AUSTRALIAN WETLANDS AND MOSQUITO CONTROL - CONTAIN THE PEST AND SUSTAIN THE ENVIRONMENT?

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ABSTRACT

Mosquitoes are a problem in coastal areas, particularly in wetlands. They are capable of transmitting diseases, some of which are not presently a problem in Australia, but which could be in the future. The framework within which mosquito control takes place includes the responsibility of Federal and State governments for wetland protection and of local government for control of mosquitoes. State governments may also have a role in research and/or support management programmes.

Australian mosquito control generally relies on chemical treatment, usually with larvicides and sometimes with adulticides. There are two growth areas in management. First is an increasing liaison between town planners and those responsible for mosquito (and midge) control to inhibit development close to breeding sites. Secondly, minimal habitat modification programmes are increasing. These seek to control the pest but not destroy wetland values. An example of this is described for Coomera Island, to the north of the Gold Coast (Qld).

INTRODUCTION

The Australian coastline is over 30,000 km long, embracing a range of climatic types from temperate to tropical. 'Coastal' lands, a band approximately 4km wide, cover an area of about 125,000 km^2 (Galloway *et al.*, 1980). Of interest here are those coastal lands which provide mosquito breeding habitats. Broadly, these occur in areas of alluvial and mud surfaces - the swamps, alluvial plains and intertidal areas which comprise approximately 41% of the Australian coastal lands. They contain highly productive ecosystems and provide a wide range of values, including biological, physical, economic, research and aesthetic ones. About 74% of Australians live on or close to the coast and so mosquitoes and people inevitably come into contact and, usually, conflict. Figure 1 illustrates the likely extent of the contact, showing the areas of potential mosquito breeding around our coast and the distribution of population.

Because of the proximity of people to the pest habitat and the resultant nuisance and health hazard it is necessary to attempt to manage the problem. This paper overviews the problem, the role of government, the responsible agencies and how they manage the problem and then focusses on a Queensland case study to illustrate some of the points made. The environmental consequences of management, from the perspective of conserving our wetlands, are also considered.

WHY ARE MOSQUITOES A PROBLEM?

Not only are mosquitoes a nuisance, but they are a public health hazard, capable of transmitting disease. They also have veterinary importance being a major source of heartworm in dogs and may carry diseases to other animals (e.g. equine encephalitis). In Australia the main mosquito-borne diseases in humans are caused by arboviruses (e.g. Ross River virus, Dengue viruses, Murray Valley Encephalitis virus and Kunjin virus). These are not often fatal, but can lead to debilitation and incur social costs in terms of productivity and health care. Ross River virus disease is the most common arbovirus in Australia. Between September 1991 and August 1992, there were 5,702 arbovirus disease reports from laboratories in Australia, 91% of which were for Ross River virus, and almost 5% for Dengue (Hargreaves and Hall, 1992). The problem is most severe in Queensland. In the 1991-92 year most of the reports (65.6%) were from that state, with nearly half (48%) of the Queensland total coming from the major coastal cities of Brisbane, Townsville, Rockhampton and Cairns. (Nearly 95% of Dengue notifications were also from Queensland). Significantly,

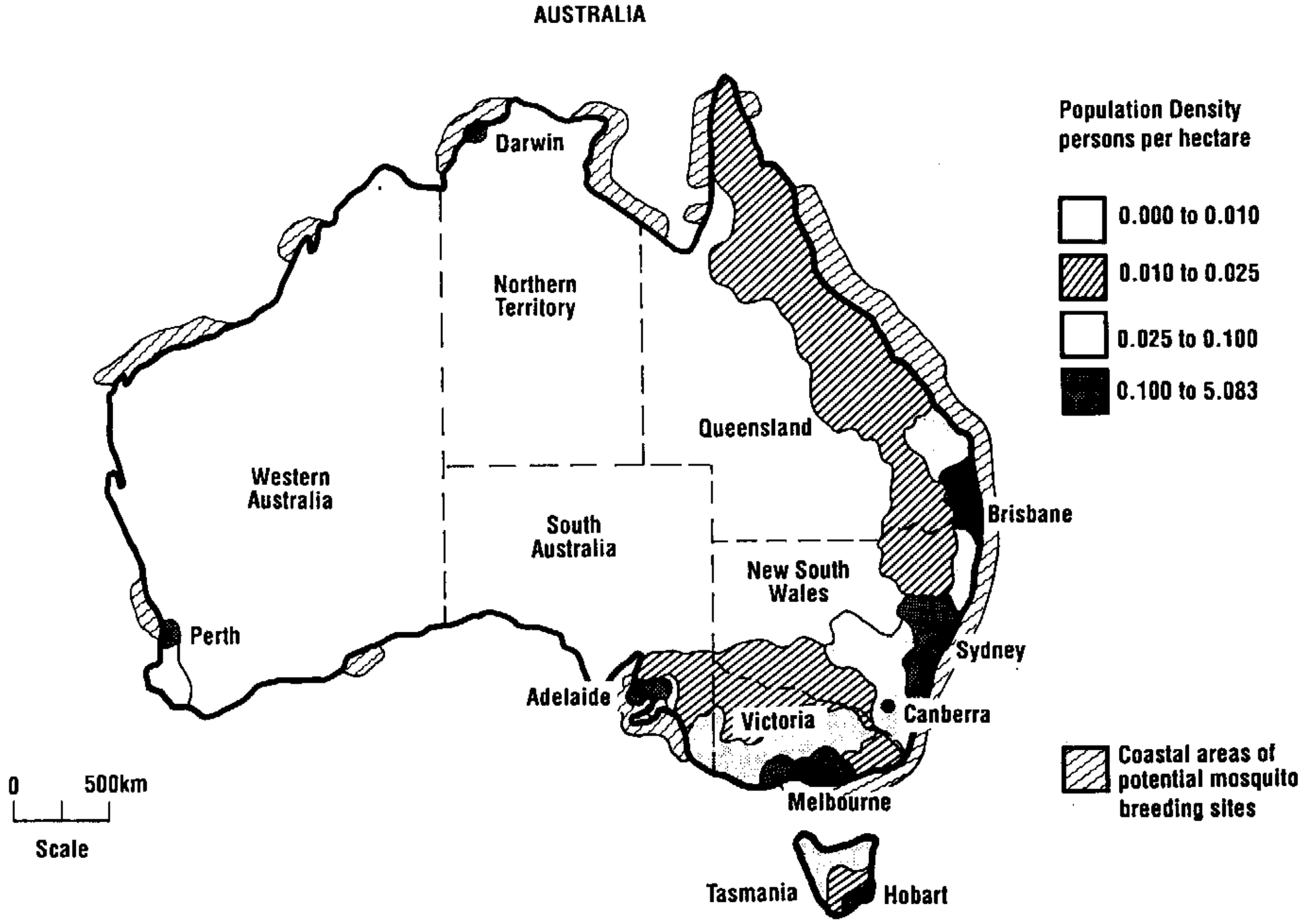

Figure 1 Potential coastal mosquito breeding habitats and population distribution (Population data: Australian Bureau of Statistics, 1986)

some of our mosquito species are capable of transmitting serious diseases which are not presently a problem in Australia.These include Malaria which is transmitted to humans by *Anopheles spp.*, and Filariasis which can be transmitted by *Aedes vigilax, An. annulipes, Culex annulirostris* and *Cx. quinquefasciatus.* Yellow Fever does not occur in Australia but *Aedes aegypti* is a known vector. Tables 1 and 2 show some of the major problem species in Australia and their human and animal disease significance.

THE MOSQUITO HABITATS

Some of the results from a survey (the Survey) conducted in 1992 via the Australian Mosquito Control Association are used here. The sample size was 38, representing all States and mainland Territories. Responses were mainly from those directly involved in mosquito management. Because of the small sample size the data were only used descriptively and were not statistically evaluated. The Survey identified the perceived major problem species (Dale,1992). Their habitats are shown in Table 3 and these include wetlands. Many are natural, but it is important to note that at least one species implicated in arbovirus disease (*Cx. annulirostris)* is found in wetlands which have been polluted by human-related activities. The major coastal vector of Ross River virus, *Aedes vigilax,* breeds in the intertidal wetlands, which are important in helping to maintain the functions of estuarine and marine systems and which may be protected at Federal, State or Local government level.

THE MANAGEMENT FRAMEWORK

To minimise the public health risk we need to manage the total 'risk' system itself. Until very recently this involved focussing entirely on the pest and its environment. More recently there has been some movement towards also controlling the pattern of human settlement via the town planning process to reduce the problem by avoiding it. Management takes place within a political and administrative framework which may help or hinder the programmes. First we need to consider the overall framework within which management takes place at Federal and State level. Next we identify the bodies responsible for 'on the ground' management. Then we consider the management methods in current use, identify developing trends and illustrate this with a case study from Queensland. Implications for wetlands are also addressed.

Table 1 Arbovirus disease vectors in Australia (Source : Marks 1982; Liehne 1991)

	Implicated as vector of disease present in Australia			
Mosquito species	Australian encephalitis[1]	Ross River virus	Dengue	Other arbovirusd
Ae. aegypti	√	√	*	*
Ae. camptorhynchus	√	√		
Ae. notoscriptus[2]		√		
Ae. vigilax	√	*		
Ae. vittiger	√			
An. annulipes				*
Cx. annulirostris	*	*		*
Cx. australicus[3]	√			*
Cx. molestus	√			*
Cx. quinquefasciastus	* (poor vector)		* (poor vector)	

* Known vector
√ In experiment is an efficient vector or supports replication of arboviruses

[1] Also known as Murray Valley encephalitis (MVE)
[2] Susceptible in New Zealand studies
[3] May have role in the pre-epidemic amplification cycle of Australian encephalitis, but rarely bites humans

Government power and wetland protection

Concern for coastal wetlands is growing at all government levels and in the public arena. So far, Australia has seen far less government control in environmental matters than has been the case in U.S.A., although this is changing. There has been little Federal government involvement, for its powers are limited by the Australian Constitution. Some headway has been made under its 'Foreign Affairs' power whereby it can ensure that international agreements are honoured. This has relevance to the management of, for example, the 40 Ramsar sites (wetlands of international significance) and to bird habitats protected under international agreements such as the Japan-Australia Migratory Birds Agreement. Nevertheless, the Federal government is usually reluctant to interfere in State matters. At the State level there are various special purpose reserves, such as Environmental Parks, Fisheries Reserves and Marine Parks. In addition, there are some statutory procedures aimed at 'properly' evaluating proposals to interfere in wetlands. Examples are the SEPP14 (State Environmental Planning Policy 14) of New South Wales and sections of the Queensland *Local Government (Planning and Environment) Act* of 1991. A balance needs to be achieved between public health interests and sustaining coastal ecosystems. The environmental protection presently offered may at best merely delay some management procedures (e.g. habitat modification) and at worst may prevent effective long term control, in some places.

Who is responsible for the day to day management? Who pays?

Mosquito management in Australia is often a local government responsibility although State and Federal agencies may be involved. Funding for control measures usually comes from the local rates and must compete with other public services such as the provision of sewerage and roads.

The Queensland management program is probably the most advanced in Australia (Chester, 1990). No funds are provided by the State government, despite the fact that much control, for example in south east Queensland, has to be carried out on Crown land. Local government authorities are wholly responsible for management, and control is mandatory under the state *Health Act* (1937-1988) Regulations. The State Health Department does offer advice, run courses and, in 1992, set up an Arbovirus Task Force which completed its report in April 1993. In Victoria the main focus of control is environmental management and public education with larviciding and adulticiding

Table 2 The veterinary significance of major Australian pest species implicated as vectors of animal disease (Source : Marks, 1982; Liehne, 1991)

	Animal disease		
Mosquito species	Heartworm (*Dirofilaria immitis*) (Dogs)	Myxomotosis (Rabbits)	Bird Malaria
Ae. aegypti	*		
Ae. notoscriptus	*	*	
Ae. vigilax	*		
An. annulipes		*	
Cx. annulirostris	*	*	
Cx. australicus		*	
Cx. quinquefasciatus	*		*

Table 3 Summary of major breeding site characteristics for the major pest species. (Source : Marks, 1982 and Liehne,1991)

Species	**Habitat characteristics**
Ae. aegypti	Urban, container breeding. Treeholes near human settlement.
Ae. camptorhynchus	Coastal - brackish and sometimes fresh water. Also found inland
Ae. notoscriptus	Tree and rock holes, fallen palm fronds (wet forests). Also container breeding.
Ae. vigilax	Saline to brackish intertidal pools, associated with *Sporobolus virgincus* (Marine couch) *Suaeda* sp. (Seablite) and *Sarcocornia* sp. (Samphire). Sometimes breeds on mangroves; numerous adults rest in mangroves.
Ae. vittiger	Temporary ground pools with marginal vegetation, sunlit and with emergent grasses.
An. annulipes	Ground and rock pools, generally fresh water. Also found in polluted and brackish water. Typical sites include large pools with filamentous algae, and among debris and hoofprints at pool margins.
Cx. annulirostris	Shallow freshwater sites, open and sunlit and with emergent vegetation. Found also in brackish and polluted waters. Often associated with drains, outfall areas, sewage treatment plants and effluent outflows.
Cx australicus	Open freshwater, in ground and rock pools. Associated with *Cx. annulirostris, Cx. annulipes* and *Cx. quinquefasciatus*. May breed in slightly brackish or polluted water. Found in effluent ouffalls and drains. Rarely bites humans.
Cx. molestus	Heavily polluted sites such as septic tanks, polluted water in rubbish dumps.
Cx. quinquefasciatus	Fresh to polluted water. Often in drains and associated with sewage treatment effluent. Adults tend to remain close to the breeding site.

when necessary. The State Government has an active surveillance program and provides financial support to the local government bodies responsible for mosquito control. Some local authorities also participate in the State monitoring and surveillance program, thereby providing a valuable data base to facilitate wise management. In Western Australia there is a growing commitment to mosquito control and the development of integrated programs. Mosquito control is carried out by local government authorities with advice from the State Health Department. The State government has provided funding for area-specific mosquito control. Another state body which is active in promoting wise management is the Waterways Commission. This body has developed several area-specific long term strategic plans (Chester and Klemm, 1990a and b) and works in close co-operation with the Queensland groups. In the Northern Territory the Medical Entomology Branch of the Department of Health and Community

Services researches, coordinates and is responsible for allocating Government funds for mosquito control. In New South Wales and South Australia relatively little attention appears to have been given to mosquito control. However some local authorities are known to take a pro-active approach to the problem and there is an active vector and virus surveillance epidemiological research program at the State level.

Research is also part of management. Wise management proceeds on a basis of understanding which is accomplished by research. Over half the organisations represented in the Survey both support, and are involved in, research (56%). Of these 58% were actively involved in research themselves and around one third (32%) supported research by providing funding. The type of research included larval and light trap counts, repellent trials, virus isolation experiments and an active involvement with State organisations.

MANAGEMENT TECHNIQUES

Management may be viewed as 'offensive', that is actively attacking the pest or its habitat or both, as compared to 'defensive' methods of avoiding the problem. The common 'offensive' control methods include:

(a) the use of chemicals, usually by larviciding the breeding habitats or adulticiding in areas close to human settlement;
(b) physical intervention which modifies breeding habitats by draining, ditching or, more recently, runnelling, a minimal impact method;
(c) biological control which often introduces predators (usually a fish species, *Gambusia affinis)*; or
(d) biochemical control introducing pathogens such as *Bacillus thuringiensis* var. *israelensis*.

Results of the Survey showed a heavy reliance on chemical control of mosquitoes, usually at the larval stage (36% of all responses) (Dale, 1992). Figure 2 shows the method of control by habitat type. The majority of chemical users relied upon Abate, a larvicide, particularly in natural environments. In other places, such as drains and irrigation-related habitats, Skeetal, Maldison (ULV) and an anonymous weedicide were used. Physical control was carried out by 19% of respondents, mainly in intertidal environments. Methods included draining, filling, impounding, Open Marsh Water Management (OMWM) and runnelling (a form of OMWM), in decreasing order of likely environmental impact. Biological control was also referred to by 19% of respondents. Introduced fish were mentioned in both natural and human affected environments (irrigation areas). Many included *Bacillus thuringiensis* var. *israelensis* under biological control. This was used especially in mangrove, saltmarsh and freshwater swamps. In the domestic container situation the use of Altosid, kerosene, salt and light oil was reported.

'Offensive' methods are generally intrusive, and the effects on non target aspects of the environment are often poorly understood (Dale and Hulsman, 1991). Chemicals, introduced predators and habitat modification each affects marsh food webs in different ways and all affect the interactions between marshes and adjacent systems to some extent.

Is there another way?

Control needs to be effected in areas which presently are experiencing a mosquito (and biting midge) problem. However, a complementary measure would be to encourage personal responsibility for some measure of protection from the pests and to ensure that future developments do not repeat the errors of earlier times by allowing (or even encouraging) human settlement close to breeding habitats. We could describe such measures as 'defensive ' in contrast to the offensive ones mentioned earlier.

Defence may be conducted at the individual, household or institutional level or involve a combination of these. Examples only are referred to here. Individual protection includes using repellents and avoiding times and places which are known to be associated with a pest problem. At the household level, screening is effective and only involves a one-off cost. At the institutional level education may be used as a vehicle to inform people about the problem and encourage personal responsibility towards its management. In the Survey, 40% of respondents cited education as a pest control measure, mainly in urban and for human-induced breeding areas as is shown by the 'other' category in Figure 2.

The problem could also be avoided by appropriately locating human habitations. Until recently, the wisdom of human intrusion close to or into pest breeding areas had not been seriously questioned by town planners in Australia (at least, not in Queensland where the major problems seem to lie). In the last year or so there has been an encouraging development. In northern New South Wales and south east Queensland vector problems are being increasingly taken into account by planning agencies (usually at local government level), when considering development proposals. It is significant that the Tweed Shire (in northern NSW) has been one of the first to incorporate into its town planning process a consideration of proximity to mosquito (and biting midge) breeding areas. Prior to granting planning approval the town planners seek advice from the pest managers as to the likely biting insect consequences of development. In this way creation of a problem by inappropriate settlement can be avoided. This is a major advance from focussing purely on the pest habitat, to recognising that the location of human settlement is also a large part of the problem. Moreover, it is one which may be more easily managed and without deleterious effects on the wetland resource, albeit subject to political, economic and social pressures. As a further, and metropolitan, example, a process is being developed in Brisbane to scrutinise planning applications for potential vector-related problems, and to take these into account when making planning decisions. Brisbane accounted for 22% of the Ross River virus laboratory reports for Queensland in 1991-92 (data from Hargreave and Hall, 1992). Whilst not proving local transmission it does indicate a large number of infected people in the area and this could increase the risk of an epidemic.

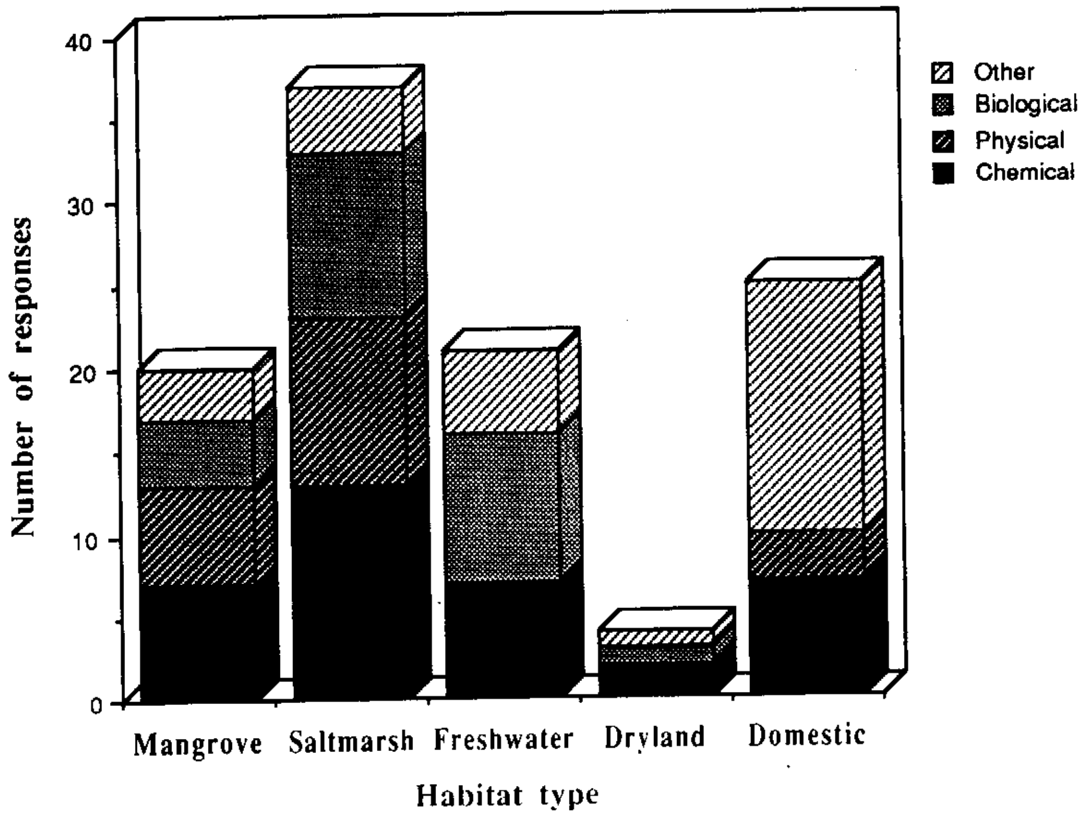

Figure 2 Mosquito management type by habitat (Source: Dale, 1992).

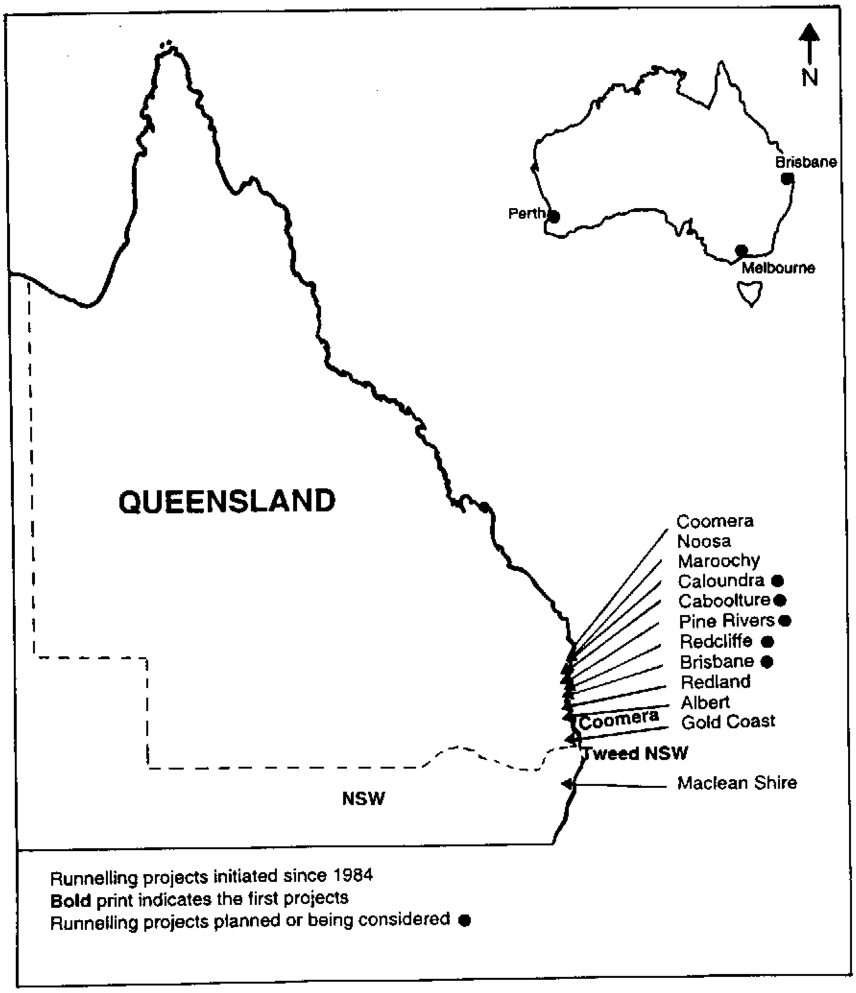

Figure 3 Location of the Coomera case study site and runnelling projects in Australia, 1993.

There are advantages to integrating a defensive approach with the offensive one. First, it may be cheaper to avoid the problem than to combat it with chemicals and earth moving ventures. Second, the environmental consequences of defence will generally be much less than for offensive measures.

However, there remain areas which are presently problematic. For these, active intervention is required. In this respect a new philosophy appears to be developing in Australia particularly as exemplified by Queensland and northern New South Wales, where it began. In the 1970's the only effective method of mosquito control was to spray with larvicides (usually Abate) from ground-based, all-terrain vehicles. Chemical spraying however is prone to the problems of resistance both from the pest and the public. In the early 1980's attention turned to developing longer term control using habitat modification. The aim was to intrude as little as possible in the wetlands, while still reducing pest numbers to below nuisance levels. A minimal form of Open Marsh Water Management (OMWM) was introduced in 1984-1985. This is runnelling. Its development is briefly described in the following case study.

QUEENSLAND CASE STUDY: THE EVOLUTION OF AN INTEGRATED PROGRAMME

A major mosquito problem species in south east Queensland is *Ae. vigilax* which transmits Ross River virus to people and heartworm to dogs. It breeds prolifically in summer in coastal intertidal wetlands. Recognising that mosquitoes do not respect political boundaries, the local authorities in south east Queensland have voluntarily amalgamated into regional groups for mosquito control. They address the problem holistically. The first group was formed in

1978 and, in 1981, crossed the state boundary to include part of New South Wales (Bell, 1989). This was the Contiguous Local Authorities Group (CLAG) which was the first to encourage and participate in research into the problem. In 1990, the number of agencies involved was expanded and the process was formalised. A coordinating Committee was established to administer the funds and these are allocated on a competitive basis. The committee, which is composed of people actively involved in mosquito research and/or control, sets research priorities, considers applications and recommends the allocation of resources. It was this research, begun in the early 1980's, which led to the runnelling programme in south east Queensland (Coomera) and northern New South Wales (Tweed Heads) (Figure 3).

The aim of runnelling was to interfere in the physical environment, but *only* insofar as it was necessary to disrupt the mosquito life-support system. This was a significant shift in viewpoint. Previously there had been a tendency to destroy the wetland, thereby also destroying the pest. The Queensland research questioned the necessity for such drastic actions, taking what could be termed a 'mosquito scale' view. Detailed environmental inventory was made over a 3 year period, of the small (8 ha.) experimental site at Coomera. With a reasonably clear idea of the environmental characteristics critical to the mosquito life cycle, we set out to modify these. The method became known as 'Runnelling' and has been described in Hulsman *et al.* (1991). Basically, it alters marsh hydrology to increase tidal flushing. It is a minimal type of Open Marsh Water Management such as has been used on the eastern seaboard of U.S.A. since the 1960's (Ferrigno and Jobbins, 1968 and reported in Dale and Hulsman, 1991). The first experimental site in Queensland was runnelled in November 1985, just prior to the mosquito breeding season. Mosquito larval numbers declined catastrophically over a 3 month period and few larvae have subsequently been found in the treated area (Figure 4). After 6.5 years, environmental monitoring indicates that the system, after

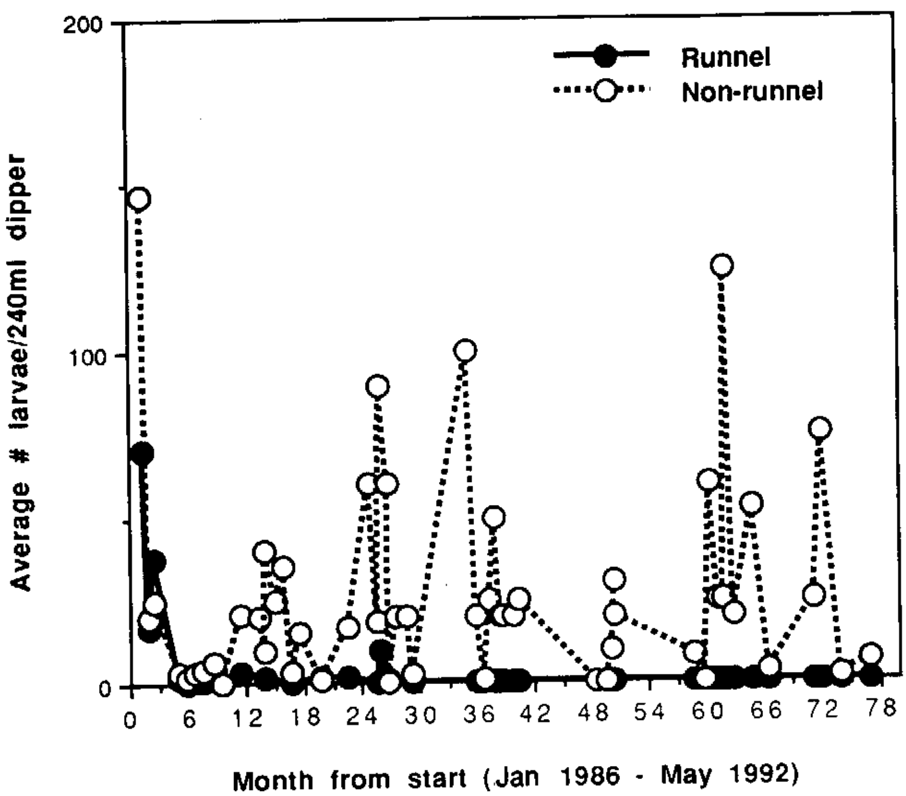

Figure 4 Larval numbers in the runnelled and untreated marsh at the Coomera Island site (Jan 1986 to May 1992).

initial changes which continued for between 3 and 5 years, has settled into a slightly wetter and less saline state than at the start. There are no significant differences between sites close to runnels or those near natural water bodies (Dale *et al.*, in press). This is illustrated, for the water table, in Figure 5. There has been a greater frequency of fish on the modified part

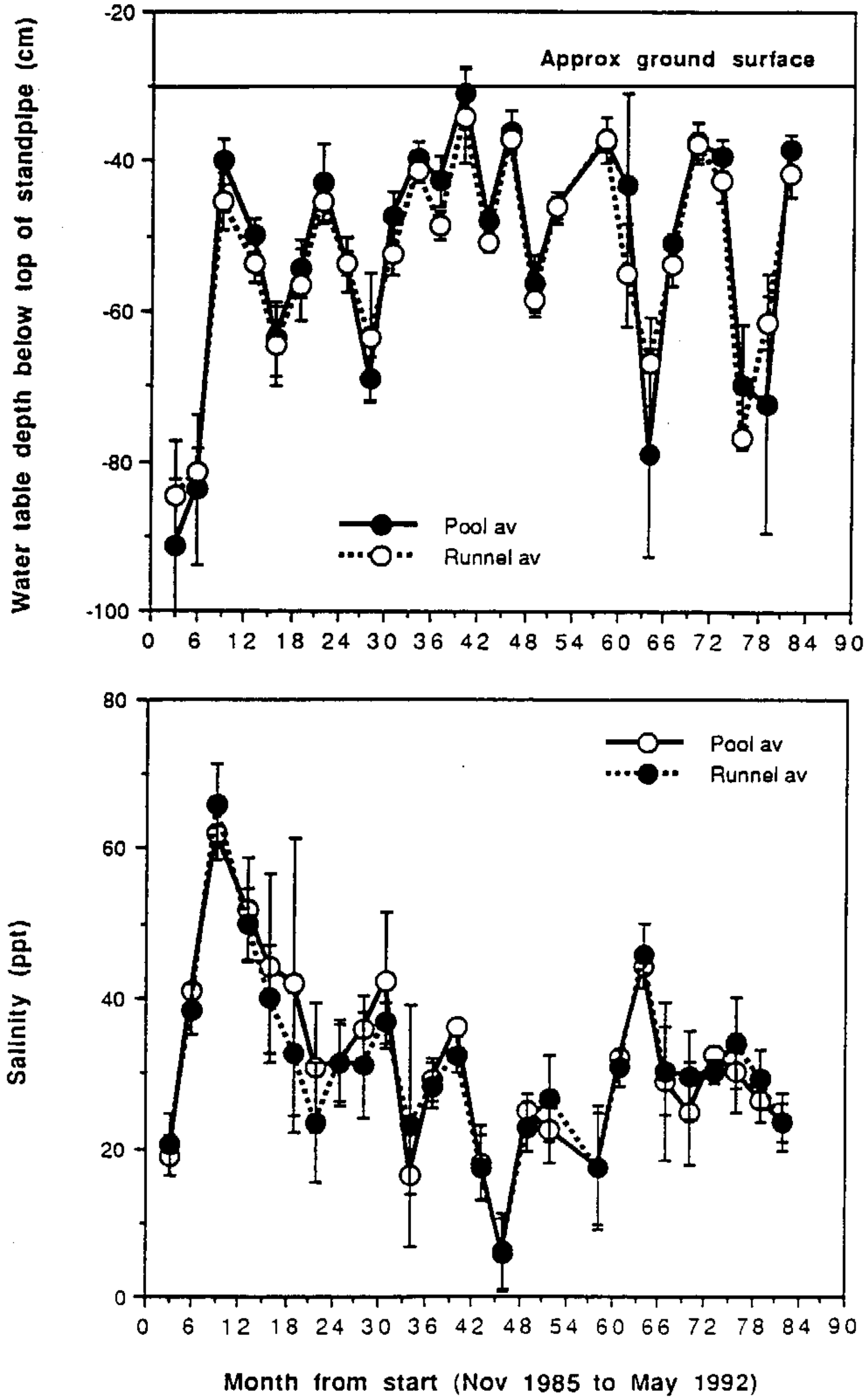

Figure 5 Water table depth and salinity near runnelled and unrunnelled sites at Coomera (Nov 1985 to May 1992).

of the marsh than in the surrounding area (Dale and Hulsman, unpublished data). The plant species composition has not changed, although the density of the grass *(Sporobolus virginicus,* Marine couch) has declined (Dale *et al.,* in press). This is not unexpected since this species is characteristic of the slightly drier, high marsh. Following the success of runnelling there are a growing number of projects in south east Queensland and in Western Australia (see Figure 3). Runnelling is also being considered in Victoria.

Recognising that legislative requirements are likely to become more stringent and that this could lead to permitting problems, careful records have been kept of the effects of runnelling on the environment. The likelihood of obtaining a permit to modify a wetland is related to the predicted impact the proposal may have. The better the knowledge base, the more informed is the decision of the permitting body. In Queensland, permits to interfere with intertidal lands are granted by the State Department of Primary Industries, under the Fisheries Act. This Department has followed closely the experimental runnelling project and, based on the observed impacts, appears to be favourably disposed towards the method, which provides increased access to the marshlands for predatory, and possibly commercially valuable, fish (Morton *et al.,* 1987). The Department of Environment and Heritage may also be involved in the permitting process, for example for proposals in Environmental or Marine Parks. To further facilitate both planning and permitting, draft guidelines have been developed based on the Massachusetts model for OMWM (Hruby and Montgomery, 1986). This specifies pre- and post- modification surveillance plus monitoring procedures and design parameters for an OMWM project. Proposals from agencies which conform to the guidelines are processed relatively rapidly (Montgomery, 1990, pers.comm.)

CONCLUSIONS

This overview raises some important issues. These include a concern over the reliance, in Australia, on chemical control and the role of government at all levels, particularly as it has implications for habitat modification. So far there has been little mosquito resistance to Abate, which is the most commonly used larvicide. Nevertheless, it is likely that there will be a resistance problem in the future and many managers are actively seeking biorationals which will have minimal impact on ecosystems, and particularly on non-target organisms, but which will also reduce pests to acceptable levels. This search must continue. Hand in hand with this goes habitat modification, particularly in areas suited to minimally intrusive methods such as runnelling. Given the increasing public and governmental concern about environmental degradation, mosquito managers are well advised to prepare strategies with this in mind. There is a need to balance the public health interests with those of the environment at large. The growing support for research which facilitates informed management decisions is to be commended, as is the increasing liaison between land use planners and mosquito managers and between local government areas. That much of this co-operation is relatively informal demonstrates a real commitment (often at individual manager level) to developing effective mosquito control. Finally, effective control of the pest should be achievable in an environmentally sustainable way by means of an integrated programme which addresses both mosquito and human breeding sites.

ACKNOWLEDGEMENT

I would like to thank the south east Queensland Local Authorities and their officers who have supported this project since 1980 and who continue to do so in many ways. Thanks go also to the many students who have assisted with the field work and to Griffith University for financial assistance from time to time. I also appreciate the helpful comments made by the reviewers.

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