Report to the Coordinator, Environmental Health Programme, Community Health, Healthcare Hawkes Bay.

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A health risk assessment for the establishment of the exotic mosquitoes *Aedes camptorhynchus* and *Culex australicus* in Napier, New Zealand.

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Summary: *Aedes camptorhynchus* is currently established in a limited region immediately north of Napier City and poses a primary hazard as a proven field vector for Ross River Virus (RR virus). Currently it is a secondary hazard to public health through nuisance biting activity. No evidence exists to suggest *Culex australicus* is present in the Hawkes Bay region. *Aedes camptorhynchus* is a brackish to saline preferring species in Australia but will readily colonise coastal and inland freshwater habitats. Assessment of habitat north of Napier to Pakuratahi Valley Road and south to Haumoana indicates *Aedes camptorhynchus* is likely to be able to spread beyond its current distribution on the Landcorp Farm.

Dispersal is most likely to be south, influenced by prevailing winds and the presence of more favourable breeding habitat, including saltmarsh (*Sarcocornia* spp.). Establishment of *Aedes camptorhynchus* in Clive and Haumoana is likely to result in further spread to human populations around Hastings and Havelock North. Present conditions in Napier will produce an increase in the area and range of habitats currently occupied by *Aedes camptorhynchus* with significant increases in adult biting activity likely to occur in the week beginning 25 January, 1999.

The current risk is an irreversible hazard to the Hawkes Bay region if *Aedes camptorhynchus* populations are left unchecked and allowed to consolidate and spread. At present, the secondary hazard (nuisance biting behaviour) is on-going. Future risk exists for the introduction and transmission of RR virus into Hawkes Bay leading to a "virgin soil" epidemic of RR virus disease. RR virus disease can be asymptomatic (particularly in children), clinical presentation is characterised by debilitating epidemic polyarthritis (EPA) that effects 20-30% of infected persons (usually young to middle aged adults) but can range from 1-50%. Sequelae can include fatigue and depression that may linger for years after infection. In Australia, significant under-reporting of RR virus cases means the magnitude of an epidemic of RR virus disease is likely to be several times higher than that recorded. RR virus is likely to be introduced into Hawkes Bay via viraemic individuals, most likely international tourists who have been in RR virus endemic regions of Australia or residents of Napier returning from holidays or work from RR virus endemic regions of Australia. Should a RR virus epidemic occur, a conservative estimate of the economic cost to the Hawkes Bay region alone is likely to be in the order of $230 thousand to $2.3 million per annum or more. This does not include the cost to the region should adverse publicity following an RR virus epidemic result in a downturn in income from tourism.

It is possible that *Aedes camptorhynchus* will spread outside the Hawkes Bay region. It is also possible that *Aedes camptorhynchus* has been introduced into Napier either via Air or Sea transport from Auckland. Given that Hawkes Bay airport is located in the centre of the mosquito breeding habitat, the likely scenario exists for mosquitoes to be spread, via air transport, to other parts of NZ.

Abbreviations used: BF – Barmah Forest virus, EPA – Epidemic Polyarthritis, HCHB – Healthcare Hawkes Bay, HIA – Health Impact Assessment, HRA – Health Risk Assessment, KUN – Kunjin virus, MVE – Murray Valley encephalitis virus, NCC – Napier City Council, RR – Ross River virus, SIN – Sindbis virus.

Scope of this Assessment. In general, a Health Impact Assessment (HIA) of a risk involves an *assessment* of a risk, *communication* of that risk to the community and *management* options for controlling or eliminating the risk. The scope of this document is solely an assessment of the risk, ie the central component of the HIA. While essentially a technical process, the subsequent risk communication, management and implementation components requires a greater degree of public input to formulate the most effective remedial strategy.

The Health Risk Assessment (HRA) is comprised of four important components:

1. An *identification of the hazard* from assessment of the available evidence on the presence of the hazard(s) that is(are) likely to cause adverse effects.
2. An *identification of the effects* the hazard.
3. An *assessment of the exposure* – estimating the magnitude, duration and frequency of human exposure to the hazard.
4. The *risk characterisation* is generated from a combination of information from the hazard identification and the exposure assessment to estimate risk associated with each scenario considered.

This HRA will address these four components at length and will make some recommendations for action in the final section.

Introduction

History

Immediately prior to Christmas 1998, Napier City Council (NCC) received complaints about unusual nuisance mosquito biting. Towards the end of the Christmas period, the NCC brought this information to the attention of the staff of the local public health service at Healthcare Hawkes Bay (HCHB).

Initial complaints originated from Bayview, a suburb approximately 6kms north of the Napier CDB and from Westshore, a suburb immediately north of the Napier CBD. Both suburbs are situated along State Highway 2 and are adjacent to expansive regions of ponded areas of saltmarsh (*Sarcocornia* spp.) along the coastal strip delimited by the main drainage of the Ahuriri estuary. During the week commencing 21 December 1998, HCHB staff collected adult and larval mosquitoes from habitat in areas surrounding the origin of the complaints.

During the week commencing 28 December 1998, specimens collected by HCHB were subsequently identified by entomologist Mr Gene Browne of Auckland University as *Aedes camptorhynchus*. These identifications have been subsequently confirmed by the author and Dr Richard Russell from the Department of Medical Entomology at the University of Sydney, NSW in Australia.

Original specimens caught were suspected to include a second exotic mosquito species, *Culex australicus,* not currently known to be present in New Zealand. Adult specimens sent to Dr Richard Russell prior to 13 January, 1998 were unable to be confirmed as *Culex australicus*.

Also during the week commencing 28 December 1998, a broad field survey was begun by HCHB staff to assess the extent of the current and potential breeding sites in the Napier region.

On 8 January 1999, HCHB contacted the author at the Department of Public Health, Wellington School of Medicine to request assistance in the compilation of a Health Risk Assessment of the impact of the mosquito introduction for the Napier-Hastings region.

On 13-14 January, 1999, the author visited Napier to assess the extent of the problem (to review current data with staff from HCHB, Napier City and Regional Councils, Department of Conservation and MAF Quarantine, to confirm mosquito identifications, inspect current and potential breeding sites and discuss likelihood of potential control strategies with HCHB staff). Information gathered during this visit form the basis of this document.

Hazard Identification

The mosquito specimens collected so far have been substantially identified as *Aedes (Ochlerotatus) camptorhynchus* (Thomson) 1869 by three entomologists; the author, Mr Gene Browne of Auckland University, and Dr Richard Russell from the Department of Medical Entomology at the University of Sydney.

A second exotic mosquito species, *Culex (Culex) australicus* Dobrotworsky and Drummond 1953, not currently known to be present in New Zealand was suspected from initial identifications. Specimens sent to Dr Richard Russell prior to 13 January, 1998 were unable to be confirmed. No individuals collected since and identified by the author have included *Culex australicus*.

This section is a review of these exotic mosquito species, their associated arboviruses and epidemiology of the diseases that have been attributed to them in the literature.

Mosquito Species

Aedes (Ochlerotatus) camptorhynchus

Aedes camptorhynchus is widely distributed on the Australian mainland from New South Wales, Victoria, Tasmania (including King and Flinders Islands), South Australia and Western Australia and is common in coastal areas in the southern and western parts of its range. It is generally regarded as a coastal, saltwater preferring species but can occur in riverine habitat inland wherever brackish water occurs, most notably the Mildura area situated approximately 360kms inland.

Aedes camptorhynchus can disperse widely from its breeding locations, usually with prevailing winds. Though no published information is available on dispersal, observations of adults collected away from breeding areas suggest that dispersal of up to 5kms is well within the capability of this species (MD.Lindsay personal communication).

Observations also suggest it will successfully breed in freshwater habitat (Liehne 1991, RC.Russell personal communication) for up to several seasons (MD.Lindsay personal communication).

As is typical for species of this genus, hatching conditions leading to a build-up of population numbers usually coincide with increased water levels in breeding habitat from tides or spring and early summer rains that flood desiccation resistant eggs laid on substrate (Russell 1998b).

In Australia, *Aedes camptorhynchus* activity can occur all year round but may be limited by lack of sufficient tidal ranges and low temperatures in the southern part of its distribution in Western Australia (MD.Lindsay, personal communication). Only a percentage of eggs hatch with initial flooding ("installment hatching"), the remainder hatching with subsequent flooding events. This strategy has evolved as a counter for the inherent uncertainty of breeding conditions and has implications for the control of populations when using larvicides. In the southern and western parts of its range, breeding is predominantly during the period March to December with a peak density occurring from June to August (Liehne 1991).

Autogenic production of eggs (after pupal emergence and before the first blood meal) by *Aedes vigilax* is widely known and is suspected also for *Aedes camptorhynchus* (P.Whelan, personal observations Busselton area, WA).

They are widely regarded as vicious biters, readily attacking humans and other animals including birds, during the day and evening.

Culex (Culex) australicus

Culex australicus is also widely distributed on the Australian mainland but generally below 17^{o}S, (Atherton and Normanton on Cape York Peninsula, north Queensland and to Beagle Bay in Western Australia). It has also been recorded from Tasmania and tentative, possibly erroneous records exist from regions in the South Pacific. The preferred location of this species varies widely but include areas of inland to coastal Australia subject to seasonally hot and dry conditions.

Larvae have been recorded from a wide range of habitat types, predominantly freshwater pools, also swamps and springs. In the southern and western part of its range, habitats include stagnant freshwater, brackish or saline swamps pools and creeks. Of note is the high productivity of contaminated irrigation channels such as those associated with piggery and treated sewage effluent but could certainly include areas of run-off from cattle or sheep grazing fields or feed-lots, and other animal grazing areas or industries with organic wastewater storage or dispersal facilities.

In Australia, adults are collected all year round except in the more southern parts of its range where it is likely to hibernate during the colder periods.

Culex australicus generally seeks shaded or underground shelter during the day. Biting activity peaks after dusk but it does not normally bite humans, preferring birds and rabbits and to a lesser extent smaller mammals such as sheep and dogs.

Associated Human Arboviruses

In Australia**,** *Aedes camptorhynchus* is a confirmed field vector for Ross River virus (Alphaviridae) (Ballard and Marshall 1986) and the principle vector in the southern mainland coast through Victoria and coastal regions in the south west of Western Australia (eg Lindsay *et al* 1992, Campbell *et al* 1989, Russell 1998a). Vertebrate hosts for RR virus include marsupials, predominantly the macropods and possums (Azuolas 1997), but also humans and domestic animals, including dogs, horses, cattle, pigs and fruit bats (Kay and Aaskov 1989, Ryan *et al* 1997)

Aedes camptorhynchus was also suspected as the main vector in an outbreak of Barmah Forest virus (BF virus) (Alphaviridae) disease in the Peel region of southwest Western Australia (Lindsay *et al* 1995b). Isolates were detected in adults trapped before and during the outbreak and evidence suggests it may not be as efficient a vector for BF virus as it is for RR virus (Lindsay *et al* 1995a).

Though studies (see Lee *et al* 1984) originally implicated *Aedes camptorhynchus* as a possible field vector for Murray Valley encephalitis virus or MVE (Flaviviridae) in Australia, recent comprehensive reviews of the disease in Australia do not mention it (MacKenzie *et al* 1994, Russell 1998b) most likely because of the absence of MVE in southeastern Australia since 1974. Sindbis (SIN) (Alphaviridae) and Kokobera (KOK) (Flaviviridae) viruses have also been isolated from *Aedes camptorhynchus* (Russell 1998b)

RR virus has been isolated from *Culex australicus* (Lindsay *et al* 1992) but it is unlikely this species is and important vector in the region from which the infected specimen was collected.

In Australia, *Culex australicus* has been shown experimentally to be capable of carrying MVE but as yet no substantial proof exists to demonstrate its importance as a field vector. MVE was isolated from field caught specimens in the Murray Valley during the February 1974 epidemic of Australian Encephalitis (Marshall *et al* 1982). It is suggested that *Culex australicus* may play an important role as an initial amplifier of annual MVE virus cycles (most likely in bird populations) prior to epidemics.

Other virus isolates from this species include Kunjin (KUN) (Flaviviridae) (Marshall 1979) and SIN (Marshall *et al* 1982) but no studies have confirmed its vector status.

Health Effects of Hazard

Aedes camptorhynchus has been defined as an efficient field vector of RR virus, while being implicated to transmission of BF virus disease (a disease clinically similar to RR virus). Evidence for transmission of MVE is poor due mainly to the lack of opportunity to investigate vector competence.

Adult mosquito specimens caught in Napier in early January 1999 were suspected to include a female *Culex australicus* but so far this identification has not been confirmed. It is most likely that the specimen was either a native species, *Culex pervigilans* Bergroth, or *Culex quinquefasciatus* Say, a species probably introduced into New Zealand from Australia prior to 1850 (Weinstein *et al* 1997). Morphologically, *Culex quinquefasciatus* is a very similar species and confirmation of *Culex australicus* would be best achieved from larval specimens. So far none have been found.

Given the unlikely threat of MVE, the remainder of this report will only consider *Aedes camptorhynchus*. This section will cover health effects of Ross River virus only. Reviews covering the effects and epidemiology of MVE, SIN, BF and KUN can be found in Boughton (1996) and Mackenzie *et al* (1994).

Table 1. RRV cases by state[a] and annual totals in Australia reported from 1991 to 1997. (from Russell 1998b, data from National Notifiable Diseases Surveillance System)

Year	ACT	NSW	NT	QLD	SA	VIC	WA	TAS	Total
1997	9	1,588	219	2,373	632	1,000	673	12	6,506
1996	1	1,041	131	4,935	25	138	1,478	74	7,823
1995	2	242	369	1,681	23	35	302	28	2,682
1994	1	317	309	3,035	26	58	95	N/A	3,841
1993	4	596	264	2,367	774	1,198	153	N/A	5,356
1992	1	317	238	4,280	106	162	687	N/A	5,791
1991	[b]N/A	402	482	1,954	N/A	390	192	N/A	3,420

[a]ACT–Australian Capital Territory, NSW–New South Wales, NT–Northern Territory, QLD–Queensland, SA–South Australia, VIC–Victoria, WA–Western Australia, Tas–Tasmania.
[b] N/A–data on Ross River virus infection not available or not separated from "arbovirus infection" data.

Distribution and Occurrence of Ross River Virus (Alphaviridae)

Of the four Australian alphaviruses, Ross River (RR), Barmah Forest (BF) and Sindbis (SIN) are known to be pathogenic; RR virus is the most prevalent of these.

RR virus was first isolated by Doherty *et al*. (1963) from collections of *Aedes (Ochlerotatus) vigilax* (Skuse) in Townsville, north Queensland. The first recorded outbreak of probable RR virus occurred in 1886 in Victoria and by the 1940's reports indicated that the disease had occurred in the Northern Territory, Queensland, the Murray Valley and South Australia (Boughton, 1996).

Table 1 is a summary of RR virus cases in Australia from 1991 to 1997. Over 35,000 cases have occurred in the last seven years but because many cases of infection do not show clinical symptoms (Boughton 1996) and due to under-reporting of cases to the National Notifiable Diseases Surveillance System (Hargreaves and Hall 1992), the real numbers are undoubtedly many times greater. In addition, improved surveillance in recent years is indicating that arboviral illnesses and RR virus in particular are significant and increasing public health problems (Boughton 1996).

RR virus appears to be enzootic throughout mainland Australia and Tasmania, Papua New Guinea, the Solomon Islands and parts Irian Jaya (Tesh *et al* 1975, Mackenzie *et al* 1994). In Australia, infections occur at any time of the year in northern Australia but predominate in the summer wet season. In southern regions, infections appear every summer but may occur at any time if conditions are suitable, usually associated with rain and/or tidal inundation of coastal marshes during the warmer seasons when vectors are most active (Russell 1995).

Lindsay *et al.* (1993) demonstrated that it is likely that several different genetic types of RR virus predominate in different regions supporting the idea that RR virus is associated with relatively immobile mammal hosts. The simultaneous appearance of RR virus outbreaks in geographically isolated areas seems to suggest persistence of the virus in the environment.

There is little doubt that transovarial transmission by *Aedes* spp., including *Aedes camptorhynchus* (Dhileepan et al. 1996), occurs at the beginning of the season prior to the seasonal peak of RR virus activity (Russell 1994).

Transmission of Ross River Virus

As stated previously, RR virus circulates enzootically between mosquitoes and reservoir populations of non-human hosts). Infection of these natural hosts is usually asymptomatic and leads to long-term immunity, but while they are viraemic, host animals can infect mosquitoes that feed upon them. In susceptible species of mosquitoes, virus particles infect the gut lining, from which the haemolymph and, ultimately, the salivary glands are also infected. After a variable period of time (the extrinsic incubation period), virus particles replicate to the point where the mosquito's saliva is infective to the mosquito's next non-immune vertebrate host.

The viral lifecycle is unobtrusively completed if the next host is a member of the reservoir population. However, if a human is bitten instead, clinical disease may result.

Outbreak Ecology of Ross River Virus

Transmission of RR virus from the enzootic cycle into the human population requires the presence of four elements before the likelihood of an epidemic dramatically increases. These are the virus, its mosquito vector, a susceptible human population and suitable climatic conditions.

The virus and its reservoir: As we have seen, the virus is dependent on the continuing presence of non-immune hosts in the reservoir population. The distribution and abundance of the reservoir population will thus affect the availability of viremic individuals to mosquitoes and young (non-immune) reservoir populations leads to increased virus activity.

The vector: A number of vector-related factors also influence the level of RR virus activity in a given area. Susceptibility (the ease with which the virus infects and replicates to infective levels in the mosquito) differs between species, as does the degree of host specificity. *Aedes camptorhynchus* are efficient vectors of the disease both because of their susceptibility to the virus and the readiness with which they bite reservoir as well as human hosts. The age and abundance of mosquitoes affects their ability to transmit the virus; older female mosquitoes are more likely to seek the protein of a second or subsequent blood meal to mature additional eggs and are thus more likely to bite after completion of the extrinsic incubation period of the virus. The greater the abundance of mosquitoes, the greater the probability of being bitten and the greater the probability that the mosquito population will include old females that have bitten both a reservoir host and a human.

The human population: The human population is susceptible to RR virus infection if individuals are non-immune and are exposed to the virus at the reservoir-mosquito-human interface. Such exposure is enhanced by human intrusions into native ecosystems by the expansion of agriculture, forestry, tourism, or similar activities. Human awareness of the disease, with use of appropriate anti-mosquito measures, has been shown to reduce the probability of infection (Weinstein and Cameron 1991). Humans are also capable of acting as hosts during transmission cycles in urban areas (Kay and Aaskov 1989)

The climate: Andrewartha and Birch (1954) identified temperature and water availability as important determinants of the abundance and distribution of animals, mosquitoes being no exception. At higher temperatures, mosquito larvae complete their development faster, allowing more generations to fit into a finite period; given that larvae are aquatic, they obviously also require water. Further, and important in this context, the extrinsic incubation period is decreased at higher temperatures and high relative humidities increase the proportion of old mosquitoes in the population (in low relative humidities, the high surface area to volume ratio of adult mosquitoes renders them susceptible to death through desiccation). Thus, climate directly affects not only the abundance of reservoir mosquitoes but also the potential for virus activity. The reservoir population and virus activity therein are also affected by climate. In seasons with high temperatures and rainfall, the vegetation upon which animal hosts depend will flourish, and more young (non-immune) reservoir hosts will be added to the temporally and spatially expanding population. Clearly climate also affects the nature and extent of human activity outdoors, completing the final link in the ecological chain of interaction between the components of the cycle that has been discussed. Where this chain of interactions remains complete and the cycle is continuous, we have an area endemic for RR virus disease in humans.

Diseases caused by Ross River Virus

Epidemiology: Several authors (Marshall and Miles 1984, Kay and Aaskov 1989, Russell 1998b) have reviewed epidemiological knowledge of the disease. Incidence has been estimated at 5 to 10 times the reporting rate (Mudge and Aaskov 1983, Curran *et al* 1997). Two points are of major importance. First, the disease demonstrates a tropical pattern (endemic, averaging about 300 notifications per 100,000 people) and a temperate pattern (epidemic, averaging less than 10 cases per 100,000 in non-epidemic years) (Weinstein 1995). In Australia during 1996, for example, the average national notification rate in Australia was 42.7 per 100,000 population but ranged from 258.4 to 339.7 per 100,000 population in divisions of Queensland (Curran *et al* 1997). Second, the age distribution of cases peaks among young and middle-aged adults, presumably reflecting the extent to which these groups are exposed to mosquitoes during outdoor activities. Clinical disease is relatively uncommon in children (Boughton 1996). Children are infected, but for immunological reasons that remain ill understood, symptomatic disease rarely develops before the teenage years. Complete recovery occurs in all cases and infection results in long lasting immunity. Ratios of clinical to sub-clinical infection may be between 1:2 (Hawkes *et al* 1985) and 1:80 (Aaskov *et al* 1981b)

Clinical Features: The predominant clinical presentation for RR virus disease is epidemic polyarthritis, or EPA. At least 20% of infected individuals develop an acute disease (Fraser and Marshall, 1989). Symptoms include extensive polyarthritis and the sudden onset of an acute aching in the muscles and joints (by far the most common symptoms) headaches, a maculopapular rash (in between 40 and 78% of patients) most commonly on the trunk and limbs but may also occur on the face and limbs. This effects chiefly the knees, ankles, wrists and fingers and extremities of the limbs (Mudge and Aaskov 1983). The intrinsic incubation periods range from 3 to 9 days but can be up to 21 days (Boughton 1996).

Most symptoms may settle in a few days but the effects of the polyarthritis may incapacitate an adult for 5-6 weeks. Recovery may take longer and nearly 25% of cases will have joint symptoms after a year or more. In one study (Seldon and Cameron 1996), over of patients still had joint pain and 45% had persistent tiredness and lethargy 15 months after original infection. Common symptoms 30 months after infection included myalgia, lymphadenopathy, headache and depression.

Relapses of arthritis and fatigue may occur after initial recovery (Condon and Rouse 1995). A chronic fatigue-type syndrome that may persist for several years occurs in about 10% of patients (Boughton 1996).

Because symptoms are non-specific, diagnosis usually relies on serological evidence of IgM antibodies to RR virus (presumptive case) or a fourfold rise in antibody titre between acute and convalescent sera (confirmed case) (MacKenzie et al. 1993).

Summary of Hazard

Aedes camptorhynchus is of concern as a vicious biting pest, capable of establishing persistent populations and engaging in year round interruption of outdoor activities, and causing irritations due to biting. In this capacity it is considered a secondary hazard but a significant nuisance.

Culex australicus is not considered to be a nuisance in this regard.

As a vector known to be capable of local transmission of RR virus and implicated in a number of outbreaks in Australia, *Aedes camptorhynchus* is considered to be a primary hazard to public health. Establishment of the mosquito in any new region with or without an appropriate animal reservoir population, but with a concomitant introduction of RR virus would lead to two possible scenarios:

The first would involve a summer epidemic with pre-amplification of virus, an explosive outbreak, with following burn out and elimination of the virus. The result would be similar to cases recorded in Pacific Island regions (see Marshall and Miles 1984, Kay and Aaskov 1989) where almost completely susceptible resident populations experienced "virgin soil" outbreaks. The magnitude of these epidemics (while not predictable) are pronounced when compared with outbreaks in RR virus endemic regions where moderate levels of immunity in the human population tend to dampen peak disease activity.

The second scenario would be endemic establishment where virus establishes in sylvan and/or domestic host populations (possums, dogs, pigs, deer, other domestic stock, and horses) where seasonal amplification may occur. Transfer to human population then becomes seasonal with a concomitant increase in the activity of the vector population and incubation of the disease.

Exposure Assessment

Status as of 17 January, 1999

As a result of the introduction of *Aedes camptorhynchus*, Napier City faces two potential hazards to public health.

Firstly, *Aedes camptorhynchus* is of concern as a vector known to be capable of local transmission of RR virus and implicated in a number of outbreaks in Australia, *Aedes camptorhynchus* is considered to be a primary hazard to public health. In Napier at present, all conditions necessary for an epidemic of Ross River virus disease exist except the presence of the virus and, though not entirely necessary, a confirmed animal reservoir population. These conditions include a susceptible population with no acquired immunity to the virus, a competent mosquito vector, an environment capable of supporting all requirements for breeding of the vector, and a climate suitable for replication and transmission of the virus.

Secondly, *Aedes camptorhynchus* is a vicious biting pest, capable of year round interruption of outdoor activities, and causing irritations due to biting. In this capacity it is considered a secondary hazard relative to its capacity to transmit arboviral disease. Should populations increase in Napier to levels that are characteristic in its endemic Australian range, there is little doubt it will become a significant nuisance.

There is increasing circumstantial evidence that viraemic humans may be capable of infecting mosquitoes that feed on them. This was first suspected in the South Pacific outbreaks, but a considerable amount of circumstantial evidence is accumulating on mainland Australia, particularly in urban areas. Thus, some RR virus activity might be possible in the absence of any other suitable host, if the virus is introduced and large populations are regularly feeding on humans. This mechanism is hypothesised to have operated during major outbreaks that have occurred in southwestern Australia (MD.Lindsay personal communication).

Extent of Current Mosquito Habitat and Distribution

The current distribution of *Aedes camptorhynchus* in the Napier District is limited to a small, well-defined geographical area north of Napier City but the potential for dispersal in the near future is increasing.

Mosquito sampling conducted prior to and including the week commencing 11 January 1999 has determined that adults and larvae of *Aedes camptorhynchus* currently exist in the coastal region bounded by the Ahuriri Estuary to the south and the Main Outfall Channel to the west (known as the "Landcorp Farm"). A further area to the south of the Estuary (known as the "Council Farm") is situated adjacent to the suburb of Tamatea, well within the influence of breeding habitat on the Landcorp Farm. The majority of complaints concerning mosquito biting have originated from Westshore and Bayview the suburbs adjoining the Landcorp Farm.

The Landcorp Farm area is flat and covers a total area of approximately 18kms^2. The suburb of Bayview is situated 1km to the north while Westshore to the east and Poraiti to the west. It is comprised of large shallow depressions with two distinct regions of *Sarcocornia* spp. dominated saltmarsh, of approximately 1-2 kms^2 in total area, within the boundary. Approximately 10-20kms of drainage channels of variable width run through and around the area. These contain stagnant ponded water and include a series of channels that drain the saltmarsh, the peripheral ditch surrounding the farm and two water-filled channels about 2m wide that run the entire length of either side of the main runway at Hawkes Bay Airport.

While the *Sarcocornia* habitats are not open to tidal influence from adjacent coastal marine habitat, they are rain-filled and also drain the surrounding areas of grass dominated land. The ponded water within is brackish to saline. Spot sampling of salinity in the peripheral drainage channels that surround the region recorded salinities on the order of 33 to 35% of full seawater (approximately 12ppt).

This Landcorp Farm region also includes the Department of Conservation controlled wildlife refuge adjacent to the suburb of Westshore. This area contains ponded habitat under a salinity influence (sourced from marine seepage) and is highly likely to contain suitable habitat.

In addition, the margins of the Main Outfall Channel which run some 9.5kms downstream to the region on main tidal influence in the Ahuriri Estuary are also dominated by shallow margins vegetated by *Sarcocornia*. Vegetation bands in this area are in the order of 10 to 500m wide along the outer (western) margin of the Channel.

South of the Main Outfall Channel and the Ahuriri Estuary is an area of lands approximately 4km^2 controlled by the Napier City Council (the "Council Farm"). This region is similar to the non-saltmarsh areas of the Landcorp Farm and is bounded to the east and south by Saltwater Creek. Tamatea and Pirimai suburbs are situated to the south of the Council Farm. Running south through these two suburbs is Purimu Stream, which drains the southern area of marsh below the Estuary. Also draining this area is the Tannery Stream running south between the suburbs of Pirimai and Onekawa.

Extent of Potential Mosquito Habitat

Aedes camptorhynchus, while currently limited to the regions outlined above, is highly likely to disperse south to additional habitats. This premise is based on two important considerations. Firstly, in its native Australian range *Aedes camptorhynchus* has been observed to colonise freshwater habitats in the absence of the more preferred brackish to saline habitats. So the potential exists for it to occupy any area of fresh, brackish or saline water with suitable vegetation, water level fluctuations and without resident potential predator populations (ie, fish such as *Gambusia* spp.) in the Napier region. Secondly, while the exact dispersal capabilities of *Aedes camptorhynchus* are not fully known, observations have confirmed that distances of up to 5kms are within the flight range capability of host-seeking adults. Wind assisted dispersal (common in *Aedes* spp in Australia) may well increase this range.

Given these facts, regions exist south of Napier City that is potential breeding sites for *Aedes camptorhynchus*. The Tutakuri, Ngaruroro and Clive Rivers all converge on the coastal strip in a large ponded estuary near the north and south sections of the Waitangi Bridge. Dispersal to this area from its current distribution is perhaps the largest "step" for *Aedes camptorhynchus* adults but well shaded, predator free habitat situated in the Purimu and Tannery Streams or via Serpentine south of Maraenui have the potential to assist the movement.

Directly to the south of this region is the Clive River foreshore and the region around the sewage pumping station at the end of Richmond Road. The Clive River foreshore contains habitat that appears to be suitable (only sighted from the air) but the ponded

Figure 1. Map of Napier and suburbs showing the Landcorp and Council Farm areas.

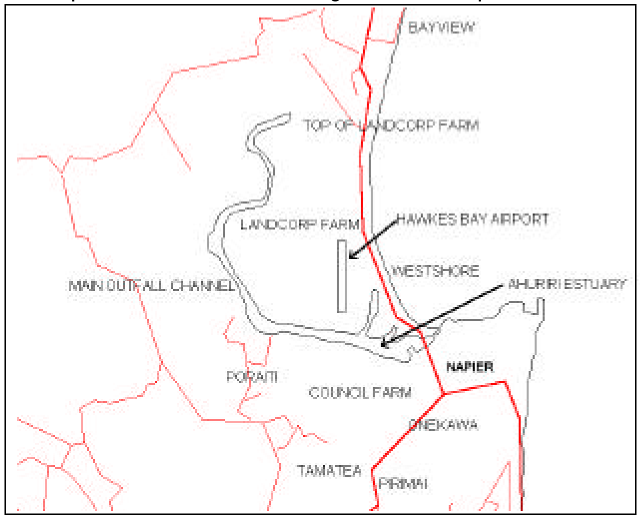


Figure 2. Region south of Napier to the Tukituki River mouth and Haumoana.

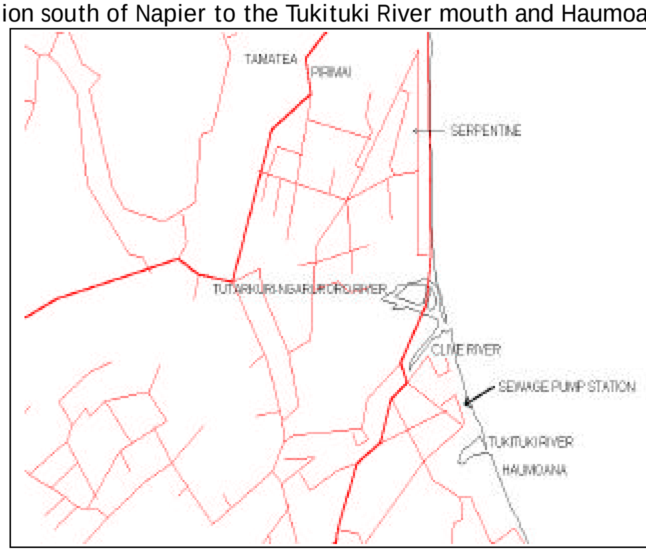
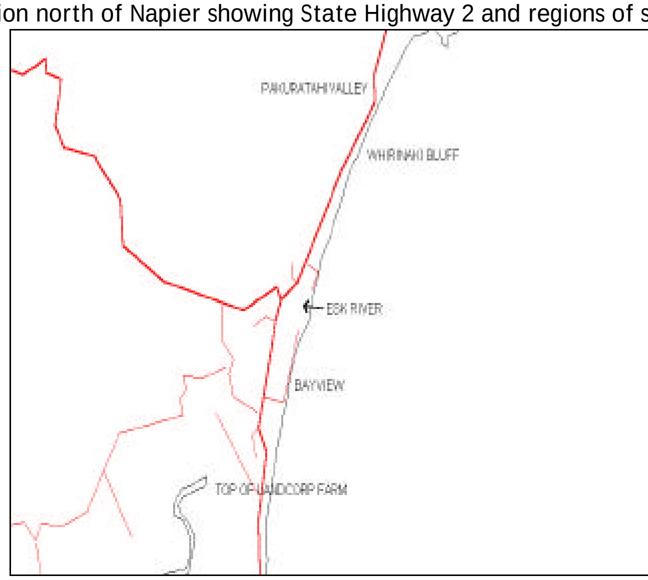


Figure 3 – Region north of Napier showing State Highway 2 and regions of suitable habitat.



habitat behind the coastal berm at the pumping station is *Sarcocornia* spp. saltmarsh very similar to that which *Aedes camptorhynchus* currently occupies on the Landcorp Farm. Less than 1km south is the Tukituki River mouth and a region of ponded swamp on the northern margin of Haumoana. Given that breeding establishes in this region, wind-assisted dispersal of host-seeking adults to Hastings and Havelock North or via breeding in ponded habitats along the margins of the Clive and Tukituki Rivers is possible.

Dispersal north of Landcorp Farm is likely to be limited by the absence of any significant areas of saltmarsh habitat but the potential exists for colonisation of freshwater habitats. Of these, the most likely habitats to support breeding include the saline and brackish extent of the Esk River mouth, effluent ponds of the Whirinaki Pan Pac pulp and timber mill, ponds along the foreshore of Whirinaki Bluff and ponded sections of streams in the Pukuratahi River Valley. Of these, the ponds at Whirinaki Bluff may be influenced by seawater intrusion.

Current Climate and Outlook

Although the Hawkes Bay District has been influenced by prevailing dry conditions, the current outlook is for periods of increasing rainfall. Observations by Heathcare Hawkes Bay staff indicate that breeding habitat on Landcorp Farm had diminished and population numbers of biting *Aedes camptorhynchus* adults had decreased considerably since the initial period of peak biting activity prior to Christmas. However after significant rainfall on the 17 of January this habitat is now suitable for the hatching of previously laid eggs.

In the period from Christmas to the present, *Aedes camptorhynchus* adults that fed during biting activity will have laid eggs in suitable habitat adjacent to where biting occurred. This may have lead to an increase in the range it occupied up to the last rainfall period prior to Christmas.

Current rainfall (as of 17 January 1999) is re-filling breeding habitat. This will create conditions ideal for hatching eggs (laid above water levels at the time of oviposition) and lead to a subsequent increase in population numbers.

Prevailing winds during the Christmas period were predominantly northerly to northwesterly and easterly. This would explain why the majority of complaints of mosquito biting away from the breeding areas occurred south (Poraiti). Given that these wind conditions prevail and that the current rains appear to be sufficient to rear the next generation of adults, it is expected that in the absence of any larval control, nuisance biting activity will peak again by the end of January 1999. While dispersal north of the currently occupied region is possible, dispersal south is more likely and of most concern as it will result in the majority of the Napier City population being exposed to biting.

It is difficult to predict how long it will take for *Aedes camptorhynchus* to disperse south to Clive and Haumoana. However it is more pertinent to state that the probability it will do so increases with establishment of stable populations of *Aedes camptorhynchus* numbers to the north and south of Napier City.

Given that breeding sites are currently limited, it would be more than reasonable to suggest an attempt at eradication might be successful and timely. The costs and risks of any eradication are likely to increase with any geographical spread so this is likely to be the best opportunity to attempt an eradication programme that New Zealand will have. Larvae under present conditions would be expected to complete development to pupal stages by the week beginning 25 January, 1999 and significant increases in adult populations would be expected soon after. Larviciding habitats prior to pupal development would help suppress adult population numbers, reduce biting, thereby reducing the overall risk of arbovirus introduction or transmission should viraemic individuals be present. In addition, the distribution of domestic stock[1] (horses, pigs, cattle, sheep), possums and perhaps birds[2] should be subject to a serological survey to determine if, or to what extent, Ross River virus exists in the region. Human surveillance should also be a considered option for reasons outlined above (see: Status as of 17th January).

Control/eradication options should be reviewed in the short term by agencies experienced in the management of saltmarsh mosquito species (such as those for *Aedes vigilax* in Queensland and the Northern Territory[3] and those for *Aedes camptorhynchus* in Western Australia[4]. As an additional precaution should some breeding habitats be missed with the initial larviciding, and given *Aedes camptorhynchus'* catholic preference for breeding habitat and relatively long dispersal ranges, it may also be sensible to establish a series of adult surveillance sites to act as sentinel sites at the limits of the expected distribution. Additional sites established south of breeding habitat on Landcorp Farm would help monitor the success of larvidicing activity.

As a final point for this section, the capacity for spread of *Aedes camptorhynchus* and its role as a vector should not be underestimated by any of the stakeholders involved in this issue. Cases of imported Dengue regularly occur in New Zealand (Marshall and Miles 1984). Recently, over 30 cases of imported Dengue fever have been reported in the New Zealand since 1996[5] but so far epidemics in NZ have not occurred due to

[1] A study by Lindsay (unpublished data) of blood-fed *Aedes camptorhynchus* found that of 646 mosquitoes, 38.7% had fed on cattle, 25.5% on horses and 19.5% on marsupials.

[2] Chickens are not usually recommended for serosurveillance in Australia as they do not reliably seroconvert for RR virus (RC.Russell & MD.Lindsay, personal communications).

[3] Darryl McGinn, Brisbane City Council, Queensland; Peter Whelan, Territory Health Services, Darwin, NT.

[4] Tony Wright and Sue Harrington, WA Health Department, Perth, Western Australia.

[5] Ministry of Health, National Surveillance Data (C.Skelly personal communication).

the absence of a competent vector. The introduction of arboviral disease into New Zealand, a primary Biosecurity issue, has a certain probability if all the conditions are in place for it to spread on introduction into New Zealand. With Ross River virus disease that probability has risen significantly with the presence of a proven temperate climate vector (southern Australia) capable of persisting in large numbers into the warmest months of the year.

Risk Characterisation for the Hawkes Bay Region

In his review New Zealand's Programme for Exclusion and Surveillance of Exotic Mosquitoes of Public Health Significance, Kay (1997) pointed out that colonisation of North Island intertidal zones by Australian coastal species were a cause for concern, particularly *Aedes camptorhynchus* because of its predominantly southern distribution in Australia. This concern has been realised and it is clear that this species has established in the Hawkes Bay region. Although initial breeding sites were limited to a region of 2 to 18km^2, the potential exists for immediate spread north of Napier to Pakuratahi Valley Road and south to Haumoana. Current rainfall in the region (as of 18 January 1999) coupled with *Aedes camptorhynchus*' capability to establish in freshwater habitats (RC Russell, personal communication) has made this even more likely.

Larval surveys to date by HCHB staff has not fully covered the extent of breeding habitat in Napier due mainly to the short time since discovery and limited resources. The absence of an experienced medical entomologist on site has resulted in further delays awaiting identification of adult and larval specimens[6]. Surveys of potential habitat through the entire coastal region north and south of Napier are planned to begin immediately, ie. 19 January 1999 (S.Garner, personal communication) and should determine the true extent of *Aedes camptorhynchus* distribution.

Of concern also is the possibility that another exotic species *Aedes (Finlaya) notoscriptus* (Skuse) 1889, already established in New Zealand and present in Napier, has shown laboratory competence for transmission of RR virus in Queensland (Doggett and Russell 1997) and may play a role in augmenting local urban transmission in susceptible areas initiated by *Aedes camptorhynchus*. It may be useful to revisit studies that have cast doubt on the vector competence of New Zealand strains of *Aedes notoscriptus* (Maguire 1994).

In terms of risk to the Hawkes Bay region, any long-term establishment of *Aedes camptorhynchus* in Napier represents an irreversible hazard with significant consequences – allowing circumstances for amplification of an introduced arbovirus (most probably RR virus from viraemic tourists) and the occurrence of large "virgin soil" epidemics of the type seen in Fiji, Western Samoa and the Cook Islands in 1979 (Aaskov *et al* 1981a, Marshall and Miles 1984).

The origin of viraemic individuals entering New Zealand is most likely to be Australia where RR virus is endemic and widespread. Viraemia usually starts before symptoms occur and can last from 1 to 6 days, usually dropping 2 to 3 days after the onset of symptoms (Kay and Aaskov 1989). However, as discussed, the incubation period will be in the order of 3 to 21 days, with an average of 7 to 9 days. As discussed by Kay (1997) this is well within the time taken for tourists to travel to New Zealand via international air-travel and either arrive at or pass through Napier. A route for transmission from endemic areas to New Zealand is thus highly probable.

In 1991, the National Health and Medical Research Council of Australia proposed that the economic cost of RR virus was approximately AUD$2,500 per case (Russell 1998b) when considering the cost of attending a medical practitioner, diagnostic testing, treatment with medications and time off work. Without accounting for indexing of the dollar from 1991 to 1999, this represents a cost of approximately NZ$2,900 per case (based on the current exchange rate of approximately $0.85). The resident population of the Hawkes Bay region at the time of the 1996 census was 239,500 people (Statistics NZ data). Given that NZ may experience the temperate pattern of RR virus infection seen in southern Australia (Weinstein 1997), non-epidemic rates of notification may be expected in the order of 10 cases per 100,000 population and up to 100 cases per 100,000 during epidemics (it is likely to be higher than this until natural population immunity increases). This translates to a cost in the range of $70,000 to $700,000 per annum for the Hawkes Bay region for treatment of the disease. If notifications represent 30% of actual cases (a conservative estimate), these costs increase to $233,000 to $2,330,000 per annum without accounting for the additional costs required to control mosquito populations and the economic injury to the tourism image of Hawkes Bay.

For Napier, the establishment *of Aedes camptorhynchus* is a local issue but with spread through the Hawkes Bay area, it becomes a regional issue, with concern focused on abatement or elimination of a nuisance pest and potential vector of arboviral disease. However, it should also be seen as a national one, with longer term potential for colonisation by *Aedes camptorhynchus* in suitable habitats present from the Coromandel

[6] Specimens brought in by the public for identification by HCHB staff have included termites, mayflies, stoneflies, various wasps, and ceratopogonids. Many larval specimens believed to be mosquito larvae were not.

Peninsula up to Northland (as suggested by Kay 1997). It should be considered that although dispersal over these types of distances (270kms from Napier along the coast to the tip of the Peninsula) may seem, at first glance, to be unlikely, dispersal of distances greater than this have occurred in Australia (eg Mildura, see Lee *et al.* 1984). Indeed, few expected the jump from Australia to Napier. So, for these reasons alone, the possibility of the spread of *Aedes camptorhynchus* to other parts of New Zealand (notably Auckland and Northland) should also be considered likely.

Finally, and in relation to what has just been discussed above, the route of introduction of *Aedes camptorhynchus* into Napier should be considered especially if mechanisms are to be put into place to prevent any further introductions by this or similar species. While evidence based on the extent of the current distribution strongly suggests that the Hawkes Bay airport was the original source, it is also likely these populations originated from individuals dispersing from the adjacent seaport.

Given the current practice of aircraft disinsection for all international flights arriving in NZ, introduction into the country via air traffic seems unlikely unless there has been a partial breakdown in disinsection procedures or arrivals of non-disinsected flights. However, two alternative (and highly speculative) scenarios are considered possible. Firstly, introduction to Auckland by container ship traffic, establishment and later spread to Napier, also via container ship on a different journey (it is also possible that mosquitoes arrived in Napier on the same journey but via the first port-of-call). Secondly, introduction to Auckland via container ship traffic, establishment and subsequent spread to Napier via air traffic.

Napier seaport receives approximately 600 vessels via Australia a year (MAF Quarantine statistics). Of these, all make their first port-of-call in NZ at the major shipping ports, predominantly Auckland and Wellington before continuing onto Napier. A proportion of these vessels use “soft-top” containers which are covered by tarpaulins. Prior to departing Australia, these would be capable of collecting enough water to encourage oviposition by *Aedes camptorhynchus* and subsequently allow larval development. MAF Quarantine officials do not inspect these tarpaulin covers. Depending on the timing of the journey and the larval period (anywhere from 10 to 20 days depending on temperature and available nutrients) it is conceivable that adults have either been introduced to Auckland or directly into Napier by a second port-of-call ship. Introduction into Wellington is very unlikely due to the absence of any suitable habitat surrounding the port.

Further consideration should also be given to the possibility of spread to other parts of the North or South Island via domestic air traffic directly from Napier (which is not subject to disinsection). This method of dispersal is highly likely given the Hawkes Bay Airport is situated in the middle of the largest mosquito populations in the region and that adult mosquito biting rates in early morning periods, eg, in the week 18 to 22 January 1999 were very high (in the order of 20-30 bites per minute, personal observations).

Regardless of the specifics of the introduction, the possibility of the presence of *Aedes camptorhynchus* in other regions of NZ, especially the North Island, should be considered in any national response.

Recommendations for Action

1. An immediate survey, subsequent to the significant rain on 17 January 1999 of all identified breeding habitat north and south of Napier to establish the full extent of the current distribution *of Aedes camptorhynchus*.
2. No evidence exists to suggest *Culex australicus* is present in the Hawkes Bay region, however person(s) identifying larval specimens should be aware of the possibility of their existence.
3. Initiate measures to treat current breeding habitat (determined by delimiting survey) with larvicides given current conditions are favourable to larval development.
4. Other options include introducing habitat modification to drain breeding sites before larval development can complete, introducing predatory fish to all local habitats capable of supporting larvae and burning across any established breeding sites that have no environmental significance to reduce the number of desiccation-resistant eggs (see Whittle *et al* 1993)
5. Establishing an adult surveillance programmes at the extent of the suspected limits of the potential distribution (Pakuratahi Valley and Haumoana) to act as sentinel sites for dispersal of adults, using sites on Landcorp Farm as a baseline.
6. Establish serological surveillance of likely vertebrate hosts for RR virus in the Hawkes Bay region, including the screening of human sera via the blood bank or health clinics (see Weinstein *et al* 1993)
7. Reconsider an important recommendation proposed by Kay (1997) to assess the status of the Brush-tailed possum (*Trichosurus vulpecula*) as a potential vertebrate host of RR virus and BF virus.
8. Procure the services of a trained mosquito taxonomist to be situated in Hawkes Bay either in the short term or for the duration of the management period. This person could provide on the spot identification of adult and larval specimens and specialist training for

public health unit staff in identification and mosquito surveillance techniques.

9. Immediate assessment by public health units of the status of *Aedes camptorhynchus'* presence in Auckland and Christchurch in particular, but also including regions capable of sustaining colonisation by this species.
10. Formation of a Technical Advisory Group (in process) to consider the content of this Risk Assessment for the next step in the Health Impact Assessment – namely Risk Communication and Management.
11. For surveillance of mosquito species other than container breeders within specifically defined zones, ovitrap surveillance methods are not adequate. A national surveillance system incorporating at least CO_2-supplemented light traps should be initiated.
12. Initiate work to create a GIS database of Napier surveillance results and expanded to include high-risk sites in NZ, particularly the North Island, for the purposes of monitoring surveillance.
13. As part of the national issue, the Ministry of Health should consider the feasibility of a Public Health group specialising in the prediction and pro-active monitoring of emerging diseases, particularly vector borne diseases. This group would act as a specialist information source for action plans, risk management strategies and responses specific to New Zealand (complimentary to Institute of Environmental Science and Research's role as a broader national surveillance database.)

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Except where otherwise referenced, information contained in Section 2 (Hazard Identification) is largely drawn from two important sources of information on Australian medical entomology. These are**: Lee DJ, Hicks MM, Griffiths M, Debenham ML, Bryan JH, Russell RC, Geary M, Marks EN.** (1987) *The Culicidae of the Australasian Region.* Volumes 3 and 7, Entomology Monograph Number 2. Australian Government Publishing Service, Canberra; and, **Russell RC.** (1993) *Mosquitoes and Mosquito-borne Disease on Southeastern Australia* (Revised Edition). University Printing Service, University of Sydney, Sydney.

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