Report of the 2nd Australian Lippia Research Workshop

Parkes, 8-9 July 2008

Burrawang West: lippia carpet on the left; post herbicide grass growth on the right.

Compiled by:
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Introduction to lippia research workshop

The National Lippia Working Group (NLWG) was formed in July 2002 (as the Murray Darling Lippia Working Group) by landholders and agency representatives in response to ongoing concern about the rapid spread of lippia and a lack of effective control methods. It conducted the first national lippia forum in Moree on 18-19 October 2004. A lippia research workshop was subsequently held on 19 October 2006 (van Klinken 2006). It was attended by researchers, many of who had only just commenced research on lippia, selected representatives from all relevant CMAs, state agencies and funding agencies and some landholders.

A second lippia research workshop was held in Parkes on 8-9 July 2008. It was attended by active lippia researchers, together with key representatives from main funding and natural resource management agencies who are in a position to provide valuable input into research priorities. In total there were 23 participants. This report is an informal summary of the discussion and outcomes of that workshop.

Workshop Objectives

The objectives of this workshop, as agreed by participants, were to:

- Determine the "state of play" of lippia research
- Identify key research gaps and synergies
- Develop a funding strategy for addressing research gaps (most existing funds end c. late 2008 to mid 2009)
- Identify communication and extension opportunities and priorities

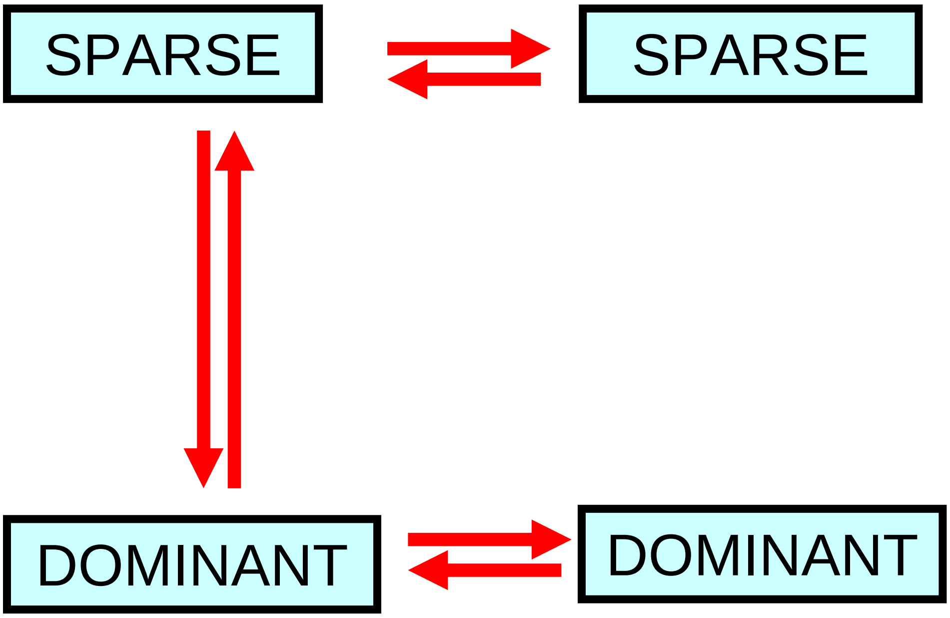
Overview of current research

Talks were presented summarizing current research projects. See Appendix 3 for research summaries provided by presentors.

Conceptual model

The workshop spent a small amount of time discussing what factors result in lippia becoming dominant, remaining dominant, becoming sparse from dominant, or remaining sparse (below). The objective was to think broadly about the factors driving lippia invasions, as a basis for subsequently identifying research priorities. The intention was not to develop a model per se.

A wide range of interacting factors were identified, especially relating to inundation patterns total grazing patterns and climate. Some important geographical differences were identified, including differing climates and land management practices.



Several unresolved issues were identified during development of the conceptual model. The following three, somewhat inter-related, questions were subsequently discussed by sub-groups.

1. *How does inundation frequency, intensity, duration and season affect lippia populations?* [Groups feedback: it depends on ground cover at the time of flooding; seasonal effects depend on the plant community and their responses; grazing is an important interacting factor]

2. *What are the best environmental flows to prevent lippia dominance?* [Groups feedback: "More water more often"; spring/summer floods with the possible exception of winter rain areas; needs to be linked with strategic grazing management; need to know what duration/depth of inundation kills lippia; can probably only realistically manage situations in wetlands through environmental flows]

3. *How do we manage lippia in wetlands versus floodplains?* [Groups feedback: need more awareness of lippia among land managers; grazing management is critical (e.g. landholder agreement for stock removal during environmental flows, if ground cover < 70%, no more than 4 mths/yr); "locking up" from grazing is not necessarily a good strategy; revegetation should use a range of grass species (including winter species in the southern areas); may need to reduce wetlands to manageably save what is left; there are less lippia management techniques available for wetlands, other than inundation; need to be clear how "remaining wetlands" are defined, especially with altered flow regimes]

RESEARCH PRIORITIES

Research questions were identified by workshop participants without reference to the funding environment. The full list of questions is provided in Appendix 4. This list was subsequently short-listed with the objective of identifying key research priorities and estimating the required resources to address them. Short-listing focused on identifying the most immediate, strategic, substantial research priorities. It was intended as a guide only, and not to be an exclusive list of future priorities.

Seven general research priorities were identified, and they are discussed below in turn (they were not ranked in any way).

1. *Ecology: improved understanding of how lippia responds to disturbance, especially fooding and grazing, particularly in relation to competitive interactions.*

This research is partially addressed through ongoing work by Jodi Price, Alice Yeates and Celine Clech-Goods. However, it was felt that

- a better understanding of mechanisms was required (e.g. through manipulative glasshouse experiments),
- the effects of flooding needed to be better tested in field surveys/experiments. The unpredictable nature of floods could be overcome through artificial flooding trials, setting up trials in areas of more predicable flooding (e.g. from environmental flows), conducting post-hoc surveys soon after flood events, or expanding the network of permanent study sites.
- a network of permanent exclosures (e.g. total exclosure, cattle exclosure only; open part of year) across the environmental distribution of lippia was required to monitor long-term responses (beyond the life of currently planned research). Some of these have already been set up (e.g. Price, Yeates) and others could leverage off existing long-term wetland monitoring.
- Landscape-scale responses to disturbance could potentially be elucidated from carefully designed surveys, and from other wetland data sets, for example IMEF (Integrated Modelling of Environmental Flows) – 3 monthly site visits, c 12 years (Neil Foster, Patrick Driver, DWE).

Resources: This priority could be addressed together with priority 7. See point 7.

2. *Predicting where lippia will become dominant at the catchment scale.*

Catchment-scale modelling at the catchment (or subcatchment) scale is necessary to predict where lippia will become dominant, to integrate broadscale drivers such as changing flooding patterns, environmental flow, changing land use, and changing livestock management. Predictions would help quantify the threat of lippia, the likely effect of environmental flows and other factors on that threat, and to help prioritise lippia management effort at the national, regional and catchment scale.

Kate Stokes has already developed a regional-scale model of lippia to examine responses to climate change using a population/physiological modelling approach. However, there is insufficient data to fit some key parameters. An alternative approach, Bayesian Belief Networks, has been used with some success for predicting parkinsonia risk in south-west Queensland, and may be relatively easily applied to lippia. It integrates research and expert opinion with available GIS layers.

Predictions would require a better understanding of the current catchment-scale distribution of lippia. Some data is available, e.g. Ian Foreman, Rod McCosker, DEC Rivers and Wetlands Unit. Ideally surveys need to be structured so as to help test hypothesese regarding the key factors driving lippia dominance.

Catchment-scale modelling needs to integrate hypotheseses regarding the interaction between lippia, natural resource management, drought and inundation (see point 1), and response to climate change. It also needs to take account geographical variation, such as with respect to seasonal rainfall patterns.

> Resources: This project, using the BBN approach, would take approximately 6-12 months of a scientist with the relevant modelling and GIS skills. It would also require access to the necessary GIS data layers, and resources to obtain more detailed distributional data collected at the right scale (if not already available). It could potentially leverage off similar projects currently being proposed for other weeds/systems (see Rieks van Klinken).

3. *Build case for identifying it as a key threatening process*

Successful nomination of lippia as a key threatening process would greatly assist in raising its profile and, potentially, obtaining resources for research and management. WWF submitted a proposal in 2003, and resubmitted it in March 2008 following no response (see correspondence 10 July 2008 from Averil Bones to Scott Charlston).

Further work may be required to develop and push this case, but will depend on feed back from the assessment panel. Work might include quantifying how lippia affects hydrology, and field validation of expected impacts (e.g. Kate Reardon-Smith) using a case-study approach. John Duggin and Neil Foster have potentially useful long-term data series.

> Resources: will depend on how the current case fares. The case-study approach would take e.g. a PhD project. Redevelopment of the submission, with additional lines of evidence, might require the assistance of a "project officer".

4. *Economic impact of lippia to production*

There is a need to quantify the current and potential impact of lippia both at the industry level and the producer level (including enterprise trade-offs between cultivation and grazing). In addition, economic modelling is required to help compare different management options, including cultivation (for improved pasture, native pasture and/or cropping), herbicide application and "doing nothing".

AWI have already conducted similar modelling for forage shrubs (using "MIDAS"). This was at the enterprise level, but could potentially be scale-up to industry level. Considerable information may already be available, for example from the 28 case-studies included in the lippia BPM.

<u>Resources</u>: Would require an economist (no idea how long it would take), and people to provide information, possibly with the assistance of a “project officer”.

5. Development of biological control

Development of effective biological control was viewed as a very high priority, as it may be the only management option in many situations. Key aspects still to be addressed include:

- resolving whether *P. nodiflora* is native or exotic to Australia (research currently underway)
- resolving the taxonomic issues surrounding *Phyla* spp. in South America
- conducting supporting research (e.g. to identify which available agents will be the most effective)
- continuing work in South America for approximately three years, including increasingly focussed survey work as the genetics become better understood, and gradually shifting focus to the work required for prioritising known agents (e.g. culturing techniques, preliminary testing)
- commencing detailed host-specificity testing of piority agents in an Australian quarantine. This could commence within the next 12 months, and completion of testing of the first agent would be expected within a further c. 18 months.

<u>Resources:</u> Funds for native-range work required from March 2009. Funds required to commence detailed host-specificity testing within the next 12 months. Funds required to resolve final genetic questions (c. 4 months work, $40k) required by September 2008.

6. Predicting the optimal windows for herbicide application

Further work was required to better characterise the optimal spraying window. Ideally trial work should be repeated geographically and through time (to account for seasonal variation). Work could also include demonstration trials for controlling small lippia patches, with the aim of showing that small infestations can be eradicated. Below-ground biomass sampling following herbicide repeated applications (dominant Lippia infestations) may provide useful insights. Integrating herbicide use with appropriate pasture management is the key to longer term management of Lippia.

<u>Resources:</u> The trial would run over two years. Some technical support and operating funds would be required (c. $24k) (Tony Cook). Additional resources may be required to repeat the trial in more than one region/catchment.

7. Lippia management: Grazing and land management

Grazing management remains the most likely management tool in many situations, particularly where agronomic techniques are not applicable (e.g. in sensitive woodlands and in wetlands). It may also be critical for preventing lippia invasions (“proofing” pastures). Useful research is already underway (especially by Jodi Price and Alice Yeates). However, existing work needs to be continued and expanded if strong management recommendations are to be made across lippias’ distribution.

Resources: This research priority is closely linked with piority 1. Together, they could be tackled with a further three-year post-doc, together with a PhD student to pick up specific aspects. Jodi Price would be well placed to continue this work.

FUNDING POSSIBILITIES

A brief discussion was held to identify potential funding sources for lippia research. This is in addition to parties that are providing inkind support, such as QDPI, CSIRO, UNE, UQ, CMAs and numerous landholders.

The current **Caring for Country** call is a possibilility, but the time-frame is tight (due 2 August 2008) and lippia may not have sufficient national profile (e.g. is not a WONS). Nontheless, submitting a funding bid would at least ensure it was "in the mix". Possible inclusions in a 12 month project would be: role-out of best practice manual, landscape-scale predictive modeling, genetics, and identifying lippia as a key threatening process (including to iconic sites). It could potentially include all/part funding for the first 12 months of a "project leader"/national coordinator. A lead agency would be required to develop the proposal (ASAP!).

The **National water initiative** (c. $10 billion) may offer opportunities, but no workshop participant was sufficiently familiar wih this program.

The **wetlands recovery project** (which has funded considerable lippia research to date) is about to end and won't be replaced. However, the PCG was very keen to see the biological control programme continued. Engagement with PCG needs to be continued to try to address alternative funding sources.

Possibilities not previously approached, and of unknown potential, include:

- RAMSAR Managers Network (David Heap): they have no funds, but have the "ear of government", and will submit funding proposals.
- The CSIRO Water for a Healthy Flagship has internal funding opportunities. Rieks is pursuing one possible avenue, but there may be more
- National Weed Centre is about to commence, but it structure, processes and opportunities has not yet been determined
- The CMA Chairs have a small amount of money to support cross- CMA projects. May be interested in supporting threatening processes or predictive modelling projects
- IMEF (Neil Foster, DWE). May be potential to add value to what they are doing already
- GRDC: there may be opportunities through "mixed farming" angle (Tony Woods knows a director)
- ARC: opportunities for leveraging industry funds through ARC-Linage grants.
- DECC Science: not sure if have funds for external research activities; they do have a river restoration program; (Dave Heap will follow up), Renee Shepherd may know details.
- LWA climate change (CCRSPI)
- Cotton coummnity Catchment CRC: opportunities unknown.
- Landcare Australia: they obtain funds from corporate sponsors
- QDPI: but do not yet officially recognise lippia as a serious weed.

- Crown Land: have funds?
- Philanthropy: e.g. Richard Pratt

Funding agences already currently engaged
- SEQ Water (have a contract with CSIRO to June 2010)
- AWI: weeds are low in their strategy for the next 3-4 years, and they are therefore an unlikely source for continued funding
- MLA

COORDINATION AND EXTENSION

Extension was identified as of ongoing importance. For example, many land managers in affected areas still are not aware of lippia and its threat. Also, Lachlan CMA was largely unaware of the work going on through the National Lippia Working Group prior to this workshop.

Identified extension priorities included:
- ensuring that the soon to be finalised Best Practice Manual is “rolled out” in away that maximises its benefits
- further work on awareness and identification. Demonstration sites were considered to be very valuable
- further promotion of “great simple messages” already coming from research and case studies (e.g. through dedicated industry publiations)

There was some discussion about the need and potential value of having a dedicated national coordinator for lippia. The consensus was that there would be considerable benefit, especially if the position was engaged through the existing National Lippia Working Group. Roles might include:
- facilitating the development and adoption of a national management strategy, including of management zones
- pursuing declarations (if considered useful), nomination as a key threatening process and recognition as a serious weed by Queensland State Government
- building interest and capacity among CMAs and Local Councils across its distribution
- coordination of aspects of the research, such as economic study
- assist in identifying new funding sources, and fostering existing funding sources, for research and management (including development of cross-regional projects).

ACTION TABLE

Hopefully most workshop attendees will have their own “private actions”. However, the following actions were identified during the course of the workshop.

Action	Who	When
Options for resourcing a national coordinator	Mary to pursue CMAs; Liz through other avenues; Scott Charlton likewise.	
Caring for Country submission:	No one nominated	Deadline is 2 August 2008
Follow up on Nomination as Key Threatening Process	Scott Charlton	
RAMSAR network funding opportunities	David Heap to pursue	
Cross-CMA projects	Mary to pursue through CMAs.	
CSIRO Water Flagship opportunities	Rieks van Klinken to pursue	

ACKNOWLEDGMENTS

We thank Parkes Shire Council for provision of meeting facilities, Lachlan CMA (especially Andrew Glasson), Bill Royal (Burrawang West), Dan Herbert (Jemalong Station) for organizing the field trip, and QMDC for providing funds to help support the workshop.

APPENDIX 1: AGENDA

<u>Wednesday 9 July 2008</u>

10.30-11.00: Morning tea (for early-comers)
11.00-11.30: Introductions and finalizing workshop objectives
11.30-12.00: Developing a framework for a lippia conceptual model
12.00-13.00: Research presentations (part 1)
13.00-13.45: Lunch
13.45-15.00: Research presentations (part 2)
15.00-15.30: Afternoon tea
15.30-16.30: Developing the conceptual model
16.30-17.00: R&D priorities: preliminary brainstorm.

Dinner at venue TBA (6.30 pm)

<u>Thursday 10 July 2008</u>

07.30-10.30: Field trip [Andrew Glasson]. Depart Coachmans Motel 7.30 am sharp.
10.30-11.00: Morning tea
11.00-12.30: R&D priorities: detailed discussion
12.30-13.15: Lunch
13.15-15.30: Finalise R&D priorities, extension priorities and actions list.

SCIENCE TALKS

<u>Ecology, genetics, impacts</u>

1. Matt McDonald: Reproductive ecology of *Phyla canescens*
2. Rieks van Klinken: The effects of disturbance, nutrients and herbivory
3. Mohammad Fatemi: Lippia - An update on the genetics and origin of *Phyla canescens*
4. Chengyuan Xu: Lippia eco-physiology
5. Lily Gorrell: The breeding system of lippia: are honeybees the achilles heel in its life cycle?
6. Ian Foreman: Lippa Management in the Macquarie Marshes and Gwydir Wetlands
7. Kate Stokes: Predicting lippia spread

<u>Management</u>

8. Tony Cook: Lippia research highlights from northern NSW
9. Jodi Price: Strategic grazing for the control of the invasive wetland weed lippia
10. Mic Julien: Biological control

APPENDIX 2: LIST OF PARTICIPANTS

Participant	Organisation
Cameron Allan	MLA
Matthew Bailey	Parkes Shire Council
Scott Charleton	NSW DPI
Tony Cook	NSW DPI
John Duggin	UNE
Mohammad Fatemi	UNE
Ian Foreman	Hassal Associate (Environ. Engineering)
Andrew Glasson	Lachlan CMA
Lily Gorrell	UNE
Mary Goodacre	AWI
David Heap	RAMSAR Management Network NSW
Mic Julien	CSIRO Entomology/Weed CRC
Warren Martin	NSW DECC
Matt McDonald	UNE
Dennis Moxey (for Rob Glehill)	Lachlan CMA (hosting)
Jodi Price	UNE
John Ryan	Forbes Shire Council
Liz Savage (for Mark Blair)	Border Rivers / Gwydir CMA
Kate Stokes	CSIRO Entomology
Rieks van Klinken	CSIRO Entomology/Weed CRC
Andrew White	CSIRO Entomology
Tony Woods	NLWG Chair
Chengyuan Xu	CSIRO Entomology

Apologies: Wal Whalley (UNE), Rob Glehill (Lachlan CMA), Shona Whitfield (Central West CMA)

APPENDIX 3: SCIENCE SUMMARIES

Matt Macdonald (UNE, Armidale): Reproductive ecology of *Phyla canescens*

Four field populations were selected in two adjacent catchments (Gwydir River and Namoi River) in the northern New South Wales section of the Murray Darling Basin.

Seed production was estimated to reach over 60 000 seeds/m^2/year. All seed was produced in the five-month period from December to April. Seed production was also a function of recent rainfall, percentage cover of *P. canescens*, and cover of other plants. Where pollinators were excluded, fruit set was reduced to zero.

To germinate, seed was found to require temperatures that alternated by at least 5°C. The presence of light and high water availability were also necessary for germination. This combination of germination requirements is common to a number of invasive species of wetland and floodplain habitats. These conditions are most likely to be met with the recession of floodwaters.

Seedbank density exceeded 7500 seeds/m^2. After 12 months of preventing seed-rain, the seedbank had decreased by 38%. At this rate it will take 10 years for the seedbank to decline to <1% of the original density. A parallel seed-burial study showed no significant decline over 13 months. However, floods are likely to increase the rate of seedbank depletion, primarily through germination of those seeds exposed to light.

Field recruitment of *P. canescens* occurred only at the one site that experienced a flood during the experimental period. The exclosures at the other three sites were not flooded and no *P. canescens* germinated, despite periods of high rainfall, and germination of a range of other species. Germination density and seedling survivorship were both reduced in the presence of existing vegetation. An opportunistic survey, following the flooding of a billabong, revealed recruitment of *P. canescens* from both seed and fragments to be almost exclusively restricted to the area that had been flooded. Seedlings were also recorded germinating directly from sheep faeces.

Rieks van Klinken, Andrew White, Alice Yeates and Celine Clech-Goods (CSIRO & UQ): Reporting on a range of ecological lippia studies.

Several projects are being conducted in southeast Queensland and northern NSW. Parts of two PhD projects (by Alice Yeates and Celine Clech-Goods) are examining ecological aspects of lippia. Alice Yeates is testing what the longterm effects of weed-shaped holes (caused for example by herbicide treatment) are on plant community structure, and how that might be influenced by grazing. Celine Clech-Goods is testing the role of nutrients and herbivory on lippia invasions using a manipulated field trial and inter-continental study respectively. A third project, funded by SEQ Water, is examining the spread, impact and management of lippia on pastoral leases surrounding Somerset and Wivenhoe Dams. The latter project is also contributing to, and extending, research being conducted by Jodi Price, Alice Yeates and Chengyuan Xu.

Mo Fatemi (UNE, Armidale): Lippia - An update on the genetics and origin of *Phyla canescens*

The use of chemicals as a method to control lippia is undesirable in environmentally sensitive areas such as the Macquarie Marshes. Biological control will be the only option in many areas. The levels of genetic diversity in lippia play a major role in determining the specificity of biological control agents. Medium to low levels of genetic diversity within and among lippia populations would increase the chances of biological control agents being effective in a range of environments. We investigated genetic diversity in 12 populations of lippia from four different catchments in Australia, eight populations from its native range in South America and five populations from France where the species is non-native and invasive. Low levels of genetic diversity were detected within some Australian regions in contrast to the Argentinean and French populations. The Australian material segregated into two disjunct regions in Argentina suggesting that Australia has experienced multiple introductions of lippia. Analysis of ITS sequences revealed that Australian populations of lippia have originated from at least two regions in Argentina. Considerable advances have been made in our genetic understanding of this species, which will have an important influence in its management and control.

Chengyuan Xu: Lippia eco-physiology

<u>Chemical properties of plant-soil system in lippia infested land</u>
Soil and plant tissue samples were analysed in lippia infested plots and nearby pasture plots from three sites with different climate and hydrodynamics, and some common patterns were observed. First, lippia infected land displayed lower soil moisture (16%-27% lower) in a dry year (2007). Second, lippia leaves contain high calcium concentration (up to 4% w/w), about 10 times of that in grass species. More than 60% of calcium in leaf tissue was calcium carbonate crystals, which existed in the spiny lithocyst structure of leaf surface. These observations suggest lippia may gain competitive advantage over pasture species in dry and/ or heavy grazing land.

<u>Intercontinental comparison</u>
The genetics and growth properties of lippia were compared among populations in Australia, Argentina and France. Lippia was multiply introduced into Australia from several regions in native range (Argentina) and the gene pool was reshuffled after introduction. The genetic diversity of Australian populations was comparable to Argentine populations. Rapid evolution happened after introduction, and Australian populations showed higher allocation to flowering, which might be related to the selectional pressure of the drier, more variable climate. Given the high potential of rapid evolution, an integrative management strategy with multiple control methods may be required for controlling this weed.

<u>Clonal Integration</u>
One glasshouse experiment was implemented to study whether lippia stolons could get sufficient maternal subsidy when they grow in light limited environments (mimic shade effect of pasture grasses). Preliminary results showed that lippia stolons connected with mother plants grew much faster than independent stolons, but no significant differences in photosynthetic capacity and respiration rate were observed. Thus, the increased growth was attributed to the from the mother plant. The carbohydrate storage in the mother plant was mainly soluble sugar, which may facilitate transportation to daughter plants. These results indicate that lippia stolons may take over native grasses by obtaining subsidy from better-located stolons.

Lily Gorrell and Caroline Gross (UNE, Armidale): The breeding system of lippia: are honeybees the archilles heel in its life cycle?

The aim of this study was to determine the breeding system of the invasive wetland weed lippia (*Phyla canescens*). Typically, weed management targets the mature plant life-stage, however, other life stages may be more critical for survival. Determining breeding systems of invasive plants may highlight sensitive life history stages that can then be targeted for control. We examined the breeding system of lippia with field and glasshouse trials. The glasshouse study found that lippia is self-compatible but not capable of auto-self pollination i.e. lippia can self-pollinate but requires a pollinator to do so. Greater seed set was found in flowers that received out-crossed pollen as compared to self-pollen. Findings were consistent in the field trials with no seed set recorded in plants with total pollinator exclusion. Field observations indicated that honeybees (*Apis mellifera)* were the major floral visitor to lippia. Findings indicate that management to control (feral) honeybee populations in lippia dominated areas may limit seed production. The method developed for feral honeybee control will be discussed as part of an integrated management approach for lippia.

Ian Foreman (GHD Hassall): Research Summary - Lippa Management in the Macquarie Marshes and Gwydir Wetlands

GHD Hassall was contracted by the CW CMA to map the current extent of Lippia in the Macquarie Marshes (MM) and the Gwydir Wetlands (GW) and provide specific recommendations on its management. The research team utilised historical data, a landholder questionnaire, fieldwork and anecdotal evidence to produce digital presence/absence maps of Lippia in an ArcGIS geodatabase format. Classified SPOT multispectral satellite imagery was also trialled as an additional tool to map Lippia in the cleared/open country of the GW and MM.

Over 100 survey sites were mapped in each catchment and extensive data recorded in the attached database including, Lippia density, extent, landuse, wetland type and water regime. For selected sites, further data on the presence of other species, control methods employed, evidence of dieback, bare ground and geo-referenced digital photographs were recorded. The literature research, field work and landholder survey are largely complete and the team are now analysing the data, preparing maps and the final report.

Kate Stokes (CSIRO Entomology, Canberra): Predicting lippia spread

This project aimed to increase information on the future response of lippia populations, in terms of numbers, densities and geographic distribution, to different environmental and management scenarios. Predicting geographic areas susceptible to weed invasion is a primary target for land managers because it increases their ability to control weed populations more economically. A population model was created for Lippia to determine the relevant biological and environmental factors influencing growth and distribution. This was achieved by statistical modelling of plant responses to environmental parameters, coupled with information on population demography of the weed, prior to conducting sensitivity analyses to identify key model parameters influencing the result. The Lippia model is embedded within a spatially-explicit simulation framework containing landscape features of the specified habitat area, incorporated as either a standard template or a real landscape (using an aerial photo or GoogleEarth image). The spatial scale of the model is adjustable to match the spatial scale at which key plant processes are understood, ensuring model compatibility. Currently this model can potentially capture future hydrological events resulting from changing climate conditions, such as an increased incidence of extreme flooding events. However, further work is needed to quantify the hydrological niche of Lippia. Using a floodplain inundation model for the River Murray the distribution of Lippia is currently being explored in relation to environmental flows.

Tony Cook (NSW DPI, Tamworth): Lippia research highlights from northern NSW

A total of three experiments have been completed between 1993 and 1995.

<u>Experiment 1: Moisture stressed lippia control</u>
Commercially acceptable levels of control were not achieved, despite the use of DP 600 and 2,4-D amine at 7L/ha. Addition of Logran or Ally to DP 600 improved control slightly. Mecoprop amine and Garlon were applied and gave low levels of control. The level of efficacy between DP 600 and 2,4-D amine were similar when comparing product rates per hectare.

<u>Experiment 2: Lippia control under favourable conditions</u>
Most DP 600 treatments resulted in at least 95% control of lippia 8 months after treatment. 2,4-D amine was not included in the experiment site. Addition of Ally, Logran and simazine slightly improved control compared to DP 600 applied singly. There was little benefit of increasing DP 600 rates from 5 to 10L/ha, as both gave excellent results (95 and 96% control). Lower rates of DP 600 and 2,4-D amine should have been examined in this experiment.

<u>Experiment 3: Lippia control using tank mixtures of DP 600 under reasonable conditions</u>
Lippia was sprayed at the pre-flowering stage, however there were some signs that patches may have been slightly moisture stressed. Levels of control were described as moderate (between the levels seen in experiment 1 and 2). The highest rate of DP 600 (10L/ha) gave 70% control five months after treatment, whereas 5L and 2.5L/ha resulted in poor levels of control (28 and 18%, respectively). Addition of Ally (10g/ha) seemed to lift levels of control when mixed with DP 600.

Jodi Price (UNE, Armidale): Strategic grazing for the control of the invasive wetland weed lippia

The aim of this project is to examine strategic grazing as a management tool for the control of lippia in wetlands. We addressed whether providing periods of rest from grazing permits native species to establish and out compete lippia in different hydrological zones in several wetland areas. Small exclosure cages (2 m x 2 m) were used on a fixed and rotational basis to preclude grazing stock, thereby providing a rest period at different stages of the year. Results suggest that maintaining native cover is an effective means of lippia control, with significant reductions in lippia biomass found with increased biomass of co-occurring species. Providing rest from grazing does promote increased growth of native species with significantly larger effect sizes found in a wet year in contrast to a dry year. The timing of rest that favoured the growth of native species differed between wetland sites, due to climatic differences and species composition (summer vs. winter active species). Complex interactions between flooding and grazing drive vegetation responses in these ephemeral wetlands, and at this stage maintaining native cover is more closely linked to flood events than grazing management *per se*. Combining strategic grazing or rest periods with environmental flow releases or natural flood events may provide increased community resilience to weed invasions and reduce the spread of lippia in these wetlands.

Mic Julien and Rieks van Klinken (CSIRO, Montpellier): Lippia biological control

A lippia biological control program commenced in 2005. Lippia (*Phylla canescens*) has been approved as a target for biological control. Extensive native range surveys, conducted largely by collaborators in the USDA Buenos Aires laboratories and at the University of Bahia Blanca, have been conducted through Argentina and surveys have been conducted in Bolivia and Chile. So far at least 21 insect species and 16 pathogens have been identified on *Phyla canescens* and its close relatives. This includes a range of organisms that may be suitable as biological agents, provided they prove to be sufficiently host-specific for release in Australia. Laboratory work is being conducted in South America to develop culturing techniques for some of these potential agents. Also, genetic work is currently being done (by Mohammad Fatemi, UNE) to determine whether or not *P. nodiflora* is native to Australia. If native, then potential agents will need to be quite host-specific to be suitable for Australia. We are aiming to commence detailed testing of the most promising biological control agents within the next 12 months, but that will be subject to funding.

APPENDIX 4: FULL LIST OF RESEARCH PRIORITIES

The following is the largely unedited list of research priorities identified in the workshop. See main report for the short list of research priorities.

Ecology

- Longterm studies/monitoring (maintaining existing sites; + extras?)
- How does lippia drain soil moisture?
- Is it "early successional"?
- Understanding competitive interactions (and flood context)
- Response to "disturbance": incorporating competitive interaction, flood, grazing [expanded work]. Including community level successional trajectories after disturbance [tolerator/competitor]

Landscape/regional-scale understandings

- Update distributional map (catchment scale)
- Predicting invasions at catchment/subcatchment scale:
  - Better distributional information (for management, and to better understand invasions, develop hypotheses)
  - Interaction between lippia & NRM & drought
  - Interaction between lippia & water flow & inundation
  - Consequences of climate change
  - Modelling: synthesis/aggregation, best-bet hypotheses to test (bring together component disciplines), including plant-community context, managing for "multiple benefits"
- What are implications of environmental flows (+ & -ve)

Lippia impacts

- link to wetland recovery and conservation?
- What interaction with general restoration efforts (e.g. fencing, revegetation)
- to flora/fauna (include birds, e.g. through smothering nest sites in Lignum)
- build case for identifying it as a key threatening process
- what impacts on livestock and native fauna through diet (toxicity; copper deficiency; feed quality etc)

Economics (production)

- management options (including do nothing) for production (& environment?); herbicide vs cultivation vs ?
- update economic impact of lippia to grazing/cropping: industry level & producer level (including enterprise trade-offs)

Management

- prioritise areas where will have best value for investment

Biological control

- Resolving P. nodiflora and argentine Phyla spp. issues
- Getting effective agents out
- Supporting research (e.g. to identify which available agents will be the most effective)

Herbicide

- predicting optimal windows for application
- integration with management
- 24D v DP600
- Case studies for managing/eradicating small patches

Grazing and land management (and interaction with flooding, herbicides, ?) [= disturbance ecology Q]

- lippia prevention/”proofing”
- How to manage sensitive woodlands/wetlands (and other places where agronomic techniques not applicable)?

Managing pollinators (seed set)

- proof of concept

Integration

- e.g. direct sowing, one-off herbicide application