INTEGRATED MOSQUITO CONTROL IN DARWIN

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Darwin, the northern gateway to Australia, is both vulnerable and receptive to a range of exotic and endemic mosquito borne diseases, including malaria, dengue, epidemic poliomyelitis and Australian encephalitis (Whelan 1981).

With a population of ca 64,000, Darwin is the largest city in the northern fifth of Australia. Close transport and cultural links to the rest of South-east Asia make the importation of exotic diseases and vectors a continuing threat (Russell et al 1984). In addition, much of the residential area of the city is in close proximity to extensive tropical wetlands, and there can be seasonally high numbers of a range of pest and potential mosquito vectors (Russell and Whelan 1986). In response, the NT Government Medical Entomology Branch (MEB) has developed an integrated mosquito control programme including mosquito monitoring and surveillance, engineering source reduction, development liaison and coordination, ground and aerial larval control, ground adult control and public education.

The tangible effects of this programme have been a steady decline in mosquito problems throughout the Darwin area, with many residential areas relatively free of mosquito pest problems. The city is free of exotic mosquito-borne diseases and relatively free of the endemic mosquito-borne diseases. Most importantly, there is a strategy and programme in place to deal with possible outbreaks of mosquito-borne disease.

BACKGROUND

Malaria was eradicated in the NT in 1962 (Black 1972) and for the next 10 years mosquito control was relatively unorganised and received little priority. Larval control was carried out by a non-specialised government squad largely reacting to public complaints. They were equipped with knapsack sprayers dispensing oil to known and minor sources of mosquitoes and carrying out some minor drain maintenance. Adult mosquito control was conducted within residential areas using thermal fogging equipment. There was no mosquito monitoring programme and no regular surveys to determine the important sources of mosquitoes. Responsibility for mosquito control was held by a committee which was composed of diverse interests and was limited in its effectiveness.

By the early 1970’s, Darwin had expanded considerably, and periodic plagues of the saltmarsh mosquito, Ae vigilax, was affecting residents in the newer and expanding northern residential suburbs. At the same time various mining projects were being considered or on line in Gove and Jabiru and there were concerns for the reintroduction of malaria. This provided the impetus for the mosquito control committee to push for the appointment of a medical entomologist in order to provide a more scientific approach to mosquito control and to reduce potential disease problems.

In 1973 a medical entomologist was appointed and the MEB was established within the Department of Health. Regular mosquito monitoring and mosquito surveys were begun. The principal species and their sources were located and an adult mosquito control programme was organised with the Darwin City Council and the Government Parks and Gardens Section. New ULV equipment was purchased for adult mosquito control around the main breeding and harbouring areas, and the urban fogging was gradually phased out. Limited drainage measures were started and attempts of larval control in the large coastal brackish swamps were made. However, the swamps were too extensive for ground applied insecticide, and the resources unavailable for adequate physical control measures.

In 1982 an initial 5 year programme was drawn up with an annual budget of $180,000 on a funding basis of 2 to 1 between the NT Government and the Darwin City Council. The needs for and details of the programme were based on the mosquito monitoring and surveillance programmes already undertaken by the MEB. With the establishment of this group, the Darwin City Council suspended their regular adult mosquito fogging operations, although they continued a ground applied larvae control programme in limited areas under the guidance of the MEB.

During the initial engineering phase, it was recognised that limited ground control operations could not cope with periodic emergencies of saltmarsh mosquitoes arising from the large coastal swamps outside the city boundaries. In response, the Health Department initiated a programme for the aerial application of larvicides. This programme had an annual budget of $20,000 and the needs were determined by mosquito surveillance and monitoring.

Most of the control efforts were undertaken in the city of Darwin, leaving ca 7,000 people, residing in the rural area, with no mosquito control operations. Public education programmes were started in recognition that rural residents, and the recreating city population, had
to rely on self protection and avoidance measures. At the same time the Department became involved in the planning processes to prevent the creation of additional mosquito problems in both the urban and rural areas. Mosquito control in Darwin is now a comprehensive and integrated programme, and is significantly reducing the pest and potential disease problems posed by mosquitoes.

**POTENTIAL MOSQUITO BORNE DISEASES**

The potential mosquito borne diseases include the endemic arboviruses such as RRV, MVE, KUN and the exotic diseases such as malaria and dengue.

Epidemic polyarthritis is the most common arbovirus disease in the NT. The MEB maintains a record of all laboratory confirmed cases and the likely points of infection (Table 1). It is probable that there are many more clinical cases for every confirmed case. While the number of cases in Darwin is less than expected on a population basis compared with Jabiru, Katherine and Nhulunbuy, certain residential areas within the town are still exposed to pest numbers of the various vectors (Fig 1).

Four cases of MVE were recorded from the NT in 1987/88 (CDI 88). One case was contracted relatively close to Darwin. Although there have been no isolations of MVE virus from mosquitoes around Darwin in recent years, serological evidence suggests that this virus, as well as KUN virus, is present in close proximity to the residential areas (L Melville pers comm). Other arboviruses have been isolated from mosquitoes in the Darwin area, including SIN, and the virus and the potential vectors occur in close proximity to residential areas. The most common potential vector, *Cx annuifloris*, has a survival rate in Darwin adequate to transmit both MVE and RRV during most months of the year (Russell 1986).

The NT, and Darwin in particular, remain vulnerable to malaria re-introduction. The *Anopheles* vectors are found near some of the residential areas. Entomological investigations have indicated that these vectors are capable of living long enough to be able to transmit the disease (Russell 1987). There is an increasing number of imported malaria cases being detected in Darwin over recent years. Each case is investigated but there is a potential problem of undetected cases in areas where vectors are abundant.

Although there are no vectors of DEN in Darwin, there have been a number of detections of imported *Ae aegypti* larvae and eggs. There have been 2 recent instances of the importation of *Ae albopictus* into Darwin. As well as being vulnerable, Darwin is also receptive to the importation of container breeding *Aedes* and there are large numbers of rain filled household containers within the residential areas. Surveys have indicated that there can be up to 14 rain filled containers per household capable of breeding mosquitoes (Whelan and Laskowski 1984).

**PROBLEM MOSQUITO SPECIES**

The principal pest and disease species in Darwin and their period of peak occurrences are shown in Table 1.

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**TABLE 1**

Epidemic Polyarthritis cases in the Northern Territory
Probable infection points for serologically confirmed cases — 1/7/83 to 30/6/89.

<table>
<thead>
<tr>
<th>Region</th>
<th>Area</th>
<th>83/84</th>
<th>84/85</th>
<th>85/86</th>
<th>86/87</th>
<th>87/88</th>
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<td>3</td>
<td>2</td>
<td>9</td>
<td>3</td>
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<td>4</td>
<td></td>
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<tr>
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<td>Jabiru</td>
<td></td>
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<td>1</td>
<td>9</td>
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<td></td>
<td>13</td>
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<tr>
<td></td>
<td>Oenapelli</td>
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<td>1</td>
<td>2</td>
<td></td>
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<td></td>
<td>4</td>
</tr>
<tr>
<td></td>
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<td>2</td>
<td>8</td>
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<td></td>
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<td>Alyangula</td>
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<td></td>
<td></td>
<td>1</td>
<td>4</td>
<td></td>
<td>6</td>
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<td></td>
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<td>1</td>
<td></td>
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<td>9</td>
<td>2</td>
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<td>4</td>
<td>8</td>
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<td></td>
<td>2</td>
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<tr>
<td></td>
<td>Other</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
<td></td>
<td>3</td>
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<td>Alice Springs</td>
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<td></td>
<td>3</td>
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<td></td>
<td>3</td>
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<tr>
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<td></td>
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<td>1</td>
<td>3</td>
<td>2</td>
<td>6</td>
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<td>2</td>
<td></td>
<td>3</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td>11</td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td></td>
<td>30</td>
<td>10</td>
<td>12</td>
<td>17</td>
<td>41</td>
<td>65</td>
<td>175</td>
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</table>
Aedes vigilax is the most abundant species in the Darwin area (Fig 2) and, as the potential vector of RRV, MVE and SIN viruses, is viewed with most concern. It is most numerous near the larger coastal swamps and occurs in relatively high numbers in residential areas adjacent to these swamps.

Aedes vigilax is the next most abundant and is a potential vector of RRV. It is by far the most troublesome pest species, with large hatches following the spring tides in the late dry season generating many public complaints. The pest problems are particularly high in the suburbs bordering Leanyer Swamp, but pest numbers penetrate well into other residential areas.

Anopheles farauti is regarded as the potential malaria vector in Darwin, and although relatively common in some localities, it is largely absent from most of the residential areas and never reaches pest proportions.

Anopheles bancrofti is more numerous than An. farauti and must be regarded as another potential malaria vector. It is an occasional pest in the suburbs bordering the larger swamps. Of the other major species only Coquillettidia xanthogaster reaches pest proportions.

An analysis of public complaints received by the MEB over a number of years has enabled the calculation of pest thresholds for Ae. vigilax and Cx. annulirostris. The pest thresholds are 50 and 600 adult mosquitoes respectively per CO2 trap night at established monitoring sites bordering the main breeding areas. The pest thresholds are useful in determining the need for additional larval surveys and increased control effort.

DISEASE SURVEILLANCE

Arbovirus Surveillance

Serologically confirmed cases of RR or MVE are reported to the Communicable Diseases Unit and then to the MEB. MVE cases receive priority and suspect cases are subject to telephone notification.

The RR information is used more as a retrospective study to determine priority areas for future virus isolation studies or mosquito control operations. However, if an outbreak occurs, the information is useful to plan control measures or public education programmes. For suspect or confirmed cases of MVE, the information forms the basis for additional mosquito monitoring and virus isolation studies, as well as adult mosquito control operations.

Isolations of arboviruses from mosquitoes are also undertaken to determine the presence of virus and the probable vectors. Mosquitoes are collected and identified and virus isolations are made by the Department of Primary Industries and Fisheries. This work has established the
importance of Cx annulirostris, Ae vigilax and Ae normanensis as probable vectors of RR in the NT.

Malaria Surveillance

Malaria surveillance in the NT relies on the ability of the health services to detect malaria cases. Once a case is confirmed the Communicable Diseases Branch is informed and begins an epidemiological investigation. This involves the examination of vector control maps and other mosquito distribution data, a review of the epidemiological data, an inspection of the case residence or places visited by the patient and mosquito trapping at the residence. CO₂ baited traps are set at the residence and at nearby mosquito breeding and harbouring areas. If the risk of subsequent transmission is high, a ULV fogging programme is undertaken around the residence and around the nearest significant breeding and harbouring area.

In recent years, many of the imported malaria cases in Darwin have not required fogging operations. This is largely due to the success of the source reduction programme around the city. As the Darwin urban area is home to nearly 50% of the NT population, these source reduction measures have a high cost benefit.

MOSQUITO SURVEILLANCE AND MONITORING

Aedes Ovitrap Programme

Aedes ovitrap programmes are run both by the MEB and the Australian Quarantine Inspection Service (AQIS) utilising ovitraps similar to WHO specifications.

The AQIS monitors ovitraps at the wharf, and airport areas, while the MEB has ovitraps throughout the suburbs and at vulnerable points of introduction such as caravan parks and interstate trucking yards. The ovitraps are inspected weekly and identifications of larvae are made by the MEB.

The aim of the programme is to intercept Ae aegypti, Ae albopictus or other exotic Aedes at the most likely points of introduction. When the AQIS recently detected Ae albopictus larva in the wharf area, the MEB carried out a container survey in the general area, and treated all available breeding sites with a super chlorine solution.

Container Surveys

The last record of Ae aegypti established in Darwin was in 1936 (O’Gower 1938), and by 1969 Darwin was regarded as Ae aegypti free. Annual wet season container surveys are carried

### Table 2

<table>
<thead>
<tr>
<th>Species</th>
<th>Habitat</th>
<th>Peak period</th>
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</thead>
<tbody>
<tr>
<td>Cx annulirostris</td>
<td>Freshwater swamps</td>
<td>January to August</td>
</tr>
<tr>
<td>Cx quinquefasciatus</td>
<td>Containers</td>
<td>Continuous</td>
</tr>
<tr>
<td>Ae notoscriptus</td>
<td>Containers, Poiluted water</td>
<td>January to June</td>
</tr>
<tr>
<td>Ae vigilax</td>
<td>Brackish reed swamps</td>
<td>August to December</td>
</tr>
<tr>
<td>An banneroi</td>
<td>Coastal reed swamps</td>
<td>February to July</td>
</tr>
<tr>
<td>An farauiti</td>
<td>Coastal reed swamps</td>
<td>March to June</td>
</tr>
<tr>
<td>Cq xanthogaster</td>
<td>Freshwater swamps</td>
<td>May to August</td>
</tr>
</tbody>
</table>

Figure 2. Species composition — mosquito monitoring collections, Darwin 1983-88. Average number of 11 selected species from weekly collections at 11 sites.
out throughout the Darwin areas as a back up to the ovitrap programme. Suburbs and streets are selected at random, and residences are surveyed for any water holding containers, with many larvae per container collected for identification. Particular surveys are also carried out in tyre yards and premises which have a high potential for the importation of larvae or eggs from Qld.

Quarantine Liaison

The MEB maintains liaison with the AQIS and assists with quarantine searches of vessels or aircraft. The MEB has assisted with aircraft disinsection trials and helped to establish that regular importation of *Anopheles* sp. from Indonesia is possible (Russell et al 1984). The close liaison enables the maintenance of a rapid detection and identification system so that timely eradication measures can be undertaken if importation of exotic mosquitoes occurs.

Larval Ground Surveys

The MEB examines and maps all of the potential mosquito breeding areas in the vicinity of Darwin using aerial photographs and ground surveys throughout the extensive swamp systems, as well as the mapping and inspection of all storm water drains, streams and water features. The initial surveys recorded the time and location of breeding, and habitat characteristics. Larval and adult sampling sites were selected and mosquito control methods and priorities were assigned to the various areas.

Larval ground surveys are a continuing feature of the mosquito control programme. Most surveys are rain or tide initiated. Follow up surveys assess the effectiveness of control operations. For tide initiated surveys, tides of over 7.3 ACD are likely to result in *Ae. vigilax* breeding in selected areas. Yearly tide predictions enable planning of vector control operations. For rain initiated surveys, falls of over 25 mm between November and January can produce hatches of *Ae. vigilax*. The results of the adult mosquito monitoring programme can initiate additional ground surveys to detect unknown sources or re-assess the control of known sources.

Adult Mosquito Monitoring

Adult mosquito trapping using CO₂ baited light traps has been conducted continuously at permanent monitoring sites around Darwin for over 9 years. Eleven sites are currently utilised, with traps set weekly near the major mosquito breeding areas. This programme allows a rapid assessment of the mosquito situation and determines the need and assesses the success of larvicide operations and the mosquito engineering works. The trap results from the various sites from 1983 to 1988 (Fig 3) depict the worst possible picture, as the sites are adjacent to continuing problem areas and hence do not reflect the large areas where breeding has been eliminated. There has been a steady decrease in mosquito numbers since the initiation of the engineering drainage programme in 1983 (Fig 4). The apparent set-back in 1988 was the result of unusual circumstances with heavy and unseasonal rains, disruptions of the drain maintenance programme and unavailability of vector control equipment.

Additional traps are set around malaria cases and near actual and potential mosquito problems associated with development projects and public complaints.

MOSQUITO CONTROL

Engineering Control

The mosquito engineering control programme is a jointly funded programme between the NT

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**Figure 3.** Mosquito monitoring collections, Darwin 1983-88. Average number of 11 selected species per trap night in weekly collections.
Government and the Darwin City Council on a 2:1 basis with an annual expenditure of $180,000. The aim of the programme is to permanently remove mosquito breeding areas. The first 5 years of the programme has resulted in a major open marsh drainage system, sub-soil drainage, a storm water drain maintenance and upgrading programme and a number of filling operations. This has reduced or eliminated many of the breeding areas adjacent to residential areas.

Open Marsh Ditching

Open unlined drains have been constructed because of the relatively cheap initial cost, the ease of construction and the flexibility for later additional drains. Over 38 km of open drains have been constructed in Ludmilla Swamp, Vesleys Swamp, Leaner Swamp and Coconut Cove Swamp, with the major effort in Leaner Swamp (Fig 5).

The drains vary in width from 1 m wide laterial drains to 4 m wide main trunk drains. The majority of drains start at storm water discharge points at the edge of residential suburbs, and continue to daily flushed tidal areas. Drain construction relies on the use of large tracked excavators using swamp mats in boggy situations. The relatively large width of the main trunk drains in the tidally influenced areas has been necessary to allow the adequate drainage of swamp lands following extended high tides or a combination of high tides and extended rainfall.

Sub-soil Drainage

A sub-soil drainage system was constructed in Casuarina Swamp where the higher capital cost was justified due to visual and environmental considerations. Dry season urban storm water flows are collected from urban drains and diverted away from the upper tidal areas via an underground pipe, to discharge direct to a daily flushed tidal area (Fig 6). The diversion of the freshwater flow resulted in the elimination of fresh and brackish water reeds and their associated mosquito breeding within the mangroves (Whelan 1988b).
was filled by scraper machines utilising sand from off-shore sand bars exposed at low tide. The entire mined area was filled, recontoured and a drainage outlet was constructed to a nearby pre-existing natural creek outlet through the frontal dunes. In another programme, flooded bomb craters in the upper high tide zone of Leanyer Swamp are being progressively filled. In this case drainage is not feasible because of the danger of unexploded bombs.

Drain Maintenance

A considerable portion of the annual expenditure on the engineering programme is currently on drain maintenance. Drain maintenance is carried out by large excavators removing silt and vegetation, or by the use of weedicides. Maintenance requirements are greatest in those drains with dry season flows, particularly those in the upper portion of the large tidally influenced coastal swamps.

Permanent Concrete Upgrading

Part of the engineering strategy includes provision to gradually upgrade the open unlined earth drainage system to reduce ongoing maintenance costs. Approximately $50,000 of the annual $180,000 appropriation is spent on concrete upgrading. Concrete drain inverters are constructed in priority areas where there is regular dry season storm drain flow land regular mosquito breeding.

Larval Ground Control

Larval ground control is directed at mosquito breeding in storm water drains, water feature areas, or in small areas of the swamps where aerial control is not possible or justified. The breeding is located by the MEB and the Council carries out the control using back-pack applicators dispensing liquid Bti or Temephos granules.

Larval Aerial Control

The larval aerial control is organised by the MEB utilising local charter companies. The main targets are the salt marsh mosquito breeding areas in Leanyer Swamp and adjacent tidally influenced swamps during the August to January period. Occasional control of Cx. annulirostris or An. bancroftii is carried out during the January to June period in the same coastal swamps when they are largely freshwater breeding sites. The area of treatment can range from 10 to 300 ha with an annual expenditure from $20,000 to $30,000.

Saltmarsh control operations are programmed on tidal predictions, with the area of likely treatment increasing with increasing maximum spring tides. Survey and treatment is usually undertaken 1 to 2 days after maximum spring tides, allowing time for the swamp to partially drain. Early wet season rains, particularly falls over 25 mm within a few days of spring tides, can also cause a large hatch and require extensive survey and treatment.

The mainstay of the programme has been the application of liquid Bti applied by helicopters. Both Bell 47 and Jet Ranger helicopters have been used with 10 m boom sprays and D6-45 or D8-45 nozzles mounted at 90 degrees to air flow. Spray heights ranged from 3 m to 10 m with 15 m swath widths and air speeds of 35 to 40 knots. The Bti is applied to 2 L/ha. The loading of the tanks is from 250L to 350L applying 50L/ha.

Trials are currently underway to evaluate the use of the Easton Spreader and the aerial application of Abate 50SG. The use of granules is required at times of adverse weather conditions or in thick vegetation or mangrove cover, where Bti liquid formulation does not give adequate control.

PLANNING AND COORDINATION

Much of the current mosquito control effort in Darwin is directed at areas of breeding that have been created or aggravated by development, poor waste disposal practices, or poor planning considerations. The MEB has an input in the planning processes to create an awareness of current mosquito problems and to prevent additional problems.

Environmental Reports

Many of the larger development projects require preliminary environmental reports or environmental impact statements. The reports are coordinated by the Environment Unit of the Conservation Commission. Entomology comment is sought by developers in the preliminary stage during preparation of the reports and by the Commission in the public comment stage after completion of the reports. Comment allows for potential pest and health problems to be appreciated early in the project development so that plans or management practices can be adjusted to avoid or reduce potential problems.

Department of Lands

The Department of Lands routinely receives applications for the development of land as well as planning urban, rural and industrial areas. The Health Department comments are routinely sought on these planning proposals, particularly if the proposal is near any existing water features or involves practices that could lead to mosquito breeding. These comments are evaluated, along with other comments, to assist in coordinated development. The Branch has developed guidelines on storm water drainage, sewage storage and disposal, the design of water features and mosquito buffer zones.

Coastal Management Technical Advisory Group

The MEB has an input through this group to other government departments, so that potential
mosquito problems can be highlighted. One practical outcome has been the publication and circulation of guidelines to prevent mosquito breeding with construction practice near tidal areas (Whelan 1988a).

PUBLIC EDUCATION

The Branch has a mosquito awareness programme utilising the various media outlets, public displays, school visits and staff training. Materials include television advertisements on self protection, container breeding and mosquito-borne disease, as well as colour pamphlets, bumper stickers and information papers. The awareness programme is particularly necessary as many people visit areas of high mosquito activity outside of Darwin where self protection measures are the only practical method of reducing person/mosquito contact.

REFERENCES


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