

# The mosquitoes of New Zealand and their animal disease significance

## Mosquito type and distribution

**Species present:** Of the 3,500 mosquito species recognised worldwide<sup>(1)</sup>, New Zealand has only 16 (Table 1), four of which are introduced. *Culex quinquefasciatus*, *Aedes australis* and *Aedes notoscriptus* are considered to have been introduced in the nineteenth and early twentieth centuries<sup>(2) (3) (4)</sup>. *Aedes camptorhynchus* has recently established in Napier and is the subject of an eradication campaign. The remaining 12 species are indigenous.

**Distribution:** The distribution of mosquito species within New Zealand is shown in Table 1. *Culex pervigilans* is the most wide spread mosquito species in New Zealand<sup>(2)</sup> and it utilises a wide range of larval habitats<sup>(5) (6)</sup>. Most of our remaining mosquitoes have restricted distributions and/or habitats. *Cx quinquefasciatus* and *Ae notoscriptus* have remained apparently stable around their original sites of introduction in Northland and Auckland from their times of introduction (around 1830 and 1900 respectively) until the 1970s. However, since then the distributions of these two species have expanded greatly to include much of the North Island and the north and northeastern areas of the South Island<sup>(6) (7) (8) (9)</sup>.

**Potential for exotic species:** Larval habitats in New Zealand are underutilized<sup>(5)</sup>. Mosquito species abundance in countries of similar size and latitude to New Zealand, such as England and Japan (with 32 and 67 mosquito species respectively), suggest that New Zealand could, perhaps, support a larger number of mosquito species. Availability of larval habitats, coupled with an increase in the international mobility of people and their products<sup>(10)</sup>, makes New Zealand vulnerable to further introductions of exotic mosquito species.

Mandatory fumigation of container shipments of used tyres coming into New Zealand has reduced the potential for introduction of exotic mosquitoes by this pathway<sup>(11)</sup>. However, recent interceptions of *Ae albopictus* and *Ae japonicus* at various sea ports, and *Ae vigilax*, *Ae vittiger* and *Cx annulirostris* on aeroplanes arriving from South Pacific countries, demonstrate the need to clearly identify mosquito entry pathways and to ensure that there is effective border control.

## Animal pathogens associated with mosquitoes in New Zealand

Mosquitoes transmit pathogens either mechanically or biologically. Biological transmission occurs when pathogens undergo obligatory development and/or multiplication within the vector before being passed to another host. Three types of pathogen are transmitted by mosquitoes: filarial nematodes, plasmodial protozoa and arboviruses. Mosquito-pathogen ecology is complex. Host-mosquito

Some mosquito-borne animal pathogens do occur in New Zealand but this country is considered free from any that are economically significant. However, there is a threat of new species of exotic mosquitoes and/or exotic mosquito-borne pathogens becoming established here.

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contact, vector competence (the efficiency of a particular mosquito to transmit a given pathogen), mosquito abundance, and feeding behaviour<sup>(12)</sup> all influence transmission. In addition, there may be regional intra-specific variation in vector competence, as well as variation in the 'compatibility' of various strains of a pathogen with a vector.

## Endemic diseases

Mosquitoes appear to transmit very few diseases in New Zealand (Table 1). However, mosquito vector ecology has not been extensively studied in this country and much remains to be learned, including the economic impact and ecological significance of diseases such as avian malaria and avian pox.

**Whataroa virus:** This is the only known mosquito-borne virus in New Zealand. The primary cycle appears to be between birds and mosquitoes<sup>(13)</sup>. Serological studies suggest that this virus also infects humans and possibly some other non-avian vertebrates<sup>(14)</sup> but no associated syndrome has been detected. Whataroa virus has been isolated from *Cx pervigilans* and *Culiseta tonnoiri* in Westland, and both of these species are believed to transmit the virus<sup>(14)</sup>. *Cx pervigilans* and *Cs tonnoiri* have also been shown to be laboratory hosts of Whataroa, as have *Opifex fuscus*, *Ae notoscriptus* and *Ae australis*<sup>(15)</sup>.

**Avipoxviruses:** These have been diagnosed from several domestic and wild bird species in New Zealand<sup>(16)</sup>. Mosquitoes have been implicated as mechanical vectors of these diseases but it is not known how significant their role is.

**Reovirus type 3:** Reovirus type 3 has been isolated from *Cx pervigilans* and *Cs tonnoiri*, and *Ae australis* and *Cs tonnoiri* have been experimentally inoculated with this virus. However, no multiplication was detected and Reovirus type 3 is not considered to be an arbovirus.

Serological evidence suggests that an unidentified flavivirus causing human disease occurs in Westland and Tauranga<sup>(17) (18)</sup>. A different virus may be present in various places in the North Island<sup>(17)</sup>. The vectors of these two viruses are unknown and there appear to be no more recent references to the viruses or the syndrome.

**Plasmodium sp:** Avian malaria is transmitted only by mosquitoes. *Cx quinquefasciatus* and *Ae australis* are known vectors overseas. Within New Zealand, the occurrence of avian malaria outside of the range of these introduced species suggests that our native *Cx pergivilans* may have a role in transmission.

*Cx quinquefasciatus* is the primary vector of avian malaria in Hawaii<sup>(19)</sup>. The increasing distribution of *Cx quinquefasciatus* through large parts of New Zealand may enhance the incidence and distribution of avian malaria here.

*Plasmodium relictum* has been isolated in New Zealand from the yellow-eyed penguin (*Megadyptes antipodes*), the Fiordland crested penguin (*Eudyptes pachyrhynchus*)<sup>(20)</sup>, the blue penguin *Eudyptula minor*<sup>(21)</sup>, the song thrush (*Turdus ericetorum*) and blackbird (*Turdus merula*)<sup>(20)</sup> <sup>(22)</sup>, the skylark (*Alauda arvensis*)<sup>(23)</sup>, the pipit (*Anthus novaeseelandiae*)<sup>(24)</sup>, the grey duck (*Anas poicilorhyncha*) and the english sparrow (*Passer domesticus*)<sup>(20)</sup>. *Plasmodium* sp. have been isolated from dottrels (Jakob-Hoff pers. comm.), and *Plasmodium cathemerium* has been reported as causing mortality of canaries and finches in the New Zealand<sup>(25)</sup>.

The significance of avian malaria in New Zealand has not been determined. However, in Hawaii, it kills native birds and predisposes them to other diseases or predation<sup>(26)</sup>.

## Exotic diseases

Exotic disease-infected mosquitoes could be transported or blown to New Zealand, and they could possibly then infect animals here. Such an event would become even more serious if the introduced pathogen could be vectored by one of our endemic mosquito species. The ability of our mosquitoes to vector exotic pathogens is largely unknown but the potential exists (Table 1).

The absence of serious arthropod borne diseases in New Zealand is largely due to its bio-geographic evolution and temperate climate. Even moderate increases in average annual temperatures due to global warming could be enough to allow the colonisation of exotic mosquitoes in New Zealand<sup>(27)</sup>. A factor that could augment the establishment of exotic disease in New Zealand is the non-immune immunological landscape of New Zealand's vertebrate fauna<sup>(28)</sup>.

**Table 1: New Zealand mosquitoes: Distribution, vector status, feeding habits, larval habitat and hosts.**

Species	Distribution*	NZ vector status	Potential vector status	Adult feeding habits	Larval habitat	Host(s)
<i>Culex (Culex) pergivilans</i>	Entire country	Whataroa [i; v] <sup>(29)</sup> Reovirus type 3 [i] <sup>(29)</sup> <i>Plasmodium relictum</i> (Avian malaria) [?v (hypothesised in this article - requires further investigation)]	Unknown	NZ's most prevalent nocturnal pest mosquito	Remarkably variable: has been found in all categories of larval habitat <sup>(9)</sup> <sup>(6)</sup> : from clean to contaminated; fresh to up to 75% sea water; still to moderately flowing	Birds, occasionally larger mammals (humans, cattle)
<i>Culex (Cux.) rotoruae</i>	ND, AK, BP.	Unknown	Unknown	Unknown	thermal pools	Unknown
<i>Culex (Cux.) astelliae</i>	AK, CL, ?ND.	Unknown	Unknown	Unknown	Leaf axils of astelias	Unknown
<i>Culex (Cux.) quinquefasciatus</i>  (Introduced)	ND, AK, WO, CL, GB, TK, HB, WI, WN, NN, MB, KA, BR, MC. Widespread in tropics, sub-tropics & warm temperate parts of the world.	None known, but suspect <i>Plasmodium relictum</i> (avian malaria) [?v]	– Except where indicated, all references are <sup>(29)</sup> <i>Wuchereria bancrofti</i> [lh; no i; v (variable)]; <i>Dirofilaria immitis</i> [lh; no i; ?v]; <i>Saurofilaria</i> sp. [lh]; <i>Oswaldofilaria</i> sp. [lh]; <i>Plasmodium</i> spp. (Avian malaria) [lh; v]; <i>Hepatozoon breinli</i> [lh; t]; Alfuy [lh]; Almpiwar [lh]; BEF [lh]; Corriparta [lh]; Dengue [mec' t]; Edge Hill [lh; t]; Eubenangee [lh]; Getah [lh]; Kokobera [lh; t]; Koongol [lh]; Kowanyama [lh]; Kunjin [lh; i]; Mapputta [lh]; MVE [lh; t; i]; RRV [lh; t; i]; RVF [lh] <sup>(30)</sup> ; Sindbis [lh; t; i]; Stratford [lh]; Trubanaman [lh; t]; Wongal [lh]; JE [i]; Myxomatosis [t; v]; Avipox spp. [?i] (Fowlpox [i]); Reovirus type 3 [surv'; not lh; ?mec' t; i]; Reticuloendotheliosis virus [i]	A domestic pest in many urban areas, including indoor nocturnal biting.	Utilises a wide variety of artificial and natural containers, esp. those polluted with organic material; frequently found in water associated with domestic activity, including drains, gully-traps, as well as subterranean water (e.g., drain sumps, service pits, wells).	A wide variety of birds and mammals: poultry, human, horse, dog, pig, cattle, rabbit, sheep

Species	Distribution*	NZ vector status	Potential vector status	Adult feeding habits	Larval habitat	Host(s)
<i>Culiseta (Climacura) novaezealandiae</i>	SL.	Unknown	Unknown	None recorded	Coastal broadleaf swamp	?Birds
<i>Culiseta (Ct) tonnoiri</i>	ND, AK, ?BR WD, ?DN.	Whataroa [lh; t; i; ?v] <sup>(14)</sup> , Reovirus type 3 [surv.; not lh; ij] <sup>(31)</sup> , Coxsackie A6 [surv.; not lh; some tj] <sup>(31)</sup>	Unknown	Dusk & night biter in forest edge and clearing habitats	Very slow moving & shaded stream margins, pools among forests	Humans, cattle, horses, pigs, sheep, poultry, rabbits and possums.
<i>Coquillettidia (Austromansonia) tenuipalpus</i>	AK, WN, FD.	Unknown	Unknown	None recorded. Rare	Herbaceous shallow margins of ponds & lakes	Unknown
<i>Coquillettidia (Coquillettidia) iracunda</i>	ND, CL, TO, HB, WD.	Unknown	Unknown	Persistent night biter in vegetated areas	Shallow margins of ponds & lakes with vegetation	Stock <sup>(2)</sup> , bites man.
<i>Opifex fuscus</i>	ND, AK, BP, WN, NN, KA, MC, DN, FD.	None known naturally, but Whataroa [lh] <sup>(31)</sup>	Unknown	Nuisance only, painful bite	Salt water spray zone rock pools	Sea birds, other coastal animals, fishermen.
<i>Aedes (Nothokusea) chathamicus</i>	Chatham Island	Unknown	Unknown	No known pest significance. Rare	Saline or brackish rock pools at or just above high tide mark	Unknown
<i>Aedes (Halaedes) australis</i> (Introduced)	WD, SC, DN, SL, SI South East Queensland, NSW, Victoria, South Australia	Reovirus type 3 [lh] <sup>(32)</sup> ; Coxsackie A6 virus [surv.; not lh; no tj] <sup>(32)</sup> ; Whataroa virus [lh; tj] <sup>(32)</sup> . Possibly <i>Plasmodium relictum</i> (Avian malaria) [??v]	<i>Dirofilaria</i> sp. [lh] <sup>(32)</sup> ; <i>Plasmodium cathemerium</i> and <i>relictum</i> [lh] <sup>(32)</sup>	Found only in vicinity of breeding habitat; bites humans	Salt water spray zone rock pools	Unknown
<i>Aedes (Ochlerotatus) antipodeus</i>	ND, AK, CL, GB, TO, HB, RI, WI, WA, WN, NN, BR, MC, DN, SI.	Unknown	Unknown	Bites humans, but gen. occurs in low numbers. Mainly winter active	Flood water ground pools, esp. in shade. Eggs are laid on mud/ slime and begin development. as soon as flooded.	Unknown. Reported biting humans, but not livestock.
<i>Aedes (Och.) subalbirostris</i>	South Eastern SO, DN, SL.	Unknown	Unknown	May bite humans, but occurs in low numbers. Rare	Ground pools with clean, fresh water	Unknown. Attracted to, but not recording biting livestock.
<i>Aedes (Och.) campitorhynchus</i> (Introduced)	HBEastern NSW, Victoria, South Australia, Tasmania, West Australia	Unknown	<i>Eperythrozoon ovis</i> [mech tj] <sup>(32)</sup> ; <i>Dirofilaria</i> sp. [lh, ?v (significance Unknown)] <sup>(33)</sup> ; MVE [lh]; myxomatosis [t, ?v] <sup>(32)</sup> ; RRV [t; ?v] <sup>(34)</sup>	Serious diurnal biting pest	Favours brackish and saline marshlands, lake and lagoon edges, ground pools, drainage ditches (but tolerates fresh water inundation)	Prefers large mammals: humans, horses, cattle.
<i>Aedes (Finlaya) notoscriptus</i> (Introduced)	ND, AK, CL, WO, BP, GB, TK, HB, WN, NN, SD, MB, MC. Australia, New Guinea, New Caledonia, Indonesia.	Whataroa virus [lh] <sup>(35)</sup>	<i>Dirofilaria immitis</i> [lh; i, ?v] <sup>(36)</sup> ; <i>Onchocerca gibsoni</i> [??v, but no supporting evidence] <sup>(35)</sup> ; <i>Wuchereria bancrofti</i> [lh] <sup>(35)</sup> ; BF [lh, tj] Dengue [lh] <sup>(37)</sup> ; MVE [lh] <sup>(35)</sup> ; Fowlpox [ij] <sup>(35)</sup> ; Myxomatosis [i; ?v] <sup>(35)</sup> ; RRV [ij] <sup>(38)</sup> ; [lh, tj] <sup>(39)</sup> ; RVF [lh, tj] <sup>(30)</sup>	Crepuscular biting pest, but occasionally bites at night also. An avid biter that can be a serious pest	A "container" breeder. Larvae have been found in a wide range of artificial and natural containers, along with natural ponds, pools and puddles. Prefers vegetated and/or shaded containers	Arboreal marsupials, cattle, horses, sheep, human, canine, rabbit, ?poultry.
<i>Maorigoeldia argyopus</i>	NO?: AK CL, WN; SO?: NN, MB, MC, WD, SL.	Unknown	Unknown	Appears to have no pest significance.	Tree holes; artificial containers.	Unknown

- \*The distribution codes refer to defined biogeographical zones<sup>(40)</sup>.
- The distribution information is sourced from Belkin<sup>(2)</sup>, Laird<sup>(6)</sup>, Laird & Easton<sup>(7)</sup>, and unpublished Ministry of Health and MAF data.
- The disease relationship codes are: i = isolation; lh = laboratory host; ni = natural infection; t = experimental transmission; mec' t = mechanical transmission; v = vector in natural environment; surv = survival<sup>(15)</sup>.
- A single question mark indicates uncertainty but considered likely.

## Conclusion

New Zealand remains free of serious mosquito-borne animal diseases. Yet there is much to learn about mosquito-borne disease here, including the potential for our endemic mosquitoes to vector exotic diseases should these enter the country. New Zealand's border control minimises the risk of a potential pathogen and/or mosquito introduction. However, risks of introduction do exist, and to this end improved exotic mosquito surveillance and outbreak response contingency plans are being developed.

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