Australian Government
Department of Agriculture, Fisheries and Forestry

Australian Plague Locust Commission

Activity Report 2003-2004

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Introduction

The Australian Plague Locust Commission was established in 1974 and began operations in late 1976. The Commission is financed by the States of New South Wales, Victoria, South Australia and Queensland, with a matching contribution from the Australian Government. The Commission consists of six Commissioners: one from each contributing State, one each from the Department of Agriculture, Fisheries and Forestry and the Department of the Environment and Heritage, and a Director assisted by permanent staff. The Director and staff are members of the Department of Agriculture, Fisheries and Forestry Australia (DAFF). The Commonwealth Scientific and Industrial Research Organisation (CSIRO) may provide an observer and other observers may be invited to attend Commissioners' meetings subject to agreement by Commissioners. The Commission is responsible to the Minister for Agriculture, Fisheries and Forestry and State Premiers.

APLC Charter

In August 2002, a Memorandum of Understanding (MOU) was signed between the Department of Agriculture, Fisheries and Forestry (DAFF) on behalf of the Australian Government and participating member States effectively replacing the original (1974) Exchange of Letters under which the APLC was established. The MOU also incorporated a Charter that replaced the original terms of reference under which the APLC had operated since its establishment.

The purpose of the APLC, as defined in the Charter, is "to control locust populations in those situations where they have the potential to inflict significant damage to agricultural industries in more than one member state." In fulfilling its charter the APLC is required to:

1. Implement a preventive control strategy to minimise economic loss to agricultural industries caused by the Australian plague locust, spur-throated locust and migratory locust, with priority given to Australian plague locust.

2. Minimise risk of locust control to the natural environment, human health and markets for Australian produce.

3. Develop improved locust management practices through a targeted research program.

4. Provide a monitoring and forecasting system for operations conducted by APLC and member states.

5. Promote and facilitate adoption of best practice in locust control by member states.

6. Participate in cooperative national and international programs for development of APLC expertise.

7. Continually review APLC operations to ensure they keep pace with the expectations of industry, community and government.

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Review of the 2003-2004 season

The 2003-2004 season was an exceptional one in several respects. Firstly, there was the extremely rapid development of the major outbreak in the Channel Country of southwest Queensland following heavy drought breaking rainfall. The scale and density of the band infestation in western Queensland in February - March 2004 was one of the largest encountered by the APLC in this area over the past thirty years and required an intensive control campaign to be undertaken by the Commission. The campaign in the Windorah-Quilpie area was highly successful not only in substantially reducing the locust population but also in validating the APLC's integrated control strategy using barrier spraying of fipronil against hopper bands together with the use of the bio-pesticide. However, despite this success other smaller scale locust infestations developed simultaneously in adjacent parts of Queensland and in northern New South Wales which were not controlled.

The frequency of autumn migration and redistribution in 2003-2004 was also exceptional, particularly in New South Wales. There appeared to be several migrations and substantial redistributions of locust populations during March and April. These were most likely a response not only to the generally dry unfavourable locust breeding conditions which prevailed during autumn in many areas but also to the un-seasonally warm meteorological conditions in April which extended the potential for locust night migration.

The year also saw the culmination of several years of collaborative research between the APLC, CSIRO and industry with the Metarhizium bio-pesticide (Green Guard) submitted for final registration in June 2004. Another significant research activity completed in 2004 was the detailed study of locust migration. The results of this study clearly indicated the presence of a migration circuit. The study also has implications in terms of control strategy since the results illustrate the potential importance of locust populations in NSW migrating northwards into Queensland and possibly South Australia in late spring. Good progress was also made in other research areas including the environmental programme and two new three-year collaborative research projects were funded under the Australian Research Council (ARC) Linkages program.

Finally, linkages were maintained with international locust organisations through APLC involvement with the United Nations Food and Agriculture Organization.

Laury McCulloch
Director

Locust situation

Australian plague locust, *Chortoicetes terminifera* (Walker)

Overview

In late spring 2003, there were localised populations in several areas in Queensland and New South Wales. Heavy rains in November led to substantial laying and early summer band formation in the Tambo-Augathella and Roma areas of Queensland and in Manilla-Boggabri-Gunnedah area of New South Wales. Heavy rains in January led to a further generation and a major infestation of bands. An intensive control campaign was conducted against the densest infestations, particularly in Queensland, but locusts from the remaining infested areas in southern Queensland and northern New South Wales invaded a large area of eastern and southern New South Wales during March, leading to a major outbreak. During March and April there appeared to be numerous cases of locust populations migrating and redistributing at night. These movements were facilitated by a period of exceptionally warm temperatures during April.

Fig 1 shows the location of meteorological districts that are referred to in this report.

New South Wales

In spring 2003, the previous year's population south west of Armidale continued to breed and by October, nymphs were evident in the Manilla-Boggabri-Gunnedah area of the Northwest Slopes and Plains district (Fig 2). During November, locusts were reported flying into the Walgett-Coonamble area (Central West Slopes and Plains). Localised areas of bands and swarms were found in December (Fig 3). However, following heavy rain in January, many swarms were found both in the Central West and Northwest Slopes and Plains and there is some evidence of migration from southern Queensland. These swarms laid, resulting in significant areas of bands during February 2004 (Fig 4). Some treatment of bands and swarms was conducted in the Central West during February and March. Wind trajectories indicate that locusts from northern New South Wales and southern Queensland migrated into a large area of eastern and southern New South Wales from mid-March onwards, and rapid redeployment of staff led to a number of control operations against the immigrant locusts. There were exceptionally warm conditions during April, which extended the potential for both day flight and night migrations allowing for further redistribution so that much of New South Wales was infested during April (Fig. 5). In the Northwest Slopes and Plains, the northern part of the Central West Slopes and in the Central Tablelands locusts encountered green conditions from rains that had fallen during late February and early March leading to the formation of dense swarms and substantial laying. Little rain fell in southern and western New South Wales and, in spite of the largely dry conditions, a widespread population of adults was present at numerous to concentration and occasionally swarm density. There were few confirmed reports of autumn laying in these dry areas in the south and west, so it is difficult to predict the size of the spring outbreak. It is considered likely that significant laying could have occurred in northern and central districts of New South Wales with smaller scale laying in southern districts. It is considered unlikely that any significant autumn laying occurred in the western districts.

Queensland

Numerous to concentration adults, along with some nymphs, were found over a wide area of the Warrego, Maranoa and Central Lowlands districts during October 2003 (Fig 2). This region had heavy rain the previous February with further rains during April, and the finding of widespread locusts of this density suggested that two generations of breeding had occurred. In the Channel Country, a low but extensive background population was present during October (Fig 2). Heavy rain in the Central Lowlands and Warrego districts during November led to laying by a significant number of swarms and formation of many bands (Fig 3). Bands were treated in the Tambo-Augathella-Morven area during late December and early January. Lower densities were found in a number of other districts.

In the second week of January, soon after peak fledging, there was widespread heavy rain over a period of a week that made many areas inaccessible. When surveys resumed in late January, few locusts remained in the Tambo-Morven area but swarms were seen over a wide area of southern Queensland and were particularly intense in the Far South West and adjacent areas of the Lower Western. Wind trajectories indicate that the while most of the locusts could have come from the Tambo-Morven area, locusts already in western Queensland or migrating from as far away as the infestations that were present in the Northwest Slopes of New South Wales would have converged on the Channel Country in mid January. During February, there were many bands throughout southern Queensland (Fig 4). Many very large bands were seen from the air in the southern Channel Country where over 130,000 ha were treated, mostly with Fipronil applied as barrier treatments, though significant areas were treated with *Metarhizium* on organic properties. The region of highest infestation is also where locusts had been treated 2 years earlier (February 2002). Elsewhere in southern Queensland, bands were of lower density but were very widespread, making effective control difficult. By early March, there were large numbers of swarms throughout southern Queensland from west of Windorah (Lower Western) to Quilpie (Far Southwest) to Charleville (Warrego) and St George (Maranoa). Swarms in the Windorah and Quilpie regions were controlled intensively though there was limited control of the lower density swarms further east. Wind trajectories indicate that some migration from the Charleville area into the Northwest Slopes and Plains of New South Wales occurred during March.

South Australia

While there was some winter rain in South Australia, the summer was dry with little local breeding except in the northern Flinders Ranges where a few bands were seen following localised storm rain in February. The extended period of warm weather during March and April provided opportunities for migration into South Australia from Queensland and New South Wales. A few adults were reported in Adelaide and some adults were found in the Riverland and Upper North during April but the only swarms seen were two low density swarms in the Upper North (Fig 5). No major locust outbreak is expected in spring.

Victoria

Few locusts were seen during spring and summer, and conditions were generally dry by autumn. Following the extended period of warm weather suitable for migration during April, adults generally at numerous and up to concentration density were reported from several areas of northern and central Victoria and one low density swarm was also seen. There were no reports of significant autumn laying although some laying is likely to have occurred. No major locust outbreak is expected in spring but localised hatchings and small scale band formation can be expected.

Spur-throated locust, *Austracris guttulosa* (Walker)

For the past several years the tropical north has received regular rains suitable for high survival of the spur-throated locust. Such rains continued this year and there were subsequent reports of swarms in a number of areas in the north. In the Central Highlands, numbers had been low the previous autumn but regular summer rains rapidly led to a serious locust outbreak, suggesting locusts had invaded from the tropical north early in the wet season. By autumn, substantial treatment of young adults in crops was required in the Central Highlands and West Central Coast districts of Queensland. The outbreak was limited to Queensland in that while there were some small populations in southern Queensland, there was little evidence of significant numbers in New South Wales. The widespread distribution of this locust in Queensland means that a serious outbreak is likely if good rains fall next summer.

Migratory locust, *Locusta migratoria* (L.)

While most of the Central Highlands had been in drought the previous year, good rains in the northern part of the Arcadia Valley had allowed survival of a small population of migratory locusts. Localised rains during October followed by rains in December, January and February resulted in a moderate outbreak that required treatment to protect crops.

Fig. 1. Meteorological districts

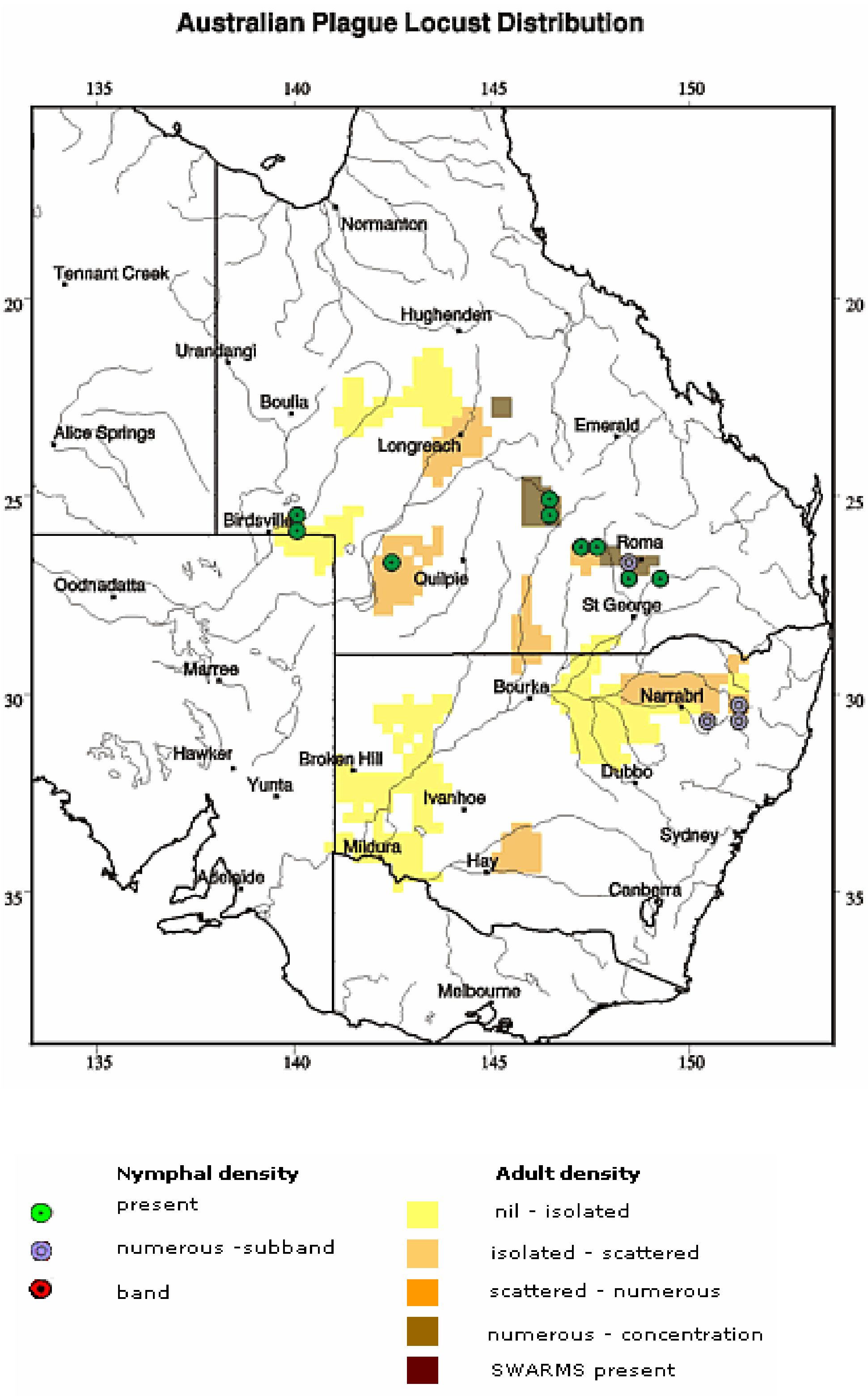

Figure 2. Distribution of Australian plague locusts: October 2003

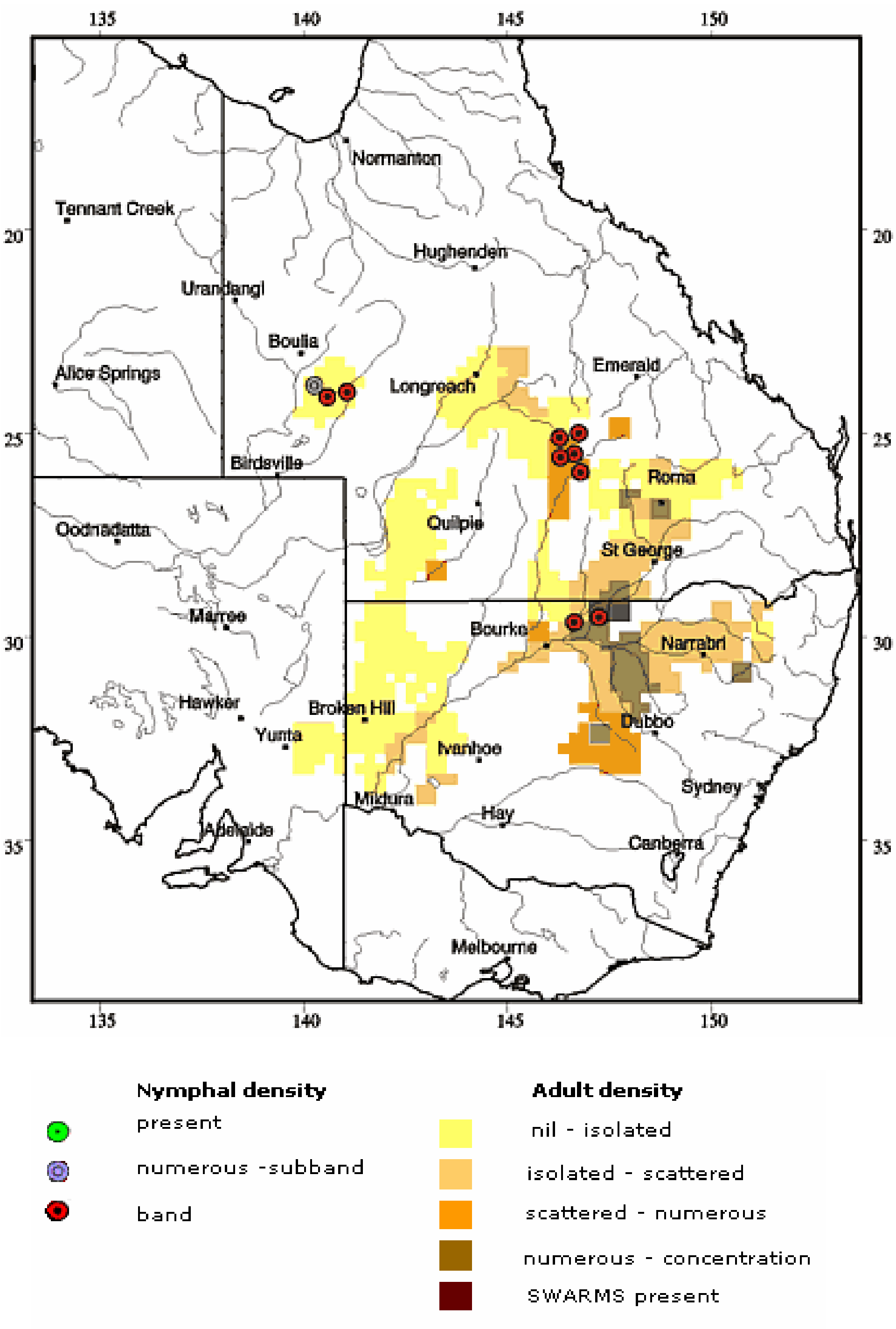

Figure 3. Distribution of Australian plague locusts: December 2003

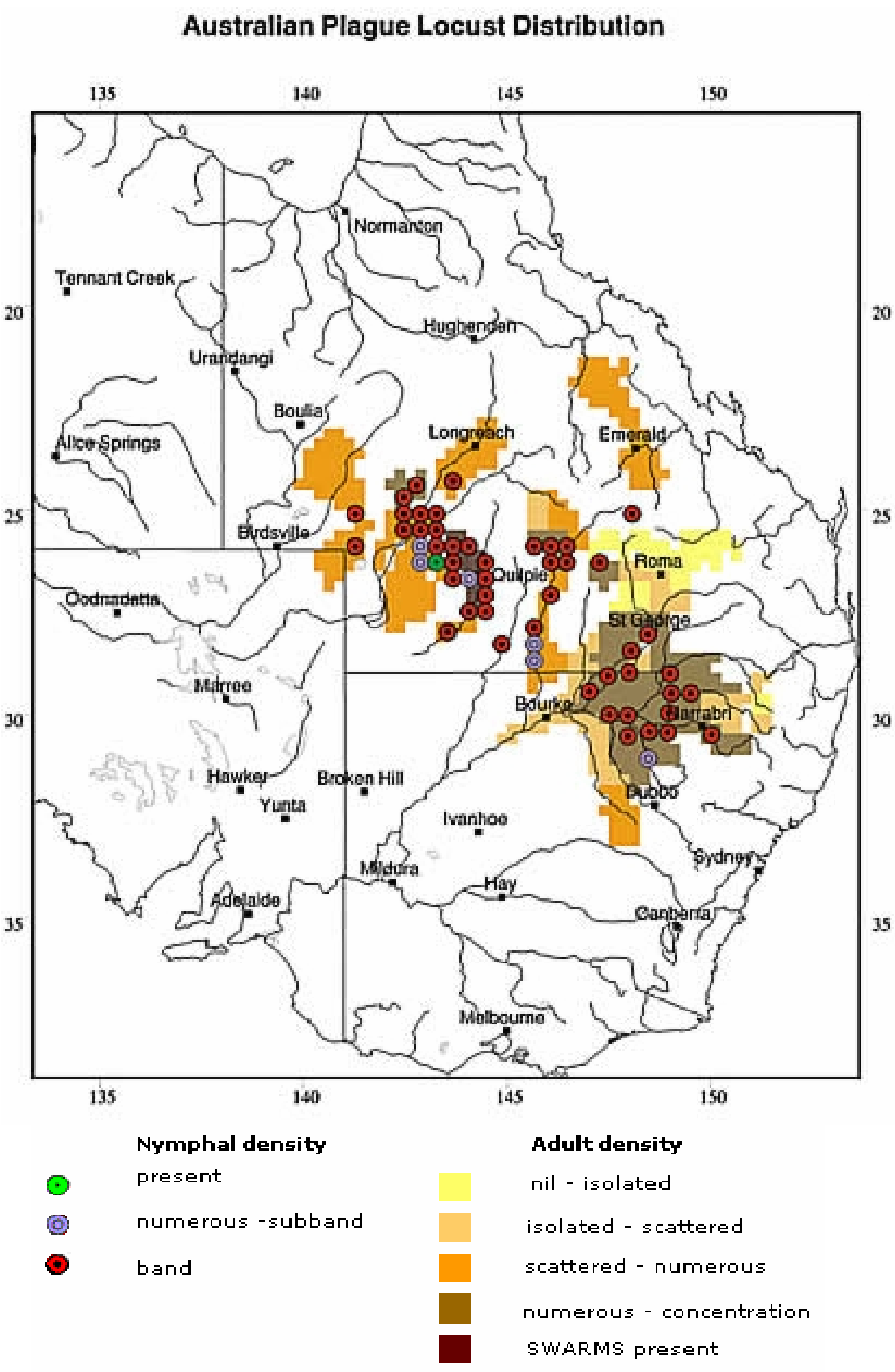

Figure 4. Distribution of Australian plague locusts: February 2004

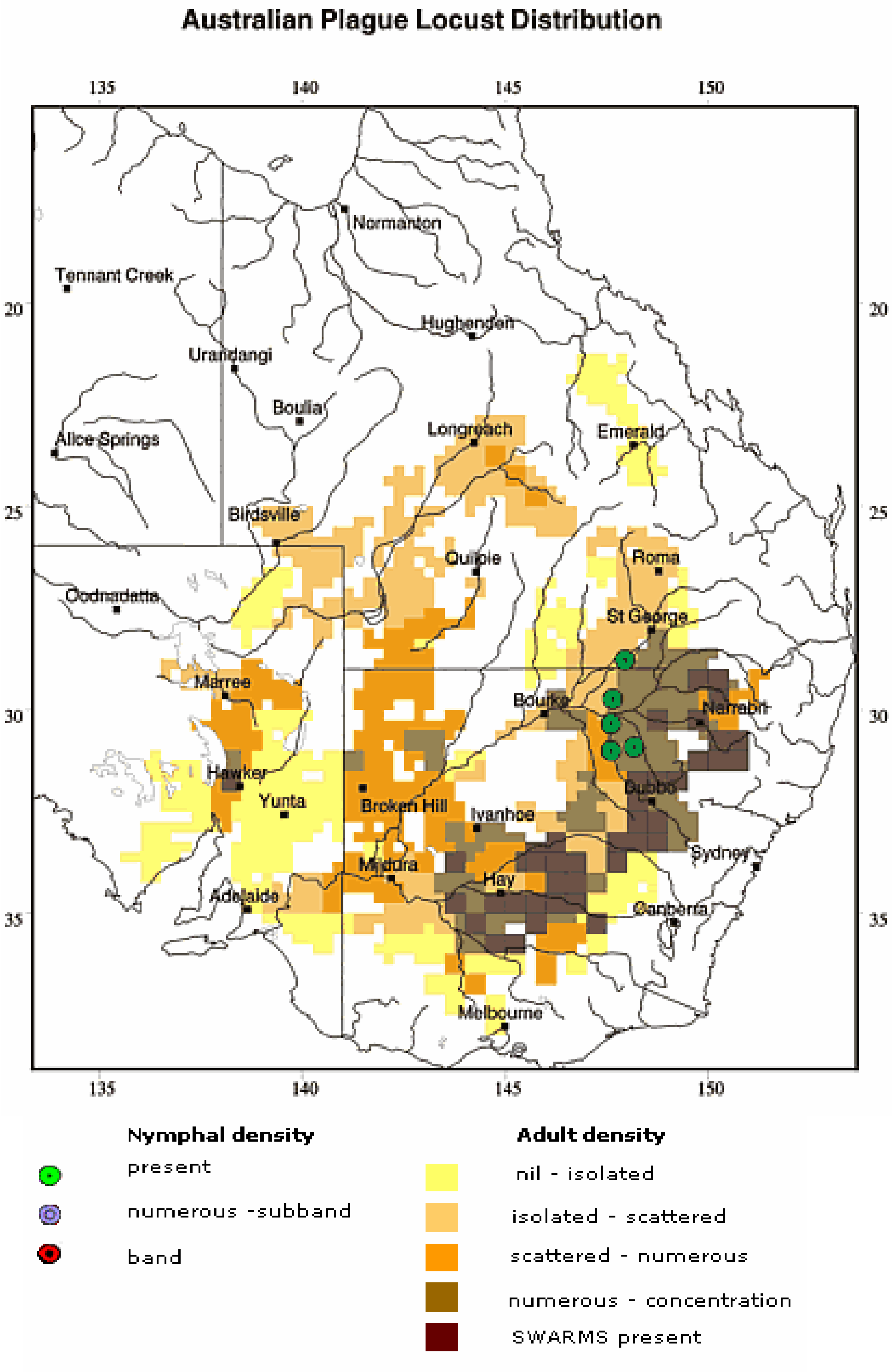

Figure 5. Distribution of Australian plague locusts: April 2004

Operations

As required under the Memorandum of Understanding, the Director drafted the Operational Plan for 2003-2004. The plan defines expected outcomes to be achieved by the APLC during the year together with outputs and risks.

Forecasting, Information and Survey

The widespread rains of February 2003 following a period of prolonged drought led to forecasts of a rapid increase in locust populations if rains continued into summer. During the population increases leading to previous outbreaks following drought, it was felt that some significant locust populations had not been detected, and the 2003-2004 season was the first opportunity to test of the effectiveness of "smart survey' (first introduced during 2001-2002) in detecting increase in local populations after drought.
With "smart survey", the Decision Support System (DSS) provided the forecaster and field officers information on locations of recent infestations, rainfall distribution, wind trajectories of likely migrations and light trap catches indicating migrations/overflights. Each field base used a network of local contacts including Rural Land Protection Board officers and landholders who report locusts when they see them or who are willing to be phoned on a regular basis to determine if locusts are present. Information from all of these sources means surveys can be more specifically targeted to areas where the risk of locust populations being present is relatively high. Surveys are conducted in other areas as well, but these are of lesser intensity.

The first successes of "smart survey" was the reporting to the Longreach Field Base of infestations of locusts first near Longreach in late September and then near Tambo during October. Subsequent field surveys found substantial low-density infestations indicating that breeding had occurred over winter. These locusts were in dry conditions but following rains in November, surveys in the Tambo-Augathella-Morven area mapped as receiving rain, detected laying by adult swarms. Further field surveys during December located bands which were subsequently controlled. Heavy rains soon after adult fledging in January delayed survey. However, when field surveys resumed there appeared to have been a significant decrease in the Tambo-Augathella population and a surprisingly high number of adult swarms were found in southwest Queensland. Some of these locusts may have migrated from infestations that were present earlier in the Northwest Slopes district of New South Wales as well as the Tambo-Augathella-Morven area. During February and March, most field staff were involved in a very large control campaign in western Queensland though several staff continued to conduct field surveys and also to conduct spray campaign in the Coonamble area of New South Wales. During the second week of March field evidence of declines in locust populations in Queensland combined with data from wind trajectories indicated migrations had occurred into parts of New South Wales from southern Queensland and possibly northern New South Wales. Field surveys were rapidly conducted in areas where wind trajectories and locust reports indicated migrations had occurred. Rapid redeployment of control teams to Bourke and Coonamble in northern and central west New South Wales allowed control to continue, against immigrant swarms. Locust populations were also found in southern parts of New South Wales in late March but at densities (predominantly numerous to concentration density with the occasional low density swarm) that did not warrant aerial control by the APLC.

Control Operations and Pesticide Use

Small-scale control operations were undertaken against a localised locust population in the Tambo area of central Queensland during December 2003. However, large-scale control measures were required to contain, and substantially reduce, a major infestation which developed in the Channel Country in February-March 2004 together with smaller scale operations in the Coonamble and Bourke areas of New South Wales. Pesticide usage in 2003-2004 was substantial (Table 1). All stocks of Adonis 8.5ulv and Adonis 3ulv were utilised during the summer campaign in the Channel Country of southwest Queensland together with 28.3 tonnes of fenitrothion ulv.

Stocks of Adonis 3ulv were replenished in March 2004 with the purchase of 12,000 litres. Following extensive operational research, Adonis 3ulv is the preferred formulation for APLC band control in pasture using a barrier spraying technique. An additional 20 tonnes of fenitrothion ulv was also purchased during the year. Green Guard (*Metarhizium*) was mainly used for large-scale aerial control of hopper bands on one organic property in southwest Queensland in February 2004 and stocks were replenished (Table 3).

The OpsManager® system was used at all control campaigns during 2003-2004. The control campaigns provided an ideal opportunity for staff to familiarise themselves with the new system, and to fully test OpsManager operationally. A number of minor modifications and areas for future improvement were identified but overall the system performed well. However, the importation and conversion of spray aircraft dGPS files did take substantial time to complete. Further modifications to OpsManager are planned and the additional workload imposed by the system will be monitored.

Estimated control costs 2003-2004

The average cost of locust control for 2003-2004, inclusive of pesticide and aircraft costs but excluding APLC staff costs, was estimated at $5.25/hectare for band control and $11.75/hectare for swarm control. Most of the cost differential between band and swarm control is attributable to higher aircraft hire costs associated with the extensive use of helicopters to locate and control locust swarms as opposed to the less expensive use of fixed wing aircraft for band detection.

Table 1: Control Operations 2003-2004

Control Base	Type	Date	Number of Targets	Insecticide sprayed (Litres)	Area Treated (km^2)
Tambo, Qld	Band	29/12/03-06/01/04	21	2870	141.3
Tambo, Qld	Swarm	10/1/2004	2	483	6.0
Coonamble, NSW	Band	16-21/2/04	16	1070	22.4
Quilpie, Qld	Band	16-27/2/04	43	6835	431.8
Windorah, Qld	Band	16-29/2/04	42	15631	880.4
Quilpie, Qld	Swarm	2-10/03/04	48	4745	207.6
Windorah, Qld	Swarm	1-8/03/04	34	4028	208.0
Bourke, NSW	Swarm	12-14/03/04	20	1918	75.6
Coonamble, NSW	Swarm	11-21/03/04	20	676	32.2
TOTAL			**246**	**38,256**	**2,005.3**

Of the area sprayed by the APLC, approximately 75% was against hopper bands (Table 2). This high proportion reflects the large and very dense nature of the band infestations present in the Channel Country during February-March 2004 and the intensive efforts taken to control these infestations.

Table 2: Pesticide (Litres) used by target type: 2003-2004

Target Type	Fenitrothion	Fipronil	Green Guard
Band control	10,322	10,839	5,235
Swarm control	11,367	n/a	n/a
Total	21,689	10,839	5,235

Table 3: Pesticide Stock: Summary 2003-2004

	Fenitrothion (tonnes)	Adonis 8.5 (litres)	Adonis 3 (litres)
On Hand 1 July 2003	46.9	6,000	4,200
Purchased 2003-2004	20.0	nil	12,000
Used 2003-2004	28.3	6,000	4,200
Stock 30 June 2004	38.6	nil	12,000

Table 4: Bio-pesticide Stock [(1)] 2003-2004

On Hand 1 July 2003	127
Purchased 2003-2004	60
Used 2003-2004	59
Transferred to NSWDPI	3
Stock 30 June 2004	125

(1) For practical reasons stocks of Green Guard are expressed as the number of 14L containers rather than kilograms of spores

Pesticide development and trials

Small-scale pesticide trials using Adonis 3 ulv and Green Guard (*Metarhizium*) were undertaken during the Tambo control campaign in late December 2003-early January 2004. Unfortunately the trials had to be curtailed due to very heavy rainfall and subsequent migration of the population. However, the Tambo (and previous) trials to evaluate Adonis

3 ulv had enabled the Commission to gain sufficient data to develop a robust barrier control technique against hopper bands. The barrier technique using Adonis 3 ulv proved highly effective both in terms of cost and efficacy in the subsequent major summer control campaign in the Channel Country during February-March 2004. The latter campaign provided an excellent opportunity to validate the APLC integrated control strategy using three control agents – Fenitrothion, Adonis and Green Guard. Whilst there were a few minor logistical issues in coordinating the use of three different products, the integrated strategy proved highly effective. Barrier spraying with Adonis was highly effective as was the use of Green Guard against a substantial infestation of hopper bands on an organic property.

For operational reasons – the need for rapid large-scale control measures in the Channel Country in February-March 2004 - planned trials on the efficacy of the Insect Growth Regulator Dimilin had to be deferred.

In late June 2004 the bio-pesticide Green Guard was submitted for final registration. This was the culmination of several years of collaborative research between the APLC, CSIRO, NSW and Queensland authorities and an industry partner, which has resulted in the development of an effective solution for locust control in environmentally sensitive areas.

Environmental Management System

A number of first year aims of the Environmental Management System were met including

- Completion of the APLC's competency based training program.
- DGPS use made mandatory in spray aircraft.
- Field Storage Agsafe accredited.
- OpsManager® tested and used operationally.
- Hazardous waste disposal contracts developed.
- Environmental management procedures established.
- Optimise barrier treatments with Fipronil.
- Passive Sampling devices for monitoring off-target drift finalised for Fenitrothion.
- APLC's sensitive areas database included in the OpsManager mapping software for field use.

Objectives and targets under the EMS will continue to be progressed.

Competency Based Training and Assessment

Development of the Competency based training and assessment manual was finalised. The manual will now be used as the basis for training of all staff

The 2003-04 control season provided an ideal opportunity to undertake competency based training and assessment for new field staff in all areas control operation. A number of training and assessment programs were developed covering key areas of control, including:

- Aircraft calibration
- Aircraft navigation
- Spraying a target
- OHS helicopter and fixed wing safe operating procedures
- Landholder consultation
- Weather monitoring
- Post spray target checking

Additional core training and assessment programs will be developed through 2004-05 as the APLC progresses towards standardising all internal training.

International linkages

The Director, Laury McCulloch, was invited to join the Desert Locust Control Committee Technical Group (DLCCTG) in February 2004. The function of this expert group is to provide technical advice to FAO and countries affected by Desert Locust. In May 2004, the Director attended a DLCCTG workshop on contingency planning in Nouakcott, Mauritania. In July 2003 the Control Officer, Peter Spurgin, undertook a mission on behalf of FAO to Tanzania to conduct field trials on the efficacy of the Metarhizium based bio-pesticide "Green Muscle" against Red locust. During July-August, David Hunter field tested the Australian bio-pesticide Green Guard against the oriental migratory locust in China and in November field tests were conducted in Mexico.

Occupational Health & Safety

There were no reportable OH&S incidents recorded during the year. Heath McRae took over the role of OH&S officer for field operations.

Administration

Meetings of APLC Commissioners were held on 16 September 2003 and 20 April 2004. The 20 April meeting was conducted by teleconference. A Pesticide Working Group comprising representatives from NSW, Queensland, South Australia and the Commission was established in April 2004. The function of the Group is to review any issues arising from the use of pesticides in locust control and to act as a forum for the exchange of information on locust control products and equipment.

An end of season staff meeting was held in Canberra in late April to review operations during the season and to start planning for the 2004-2005 season.

Staffing

The Commission's staffing position at 30 June 2004 is shown in Table 5. Staff were away from base for 1284 days, reflecting the very busy nature of the season. The new Director, Laury McCulloch, commenced with the Commission on 19 January 2004. Mr McCulloch had previously worked with the APLC in a variety of positions including Deputy Director in the 1980's. He has extensive experience in locusts both in Australia and internationally through the UN Food and Agriculture Organisation for which he has worked for many years as a consultant on locust management.

Dr Hunter, who had been working under contract following his retirement as the Commission's entomologist in 2003, left the Commission in May 2004. Dr Hunter had worked with the APLC since 1977 and had made a number of substantial and important contributions to research on the Australian plague locust.

Several field officers left the Commission during the year. However, in overall terms the Commission retains a core of highly experienced and professional staff.

Table 5: Staffing position at 30 June 2004 and days away from Base 2003-2004

Officer	Position	Period Employed	Days away from base
E. Deveson	GIS Manager	Throughout	**15**
R. Graham	OIC Broken Hill	Throughout	**92**
G. Hamilton	Director	To 18.1.2004	**0**
D. Hunter	Entomologist	To 6.5.2004	**47**
T. Jenkins	OIC Longreach	Throughout	**105**
M. Macfarlane	Field Officer	To 18.12.2003	**40**
L. McCulloch	Director	From 19.1.2004	**23**
H. McRae	Assistant Operations Manager	Throughout	**72**
D. Murray	Field Officer	To 3.6.2004	**118**
J. Nolan	OIC Narromine	Throughout	**124**
A. Rodgers	Field Officer	From 10.10.2003	**108**
K. Sanson	Field Officer	Throughout	**152**
W. Spratt	Operations Manager	Throughout	**36**
P. Spurgin	Control Officer	Throughout	**51**
P. Story	Environmental Officer	Throughout	**93**
P. Walker	Forecasting Officer	Throughout	**18**
J. Wardle	Field Officer	From 26.9.2003	**102**
S. Wilson	Field Officer	10.10.2003 - 25.3.2004	**88**
I. Wright	Administration Officer	Throughout	**0**

Finance

Revenue in 2003-2004 amounted to $3.002 million (Appendix 1). This followed a decision by Commissioners at the 47th meeting to reduce funding for 2003-2004 by $0.5 million due to the high level of the reserve fund and the locust outlook which, due to the continued drought in Eastern Australia, did not envisage any major control activity in the spring of 2003.

Due to the extensive control operations undertaken, particularly in the summer and autumn, expenses for 2003-2004 amounted to $4.29 million (Appendix 2) resulting in an operational loss of $1.29 million. The operational loss was covered from APLC accumulated results carry-over (Appendix 3), which, after deducting the amount for the operational loss in 2003-04, amounted to $1.78 million at 30 June 2004. The 2003-2004 season clearly demonstrated the benefit of the carryover mechanism whereby the Commission significant can access significant additional funds to undertake large-scale control operations.

Research

Research Review Committee

The Research Committee comprising APLC Commissioners Dr M. Campbell, J. Holland and Dr Myron Zalucki of the University of Queensland as the external member met with Canberra staff on 15 September 2003. Mr J. Wrenford attended the meeting as an observer. APLC staff presented reports on research carried out during the year.

The Committee noted that the scarcity of field populations of the Australian plague locust during 2002-2003 had impacted on opportunities to progress some aspects of the APLC research program. In addition, the committee also encouraged further APLC involvement with external research collaborators through the ARC linkage grants mechanism.

Summaries of research in progress

The following research summaries provide an overview of current research activities being undertaken by the Australian Plague Locust Commission. The research summaries are not considered to constitute publication as the investigations are often incomplete and any results presented tentative.

Use of fipronil to control infestations of Australian plague locust nymphs (P. Spurgin)

Following rain during late October 2003, there was a significant population of maturing adults of the Australian plague locust, *Chortoicetes terminifera*, in the Tambo area. The following generation of nymphs required control, presenting an ideal opportunity for further tests of efficacy of fipronil (formulated as Adonis 3UL) applied with wide intervals between spray runs. Trials during 2002 in Western Queensland demonstrated that a 500 m interval between spray runs with Adonis 3UL ulv at a mean dose of 0.25 g a.i./ha, could effectively control nymphs in bands moving ca. 100 m/day through sparse rangeland vegetation (Mitchell grass, *Astrebla sp.* and Button grass, *Dactyloctenium radulans*).

The aim of these trials was to test Adonis 3UL with spray run intervals of 200 and 300 m on less mobile mid to late instar bands (1,000-2,000 nymphs/m^2, band length 5-100 m) moving 30 to 50 m/day in dense tussock grass (Buffel grass, *Cenchrus ciliaris*), and compare the efficacy results directly with those from blanket treatments using fenitrothion ulv. In addition, selected blocks were sampled for fipronil and its three breakdown metabolites on vegetation to determine the deposition profile across treated areas. Grass samples were collected from the centre of the block at 50 m intervals in a transect taken perpendicular to the direction of spray runs, along the line of drift. Spraying was carried out using a spray aircraft equipped with Micronair AU5000 rotary atomisers (45^0 blade setting used with flying speed of 185 km/h) and DGPS track guidance equipment, and flying at a height of approximately 10 m in a crosswind of >2 m/s.

In January 2004, Adonis 3UL ulv was applied to 8 blocks covering at total of 9,694 ha, while fenitrothion ulv was applied to 11 blocks covering 3,657 ha. Six of the Adonis blocks were sprayed at a 200 m interval between spray runs (flow rate of 14 L/min for a volume area rate [VAR] of 210 mL/ha, mean dose of 0.63 g a.i./ha), and 2 blocks were sprayed at a 300 interval (flow rates of 10 and 14 L/min used, with VARs of 105 and 140 mL/ha, and mean doses of 0.32 and 0.42 g .a.i/ha respectively). All 11 fenitrothion blocks were treated using standard APLC drift spraying, blanket technique: spray applied at track interval of 100 m from a height of 10 m, with micronairs set at a 50^0 blade angle and a flow rate 10 L/min, giving a VAR of 210 mL/ha and dose of 267 g a.i./ha.

For the week after spraying, selected bands in each block were monitored daily for density, distance moved and level of mortality. For targets treated at the 200 or 300 m interval, there was little difference in the time taken (48-96 h) for bands in to reach the >95% reduction in the numbers considered to be effective control. Bands in these blocks moved 20 to 100 m before breaking up and dying. Bands in the block treated at a 300 m interval between runs and at the lower dose (10 L/min flow rate, mean dose of 0.32 g a.i./ha) took 7 days to reach this same level of control with bands marching a total of 65 to 325 m. In the blocks treated with fenitrothion, nymphs declined by >95% within 24-72 h. The fipronil residues on grass samples collected 1 to 4 h after spraying of the 10 l/min, 300 m block, 2-

3 m/s wind suggested that the treatment had produced a irregular blanket deposition pattern (low overall dose with irregular areas of higher dose) across the block. The irregular dose led to the longer period to reach high mortality as locusts in some bands did not die until they marched into an area of higher dose. .

These trials demonstrated that fipronil applied to mobile bands at wide intervals between spray runs could achieve as high a level of control as that obtained from blanket treatments with fenitrothion. Use of this technique allows significant cost savings through reductions in total pesticide use and spray aircraft time per block. The effectiveness of the barrier technique was further demonstrated when operational control using this method was carried out during February/March 2004 in western Queensland. Forty targets with a total area of 86,000 ha were treated with Adonis 3UL at 300 and 500 m spray intervals (mean doses of 0.42 and 0.25 g a.i./ha). The extensive population of nymphs in bands within this area declined substantially, significantly reducing the potential for adult swarm formation and large-scale migration.

In the range of vegetation and environmental conditions commonly encountered during APLC control operations, a spacing of 300 out to 500 m between spray runs is likely to be the optimum distance for control marching bands of Australian plague locust.

Sub-lethal effects of fenitrothion and fipronil on Australian native vertebrates (P. Story)

Ongoing collaborative research between the APLC and the University of Wollongong, Texas Tech University and the Australian National Research Centre for Environmental Toxicology continued throughout 2003-2004. The primary focus was an investigation into the sub-lethal effects of the organophosphorus insecticide fenitrothion on the dasyurid marsupial, the fat-tailed dunnart *Sminthopsis crassicaudata.* Dunnarts were fed 30 mg/kg of fenitrothion and effects on aerobic metabolism measured during cold exposure and exercise performance (run duration and oxygen consumption while running at 1 m/sec). Running endurance declined by over 50% for up to 5 days after dosing, but peak metabolic rate at this running speed (8.9 times the basal metabolic rate) and cost of transport were unaffected. Peak metabolic rate and cumulative oxygen consumption during a 1 hr exposure to conditions equivalent to -20°C did not change following fenitrothion ingestion, with the peak metabolic rate averaging 10 times the basal rate. The research indicates that fenitrothion-induced exercise fatigue is not due to limitations in oxygen or substrate delivery to muscle or in their uptake *per se*, but more likely relates to decreased ability to sustain high-frequency neuromuscular function. This research is an important step in identifying the sublethal effects of insecticides on Australian native fauna and will be replicated over the coming year. Plans are underway to examine similar effects *in situ*.

Field research was also undertaken during 2003-2004. During locust control operations in southwest Queensland, avian diversity and abundance was observed before and after spraying. Birds were also captured to determine fenitrothion exposure using plasma cholinesterase (ChE) inhibition as a biomarker. Birds were captured in mist nets and small blood samples taken prior to spraying and at 18 and 66 hr after showed that plasma total cholinesterase and acetylcholinesterase activities were inhibited to approximately 20% and 50% and of pre-spray enzyme levels in brown song larks and zebra finches, respectively. Active locust bands, in the 3rd-4th instar, were seen to attract an unusually diverse assemblage of birds. Both locusts and granivorous birds fed heavily on grass seeds and a large number of insectivorous species consumed locusts. Following spraying, there was an indication of reduced displays by male brown song larks, possibly due to the markedly reduced density of live insects. Cholinesterase reactivation, performed on blood from birds to identify the presence of inhibited ChEs, was seen in 8 of 18 individuals tested from 5 species, including a raptor, three insectivores and a granivore. This exposure of species in a variety of trophic levels demonstrates the potential for sub-lethal impacts of fenitrothion during locust control operations.

To enhance links relating to wildlife toxicology between our organisations, a number of international exchanges were undertaken, all funded through an ARC International Linkage grant (LX0237512). University of Wollongong staff spent time at Texas Tech University verifying quality control techniques used in cholinesterase assays and analysing blood samples taken from Australian terrestrial native vertebrates during locust control campaigns. Two PhD candidates from Texas Tech University worked with University of Wollongong and APLC staff to investigate the sublethal effects of fenitrothion and fipronil on Australian fauna, and research results were presented at the Society of Environmental Toxicology and Chemistry's annual world congress in Salt Lake City (Utah, USA) in November 2003.

Effects of fenitrothion and fipronil on non-target invertebrates (P. Walker)

Sampling of the duration of effects of fenitrothion and fipronil on non-target invertebrates was conducted from the time of treatment during February 2002 until January 2004 when the area was treated again to control the dense locust bands present. During the 2 years of assessment, over 153,000 invertebrates were collected and sorted. As in previous APLC invertebrate impact studies with fenitrothion, ants and Collembola were found to be the most useful indicator groups as they were caught in high enough numbers for statistical analysis and showed sensitivity to the insecticides. Both groups are being sorted into morpho-species to determine the effect of spraying on diversity and community structure.

During a locust control campaign in the Tambo-Augathella area (Queensland) in January 2004, three methods were used to measure the effect of fipronil on termites. Fipronil was applied using standard APLC operating procedures (at a rate of 0.5-1.25 a.i./ha). Due to constraints on personnel and resources, sampling was limited and so the results are considered as preliminary, requiring further replication. Termite mounds in an area about to be sprayed with fipronil and in an unsprayed area were damaged just prior to insecticide application. A 10 cm diameter hole was made in the mound to expose the internal chambers. The health of colonies was assessed by scoring repair activity as: inactive (unable to coat the interior surface of the hole), active (able to do this repair but without necessarily completely filling the hole) or very active (reconstructing the mound to its original form. At 3 weeks after spraying, repair activity of 10 mounds in the sprayed area was scored as: 20% inactive, 30% active and 50% very active. Repair activity was similar in the unsprayed area: of the 18 mounts assessed, 17% were inactive, 11% were active and 72% were very active. By 7 weeks, repair activity of mounds in the sprayed area was 100% very active. At the time the mounds were damaged again, all were actively defended by soldier termites.

In the same area, the effect of fipronil on termite foraging activity was assessed using baits and by examining cattle dung. Two types of bait were tested: wooden stakes and paper rolls. Stakes of seasoned, untreated mountain ash (*Eucalyptus regnans*) were placed on the soil surface after brushing aside any leaf litter present. Toilet rolls (unscented, unbleached) were buried upright in the soil after reinforcing with packing tape. Baits were soaked in water prior to placement to increase their attractiveness to termites. Sets of baits (6 of each type, laid out 5m apart, alternately in a 3 by 4 grid pattern) were placed in two areas sprayed with fipronil and in two unsprayed areas on the day before treatment. At 3 weeks after spraying, the percentage of wooden stakes infested with termites was variable. At one

sprayed location, termites had damaged 66.7% of the baits but at the other sprayed site none were damaged. Similarly, at one control site 50% of the wooden stakes were damaged but none at the other site. However, by 7 weeks more consistent results were obtained with 80-100% of stakes placed in sprayed and unsprayed areas showing damage. Termite damage in toilet rolls was less frequent and less extensive but was similar between unsprayed and sprayed areas, ranging between 25-60%. Very few baits contained termites at the time of inspection so they appear to be of little use in measuring species diversity.
Transects of cattle dung pats, to determine the presence of termites or termite damage, also did not detect any adverse effect of spraying on foraging activity. On the sprayed site, 35%, 69% and 65% of the pats inspected had live termites present at –1 day, 3 and 7 weeks from spraying, respectively. No dead termites were found in the sprayed areas. In an unsprayed area, the percentage of pats infested with termites decreased from 60% at –1 day to 40% at 3 weeks from spraying but this site could not be assessed at 7 weeks post spraying due to the absence of dung pats after cattle were removed from the area.

Further fipronil impact studies are planned for the 2004-2005 season to compare blanket versus barrier applications. Areas previously sprayed by the APLC for the control of locusts will also be sampled using a proposed ‘rapid’ sampling method whereby the main invertebrate groups likely to be affected by spraying (ants and Collembola) are targeted using pitfall traps and yellow-pan traps. Foraging activity of termites in cattle dung and baits will also be assessed using the various methods used during 2004.

Application of *Metarhizium* to control locusts in dense vegetation (D. Hunter)

The drought conditions meant that there were few locusts in Australia so to test the dosages of *Metarhizium anisopliae* var. *acridum* required against locusts in thick vegetation, field trials were carried out overseas. A dose of 12-25 g spores of *M. a.* var. *acridum* has been shown to result in high mortality of the Australian plague locust in sparse to moderate vegetation. But the modelling of Scanlan et al (2001: Ecological Modelling 136: 223-236) indicated higher doses would be required in tall or thick vegetation. Tests carried out in Henan province against the oriental migratory locust, *Locusta migratoria manilensis* during August 2003 showed that in 100 ha areas of dense soya beans, doses of 125 g and 50 g spores in 1125 mL soya bean oil per hectare resulted in a 65% and 76% decline in locust numbers within 11 days. There was no effect on natural enemies the most common of which were robber flies (Diptera: Asilidae) (*Ommatius* spp.; *Promachus* spp) and Bombyliid flies (*Anastoechus chinensis*). Further checks could not be conducted because heavy rain prevented access.

Further field trials testing *Metarhizium* against locusts in tall vegetation were carried out during November 2003, in Mexico. In the past, 50 g *Metarhizium* spores per hectare caused high mortality of late instar nymphs of *Schistocerca piciefrons* in thick vegetation. A low dose (25 g/ha) of both the Australian isolate and the Mexican isolate were applied in 2L oil /ha) in tall (1.5-3 m) sorghum and maize crops. Both the Australian isolate and Mexican isolate led to a 60-70% decline in locust numbers after 14 days, with no change in the untreated area. There was no further decrease by 3 weeks. Further studies on doses in thick vegetation are required.

Behaviour of Plague Locust hopper bands (D. Hunter, P. Spurgin & L. McCulloch)

In June 2004, analysis of field data on the behaviour of hopper bands of the Australian plague locust collected over a number of years commenced. The data is being analysed to determine key factors impacting on (i) the detection of hopper bands from the air; and (ii) the rate of, and variations in, the movement of hopper bands.

Analysis of the data indicates that key factors in determining the visibility of hopper bands from the air is marching behaviour which, in turn, is largely a function of ground temperature. Also important is the size and density of the band front: small (<30 metres) bands are usually not detected from the air nor are bands which do not have high densities at the band front. The type of vegetation cover also impacts on visibility from the air with bands usually difficult to detect where vegetation is sparse. It is envisaged that an analysis of the data will result in the development of operational guidelines to optimise the timing of aerial surveys for band detection.

The same factors that determine band visibility from the air - ground temperature, band size, band density and vegetation cover - also influence the rate of band movement. Analysis of data on band movement both in the interior and agricultural zone clearly demonstrates that large (>100m) dense bands present under hot summer conditions move considerably further than small bands present under cooler spring conditions. The results of the analysis support the findings of Clark (1949: CSIRO Bulletin No. 245) on band behaviour in the agricultural zone in spring. The use of barrier spraying which relies to a large degree on bands being sufficiently mobile to traverse a sprayed area, has led to further studies on factors affecting band movement in various situations. The aim is to use knowledge of movement of both large and small bands in both the interior and agricultural zone to optimise spacing between barriers so that spacing is sufficiently robust to ensure maximum mortality of both rapidly moving large and slower moving small bands is achieved.

Decision Support System (T. Deveson)

The DSS computer server was upgraded to a Sunblade 1500 with operating system and application configuration - UNIX Solaris 8, SAMBA filesharing, ArcInfo/ArcGIS 8, Arcview 3.X, Arcview 8.X. The new user entry interface to the DSS uses Common Desktop Environment (CDE) workspace menus. These changes have been included in an updated 'Forecasting Procedures Manual' that includes appendices detailing specific instructions on operating and maintaining the various components of the DSS.

Monthly locust distributions from 1970 to the present have been digitised giving continuous monthly locust distributions covering more than 30 years. APLC historical survey data from 1977 – 1986 along with locust distribution information from CSIRO and Rural Lands Boards during the 1970s was plotted as digitised point features in a format similar to more recent data from APLC locust bulletins.

Detailed maps for use with OpsManager, formatted for MapInfo – MapX Geoset V4.5 were generated for each 1:1 million map sheet in eastern Australia. The maps include a number of layers of data, some or all of which can be used depending on the data required: topographic information, property boundaries, land use for nature conservation and organic agriculture, and a 25m LANDSAT TM satellite image mosaic.

Within the DSS, batch runs of the Dymex model can be initiated for multiple locations using meteorological data generated from ArcInfo. Eastern Australia was divided into 830 grid cells of 0.5 X 0.5 degrees, and for each cell Dymex models locust development and density. The models were tested for several seasons with the *Austracris guttulosa* and outputs compared to following season's distribution. Subsequent modifications were made to the mortality factors in the model for this species to adjust inter-generation population increase. Tests were also run for *C. terminifera* for 2002.

Locust Migration (Ted Deveson)

Flight trajectories obtained from a Bureau of Meteorology (BoM) wind circulation model were compared with insect movements detected by insect monitoring radars at Thargomindah (Qld) and Bourke (NSW) for the period September 1999 – October 2000. Comparison of mean directions of the two data sources showed that wind trajectories drawn from BoM LAPS (Limited Area Prediction System) analysis outputs were within 60^{o} of observed radar displacement direction on 85% of nights. Independent interpretation of IMR vertical profile graphics identified eight potential migratory overflights, several of which corresponded to migration events inferred from locust distribution changes. Predominant long term upper-level winds were examined by the generation of daily (2100h AEST) instantaneous wind vectors for 300m and 600m height levels from the period 1996-2002.

The development of recent outbreaks of the Australian plague locust has been traced using traditional survey data combined with information from several modern technologies including simulation of windborne transport trajectories, direct observation with entomological radar and satellite imagery. The results indicate that during several outbreaks, significant numbers of the locusts from the spring generation in the southern and eastern parts of the species' range, including agricultural areas, migrated to the summer rainfall areas in arid western Queensland. Migration from swarm populations in New South Wales to western Queensland in November and December 1999 contributed to a rapid population increase that, over a sequence of generations, led to the major infestation of agricultural areas in March-April 2000. There is evidence that northward migrations from agricultural areas to the inland also occurred during 1995, 1997 and 2000. These observations suggest that *C. terminifera* is characterised by a pattern of exchange migration across much of its geographic range: the common southward migrations during autumn into the winter rainfall areas are balanced by northward migrations during late spring into summer rainfall areas.

External research collaboration

In 2003-2004 the APLC was involved in collaborative research through the following Australian Research Council (ARC) Agreements:

ARC Linkage Grant LP0348025 "*Forecasting locust outbreaks: Evaluation of an insect monitoring radar network*". University of New South Wales. Commenced May 2003

ARC SPIRT Grant C00106571: *Organophosphate pesticides and locust control: sublethal effects on terrestrial vertebrates*". Wollongong University. Completed December 2003.

Two additional ARC Linkage grant applications were approved in 2003-2004. The research to be undertaken through these agreements will assist the APLC further its understanding of the environmental effects of locust control. The two new grants are:

ARC Linkage Grant LP0453498 - *Developing an new approach to aquatic pollutant assessment combining time integrated sampling with toxicity testing.* National Research Centre for Environmental Toxicology (NRCET). Commenced January 2004

ARC Linkage Grant LP0455803 - *Evaluating sublethal and developmental effects of fipronil, a persistent pesticide, on Australian native vertebrates.* University of Wollongong, Texas Tech University. Commenced June 2004

Publications

Milner, R.J., L. Barrientos-Lozano, F. Driver & **D.M. Hunter (**2003). A comparative study of two Mexican isolates with an Australian isolate of *Metarhizium anisopliae* var. *acridum*—strain characterisation, temperature profile and virulence for the wingless grasshopper, *Phaulacridium vittatum*. *Biocontrol* 48: 335-348.

Story, P.G. (2004). Occurrence of *Sminthopsis virginiae virginiae* (Tarragon 1827) and *Rattus leucopus cooktownensis* (Tate 1951) in north Queensland sugarcane. *Memoirs of the Queensland Museum* 49: 269-270.

Story, P.G., L. Astheimer, W.A. Buttemer, M.J. Hooper, K. Fildes & J. Szabo (2003). Walking the talk: Why mere legislative compliance is no longer enough for environmentally responsible locust control in Australia. *Proceedings of the Society of Environmental Toxicology and Chemistry/Australasian Society for Ecotoxicology 2003 Conference,* Christchurch, New Zealand.

Szabo, J., L. Astheimer, **P.G. Story**, M.J. Hooper & W.A. Buttemer (2003). Avian-locust interactions: Implications for risk of pesticide exposure. *Proceedings of Society of Environmental Toxicology and Chemistry/Australasian Society for Ecotoxicology 2003 Conference,* Christchurch, New Zealand.

Szabo, J., L. Astheimer, **P.G. Story** & W.A. Buttemer (2003). Birds, locusts and pesticides: managing an ephemeral feast. Managing an ephemeral feast: The risks of locust control pesticides to Australian birds. *Wingspan* 13: 10-15.

Walker P.W. (2003). Impact of locust control agents on non-target invertebrates in far-western Queensland. Poster presented at the combined 34th Australian Entomological Society/6th Invertebrate Biodiversity & Conservation Conference, Hobart, October 2003.

Appendix 1: Revenue 2003-2004 ($'000)

Australian Government contribution	**1,326**
Member States contributions [1]	**1,318**
Australian Government (Additional funding: Overhe	**311**
Member States [1] (Additional Charge: Overheads)	**39**
Interest revenue	**--**
Net gain on sale of fixed assets	**--**
Other revenue	**8**
Total revenue	**3,002**

[1] Member State contributions: NSW (32.5%), Victoria (10%), South Australia (5%) and Queensland (2.5%)

Appendix 2: Expenses 2003-2004 ($'000)

Employee Expenses	
Employee Remuneration	888
Superannuation	154
Leave expense	109
Other employee On Costs	25
Staff Training and Development	3
Total Employee Expenses	**1,179**
Supplier Expenses	
Insecticide Expensed	567
Bio-Pesticide Expensed	102
Helicopter Charter	351
Fixed Wing Aircraft Charter	86
Aerial Spray Aircraft	327
Aviation Fuel	77
Control Operations: Equipment and Freight	56
Light Trap Operations	47
Other Technical and Field Expenses	34
Vehicles	318
Travel	190
IT, Communications & Office Equipment	169
Contractors inc CSIRO	34
Human Resource Services	12
Overhead Allocation (Internal Business Unit)	115
Other Administrative	13
Corporate Expenses	335
General Office Supplies	10
Purchase of Publications and Data	27
Production of Publications	6
Property and Accommodation	174
Memberships and Conferences	5
Consultancy Services	9
Public Relations and Marketing	3
Grants	-
Legal Expenses	6
Total Supplier Expenses	**3,071**
Depreciation and Amortisation	46
Total Other Expenses	**46**
Total Expenses	**4,296**
Total Revenue	**3,002**
Net Operational result (Loss)	**(1,294)**

Appendix 3: Accumulated results ($'000)

Accumulated results carry over: 1 July 2003	**3,079**
Net result 2003-2004 (Loss)	**1,294**
Accumulated results Carry over: 30 June 2004	**1,785**