
Casuarinaceae	*Allocasuarina littoralis*			4	0
Fabaceae	*Pultenaea myrtoides*	7	0		
Mimosaceae	*Acacia hubbardiana*	8	0		
	Acacia concurrens			16	0
Myrtaceae	*Callistemon* sp.	27	0		
	Eucalyptus sp.			7	0
	Lophostemon suaveolens			3	0
	Melaleuca linariifolia	13	16*		
	Melaleuca nodosa			8	0
	Melaleuca viridiflora	15	0		
	Melaleuca quinquenervia	29	10	82	30
Pinaceae	*Pinus* sp.	14	0	1	0
Proteaceae	*Grevillea leiophylla*	4	0		
Rhamnaceae	*Alphitonia excelsa*			41	0

* Larvae distinctly different to *P. lithochlora* larvae collected on *M. quinquenervia*

In August 1999, we completed our seasonality surveys of *P. lithochlora* at Morayfield in SQ and Tyagarah in nNSW. We started these surveys in June 1997, where 50 *M. quinquenervia* trees were searched at each site and the number of colonies was recorded. From January 1998, we surveyed 100 trees at each site. Surveys were also conducted at a third site, Byron Bay (141 km S of Brisbane) until August 1998, however field numbers were consistently low (3.6 colonies/100 trees over 12 months) and surveys were terminated in August 1998. The complete results for all surveys are given in Figure 6. During 1999, populations peaked at both sites in February at 15 colonies/100 trees and 25 colonies/100 trees at Tyagarah and Morayfield respectively. Field numbers dropped dramatically in March and remained relatively low for the rest of the year. No colonies could be found at Tyagarah in April while only 2 colonies/100 trees could be found at Morayfield.

Over the last three years there appears to be no seasonal trends in the data. Peak populations could occur any time at Tyagarah, though numbers remained relatively consistent at this site, at least until 1999. Morayfield was characterized by having extreme changes in field populations, changing rapidly from very low levels (6 colonies/100 trees) to very high levels (38 colonies/100 trees) within one month. Indeed, this site on average had the lowest population level, yet recorded the six highest monthly recording levels.

Due to restricted numbers of adults available for experimentation, we were limited to opportunistic laboratory host-range testing during 1999. *Poliopaschia lithochlora* females oviposited on four *Callistemon* spp.; *C. citrinus*, *C. linearis*, *C. rigidus* and *C. viminalis*. Immatures only developed into adults on two species, *C. viminalis* and *C. rigidus*. Mortality of immatures on *C. rigidus* was very high (up to 98%), and only a single deformed adult was reared. Mortality on *C. viminalis* was 50% and the emerging adults appeared to be smaller than those reared on *M. quinquenervia*. Development on these *Callistemon* spp. took approximately three times longer than on *M. quinquenervia*. Presently, larvae are also developing on *C. linearis* but are yet to pupate. In other trials, P. *lithochlora* did not oviposit on *C. citrinus*, *C. pachyphyllus*, *Eucalyptus robusta*, *Melaleuca alternifolia*, *M. nodosa*, and *M. linariifolia*.

All field data from NQ, SQ and nNSW indicate that the field host-range of *P. lithochlora* is restricted to plant species in the *M. leucadendra* complex, including *M. dealbata*, *M. leucadendra*, *M. quinquenervia* and *M. viridiflora*. However, our restricted laboratory cage tests indicate that some *Callistemon* spp. may be alternate hosts. More laboratory tests are required to confirm the specificity of this insect.

Pea gall - *Lophodiplosis indentata* (Diptera: Cecidomyiidae)

Pea galls on *M. quinquenervia* are formed by two species of Cecidomyiidae, *Lophodiplosis indentata* and *L. denticula*. Both species are found in NQ, though *L. indentata* is more abundant. *L. denticula* has not been collected in SQ and nNSW. The galls occur on the young foliage of *M. quinquenervia* and persist on older leaves following emergence of the insect. The young foliage is deformed and significant rounded thickening occurs in the leaf tissue. Like many galls, pea galls may act as nutrient sinks causing a reduction in plant vigor.

In 1999, pea galls were recorded in over 80% of field searches conducted on *M. quinquenervia*, and from over 75% of sites. Many pea galls were also collected from other species in the *M. leucadendra* complex to check species diversity, specificity and parasitisation. All specimens reared from *M. quinquenervia* in SQ appear to be *L. indentata*. These field-collected adults were used to supplement the laboratory colony. This colony, which was established in 1998, was terminated in November when the plants became infested with the melaleuca psyllid, *Boreioglycaspis melaleucae*. Although the flies can be easily reared on healthy plants, the psyllid frequently contaminates the colony, killing the gall-infested saplings. A new colony will be established in 2000.

In preliminary life-history studies, adults of *L. indentata* were released into cages for two days, then removed. When gall formation was recorded, galls were inspected daily for emergence, and emerging adults were preserved. Development time from egg to adult was 71.7 d for females (range = 52-96 d) and 69.8 d (range = 57-86 d) for males. The male to female sex ratio was approximately 6:4.

All records indicate that *M. quinquenervia* is the sole host of *L. indentata*. It is likely that this species is very specific, indicating it has potential as a biological control agent. Laboratory host-range experiments are needed to confirm specificity.

Impact studies are planned to assess the ability of these flies to damage *M. quinquenervia*. Pairs of adults will be released into enclosures containing small, potted saplings of *M. quinquenervia*. In another enclosure, potted saplings of equal size and age will be left untreated as controls. Following gall development and complete emergence of adults, the plants will be measured for height, stem diameter, foliage production, leaf area, wet weight, and dry weight, for comparison with control plants. This experiment will be replicated at least three times. A second, similar experiment will expose the saplings to successive generations of *L. indentata*. Results should give us a valuable insight into the impact of *L. indentata* on the growth of *M. quinquenervia*.

***Careades plana* (Lepidoptera: Noctuidae)**

The larvae of the noctuid moth, *Careades plana* feed on the leaves of *M. quinquenervia*. In previous surveys of *Melaleuca* spp. in Australia, this moth was only found in very low numbers on *M. quinquenervia* at twelve field sites in NQ. This year, we collected *C. plana* feeding on *M. cajuputi* at an additional site, McDowell Billabong near the Daintree River. In 1998, *C. plana* was collected at two sites in southern Thailand on *M. cajuputi*. *Melaleuca cajuputi* is the only species in the *M. leucadendra* complex that grows naturally in Indonesia, Malaysia, Thailand and Vietnam. In August 1999, a specimen collected from Pattani Province in southern Thailand was compared with a larva collected from NQ using analysis of the D2 gene, and confirmed to be the same species. In

November, surveys at another three sites in southern Thailand found large numbers of *C. plana* larvae feeding on the leaves of *M. cajuputi*.

The field host-range of *C. plana* appears to be restricted to two species in the *M. leucadendra* complex indicating that this insect has potential as a biological control agent. Insufficient numbers have been collected in Australia to facilitate colonization or a host-testing program. Surveys are planned in 2000 to locate populations of these moths in stands north of the Daintree River in NQ. Failing this, specimens from Thailand could be shipped directly to quarantine facilities in Florida.

Melaleuca Sawfly – *Lophyrotoma zonalis* (Hymenoptera: Pergidae)

Lophyrotoma zonalis was one of the first biological control agents for *M. quinquenervia* studied at the ABCL. This insect is mostly found in NQ where its larvae defoliate *Melaleuca* trees. It was shipped to the Gainesville quarantine facility in May 1992, and it is presently awaiting approval for release. Larvae of this sawfly are aggressive feeders and can cause extensive defoliation. Because larvae pupate in the bark of the tree and not the soil (like many other sawflies), it could be an effective biological control agent in the wetlands of southern Florida, including the Everglades.

In August, Dr. Peter Oelrichs from the National Research Center for Environmental Toxicology (NRCET) in Brisbane contacted the ABCL regarding sawfly toxicity. Dr. Oelrichs has researched cattle poisoning by the larvae of *Lophyrotoma interrupta*, a sawfly found in Queensland that feeds on *Eucalyptus melanophloia* (Oelrichs 1982, McKenzie et al. 1984). He has subsequently published research findings on the toxicity of sawfly larvae from countries on three continents, Australia, Denmark and South America (Oelrichs et al. 1999). From these sawflies, two toxins were isolated, Lophyrotomin and Pergidin. Dr. Oelrichs suggested that *L. zonalis* should be tested for these toxins. Freeze-dried larvae where shipped to the NRCET from the Gainesville quarantine facility. Dr. Oelrichs analyzed them in November, and both toxins were extracted in significant levels.

Although the larvae are toxic, there are distinct differences between the larval habits of *L. zonalis* and other sawflies implicated in animal poisonings around the world. In each case of poisoning, the larvae were congregating in large numbers on the ground beneath trees, probably for pupation. *Lophyrotoma zonalis* pupates in the papery bark of *Melaleuca* trees, and is rarely found on the ground, and never in large congregations. If the insect is to be released in Florida, at most risk will be animals inhabiting the trees, mostly birds. Some toxicity trials have been conducted in the U.S., though further tests may be needed, possibly incorporating behavioural studies. The larvae may be unpalatable to many animals due to the essential oils found in the leaves of *M. quinquenervia*.

In December, heavy defoliation of *Melaleuca* spp. trees was observed in NQ. In a 10-15 km area south of Ingham, many trees had been heavily damaged. Numerous larvae, prepupae and pupae were located on and in the bark of defoliated trees. Smaller isolated areas of defoliation were also observed north of Cairns, mainly on *M. leucadendra and M. dealbata*. Large numbers of adults were observed flying around the base of a defoliated *M. dealbata* tree, possibly swarming before mating. Many larvae were collected and freeze-dried for further toxicity testing if it is required.

Other Insects

During 1999 new areas were surveyed, not only to gather taxonomic, host and distribution records on existing agents, but also to locate new insects that have the potential to control *M. quinquenervia*. Permits have also been acquired for coastal wetland National Parks in tropical and temperate areas along the east coast of Australia, where further exploration is planned for 2000.

Two collection trips were made to the Northern Territory during 1999. Although *M. quinquenervia* does not grow natively in this region, several close relatives in the *M. leucadendra* complex are endemic. Leaf feeding weevils collected near Darwin on *M. cajuputi* fed heavily on *M. quinquenervia* saplings in the laboratory. However, no oviposition occurred on these plants.

In November, *Melaleuca cajuputi* was surveyed in southern Thailand in Southeast Asia. The composition of herbivores and observable damage was distinctly different from Australian *Melaleuca* sites. Two unknown weevil species and a flea beetle were observed feeding on the leaves of *M. cajuputi*. Lepidoptera tip-binders and borers and several leaf-feeding Geometridae, Psychidae and Xyloryctinae (?) larvae were also abundant. Two species of interest are being reared in Thailand by cooperators for identification purposes. Larvae of the noctuid moth, *Careades plana* were found in very high numbers (see section on *C. plana*).

<u>Field Collections</u>

During 1999, we made 185 field search collections of eight *Melaleuca* spp. in the *M. leucadendra* complex. A breakdown of collections for these and other plant species is given in Table 4. Most field searches were conducted for seasonal phenology studies of the bud gall fly, *Fergusonina sp.* (Diptera: Fergusoninidae) and the tube-dwelling moth *Poliopaschia lithochlora* (Lepidoptera: Pyralidae), and for collecting specimens of these insects for laboratory colonies, experimentation, taxonomy and distribution records. We also made 18 supplementary collections of other plant species to verify the host-range of these two insect species.

Table 4. Summary of field search collections made during 1999 in north Queensland (NQ), southeast Queensland (SQ), northern NSW (nNSW), southern NSW (sNSW), Northern Territory (NT), and Thailand (T).

Plant Family	Species	Number Collections	Number Sites	Regions
Mimosaceae	*Acacia hubbardiana*	1	1	SQ
Myrtaceae – *M. leucadendra* complex	*M. argentea*	2	2	NT
	M. cajuputi	16	15	NQ/NT/T
	M. dealbata	7	6	NQ/SQ
	M. leucadendra	8	6	NQ/NT
	M. nervosa	6	6	NQ
	M. quinquenervia	132	46	NQ/NT/sNSW/ SQ/nNSW
	M. stenostachya	3	2	NQ
	M. viridiflora	11	11	NT/NQ/SQ
Other Myrtaceae	*Callistemon viminalis*	1	1	SQ
	Leptospermum laevigatum	2	2	SN/SQ
	L. polygalifolium	2	1	SQ
	Leptospermum sp.	6	3	SQ
	Melaleuca linariifolia	1	1	SQ
	M. minutifolia	1	1	NQ
	Melaleuca sp.	1	1	SQ
Unknown	Undet. sp.1	1	1	SQ
	Undet sp.2	2	1	SQ

<u>Field Plot</u>

In September 1999, we completed a field plot experiment at the ABCL. The experiment started in 1996 to obtain host-range data on potential biocontrol agents of *M. quinquenervia*. The experimental design was a randomized, complete block array of nine plants (eight species) in five blocks. The nine Myrtaceae planted were: *M. quinquenervia* ex. Florida, *M. quinquenervia* ex. QLD, *M. alternifolia* (Tea Tree), *Callistemon viminalis* (Weeping Bottlebrush), *Eucalyptus cinerea* (Silverdollar Tree), *Eugenia uniflora* (Surinam Cherry), *Myrciaria cauliflora* (Jaboticaba), *Psidium guajava* (Guava), and *Syzygium jambos* (Rose Apple). These taxa were chosen on the basis of their phylogenetic relatedness to *M. quinquenervia*, economic importance to Florida and availability in Australia. The experimental plants were sprayed with insecticide to ensure clean plants prior to planting. Surveys were conducted every two weeks for the first year, then every four weeks thereafter. All herbivorous insects on *M. quinquenervia*, their life stage, abundance and habit were recorded. Only known herbivores of *M. quinquenervia* were recorded on the remaining tree species.

Field plot experiments provide a means of obtaining host-range data on potential biological control agents in a more natural environment than laboratory/glasshouse host testing. This data can be used to supplement and verify laboratory results, indicating deficiencies in testing techniques and identifying laboratory artefacts (e.g. cage effects).

Over a period of three years, four high priority *M. quinquenervia* biological control agents moved into the experimental field plot from surrounding paperbark trees. These insects: pea gall fly *Lophodiplosis indentata* (Cecidomyiidae), bud gall fly *Fergusonina* sp. (Fergusoninidae), tube-dwelling moth *Poliopaschia lithochlora* (Pyralidae), and sap-sucking psyllid *Boreioglycaspis melaleucae;* have proven to be specific in field surveys and laboratory testing. In the field plot they were observed on *M. quinquenervia* trees only, confirming their specificity. Further analysis should determine if a preference exists for *M. quinquenervia* ex. QLD plants over those sourced from the exotic range in Florida.

Laboratory cage and sleeve choice feeding tests of the leaf-blotching mirid, *Eucerocoris suspectus*, (Hemiptera: Miridae) were reliable indicators for predicting feeding on test plants in the field plot. However, choice cage oviposition tests indicated that *P. guajava* was not an acceptable host, yet *E. suspectus* completed its development on this species in the field plot. These tests failed to predict oviposition habits under resource-limiting conditions when large numbers of *E. suspectus* had destroyed most of the young foliage on *M. quinquenervia* trees, their primary food source. Under these circumstances the mirid oviposited, and completed its development, on *C. viminalis*, *E. uniflora*, *M. quinquenervia*, and *P. guajava*. As a result, *E. suspectus* has been eliminated as a potential biological control agent. No-choice cage oviposition tests may well have predicted results observed in the field plot.

Melaleuca quinquenervia herbivores not screened for specificity in the laboratory also infested trees in the field plot. *Pterygophorus insignis* (Hymenoptera: Pergidae) and tip-binding Tortricidae (Lepidoptera) larvae were collected on *M. quinquenervia* as well as *C. viminalis*. *Callistemon viminalis* is a valued ornamental tree grown in Florida. No further host testing is planned for insects with a host-range outside the *M. leucadendra* complex.

Although the experiment was completed in September, the plot is being maintained for controlled releases. Unexplored national park wetlands in QLD and NSW are being surveyed for new agents to control *M. quinquenervia*. We plan to release these potential agents into the field plot to supplement laboratory and field host specificity trials.

Surveys for new biological control agents in previously unexplored areas: the Atherton tablelands in NQ, the Northern Territory, sNSW, and Thailand; accounted for many collections. Outcomes of these surveys are outlined in the "Other Insects" section. Collections were also made of *Lophyrotoma* *zonalis* (Hymenoptera: Pergidae) larvae for toxicity studies, and of pea galls and *Careades plana* (Lepidoptera: Noctuidae) larvae for colony maintenance and establishment.

Insect Identifications

The majority of the insect identifications were associated with the *Fergusonina* research. In June, wasp parasitoids from *Fergusonina* galls were sent to Dr. Chris Burwell at the QLD Museum. The resultant identifications have contributed greatly to an understanding of the parasitoid complex associated with this gall and link with data accumulated from gall emergence studies to form the basis of a paper about the effects of parasitism on gall populations. Associated with these studies, representatives of the adult and larval wasp parasitoids were sent to Felice Driver at CSIRO in Canberra for DNA sequencing. Using this molecular technology we were able to associate the biology of the small, non-descript parasitoid larvae with their adult forms.

Expanding upon our knowledge of wasp gall-formers and their parasitoids two further shipments, in June and August, were also sent to Chris. These specimens covered emergence associated with the variety of galls found on *Melaleuca* spp. across the history of this project. The identifications have given us valuable insight into the roles of wasp gall-associates.

In July, all available specimens of the *Fergusonina* fly were taken back to the University of Adelaide with Gary Taylor. He will use them to carry out species level identifications of the bud-gall flies found on each *Melaleuca* spp.

Continuing studies on *Poliopaschia lithochlora* through 1999 saw a number of specimens reared from both *M. quinquenervia* and a *Leptospermum* sp. Adult specimens were sent to Dr. Alma Solis at the ARS-Systematic Entomology Laboratory in Washington, D.C. Dr. Solis was not able to distinguish the moths reared from the separate host plants. Additional specimens were sent to Felice Driver at CSIRO in Canberra for DNA sequencing of the D2 gene. Consistent differences in the D2 gene indicate that the specimens reared from *Leptospermum* are not *P. lithochlora* as earlier suspected. We also used the DNA sequencing technology to determine the relatedness of *Careades plana* from NQ and Thailand. Specimens collected from both countries had exactly the same D2 gene sequence, indicating they are same species.

Ecology of *Melaleuca* in Australia

Scientists from USDA-ARS, Ft. Lauderdale visited in late November until mid December to study the ecology of *Melaleuca quinquenervia* in Australia. Investigations were performed to study the regeneration potential of *M. quinquenervia*: including biomass allocation, seed production, seed set and seed viability, and rate of seed rain. Litter samples collected by our collaborator Dr. Margaret Greenway (Griffith University – Brisbane) are being re-examined to estimate the percentage of aborted reproductive structures.

Biomass Allocation. Thirteen trees of different sizes were harvested from a site in Morayfield, SQ, in order to analyze the allocation of biomass. Tree samples were cut down and partitioned into trunk, branch, twig, leaf, and seed biomass. This information is being used to validate published biomass allocation equations from trees in Florida. Using the data collected in Morayfield, the correlation between trunk diameter and standing biomass was high ($r^2 = 0.83$). This indicates that Australian *M. quinquenervia* fit the biomass equation developed in Florida.

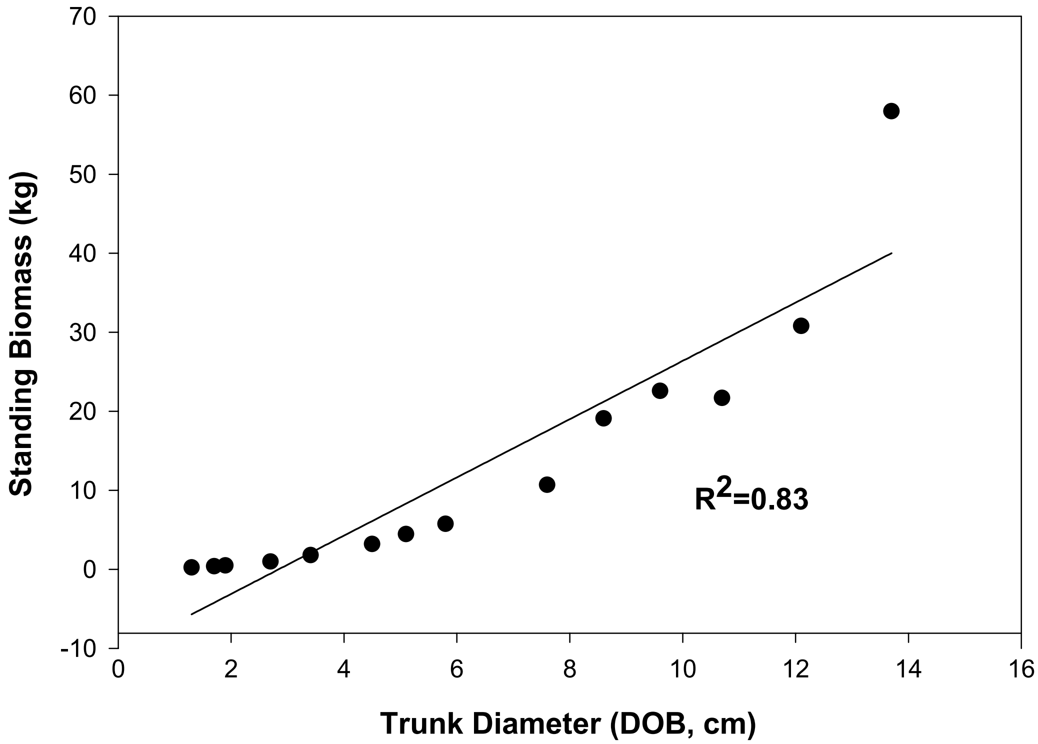

Fig. 10. Linear Relationship between trunk diameter and standing biomass in Australian *M. quinquinervia* trees.

Seed Dynamics. The regeneration potential of *M. quinquenervia* was quantified by measuring seed production and seed set, and by testing the viability of those seeds. Results show that Australian *M. quinquenervia* trees produce considerably less seeds than those in Florida, and the smaller seed set has a lower rate of viability (Table 5). Urban trees had longer clusters, more capsules per cluster, and more seeds per cluster. This may be attributed to lower plant density in urban locations and reduced competition. Seed germination, viability, and fill are considerably lower than documented for *M. quinquenervia* in Florida.

Table 5. Measurements of *Melaleuca quinquenervia* clusters, capsules and seeds

Site Type	Location	Mean Cluster Length in mm	Mean no. of Capsules/ Cluster	Mean Capsule diameter in mm	Mean no. Seeds/ Capsule	% Seed Germination	% Seed Viability	% Seed Fill
URBAN	Indooroopilly	56.71	16.00	5.23	232.00	0.78	0.95	5.98
	Bribie Island	68.35	11.35	5.82	312.80	2.18	2.32	10.53
	Graceville	80.95	32.53	5.93	332.00	4.65	5.65	7.28
	Graceville	63.05	26.55	5.89	315.00	2.37	2.55	7.92
	Mean	**67.26**	**21.60**	**5.72**	**297.95**	**2.50**	**2.87**	**7.92**
NATURAL	Bribie Island	58.67	19.00	5.74	251.00	3.25	4.06	11.94
	Peregian	46.73	16.82	5.99	272.20	1.33	1.63	3.45
	Darra	48.17	15.70	5.38	252.50	3.10	3.50	7.65
	Darra	44.29	15.50	5.61	224.60	0.68	0.88	6.94
	Pottsville	46.58	14.11	5.72		0.16	0.89	11.98
	Mean	**48.89**	**16.22**	**5.69**	**250.08**	**1.70**	**2.19**	**8.39**

Flower and Bud Abortion. Analysis of leaf litterfall samples taken over a two-year period from Logan, SQ shows that high levels of flowers and buds are aborted. This is in dramatic contrast to the low levels of flower and bud abortion reported in Florida (Van & Rayachhetry, unpublished data). Table 6 shows the monthly percentage of damaged and undamaged flowers and buds. During the winter when flowering is at its peak, over 36 % of the flowers and buds are aborted. It appears from close inspections of the buds that insect feeding causes a considerable amount of the loss. We intend to determine which insects are most responsible for the feeding and investigate their potential as biological control agents.

Table 6. Percentage of aborted flowers and buds

DATE	% FLOWERS DAMAGED	% BUDS DAMAGED
11-Jul-97	5.6	19.8
9-Aug-97	6.0	16.8
7-Sep-97	6.1	37.0
4-Oct-97	13.2	46.3
1-Nov-97	21.8	55.1
29-Nov-97	33.1	51.5
27-Dec-97	21.0	48.9
24-Jan-98	16.6	19.9
21-Feb-98	16.7	36.2
21-Mar-98	15.7	36.4
18-Apr-98	25.4	45.2
Total	16.5	37.5

Survey for Pathogens of Melaleuca

Fungal pathogen surveys were conducted during November and December by Dr. Min Rayachhetry, Alex Racelis, and ABCL Staff. Collections were made from many of the species in the *Melaleuca leucadendra* complex. Additionally, most of the sampling was conducted in the Townsville – Cairns area in NQ, where *Melaleuca* diversity is highest and climatic conditions are most similar to south Florida. As of January 2000, 15 different pathogens have been isolated and identified (Table 7). Dr. Roger Shivas (Plant Pathologist, Queensland Department of Primary Industries, Indooroopilly) has been contracted to identify the pathogens. Dr. Rayachhetry is currently assessing the potential of the fungi for pathogenicity studies.

Table 7. List of pathogens isolated from *Melaleuca* spp.

Pathogen Name	Plant Host	Collection Locality
Fusarium sp.	*M. dealbata*	Townsville, QLD
Pestalotiopsis sp.	*M. leucadendra*	Mt. Molloy, QLD
Candida sp.	*M. nervosa*	Mareeba, QLD
Phyllosticta sp. 2	*M. quinquenervia*	Byron Bay, NSW
Fusarium sp.	*M. quinquenervia*	E. Kennedy Nat'l Park, QLD
Pestalotiopsis sp.	*M. quinquenervia*	E. Kennedy Nat'l Park, QLD
Aspergillus sp.	*M. quinquenervia*	E. Kennedy Nat'l Park, QLD
Guignardia sp.	*M. quinquenervia*	E. Kennedy Nat'l Park, QLD
Phyllosticta sp.	*M. quinquenervia*	E. Kennedy Nat'l Park, QLD
Phyllosticta sp.	*M. quinquenervia*	Mission Beach, QLD
Pestalotiopsis sp.	*M. quinquenervia*	Pottsville, NSW
Phyllosticta sp.	*M. viridiflora*	Mission Beach, QLD
Phyllosticta sp.	*M. viridiflora*	Mt. Molloy, QLD

Biological Control of Lygodium

Old World climbing fern, *Lygodium microphyllum* is an invasive weed in south Florida where it threatens many wetland communities in the Everglades ecosystem. *Lygodium microphyllum* is native to wet areas in the Old World tropics and subtropics including Africa, India, Southeast Asia, Australia and the South Pacific. The fern entered Florida as a commercial ornamental plant and was first documented to have become naturalized in 1965. However its explosive growth and rapid spread are relatively recent and it is now causing concern because of its dominance over native vegetation in many communities. Land managers indicate that *L. microphyllum* has hit a "critical mass" and is beginning an exponential rate of expansion across the wetlands of Florida. New evidence indicates that this plant may also threaten the citrus and timber industries. The biological control program was initiated for *L. microphyllum* due to strong demand by stakeholders in south Florida for a biological control solution to this rapidly spreading invasive weed. Dr. Robert Pemberton (ARS-Ft. Lauderdale) is the project leader.

Lygodium microphyllum is considered to be a good target for biological control. First, it belongs to a taxonomically isolated group, not closely related to native or economic plants in Florida. Second, the plant is not known to be a weed in its native range. Third, non-biological control methods are environmentally damaging and too expensive to use on the scale required to control the plant.

During 1999, exploration was conducted in Australia, Indonesia, Malaysia, Singapore, and Thailand. Many new herbivores of *Lygodium microphyllum* were collected (Table 8). Host-range testing is underway with two leaf-feeding pyralids, *Cataclysta camptozonale* and *Neomusotima* sp. Australian regulatory authorities have given us permits to import *Lygodium* insects from Southeast Asia and to import threatened Florida fern species into the Brisbane quarantine. We can now assemble the key test plants and candidate insects from both Australia and Southeast Asia in Brisbane for full or partial host-range testing. This expands the research capabilities of ABCL and could potentially shorten the process from discovery to exportation of biological control agents.

Table 8. List of herbivores collected from *Lygodium microphyllum*

Name	Collection Locations	Host Plant
Cataclysta camptozonale Lepidoptera: Pyralidae	Australia (Queensland)	*L. microphyllum* *L. reticulatum*
Neomusotima sp Lepidoptera: Pyralidae	Australia (Queensland & Northern Territory), Indonesia, Malaysia, Singapore, Thailand	*L. microphyllum*
Nymphulinae sp. Lepidoptera: Pyralidae	Malaysia, Singapore, Thailand	*L. microphyllum*
Callopistria sp. Lepidoptera: Noctuidae	Australia (Northern Territory) Indonesia, Thailand	*L. microphyllum*
Lepidoptera: Limacodidae	Thailand	*L. microphyllum*
Lepidoptera: Tortricidae	Thailand	*L. microphyllum*
Tube-dweller Lepidoptera	Malaysia	*L. microphyllum*
Stem-borer Lepidoptera: Pyralidae	Malaysia	*L. microphyllum*
Neostrombocerus albicomus Hymenoptera: Tenthridinidae	Malaysia, Singapore, Thailand, Vietnam	*L. flexuosum*
Tortoise beetle Coleoptera: Chrysomelidae	Australia (Northern Territory)	*L. microphyllum*
Flea beetle Coleoptera: Chrysomelidae	Thailand	*L. japonicum*
Leaf-miner Diptera: Agromyzidae	Malaysia	*L. microphyllum*
Hemiptera: Miridae	Australia (Northern Territory)	*L. microphyllum*
Homoptera: Membracidae	Australia (Northern Territory)	*L. microphyllum*
Thrips Thysanoptera	Malaysia, Thailand	*L. microphyllum*
Floracarus sp. Eriophyidae	Australia	*L. microphyllum*
Mite Acarina: Eriophyidae	Australia, Indonesia, Malaysia, Singapore, Thailand	*L. microphyllum*

Lygodium Research in Australia

Exploration efforts for natural enemies of *L. microphyllum* have been conducted in Queensland (7), New South Wales (2), and the Northern Territory (2). *Lygodium microphyllum* is not a weed in any of these habitats. Two pyralid moths have been collected and established in culture. *Cataclysta camptozonale* has been collected from Cairns in the tropical north of QLD and from Brisbane in the subtropics. A second species, *Neomusotima* sp., has been collected from NQ across to Darwin in the Northern Territory. A leaf-galling mite *Floracarus* sp. (Eriophyidae) has been collected in SQ.

Several sites in the Northern Territory and north Queensland were visited twice in late 1999 to survey and collect herbivores during the dry and wet seasons. Ample rainfall throughout the range *of L. microphyllum* stimulated luxuriant growth and an abundance of herbivores. Rainfall patterns often influence the numbers and types of insects present. Our close proximity to collection locations allows ABCL staff to take advantage of these seasonal changes. Insects that may be uncommon during certain times of the year can become seasonally abundant. For example, in north Queensland we noted heavy defoliation of the fern by *Cataclysta camptozonale* at one our sites near Innisfail. This site had been recently inundated by localized heavy rainfall. The population of the moth appeared to be synchronized with the flush of new growth.

Field collections in the Northern Territory revealed 12 new insects feeding on *Lygodium*. Of the eight Hemipteran spp. (true bugs), most appear to be transitory herbivores, using the plant for supplemental nutrition. Four beetle species (2 Chrysomelidae and 2 Curculionidae) were found feeding extensively on the foliage. These beetles were field collected and returned to Brisbane for rearing, but to date, all beetle species have failed to reproduce in culture.

Australian Exploratory Trips

- New South Wales, Wollongong to Queensland Border, Mar. 29– April 1, 1999. The southern limit of *L. microphyllum* was determined to be Ballina, NSW. Plant samples and insects were collected.

- Northern Territory, Darwin to Jabiru, April 26-29, 1999. Located several stands of *L. microphyllum, L. flexuosum,* and *L. japonicum* in Litchfield National Park and Darwin Harbor.

- North Queensland, Cairns to Port Douglas, May 17-21, 1999. Extensive collections of *L. microphyllum* agents were made. Two species of Pyralidae were collected from *L. microphyllum* and *L. reticulatum*.

- Southeast Queensland, ongoing. Several study sites were identified near Brisbane for plant phenology studies. The pyralid moth, *Cataclysta camptozonale*, was collected from numerous locations and is in culture at ABCL.

- Northern Territory, Darwin to Katherine, Oct 4-7, 1999. Returned to Litchfield to collect *L. microphyllum* agents. Located *L. microphyllum* in isolated wet habitats along Katherine River and nearby springs.

- North Queensland, Townsville to Cairns, Dec 6-9, 1999. Explored Townsville area and points north to Cairns. Collected plant samples for disease identification.

Herbivores Collected

Leaf Feeding Moth - *Cataclysta camptozonale* (Lepidoptera: Pyralidae)

Cataclysta camptozonale has been collected from subtropical SQ to tropical NQ. In NQ it has been collected from both *Lygodium microphyllum* and *L. reticulatum.* Heavy damage to *L. microphyllum* has been noted in NQ despite high levels of predation and egg parasitism. Larvae skeletonize *L. microphyllum* leaves, sometimes consuming much of the new growth. In laboratory cultures, larvae consume all the foliage, and scarify the stems, which results in plant death.

Developmental studies of *C. camptozonale* were conducted on two hosts, *L. microphyllum* and *L. japonicum*. Females laid an average of 25 eggs either singularly or in clusters on the upper surface of mature pinnae. Longevity of adult females was 6.2 days. Time from egg to adult was 44 days at 24 ^{o}C for both plant species. *C. camptozonale* appears to have four larval instars. Pupae can be sexed due to the presence of a slit in the middle of the second to last tergite in males. The sex ratio of the laboratory colony used in this test was slightly female biased with a male to female ratio of 43:57.

Preliminary host-range tests have commenced with *C. camptozonale*. Fifteen fern species will be tested in no-choice tests (Table 9). It appears from initial results that *C. camptozonale* larvae develop only on

Lygodium spp., including the North American endemic *L. palmatum*. Further testing is needed to confirm the host-range and critical minimum survival temperature of this pyralid.

Table 9. List of plant species used in preliminary host-range tests

Species	Selection Criteria	Family
Lygodium microphyllum from Florida	acceptance of Florida form	Schizaceae
Lygodium microphyllum from Australia	Old World climbing fern	Schizaeceae
Lygodium japonicum	close relative	Schizaeceae
Lygodium palmatum	closest relative in N. America	Schizaeceae
Anemia adiantifolia	rare in Florida, in same habitat	Schizaeceae
Actinostachys pennula	rare in Florida, in same habitat	Schizaeceae
Osmunda regalis	family representative, ornamental	Osmundaceae
Cyathea cooperi	family representative, ornamental	Cyathaceae
Asplenium nidus	family representative, ornamental	Aspleniaceae
Pteridium aquilinum	family representative, in same habitat	Dennstaediaceae
Nephrolepis biserrata	family representative, ornamental	Dryopteridaceae
Adiantum capillus-veneris	family representative, ornamental	Pteridaceae
Salvinia molesta	family representative, well known weed	Salviniaceae
Rumohra adiantifolis	family representative, ornamental	Dryopteridaceae
Phlebodium aureum	family representative, ornamental	Polypodiaceae

<u>Leaf Feeding Moth – *Neomusotima* sp. (Lepidoptera: Pyralidae)</u>

Neomusotima sp. (see inset photo), which we call the 'boomerang' due to the distinctive markings on its forewings, has been collected from all the sites in tropical NT and NQ. This species is collected from nearly every location including isolated patches of *L. microphyllum*. It returns quickly after bush fires to feed on the new growth, indicative of its ability to search and colonize *L. microphyllum*. Further, high levels of defoliation caused by *Neomusotima* sp. has been observed in NQ in both the wet and dry seasons.

Neomusotima sp. has been collected from Australia and the wet tropics of Southeast Asia. In order to determine if we were dealing with a complex of species across this wide distribution, we used a molecular genetic tool to analyze the DNA of the different populations. Molecular sequencing of the mitochondrial D2 gene showed an exact match between the specimens from Australia and Southeast Asia. This indicates that both populations are likely to be the same species. Specimens have been forwarded to Dr. Alma Solis at the ARS-Systematic Entomology Laboratory for determination and description of this new species.

Developmental parameters (fecundity & longevity) appear to be very similar to *C. camptozonale*. *Neomusotima* sp. has only been collected in tropic regions thus far. The distribution of the moth could indicate that it is not tolerant of the cooler winter climates of the sub-tropics. Further studies are planned to determine the critical minimum temperature for this species.

Leaf Feeding Moth - *Callopistria* sp. (Lepidoptera: Noctuidae)

Callopistria sp. has been collected on several occasions in both the NT and NQ. In each case, this species was collected singularly and we were unable to start a culture. Mature *Callopistria* sp. larvae are quite large and consume large amounts of *L. microphyllum* foliage to complete their development. We intend to sequence the D2 gene from individuals collected in Australia and Southeast Asia to determine whether they are different species. We will continue to search intensively for greater numbers of this rare but potentially valuable biological control agent.

Leaf Galling Mite - *Floracarus* sp. (Acarina: Eriophyidae)

Field collections in the Brisbane area have documented the damage caused by the mite *Floracarus* sp. (Eriophyidae) on *L. microphyllum*. Feeding by the mite on the new growth causes the pinnae (leaf) margins to curl. It also appears that the mite feeding leads to disease transmission, as the feeding is associated with a black streaking and necrosis of the pinnae. Similar damage has been noted in Southeast Asia as well. Fungi were isolated from the necrotic patches associated with the mite damage. The causal agent was identified as *Botryospheria* sp., which is believed to be a secondary pathogen, associated with leaf damage.

We intend to compare the mite populations from Australia with SE Asia using molecular DNA tools. Analysis of the DNA (D2 gene) should indicate whether we have different species feeding on *Lygodium* across its range. Dr. Danuta Knihinicki of NSW Agriculture identified the mite as Floracarus sp. and intends to describe it as a new species. Field studies are continuing to determine the life cycle and host-range of the mite.

Eriophyid mite species have been used in other weed biological control programs, ie. skeletonweed, *Chondrilla juncea*. In some cases they have proven to be highly specific and damaging. In practice it can be difficult to receive permission to import mites into the US. The reason being that most quarantine facilities are not designed to contain mites. Since *Floracarus* sp. is endemic locally, we are able to conduct the screening at ABCL without quarantine restrictions.

Lygodium Research in Southeast Asia

Southeast Asia is a region rich in biodiversity. The insect fauna can be quite different to that found in Australia. By expanding our search area into the wet tropics of Southeast Asia we increase our chances of finding additional biological control agents for *L. microphyllum*, and potentially *L. japonicum*. Tony Wright leads the exploration and evaluation of agents from this region (Fig 14). Tony has considerable experience and contacts in this area as a result of his successful biological control program against water hyacinth.

Southeast Asian Exploratory Trips
Several trips were undertaken during the year. Whenever possible, more than one country was visited per trip in order to maximize efficiency. In addition, information was gathered on other weedy species of US interest including *Lygodium japonicum*, *Paederia foetida* and *Dioscorea* spp.

- March - 99 Malaysia
- May 99 - Thailand, Malaysia, Indonesia (Sumatra)
- August 99 - Thailand, Malaysia, Singapore
- October 99 - Singapore
- November 99 - Singapore, Malaysia, Thailand

Herbivores Collected

Sawfly - *Noestrombocerus albicomus* (Hymenoptera: Symphyta)

The first project collections of the Lygodium sawfly were from northern Thailand in 1998. During this year several collections were made on *L. flexuosum* at eight sites in northern and southern Thailand and in northern and mid-peninsula Malaysia. Laboratory colonies were established in Bangkok and Brisbane. DNA sequence comparisons of specimens in Thailand, Malaysia and Vietnam (specimens collected in 1996 by Dr Thai Van, USDA Fort Lauderdale) indicated a single species. This species was identified by Dr David Smith, ARS-Systematic Entomology Laboratory, as *Neostrombocerus albicomus* Konow (Selandriinae). Although *L. microphyllum* is damaged by the insect, field observations and laboratory studies strongly indicate *L. flexuosum* is the primary host. It is also possible the sawfly uses *L. japonicum* as a host.

Leaf Feeding Moth - *Neomusotima* sp (Lepidoptera: Pyralidae)

This insect was first collected in Thailand in 1998 and further collections were made this year. It is the most widely distributed moth on *Lygodium* in the region and is known to occur throughout Thailand, Malaysia, Singapore and Indonesia. We introduced it into quarantine in Australia for rearing, however it was subsequently also found in northern Australia and the colony was terminated in favor of working on Australian material. Further work on this species in Southeast Asia will be limited to field studies.

Leaf Feeding Moth - *Musotima* sp. (Lepidoptera: Pyralidae)

This moth is known to occur in southern Thailand, Malaysia and Singapore. D2 gene studies on a specimen collected from Selangor, Malaysia, indicates that it is close to *Cataclysta camptozonale* found in Australia. It was imported into ABCL quarantine, where a colony is now being reared for further study. In quarantine, adults live up to 10 days and very damaging populations of larvae develop quickly on *L. microphyllum*, *L. japonicum and L. palmatum*. Preliminary results suggest pupae from *L. japonicum* are smaller than those reared on *L. microphyllum*, although the pupal duration is similar at around 9 days. In culture, males are significantly smaller than females and the ratio of males to females is 1:1.5. Further D2 gene comparisons of Malaysian specimens with those from Thailand and Singapore are planned.

<u>Leaf Feeding Moth - *Callopistria* sp. (Lepidoptera: Noctuidae)</u>

A medium size moth, *Callopistria* sp. was collected on several occasions in Thailand on both *L. flexuosum* and *L. microphyllum*. Although quite damaging to the host plant, larvae have only been found in very low numbers, often only one or two per site, possibly due to parasitism or predation. Four species of *Callopistria* have been recorded from *Lygodium* in the literature, and one of these was also reported to attack native ferns in Australia. Early advice from the ANIC suggested that our Southeast Asian specimens are a different species to our Australian specimens. However, experts in the group are at the BMNH and we aim to have identification undertaken in 2000.

<u>Leaf Galling Mite – (Acarina : Eriophyidae)</u>
Eriophyid mites occurred in all areas surveyed, with large populations and heavy damage seen at sites in eastern and southern Thailand, central and northern Malaysia and Sumatra. "Galling" of the leaflets results from mites rolling the edges. In Sumatra, collaborator Dr R. Desmier de Chenon has studied the incidence and effects of mites on *L. microphyllum* and he detailed these at the November workshop in Kuala Lumpur. He related the incidence of disease on leaflets (as seen elsewhere in Malaysia, Thailand and Australia) to mite presence (Table 10). Mites and galls were most numerous at low-altitude *Lygodium* sites, with leaflets of all ages affected. While there was more disease incidence at low altitudes, there was also a much lower incidence of predator phytoseid mites on the *L. microphyllum*.

Table 10. Incidence of eriophyid mite leaf galling and disease on *L. microphyllum* at two different altitudes.

Site	No. leaves sampled	Percentage of leaves Galled	Percentage of leaves with disease
Simarjarunjung, Sumatra 1200 M	455	5.1	61.5
Tonduhan, Sumatra 300 M	117	35.8	93.9

<u>Leaf Feeding Moth - (Lepidoptera: Limacodidae)</u>
Unidentified limacodid larvae were collected on *L. microphyllum* in Thailand. So far attempts to rear the insects to adult, for identification or laboratory breeding, have not succeeded.

<u>Leaf Feeding Moth - (Lepidoptera: Tortricidae)</u>
Larvae of an unidentified tortricid were collected on *L. microphyllum* at six sites in southern Thailand. Preliminary investigations suggest the moth belongs to the *Archips machlopis* species-group and if so it is likely to be polyphagous. Identification by the group expert Mr Kevin Tuck, BMNH, has been arranged for early 2000.

<u>Thrips -Thysanoptera</u>
Thrips are an extremely common herbivore in Southeast Asia, sometimes occurring in large numbers and very damaging to *L. microphyllum*. There are four genera known from ferns, *Monilothrips, Indusiothrips* and two undescribed genera. Dr Laurence Mound, ANIC, has advised us that our *Lygodium* thrips is a member of one of the undescribed genera of which specimens have been collected from Singapore, western Malaysia, Bali and the Ryukus. Dr Mound forwarded our specimens to Dr Shuji Okajima, Tokyo University of Agriculture, who plans to describe the insect.

Plant Bugs - Hemiptera

Several Hemiptera species have been observed on *Lygodium*. Two of these were collected for rearing, however this was unsuccessful.

Flea Beetles - Coleoptera

Most beetles seen on *Lygodium* appear to be just resting. An unidentified chrysomelid from *L. flexuosum* in northern Thailand was introduced to quarantine. While rearing on *L. microphyllum* was not successful, heavy damage was inflicted on *L. japonicum* and the beetles bred well. Adults cause heavy defoliation of the leaves, while the larvae feed on the roots and rhizome. *Lygodium japonicum* is reported to be weedy in central and north Florida. If a biological control program is initiated for *L. japonicum,* this agent shows excellent promise.

Research Plans for 2000

Our research plans for 2000 include additional foreign exploration and intensive host-range testing of the agents, which have been discovered thus far. Exploration in Southeast Asia will focus on the cooler subtropical areas including, Hong Kong, Taiwan, and northeast Thailand. We will also attempt to recover and culture the stem-boring Lepidoptera collected in Singapore. In Australia, field studies will focus on the host-range and biology of the eriophyid mite, *Floracarus* sp. Exploration will continue in the subtropics of SQ between Brisbane and Rockhampton. Preliminary host-range testing of *Cataclysta camptozonale* will be completed, with delivery to the Gainesville quarantine by May 2000. Screening of *Neomusotima* sp., and the *Musotima* sp. from Singapore should be completed in late 2000. Every effort is being made to 'fast track' agents for *L. microphyllum* due to the rapid spread of this invasive weed in Florida.

Biological Control of Paederia

Paederia foetida is an invasive weed across the southeastern U.S., especially in Florida. ARS cooperators in Ft. Lauderdale (R. Pemberton & P. Pratt) have conducted an initial biological control feasibility study for the Southwest Water Management District in Florida. It is likely that a biological control program will be developed, and ABCL is geographically well positioned to play a role in the foreign exploration.

Paederia foetida is widely distributed across the temperate, tropical and subtropical areas of east Asia. ABCL staffs have located the plant in several locations in Southeast Asia. *Paederia* species occur from the cool subtropics of northern Thailand down the Malay peninsula to tropical Singapore. Consumption of *Paederia* as a vegetable is common in Thailand, much less so in Malaysia, so plants are commonly cultivated in Thailand. During exploration as part of the Lygodium project, *Paederia* was observed in several localities, in Thailand in the provinces of Songkhla, Nakhon Si Thammarat (specimen sent to B. Pemberton), Surat Thani, Chiang Mai and Phetchaburi; and in Malaysia in Pahang. Often, *Paederia* was noticed simply because it was growing with or near *L. microphyllum*.

Eight species are listed for Thailand (Table 11). Many of the species can only be identified by their flowers and fruit, which are not present year round. We will continue to collect information on *Paederia* spp. in conjunction with *L. microphyllum* exploration.

Table 11. Distribution of *Paederia* spp. in Thailand

Species	Location
P. calycina Kurz	Southwestern
P. foetida Linn.	Mae Hong Son to Central and down the Peninsula
P. hirsuta Craib	Central
P. kerrii Craib	Chiang Mai
P. linearis Hook.	Northern, Central and Peninsula
P. pilifera Hook.	Northern
P. pilosa Roxb.	Southeastern
P. tomentosa Bl. var. *glabra* Kurz	Northern, Southwestern and Peninsula

Biological Control of Hydrilla

The aquatic plant, *Hydrilla verticillata* (Hydrocharitaceae), continues to be a problem weed in several regions of the United States since its introduction in the early 1950's. Hydrilla forms dense mats at the water surface, impeding water flow. It causes extensive environmental, economic and recreational problems including reductions in fish stocks, hampering flood control and irrigation, and obstructing navigation. Herbicidal and mechanical controls have been ineffective and very expensive. Following worldwide surveys for biological control agents of hydrilla in its native range, insects were introduced into the U.S. from Australia and parts of Asia. These agents, two *Bagous* (Coleoptera: Curculionidae) weevils and two *Hydrellia* (Diptera: Ephydridae) flies, have not established or have had a limited impact on the growth hydrilla, and new agents are needed.

Intensive surveys of hydrilla conducted by ABCL staff were completed in 1992. However, while in southern Thailand in November of this year, we visited several hydrilla sites. Collections were made at the Thale Noi Bird Sanctuary and on Highway 4151 south of Nakhon Si Thammarat (Fig 16). Hydrilla at both these sites was growing in isolated areas in very small mats. A portable berlese funnel as well as hand searching was used to process the collected plant material. Small numbers of Nymphuline (Pyralidae), *Hydrellia* and *Donacia* (Coleoptera: Chrysomelidae) larvae were collected. Unfortunately, this material had to be processed quickly, possibly reducing the efficiency of the extraction process.

The center of origin of hydrilla is unclear though many botanists feel its origin lies in the warmer regions of Asia. Indonesia, Thailand, Malaysia and Vietnam have been lightly surveyed for hydrilla insects, and more extensive surveys could be useful in finding new agents. The sparse nature of hydrilla in southern Thailand suggests that natural enemies are controlling this plant. Additionally, insects collected from these habitats would be adapted to permanently flooded sites, such as lakes, irrigation canals and reservoirs. ABCL and ARS collaborators intend to canvas cooperators across the US to develop new support for exploration in Southeast Asia.

Biological Control of Pink Hibiscus Mealybug

The Pink Hibiscus Mealybug (PHMB), *Maconellicoccus hirsutus* (Green) (Hemiptera: Pseudococcidae) has recently entered California and poses a serious threat to the forestry, agricultural, horticultural and tourist industries of the southern USA. It attacks 215 genera of economically useful plants worldwide. Chemical control is ineffective and Encyrtidae (Hymenoptera) parasitoids have been successfully used in biological control of PHMB elsewhere. The ARS European Biological Control Laboratory, in cooperation with the ARS Australian Biological Control Laboratory and APHIS is carrying out foreign exploration for PHMB natural enemies. Collections from Queensland, Australia in 1998 and 1999 were shipped to the ARS quarantine, Newark, Delaware. Four Encyrtidae parasitoids, *Leptomastix nigricoxalis*, *Anagyrus dactylopii*, *Gyranusoidea indica* (new records*)*, *A. kamali*, and a new species of Coccinellidae predator, *Crypytolaemus sp.* were reared. PHMB is not a recognized pest in Australia. Little is known about the importance of natural enemies in keeping the pest status of *M. hirsutus* at an acceptable level in Australia. The objectives of the work will be to identify and quantify mealybug and natural enemy numbers and stages, percent parasitism and hyper-parasitism, resulting in the evaluation and selection of natural enemies in Australia for implementation in a biocontrol program of *M. hirsutus* in the USA.

In late 1999, we began research on biological control of *M. hirsutus*. Our objectives in Australia are to: 1) collect and preserve specimens of natural enemies and their hyperparasites for determination by taxonomists, and characterisation by geneticists, 2) elucidate seasonal differences in parasitoid guilds, 3) quantify field parasitism for each parasitoid species, 4) evaluate importance of parasitoids based on destruction of mealybug stages in field experiments, 5) prioritize parasitoid species for selection and shipment to the USA for mass rearing.

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ABCL Staff Publications

The following is a list of publications, authored or co-authored by ABCL staff members, which are in press or were published during 1999.

Burrows, D.W. and J. K. Balciunas. 1999. Host-range and distribution of the Melaleuca leaf-blotching Bug, *Eucerocoris suspectus* (Hemiptera: Miridae), a potential biological control agent for the paperbark tree, *Melaleuca quinquenervia* (Myrtaceae). Environmental Entomology. 28:290-299.

Goolsby, J.A., J.R. Makinson, & M. Purcell. (in review) Seasonal phenology of the gall-making fly, *Fergusonina* sp. (Diptera: Fergusoninidae) and its implications for biological control of *Melaleuca quinquenervia*. Journal of Australian Entomology.

Goolsby, J.A., K.E. Galway, J.R. Makinson, M.P. Purcell, T.W. Wright (1999) New Directions for the USDA-ARS Australian Biological Control Laboratory. 10th International Symposium on Biological Control of Weeds, Bozeman, Montana. 4-9 July 1999.

Goolsby, John A. and Wright, Tony (1999) Exploration in Australia and Southeast Asia for biological control agents of *Lygodium microphyllum*, Climbing maidenhair or Old World Climbing Fern. 99th Australian Entomological Society Annual Meeting, Canberra, ACT. Sept 28th, 1999

Julien, M.H., Griffiths, M.W. and Wright, A.D. (1999) "Biological Control of Water Hyacinth. The weevils, *Neochetina bruchi* and *N. eichhorniae*: biologies, host-ranges, and rearing, releasing and monitoring techniques for biological control of *Eichhornia crassipes*" ACIAR Monograph No. 60, 87pp.

Pemberton, R.W., Wright, A.D. and Goolsby, J.A. (1999) (Abstract only) Foreign exploration for biological control agents of *Lygodium microphyllum*, a wetlands weed of the Florida Everglades. 10th International Symposium on Biological Control of Weeds, Bozeman, Montana. 4-9 July 1999.

Purcell, M.F., K.E. Galway, J.A. Goolsby, J.R. Makinson and D. Mira (1999). Field Plot Experiments: a Method for Assessing Host Range. 10th International Symposium on Biological Control of Weeds, Bozeman, Montana. 4-9 July 1999.

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Appendix: 1999 ABCL Field Explorations

Plant Codes

Ahb	*Acacia hubbardiana*
Cvm	*Callistemon viminalis*
CHar	*Christella arida*
DPas	*Diplazium asperum*
DPes	*Diplazium esculentum*
EHcr	*Eichhornia crassipes*
HYsp	*Hydrilla* sp.
Lfl	*Lygodium flexuosum*
Lmc	*Lygodium microphyllum*
Ljp	*Lygodium japonicum*
Lrt	*Lygodium reticulatum*
Lsp	*Lygodium* sp.
LPlg	*Leptospermum laevigatum*
LPpg	*Leptospermum polygalifolium*
LPsp	*Leptospermum* sp.
Mag	*Melaleuca argentea*
Mcj	*Melaleuca cajuputi*
Mdl	*Melaleuca dealbata*
Mlb	*Melaleuca leucadendra*
Mlr	*Melaleuca linariifolia*
Mmn	*Melaleuca minutifolia*
Mnv	*Melaleuca nervosa*
Mqn	*Melaleuca quinquenervia*
Msp	*Melaleuca* sp.
Mst	*Melaleuca stenostachya*
Mvr	*Melaleuca viridiflora*
Psp	*Paederia* sp.
RUal	*Rubus alceifolius*
SIac	*Sida acuta*
Undet	*Undetermined species*

Collection #	Date	Host	Site	State/ Province	Country
99001	5-Jan-99	Mqn	Morayfield	QLD	AUSTRALIA
99002	13-Jan-99	Mvr	El Arish	QLD	AUSTRALIA
99003	15-Jan-99	Mlb	Centenary Lakes	QLD	AUSTRALIA
99004	19-Jan-99	Mqn	Peregian	QLD	AUSTRALIA
99005	20-Jan-99	Mqn	Woodburn	NSW	AUSTRALIA
99006	20-Jan-99	Mqn	Tyagarah	NSW	AUSTRALIA
99007	20-Jan-99	Mqn	Pottsville	NSW	AUSTRALIA
99008	2-Feb-99	Mqn	Morayfield	QLD	AUSTRALIA
99009	4-Feb-99	Mqn	Wild Horse Mountain	QLD	AUSTRALIA
99010	4-Feb-99	Mqn	Roy's Road	QLD	AUSTRALIA
99011	4-Feb-99	LPpg	Racecourse Rd	QLD	AUSTRALIA
99012	4-Feb-99	Ahb	Racecourse Rd	QLD	AUSTRALIA
99013	4-Feb-99	Cvm	Racecourse Rd	QLD	AUSTRALIA
99014	4-Feb-99	Mqn	Racecourse Rd	QLD	AUSTRALIA

99015	10-Feb-99	Mlr	Morayfield	QLD	AUSTRALIA
99016	10-Feb-99	Mqn	Morayfield	QLD	AUSTRALIA
99017	15-Feb-99	Mqn	Woodburn	NSW	AUSTRALIA
99018	15-Feb-99	Mqn	Tyagarah	NSW	AUSTRALIA
99019	15-Feb-99	Mqn	Pottsville	NSW	AUSTRALIA
99020	18-Feb-99	Mqn	Peregian	QLD	AUSTRALIA
99021	18-Feb-99	Mqn	Sunshine Coast Motorway	QLD	AUSTRALIA
99022	18-Feb-99	LPsp	Racecourse Rd	QLD	AUSTRALIA
99023	25-Feb-99	Mqn	Racecourse Rd	QLD	AUSTRALIA
99024	25-Feb-99	LPpg	Racecourse Rd	QLD	AUSTRALIA
99025	25-Feb-99	LPsp	Racecourse Rd	QLD	AUSTRALIA
99026	25-Feb-99	Mqn	Wild Horse Mountain	QLD	AUSTRALIA
99027	26-Feb-99	Mqn	Welsby Lagoon, Bribie Island	QLD	AUSTRALIA
99028	3-Mar-99	Mqn	Morayfield	QLD	AUSTRALIA
99029	3-Mar-99	Mqn	Caloundra Exit	QLD	AUSTRALIA
99030	3-Mar-99	Mqn	Glasshouse Mountains Rd	QLD	AUSTRALIA
99031	3-Mar-99	LPsp	Morayfield	QLD	AUSTRALIA
99032	4-Mar-99	Mqn	Bribie Island Rd	QLD	AUSTRALIA
99033	5-Mar-99	Mqn	CSIRO Long Pocket Labs	QLD	AUSTRALIA
99034	9-Mar-99	Mqn	Roy's Road	QLD	AUSTRALIA
99035	9-Mar-99	Mqn	Peregian	QLD	AUSTRALIA
99036	9-Mar-99	Mqn	Marcoola	QLD	AUSTRALIA
99037	9-Mar-99	Mqn	Coolum Airport	QLD	AUSTRALIA
99038	11-Mar-99	Mqn	Roy's Road	QLD	AUSTRALIA
99039	17-Mar-99	Mqn	Woodburn	NSW	AUSTRALIA
99040	17-Mar-99	Mqn	Tyagarah	NSW	AUSTRALIA
99041	17-Mar-99	Mqn	Pottsville	NSW	AUSTRALIA
99042	18-Mar-99	Mqn	Roy's Road	QLD	AUSTRALIA
99043	18-Mar-99	Undet	Coonowrin Creek	QLD	AUSTRALIA
99044	24-Mar-99	Mqn	CSIRO Long Pocket Labs	QLD	AUSTRALIA
99045	25-Mar-99	Mqn	CSIRO Long Pocket Labs	QLD	AUSTRALIA
99046	25-Mar-99	Mqn	Bell's Creek Road	QLD	AUSTRALIA
99047	30-Mar-99	Mqn	Morayfield	QLD	AUSTRALIA
99048	31-Mar-99	Mqn	Bracken Ridge	QLD	AUSTRALIA
99049	31-Mar-99	Msp	Bracken Ridge	QLD	AUSTRALIA
99050	6-Apr-99	Mqn	Chelmer	QLD	AUSTRALIA
99051	6-Apr-99	Mqn	Peregian	QLD	AUSTRALIA
99052	6-Apr-99	Mqn	Coolum Airport	QLD	AUSTRALIA
99053	8-Apr-99	Mqn	Morayfield	QLD	AUSTRALIA
99054	12-Apr-99	Mqn	Chelmer	QLD	AUSTRALIA
99055	15-Apr-99	Mqn	Woodburn	NSW	AUSTRALIA
99056	15-Apr-99	Undet	Woodburn	NSW	AUSTRALIA
99057	15-Apr-99	Mqn	Tyagarah	NSW	AUSTRALIA
99058	15-Apr-99	Mqn	Pottsville	NSW	AUSTRALIA
99059	22-Apr-99	Mqn	Racecourse Rd	QLD	AUSTRALIA

99060	28-Apr-99	Mqn	Morayfield	QLD	AUSTRALIA
99061	4-May-99	Mqn	Peregian	QLD	AUSTRALIA
99062	11-May-99	Mqn	Woodburn	NSW	AUSTRALIA
99063	11-May-99	Mqn	Tyagarah	NSW	AUSTRALIA
99064	11-May-99	Mqn	Pottsville	NSW	AUSTRALIA
99065	29-Mar-99	Mqn	Narooma	NSW	AUSTRALIA
99066	30-Mar-99	Mqn	Woolongong	NSW	AUSTRALIA
99067	30-Mar-99	Mqn	Captain Cook National Park	NSW	AUSTRALIA
99068	31-Mar-99	Mqn	Wamberal Lagoon	NSW	AUSTRALIA
99069	31-Mar-99	LPlg	Myall Lakes National Park	NSW	AUSTRALIA
99070	31-Mar-99	Mqn	Myall Lakes National Park	NSW	AUSTRALIA
99071	1-Apr-99	Mqn	Pier Rd, Coffs Harbour	NSW	AUSTRALIA
99072	1-Apr-99	Mqn	Yuragir Wetlands	NSW	AUSTRALIA
99073	26-Apr-99	Mlb	Lameroo Beach	NT	AUSTRALIA
99074	26-Apr-99	Mcj	East Point Reserve	NT	AUSTRALIA
99075	27-Apr-99	Mlb	Berry Creek	NT	AUSTRALIA
99076	27-Apr-99	Mcj	Manton River, Stuart Hwy	NT	AUSTRALIA
99077	27-Apr-99	Mvr	Litchfield National Park	NT	AUSTRALIA
99078	28-Apr-99	Mvr	Mamukala Billabong, Kakadu	NT	AUSTRALIA
99079	17-May-99	Mlb	Centenary Lakes	QLD	AUSTRALIA
99080	17-May-99	Mqn	Centenary Lakes	QLD	AUSTRALIA
99081	17-May-99	Mvr	Centenary Lakes	QLD	AUSTRALIA
99082	17-May-99	Mdl	Centenary Lakes	QLD	AUSTRALIA
99083	19-May-99	Mmn	Mt Malloy Rd	QLD	AUSTRALIA
99084	19-May-99	Mcj	McDowell Billabong	QLD	AUSTRALIA
99085	20-May-99	Mqn	Cairns Refuse Transfer Facility	QLD	AUSTRALIA
99086	13-May-99	Mqn	Chelmer	QLD	AUSTRALIA
99087	25-May-99	Mqn	Morayfield	QLD	AUSTRALIA
99088	25-May-99	Mqn	Bracken Ridge	QLD	AUSTRALIA
99089	25-May-99	Mqn	Nudgee	QLD	AUSTRALIA
99090	26-May-99	Mvr	Forest Drive, Cardwell	QLD	AUSTRALIA
99091	31-May-99	Mqn	Peregian	QLD	AUSTRALIA
99092	31-May-99	Mqn	Coolum Airport	QLD	AUSTRALIA
99093	1-Jun-99	Mqn	Brown Lake, Stradbroke Is.	QLD	AUSTRALIA
99094	1-Jun-99	Mqn	18 Mile Swamp, Stradbroke Is.	QLD	AUSTRALIA
99095	1-Jun-99	Mqn	Blue Lake Beach, Stradbroke Is.	QLD	AUSTRALIA
99096	1-Jun-99	Mqn	Adder Rock,	QLD	AUSTRALIA

			Stradbroke Is.		
99097	1-Jun-99	Mqn	Flinders Beach Rd, Stradbroke	QLD	AUSTRALIA
99098	3-Jun-99	Mqn	Racecourse Rd	QLD	AUSTRALIA
99099	3-Jun-99	LPsp	Racecourse Rd	QLD	AUSTRALIA
99100	3-Jun-99	Mqn	Caloundra Exit	QLD	AUSTRALIA
99101	3-Jun-99	LPsp	Caloundra Exit	QLD	AUSTRALIA
99102	15-Jun-99	Mqn	Woodburn	NSW	AUSTRALIA
99103	15-Jun-99	Mqn	Tyagarah	NSW	AUSTRALIA
99104	15-Jun-99	Mqn	Pottsville	NSW	AUSTRALIA
99105	22-Jun-99	Mqn	Morayfield	QLD	AUSTRALIA
99106	24-Jun-99	Mqn	Big Fish	QLD	AUSTRALIA
99107	24-Jun-99	Undet	Coonowrin Creek	QLD	AUSTRALIA
99108	8-Jul-99	Mqn	Peregian	QLD	AUSTRALIA
99109	8-Jul-99	Mqn	Coolum	QLD	AUSTRALIA
99110	8-Jul-99	Mqn	Marcoola	QLD	AUSTRALIA
99111	8-Jul-99	Mqn	Coolum Airport	QLD	AUSTRALIA
99112	16-Jul-99	Mqn	Blue Lake Beach, Stradbroke Is.	QLD	AUSTRALIA
99113	16-Jul-99	Mqn	Flinders Beach Rd, Stradbroke Is	QLD	AUSTRALIA
99114	21-Jul-99	Mqn	Woodburn	NSW	AUSTRALIA
99115	21-Jul-99	Mqn	Tyagarah	NSW	AUSTRALIA
99116	21-Jul-99	Mqn	Pottsville	NSW	AUSTRALIA
99117	22-Jul-99	Mqn	Morayfield	QLD	AUSTRALIA
99118	27-Jul-99	Mqn	Peregian	QLD	AUSTRALIA
99119	29-Jul-99	Mqn	Wild Horse Mountain	QLD	AUSTRALIA
99120	29-Jul-99	Mqn	Roy's Road	QLD	AUSTRALIA
99121	3-Aug-99	Mqn	Woodburn	NSW	AUSTRALIA
99122	3-Aug-99	Mqn	Tyagarah	NSW	AUSTRALIA
99123	3-Aug-99	Mqn	Pottsville	NSW	AUSTRALIA
99124	5-Aug-99	Mqn	Wild Horse Mountain	QLD	AUSTRALIA
99125	18-Aug-99	Mqn	Morayfield	QLD	AUSTRALIA
99126	19-Aug-99	Mqn	Wild Horse Mountain	QLD	AUSTRALIA
99127	19-Aug-99	Mqn	Roy's Road	QLD	AUSTRALIA
99128	19-Aug-99	Mqn	Racecourse Rd	QLD	AUSTRALIA
99129	19-Aug-99	LPsp	Racecourse Rd	QLD	AUSTRALIA
99130	3-Aug-99	Mdl	Centenary Lakes	QLD	AUSTRALIA
99131	3-Aug-99	Mnv	Speewah Drive	QLD	AUSTRALIA
99132	3-Aug-99	Mdl	Big Mitchell Creek	QLD	AUSTRALIA
99133	4-Aug-99	Mlb	Teamsters Memorial Park	QLD	AUSTRALIA
99134	4-Aug-99	Mdl	Port Douglas Turnoff	QLD	AUSTRALIA
99135	4-Aug-99	Mcj	McDowell Billabong	QLD	AUSTRALIA
99136	2-Aug-99	Mlb	Cairns Airport	QLD	AUSTRALIA
99137	4-Aug-99	Mlb	Cairns Airport	QLD	AUSTRALIA
99138	4-Aug-99	Mdl	Clifton Beach	QLD	AUSTRALIA

			turnoff		
99139	5-Aug-99	Mnv	Kennedy HWY	QLD	AUSTRALIA
99140	5-Aug-99	Mvr	Kennedy HWY	QLD	AUSTRALIA
99141	5-Aug-99	Mnv	Agricultural College turnoff	QLD	AUSTRALIA
99142	5-Aug-99	Mst	Mt Molloy-Mt Carbine Rd	QLD	AUSTRALIA
99143	5-Aug-99	Mst	Luster Creek	QLD	AUSTRALIA
99144	5-Aug-99	Mnv	Mareeba-Mt. Molloy Rd	QLD	AUSTRALIA
99145	5-Aug-99	Mnv	Gilmore Rd.	QLD	AUSTRALIA
99146	18-Aug-99	Mvr	Maryborough-Harvey Bay Rd	QLD	AUSTRALIA
99147	18-Aug-99	Mdl	Harbour Road	QLD	AUSTRALIA
99148	18-Aug-99	Mdl	Harvey Bay Beachfront	QLD	AUSTRALIA
99149	19-Aug-99	Mvr	Poona National Park	QLD	AUSTRALIA
99150	31-Aug-99	Mqn	Fitzgibbon	QLD	AUSTRALIA
99151	30-Aug-99	Mqn	Bracken Ridge	QLD	AUSTRALIA
99152	30-Aug-99	Mqn	Nudgee	QLD	AUSTRALIA
99153	24-Aug-99	Mqn	Peregian	QLD	AUSTRALIA
99154	26-Aug-99	Mqn	Bell's Creek Road	QLD	AUSTRALIA
99155	31-Aug-99	Mqn	Woodburn	NSW	AUSTRALIA
99156	31-Aug-99	Mqn	Tyagarah	NSW	AUSTRALIA
99157	31-Aug-99	Mqn	Pottsville	NSW	AUSTRALIA
99158	7-Sep-99	Mqn	Flinders Beach Rd, Stradbroke	QLD	AUSTRALIA
99159	7-Sep-99	Mqn	Blue Lake Beach, Stradbroke Is.	QLD	AUSTRALIA
99160	14-Sep-99	Mqn	Morayfield	QLD	AUSTRALIA
99161	16-Sep-99	Mqn	Sunshine Coast Motorway	QLD	AUSTRALIA
99162	20-Sep-99	Mqn	Peregian	QLD	AUSTRALIA
99163	28-Sep-99	Mqn	Woodburn	NSW	AUSTRALIA
99164	28-Sep-99	Mqn	Pottsville	NSW	AUSTRALIA
99165	23-Sep-99	Mqn	Roy's Road	QLD	AUSTRALIA
99166	6-Oct-99	Mqn	Roy's Road	QLD	AUSTRALIA
99167	12-Oct-99	Mqn	Bracken Ridge	QLD	AUSTRALIA
99168	21-Oct-99	Mqn	Sunshine Coast Motorway	QLD	AUSTRALIA
99169	25-Oct-99	Mqn	Brown Lake, Stradbroke Is.	QLD	AUSTRALIA
99170	4-Oct-99	Mar	Elizabeth River	NT	AUSTRALIA
99171	4-Oct-99	Mcj	Elizabeth River	NT	AUSTRALIA
99172	5-Oct-99	Mvr	Tabletop Swamp	NT	AUSTRALIA
99173	6-Oct-99	Mar	Burrel Creek, Stuart HWY	NT	AUSTRALIA
99174	13-Oct-99	Mqn	Terrigal Rotary Club Park	NSW	AUSTRALIA
99175	13-Oct-99	LPlg	Magenta	NSW	AUSTRALIA
99176	13-Oct-99	Mqn	Tuggerah Lake,	NSW	AUSTRALIA

99177	14-Oct-99	Mqn	The Entrance Wamberal Lagoon Reserve	NSW	AUSTRALIA
99178	14-Oct-99	Mqn	Manly Golf Club	NSW	AUSTRALIA
99180	25-Oct-99	Mqn	Blue Lake Beach, Stradbroke Is.	QLD	AUSTRALIA
99181	25-Oct-99	Mqn	Flinders Beach Rd, Stradbroke Is	QLD	AUSTRALIA
99182	28-Oct-99	Mqn	Pottsville	NSW	AUSTRALIA
99183	28-Oct-99	Mqn	Tyagarah	NSW	AUSTRALIA
99184	12-May-99	Mcj	Klong Lawone, Shakopang Vill.	Rayone	THAILAND
99185	8-Aug-99	Mcj	betw Pattani and Hat Yai	Pattani	THAILAND
99186	9-Aug-99	Mcj	Cha Uat	NST	THAILAND
99187	9-Aug-99	Mcj	nr. Cha Uat	NST	THAILAND
99188	10-Aug-99	Mcj	Heading N on Road 401	NST	THAILAND
99189	9-Aug-99	Mcj	Bo Lo Village #1	NST	THAILAND
99190	13-Nov-99	Mcj	Sogom #2, Sagom Village	Songkhla	THAILAND
99191	13-Nov-99	Mcj	Coast Road	Pattani	THAILAND
99192	14-Nov-99	Mcj	Bo Lo #2	NST	THAILAND
99193	15-Nov-99	Mcj	Sichon Technical School	NST	THAILAND
99194	15-Nov-99	Mcj	Ban Don Sau-Thong	Surat Thani	THAILAND
99195	6-Dec-99	Mqn	Bambaroo	QLD	AUSTRALIA
99196	7-Dec-99	Mvr	Tully-Mission Beach Road #1	QLD	AUSTRALIA
99197	7-Dec-99	Mvr	Tully-Mission Beach Road # 2	QLD	AUSTRALIA
99198	7-Dec-99	Mqn	E. Kennedy National Park #2	QLD	AUSTRALIA
99199	8-Dec-99	Mnv	Big Mitchell Creek	QLD	AUSTRALIA
99200	16-Dec-99	Mqn	Woongoolba	QLD	AUSTRALIA
99201	16-Dec-99	Mqn	Harris Rd, Woongoolba	QLD	AUSTRALIA
99202	16-Dec-99	Mqn	Jacobs Well	QLD	AUSTRALIA
99203	8-Dec-99	Mst	Mt Molloy-Mt Carbine Rd	QLD	AUSTRALIA
99204	8-Dec-99	Mlb	Jones St, Mossman	QLD	AUSTRALIA
AU99001	13-Jan-99	Lmc	Bramston Beach Road Site 1	QLD	AUSTRALIA
AU99002	13-Jan-99	Lrt	Bramston Beach Road Site 1	QLD	AUSTRALIA
AU99003	13-Jan-99	Lrt	Etty Bay	QLD	AUSTRALIA
AU99004	13-Jan-99	Lmc	El Arish	QLD	AUSTRALIA
AU99005	13-Jan-99	Lmc	EL Arish/ Mission Beach	QLD	AUSTRALIA
AU99006	13-Jan-99	Lrt	Wongaling	QLD	AUSTRALIA

			turnoff		
AU99007	13-Jan-99	Lrt	Carmoo Creek	QLD	AUSTRALIA
AU99008	13-Jan-99	Lrt	Silky Oak Creek	QLD	AUSTRALIA
AU99009	13-Jan-99	Lmc	Tully Hull Road	QLD	AUSTRALIA
AU99010	14-Jan-99	Lrt	Miallo	QLD	AUSTRALIA
AU99011	14-Jan-99	Lrt	Miallo	QLD	AUSTRALIA
AU99012	14-Jan-99	Lmc	Daintree Ferry	QLD	AUSTRALIA
AU99013	14-Jan-99	Lrt	Daintree Ferry	QLD	AUSTRALIA
AU99014	14-Jan-99	Lmc	Daintree Ferry	QLD	AUSTRALIA
AU99015	14-Jan-99	Lrt	Stewart Creek Rd	QLD	AUSTRALIA
AU99016	14-Jan-99	Lmc	Pet Cemetery	QLD	AUSTRALIA
AU99017	10-Feb-99	Lmc	Peregian Beach	QLD	AUSTRALIA
AU99018	25-Feb-99	Lmc	Coonowrin Creek	QLD	AUSTRALIA
AU99019	13-Apr-99	Lmc	Lagoon Rd	QLD	AUSTRALIA
AU99020	9-Mar-99	Lmc	Yellowood Close, Tewantin	QLD	AUSTRALIA
AU99021	9-Mar-99	Lmc	Elanda Point	QLD	AUSTRALIA
AU99022	9-Mar-99	Lmc	Harry's Hut Turnoff	QLD	AUSTRALIA
AU99023	25-Mar-99	Lmc	Lagoon Rd	QLD	AUSTRALIA
AU99024	1-Apr-99	Lmc	Wardell Turnoff, Richmond River	NSW	AUSTRALIA
AU99025	26-Apr-99	Lmc	Lameroo Beach	N.T.	AUSTRALIA
AU99026	27-Apr-99	Lmc	Anniversary Creek	N.T.	AUSTRALIA
AU99027	27-Apr-99	Lfl	Burrell Creek	N.T.	AUSTRALIA
AU99028	27-Apr-99	Lmc	Litchfield	N.T.	AUSTRALIA
AU99029	26-Apr-99	Ljp	Lameroo Beach	N.T.	AUSTRALIA
AU99030	18-May-99	Lrt	Koombooloomba Dam Road	QLD	AUSTRALIA
AU99031	18-May-99	Lmc	Martyville	QLD	AUSTRALIA
AU99032	19-May-99	Lrt	Highlands Drive	QLD	AUSTRALIA
AU99033	19-May-99	Lrt	McDowell Billabong	QLD	AUSTRALIA
AU99034	19-May-99	Lmc	McDowell Billabong	QLD	AUSTRALIA
AU99035	19-May-99	Lmc	Daintree Ferry	QLD	AUSTRALIA
AU99036	20-May-99	Lmc	Refuse Transfer Facility, Cairns	QLD	AUSTRALIA
AU99037	1-Jun-99	Lmc	Blue Lake Beach, Stradbroke Is	QLD	AUSTRALIA
AU99038	1-Jun-99	Lmc	Adder Rock, Stradbroke Is	QLD	AUSTRALIA
AU99039	1-Jun-99	Lmc	18 Mile Swamp, Stradbroke Is	QLD	AUSTRALIA
AU99040	1-Jun-99	Lmc	Flinders Beach Rd, Stradbroke Is	QLD	AUSTRALIA
AU99041	22-Jun-99	Lmc	Lagoon Rd	QLD	AUSTRALIA
AU99042	26-Aug-99	Lmc	Lagoon Rd	QLD	AUSTRALIA
AU99043	4-Oct-99	Lmc	Lameroo Beach	N.T.	AUSTRALIA
AU99044	5-Oct-99	Lmc	Anniversary Creek	N.T.	AUSTRALIA
AU99045	5-Oct-99	Lmc	Wangi	NT	AUSTRALIA

AU99046	6-Oct-99	Lmc	Edith Falls, Katherine	NT	AUSTRALIA
AU99047	7-Dec-99	Lrt	South Mission Beach	QLD	AUSTRALIA
AU99048	7-Dec-99	Lmc	E. Kennedy National Park	QLD	AUSTRALIA
AU99049	8-Dec-99	Lmc	McDowell Billabong	QLD	AUSTRALIA
AU99050	9-Dec-99	Lmc	Martyville	QLD	AUSTRALIA
AU99051	16-Dec-99	Lmc	Carbrook Creek	QLD	AUSTRALIA
ID99001	18-May-99	DPas	Oil Palm Plantation Site1	N Sumatra	INDONESIA
ID99002	18-May-99	DPas	Oil Palm Plantation Site 2	N Sumatra	INDONESIA
ID99003	19-May-99	Lmc	Tanjungbalai	N Sumatra	INDONESIA
ID99004	19-May-99	Lfl	Tanjungbalai	N Sumatra	INDONESIA
ID99005	20-May-99	SIac	Tanah Gambus Estate	N Sumatra	INDONESIA
ID99006	20-May-99	DPes	Tanah Gambus Estate	N Sumatra	INDONESIA
ID99007	20-May-99	Lfl	Site 1, Tanah Gambus Estate	N Sumatra	INDONESIA
ID99008	20-May-99	Lmc	Site 2, Tanah Gambus Estate	N Sumatra	INDONESIA
ID99009	20-May-99	Lfl	Block 7, Tanah Gambus Estate	N Sumatra	INDONESIA
ID99010	21-May-99	DPes	nr. Marihat Research Station	N Sumatra	INDONESIA
ID99011	22-May-99	CHar	nr. Lake Toba	N Sumatra	INDONESIA
ID99012	22-May-99	Undet	nr. Lake Toba	N Sumatra	INDONESIA
MA99001	16-Mar-99	Lmc	nr. Palace of Golden Horses	Selangor	MALAYSIA
MA99002	17-Mar-99	Lmc	Rimba Ilmu	Selangor	MALAYSIA
MA99003	22-Mar-99	Lmc	Mines Beach Resort	Selangor	MALAYSIA
MA99004	22-Mar-99	Lmc	nr. Palace of Golden Horses	Selangor	MALAYSIA
MA99005	17-Apr-99	Lfl	Kuala Lumpur Lake Garden		MALAYSIA
MA99006	20-Apr-99	Lmc	Crop Protection Division, DOA		MALAYSIA
MA99007	24-Apr-99	Lmc	Kuen Cheng Chinese School		MALAYSIA
MA99008	15-May-99	Lmc	Nilai Memorial Park	Negeri Sembilan	MALAYSIA
MA99009	15-May-99	Lmc	Oil Palm plantation	Selangor	MALAYSIA
MA99010	16-May-99	Lmc	Sungai Nibong	Selangor	MALAYSIA
MA99011	4-Jun-99	Lmc	Kampung Kelan Satu		MALAYSIA
MA99012	5-Jun-99	Lfl	Sheraton Langkawi Beach Hotel	Kedah	MALAYSIA

MA99013	4-Jul-99	Lmc	Bunga Melur 16 Road		MALAYSIA
MA99014	4-Jul-99	Lmc	Jalen Bunga Melur 16		MALAYSIA
MA99015	16-Jul-99	Lmc	Kampung Cheras Baru		MALAYSIA
MA99016	19-Jul-99	Lmc	Simpang Tungku Putra		MALAYSIA
MA99017	25-Jul-99	Lmc	Jalan Setiamurni 3 / Jalan Bringin		MALAYSIA
MA99018	25-Jul-99	Lmc	Jalan Setiamurni 3 / Jalan Bringin		MALAYSIA
MA99019	8-Aug-99	Lmc	Kg. Temin	Pahang	MALAYSIA
MA99020	8-Aug-99	Lmc	Kuala Kerau	Pahang	MALAYSIA
MA99021	8-Aug-99	Lmc	Kg. Ketam	Pahang	MALAYSIA
MA99022	12-Aug-99	Lmc	3km from Kakak	Pahang	MALAYSIA
MA99023	12-Aug-99	Lmc	Indah Mentakab Garden	Pahang	MALAYSIA
MA99024	12-Aug-99	Lmc	22km E Maran	Pahang	MALAYSIA
MA99025	13-Aug-99	Lmc	Kampung Sungai Soi	Pahang	MALAYSIA
MA99026	13-Aug-99	Lmc	Kampung Ketapong	Pahang	MALAYSIA
MA99027	14-Aug-99	Lfl	Jalan Bunga Malur (?) 16		MALAYSIA
MA99028	24-Sep-99	Lmc	10 mile stone, Senawang	Negeri Sembilan	MALAYSIA
MA99029	24-Sep-99	Lmc	11 mile stone, N of Gemas		MALAYSIA
MA99030	24-Sep-99	Lmc	Batu Anam	Johor	MALAYSIA
MA99031	25-Sep-99	Lmc	Estate Moakil		MALAYSIA
MA99032	25-Sep-99	Lmc	Sungai Karas		MALAYSIA
MA99033	25-Sep-99	Lmc	Bukit Banang Golf Course	Johor	MALAYSIA
MA99034	26-Sep-99	Lmc	Kukup Golf Course Resort	Johor	MALAYSIA
MA99035	26-Sep-99	Lmc	Taman Ramba	Johor	MALAYSIA
MA99036	4-Nov-99	Lmc	Parit Merlong Rangit	Johor	MALAYSIA
MA99037	5-Nov-99	Lmc	Ulu Tiram Utara	Johor	MALAYSIA
MA99038	5-Nov-99	Lmc	Road #3, South of Mersing	Johor	MALAYSIA
MA99039	5-Nov-99	Lmc	125km S Kuantan	Pahang	MALAYSIA
MA99040	5-Nov-99	Lmc	Kampung Ketapong	Pahang	MALAYSIA
MA99041	6-Nov-99	Lmc	nr Kg Belok	Pahang	MALAYSIA
MA99042	8-Nov-99	Lmc	Jalan Melur 16	Kuala Lumpur	MALAYSIA
MA99043	8-Nov-99	Lmc	Taman Teratai		MALAYSIA
MA99044	9-Nov-99	Lmc	Nilai Memorial Park	Negeri Sembilan	MALAYSIA
MA99045	9-Nov-99	Lmc	HWY to Melaka, 237 milestone		MALAYSIA

MA99046	10-Nov-99	Lmc	Templers Park	Selangor	MALAYSIA
MA99047	11-Nov-99	Lmc	Kg Air Putih	Pulau Pinang	MALAYSIA
MA99048	11-Nov-99	Lmc	Kg Bukit Minyak	Penang	MALAYSIA
MA99049	12-Nov-99	Lmc	Kampung Baru	Perak	MALAYSIA
MA99050	12-Nov-99	Lmc	Kg. Changkat Jering	Perak	MALAYSIA
MA99051	11-Dec-99	Lmc	Oil Palm plantation	Selangor	MALAYSIA
MA99052	19-Dec-99	Lmc	Taman Teratai		MALAYSIA
MA99053	25-Dec-99	Lmc	Taman Wetland	Selangor	MALAYSIA
MA99054	25-Dec-99	Lmc	Mukim Pasir Panjang	Negeri Sembilan	MALAYSIA
MA99055	25-Dec-99	Lmc	Teluk Kemang	Negeri Sembilan	MALAYSIA
SN99001	8-Oct-99	Lmc	Hindhede Track		SINGAPORE
SN99002	9-Oct-99	Lmc	Belukar Track		SINGAPORE
SN99003	10-Oct-99	Lmc	Site S1		SINGAPORE
SN99004	10-Oct-99	Lmc	Site S2		SINGAPORE
SN99005	11-Oct-99	Lmc	Upper Pierce Reservoir		SINGAPORE
SN99006	2-Nov-99	Lmc	Belukar Track		SINGAPORE
SN99007	2-Nov-99	Lmc	near WH Pool		SINGAPORE
SN99008	3-Nov-99	Lmc	near Reservoir Inlet		SINGAPORE
TH99001	19-Apr-99	Lmc	Sagom Village	Songkhla	THAILAND
TH99002	19-Apr-99	Lmc	Post mark #73, Road no. 4086	Songkhla	THAILAND
TH99003	20-Apr-99	Lmc	Luhbohlausa Village	Narathiwat	THAILAND
TH99004	20-Apr-99	Lmc	Ban Pra Bud Village	Songkhla	THAILAND
TH99005	27-Apr-99	Lfl	Ban Pong Village	Chiang Mai	THAILAND
TH99006	27-Apr-99	Lfl	Mae Jo Dam, Ban Pong Village	Chiang Mai	THAILAND
TH99007	29-Apr-99	Lfl	Ban Pong Village	Chiang Mai	THAILAND
TH99008	11-May-99	Lfl	Klong Pla Kang Waterfall	Rayong	THAILAND
TH99009	11-May-99	Lsp	Klong Pla Kang Waterfall	Rayong	THAILAND
TH99010	11-May-99	Lmc	Klong Lawone, Shakapong Village	Rayong	THAILAND
TH99012	12-May-99	Lmc	Klong Yai District	Trat	THAILAND
TH99013	13-May-99	Lsp	Klong Pla Kang Waterfall	Rayong	THAILAND
TH99014	5-Aug-99	EHcr	Mae Jo	Chiang Mai	THAILAND
TH99015	5-Aug-99	Lfl	Ban Pong Village	Chiang Mai	THAILAND
TH99016	6-Aug-99	Ral	Aang Ka Trail	Chiang Mai	THAILAND
TH99017	6-Aug-99	Psp	Road to Mae Chaem	Chiang Mai	THAILAND
TH99018	6-Aug-99	SIac	nr Om Khut Village	Chiang Mai	THAILAND

TH99019	7-Aug-99	Lmc	Sagom Village	Songkhla	THAILAND
TH99020	7-Aug-99	Lmc	Ban Pak Bang Sagom School	Songkhla	THAILAND
TH99021	8-Aug-99	Lmc	Luhbohlausa Village	Narathiwat	THAILAND
TH99023	9-Aug-99	Lmc	Road # 408	Songkhla	THAILAND
TH99024	9-Aug-99	Lmc	Bo Lo Village	NST	THAILAND
TH99027	9-Aug-99	Lmc	nr Rajhabat Institute	NST	THAILAND
TH99028	10-Aug-99	Lmc	Tambol Photong	NST	THAILAND
TH99030	10-Aug-99	HYsp	Sapan Klai, Sakeaw Village	NST	THAILAND
TH99031	10-Aug-99	Lmc	nr Rajhabat Institute	NST	THAILAND
TH99032	5-Aug-99	Lfl	Ban Pong Village	Chiang Mai	THAILAND
TH99033	24-Oct-99	Lmc	Japanese Factory	Nakhon Nayok	THAILAND
TH99034	24-Oct-99	Lmc	Moo 7, Srisa Kabuea	Nakhon Nayok	THAILAND
TH99035	13-Nov-99	Lmc	Ban Pak Bang Sagom School	Songkhla	THAILAND
TH99036	14-Nov-99	Lmc	Road # 408	Songkhla	THAILAND
TH99037	14-Nov-99	Psp	Ban Hua Node, Moo 1, Road 408	Songkhla	THAILAND
TH99038	14-Nov-99	Lmc	Site 1	NST	THAILAND
TH99039	14-Nov-99	Lmc	near Ban Tun Village	NST	THAILAND
TH99040	15-Nov-99	Lmc	Tambol Photong	NST	THAILAND
TH99041	15-Nov-99	Lmc	near Sichon Technical School	NST	THAILAND
TH99042	15-Nov-99	Lmc	Nr. Ban Don Sau Thong Village	Surat Thani	THAILAND
TH99043	17-Nov-99	Lfl	roadside SE of Doi Inthanon	Chiang Mai	THAILAND
TH99044	17-Nov-99	Psp	Road to Mae Chaem	Chiang Mai	THAILAND
TH99045	17-Nov-99	Psp	on road to Hot	Chiang Mai	THAILAND
TH99046	20-Apr-99	Lfl	Luhbohlausa Village	Narathiwat	THAILAND
TH99047	8-Aug-99	Lfl	Luhbohlausa Village	Narathiwat	THAILAND
TH99049	13-Nov-99	Lmc	Sagom Village	Songkhla	THAILAND