Vectors and vector borne diseases: Ecological research and surveillance development in New Zealand

Risk Assessment

A cross departmental research pool funded project

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Graham Mackereth, Rachel Cane, Amy Snell-Wakefield, David Slaney, Dan Tompkins, Richard Jakob-Hoff, Peter Holder, Susan Cork, Katharine Owen, Allen Heath, Helen Brady, Joanne Thompson

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Contents

List of Tables

Introduction

The purpose of this risk assessment was to inform a cross-departmental research pool (CDRP) project on the risks posed by vectors and vector borne diseases. The information was used to determine what laboratory capability, surveillance and research was needed for different vectors or disease agents.

The project was sponsored by the Ministry of Agriculture and Forestry (MAF) with the support of the Department of Conservation (DOC), Ministry of Health (MOH), Institute of Environmental Science and Research (ESR), Biosecurity New Zealand (BNZ) and Landcare Research, and was funded from the CDRP fund managed by the Foundation for Research, Science and Technology (FRST).

The aims of the project were to develop field and laboratory tools for use in surveillance for vectors or vector borne diseases and to develop research tools for understanding the ecology of selected vectors in New Zealand.

This report presents a risk assessment for vectors and vector borne diseases. In making this assessment every effort has been made to heed the interests of each department and the expert opinion of people from each agency and discipline, representing economic, environmental, and health. The risk assessment team have identified risks and uncertainties associated with agents and vectors that in their view should be managed or researched.

The outcome of this assessment is a fairly comprehensive table of vectors and vector borne agents relevant to New Zealand. The risks associated with a vector are considered separately from the importance of the agent. The dependence of the two is recognised in a combined priority rating (high, medium and low) for the agent.

The primary purpose of the table is to inform the subsequent stages of the project by identifying for each important agent and vector, their associated surveillance needs, research needs and laboratory capability needs. The tables also act as a useful guide and quick reference when considering a specific agent or vector.

The tables will be kept updated and any errors, omissions, or new information should be forwarded to Graham.Mackereth@maf.govt.nz.

Methods

The assessment team

A risk assessment team comprised of representatives from a range of New Zealand agencies was assembled to tackle the assessment. Each team member and adviser contributed to the risk assessment according to their expertise or availability. Team members were:

- Graham Mackereth, BNZ IDC Wallaceville, Team Manager
- Peter Holder, BNZ IDC Lincoln
- Susan Cork, BNZ IDC Wallaceville
- Katie Owen, BNZ Wellington
- Rachel Cane, NZ BioSecure
- Amy Snell-Wakefield, NZ BioSecure
- Dan Tompkins, Landcare Research
- David Slaney, ESR
- Helen Brady, ESR
- Richard Jakob-Hoff, Auckland Zoological Park
- Allen Heath, AgResearch
- Joanne Thompson, Veterinary Consultant

To develop and assess the risk of vectors and importance of agents, lists of these organisms were tabulated from the literature and numerous unpublished departmental reports. Tables 1 to 6 contain these data, three tables for vectors and three for agents. Parts of each table were sent to recognised experts and circulated within the assessment team for completion.

Vector tables

For convenience vectors were divided into three tables: Table 1: Mosquitoes, Table 2: Ticks and mites, and Table 3: Other insects (flies, midges, sandflies, blackflies, fleas and lice).

The content (columns) of the vector tables is as follows:

- Genus and species name

  The convention adopted was to sort each table firstly by the occurrence in New Zealand (endemic – blue shading, introduced – green shading, or exotic- orange shading) and secondly by the vector risk assessment (high – light blue shading, medium- yellow shading and low – grey shading). We have tried to adopt the correct nomenclature. With respect to mosquito taxonomic nomenclature, we have followed international journal standards of not recognising the elevation of the sub-genus *Ochlerotatus* to genus level.

- Hosts

  This column contains for each vector a list of known and/or suspected hosts.

- Environment

This column collated relevant information on the larval habitat, behaviour (particularly feeding habits), and distribution (here and overseas) and information on interceptions. This information was then used to assess the risk of introduction or re-introduction to New Zealand and the risk of establishment or spread in New Zealand. These are important to assessing the overall vector risk.

- Disease agents

In this column the disease agents transmitted by the vector are listed. The convention adopted was to place the genus in bold type and list the species of agent subsequently. Agents and vectors listed in blue text indicate presence in New Zealand. The following abbreviations were used for agents:

AHS	African Horse Sickness
BEF	Bovine ephemeral fever
BF	Barmah Forest virus
EEE	Equine encephalitis virus
EHD	Epizootic Haemorrhagic Disease
JAV	Johnson Atoll virus
JE	Japanese encephalitis virus
MVE	Murray Valley encephalitis
REV	Reticuloendotheliosis virus
RRV	Ross River virus
RVF	Rift Valley Fever
SLE	Saint Louis encephalitis
VEE	Venezuelan equine encephalitis
VS	Vesicular stomatitis
WEE	Western equine encephalitis
WNV	West Nile virus

From this information the assessment team compiled the remaining three columns containing the vector risk assessment, identified research questions, and surveillance needs.

- Vector risk assessment

This column summarises the main factors contributing to the vector's assessed risk, such as entry risk, abundance, host preferences, and what is known about its vector competence. Risk was broadly assigned in three categories: low –grey shading, medium – yellow shading and high – light blue shading. Any agents associated with the medium and high risk vectors were tabulated in the agent tables.

The potential importance of exotic mosquitoes was assessed in accordance with their potential range of hosts, potential abundance, potential distribution, known ability to vector agents, their introduction risk (as determined by the number of interceptions, ovipositioning and desiccation resistance of eggs, occurrence in countries with close trading and travel links), and their establishment risk (as determined by Hotspots modelling (55,56) or by comparing the climate in New Zealand with their known overseas distribution).

Overall, the vector risk assessment for a given vector is complex. If the vector is present, then it may vector endemic disease(s) and may be capable of vectoring exotic disease(s). This competence may be known as is the case for some introduced vectors, or unknown as is the case with many endemic vectors. If a competent vector is exotic then its entry pathways and establishment risks are the foremost considerations in assessing vector risk.

The vector risk assessment discounted mechanical vectors of disease, in favour of biological vectors. Also discounted, were secondary vectors that only become involved in transmission during the peak of an epidemic mediated by primary vectors.

The risk assessment did not consider other impacts posed by the vector, such as nuisance biting, although some vectors, such as sheep scab, have impacts sufficient to justify vector surveillance and biosecurity measures.

- Ecological research questions

It was noted that much about the role or potential role of vectors in New Zealand was uncertain or unknown. Where appropriate the assessment team recorded key questions that arose concerning a vector.

- Vector surveillance

In this column existing surveillance for vectors was listed and comments were made concerning the need for surveillance. Existing surveillance programmes or tools are in blue text.

For convenience, a summary of the vectors assessed as medium or high risk are listed in Table 7.

In completing the tables much use was made of the work of those who have published in this area and we have tried in all cases to acknowledge this contribution, however, with the structure of information in the table there may be a lack of acknowledgement in some cells.

Agent tables

For convenience the agents were divided into three tables: Table 4: Viruses, Table 5: Haemoparasites (also including Haemosporidia, Piroplasms, Haemogregarine, Rickettsias, Trypanosomes, Mycoplasma and bacteria) and Table 6: Nematodes. The tables present each agent and its associated vectors.

The content (columns) of the agent tables is as follows:

- Family, genus and species name

The convention adopted was to sort each sub-table firstly by the occurrence in New Zealand (endemic – blue shading, introduced – green shading, or exotic- orange shading) and secondly by the agents importance (high – light blue shading, medium- yellow shading and low – grey shading).

- Vectors

This column contains for each agent a list of known vectors. The convention was to place the principal vectors first with less competent vectors following. The risk assessment shading (low, medium, high) of the vector column reflected the vector risk calculated in the vector tables and adjusted for the complexity arising if the agent was associated with more than one vector of different risk category.

- Disease agent hosts

This column collated the non-vector hosts in which the agent was known to be present or cause disease.

- Location

In this column the location of the agent was listed with New Zealand locations in blue text.

From this information the assessment team completed the remaining four columns: agent importance, agent priority, research questions, and agent surveillance.

- Agent importance

This column summarises the main factors contributing to the agent's importance to wildlife, human heath, companion animals and trade. Importance was assigned to three categories: low –grey shading, medium – yellow shading and high – light blue shading. The criteria for determining the importance of the agent to trade was as follows:

    - High importance: An Office International des Épizooties (OIE) listed disease agent that is not present in New Zealand (exotic) and is a requirement for country freedom certification by most importing countries.
    - Medium importance: A disease agent that is not present in New Zealand (exotic) but is not listed by the OIE and is a requirement for country freedom by a very small number of importing countries.
    - Low importance: Agents were not necessarily listed.

- Agent priority

To derive a priority the importance of the agent and vector risk were combined to give the lowest of either assessment. This approach emphasised the dependence of these agents on vectors. So if either vector risk or agent importance was low the agent priority was low. If both were medium the agent priority was medium. If one was medium and the other high the agent priority was medium. If both were high the agent priority was considered high. For convenience, a summary of the agents with medium or high priority are listed in Table 8.

- Research questions

It was noted that much about the role or potential role of agents in New Zealand was uncertain or unknown. Where appropriate the assessment team recorded key questions that arose about an agent.

- Agent surveillance

In this column the type of surveillance, target, and tools appropriate to the agent were identified. The target refers to the object on which surveillance should be conducted, such as vector or host tissues. Tools refer to laboratory assays or methods appropriate to the agent. Where surveillance types, targets, and tools are currently in place in New Zealand the text was in blue font.

Results

Based on Tables 1 to 3, 34 vectors were identified as having medium or high risk: 20 mosquitoes, nine ticks, one blackfly, two fleas, and two lice (Table 7). In addition, based on Tables 4 to 6, 109 agents were identified as having medium or high importance, and of these, 48 were identified as having medium or high agent priority (combined vector risk and agent importance): 11 viruses, 28 haemoparasites, six other bacteria, and three nematodes (Table 8). These agents were vectored by a broad range of species. The nature of the risk varied and the reader is directed to the tables and methods section to determine how the risk arises and what management is appropriate.

Mosquitoes

Table 1 shows the mosquito risk assessment and the associated research questions and surveillance needs. The risk assessment identified 10 high risk mosquito species (six present, four exotic) and 10 medium risk mosquito species (two present, eight exotic).

New Zealand has 12 endemic mosquito species. There are four introduced mosquito species (one, *Aedes camptorhynchus*, is being eradicated). Thirteen exotic mosquito species (or mosquito species complexes) were examined.

Research

It was observed by the assessment team that many aspects of the biology and in some cases taxonomy of our native species are unknown. The research questions arising for endemic mosquitoes were in general:

- Are they competent vectors of exotic vector borne diseases?
- What agents are they vectoring in New Zealand?
- What are the mosquitoes host preferences?
- What role does the mosquito play in the emergence of avian malaria in New Zealand?

The research questions arising for introduced mosquitoes were in general:

- What agents are they vectoring in New Zealand?

Note: As part of the CDRP project research is underway to address the questions raised about introduced and endemic mosquitoes.

Hotspots modelling (55,56) has determined the potential distribution of a number of important exotic mosquitoes, however, six additional mosquitoes were identified that could be modelled in this way.

Surveillance

Existing surveillance for some mosquitoes occurs at ports and airports around the country in accordance with the World Health Organisation (WHO) requirements. Surveillance also occurs in saltmarshes around the country under the national saltmarsh mosquito surveillance programme, as well at sites under eradication programmes for the Southern Saltmarsh mosquito, *Aedes camptorhynchus*. The question arises as to whether this surveillance is effective for the high and medium risk mosquito species identified. Mosquitoes utilising other habitats (non-salt-marsh habitat away from ports) such as

Culex annulirostris and *Culex gelidus*, may not be detected, nor may container breeding mosquitoes away from ports or airports. In the absence of additional active surveillance programmes it is essential that passive surveillance mechanisms, such as reports of nuisance biting, are enhanced.

Mosquito identification is an essential component of managing the risks associated with mosquitoes. Currently this is done by morphology. Collection and taxonomic identification of the mosquitoes associated with nuisance biting should be encouraged.

Ticks and mites

Details of the risk assessment are shown in Table 2. No mites were identified as medium or high risk vectors. Six species of ticks were considered high risk (three endemic, three exotic) and three medium risk (one introduced, two exotic). All three endemic ticks, *Ornithodoros capensis*, *Ixodes eudyptidis* and *Ixodes uriae*, were associated with seabirds. The introduced species, *Haemaphysalis longicornis*, is associated with domestic animals, livestock and birds.

The potential role of ticks as vectors of disease to humans and livestock in New Zealand is similar to their role in other temperate climates, such as the United Kingdom. Ticks can maintain disease agents for long periods of time and as a result, agents reach and maintain a high prevalence in ticks. For this reason, introduced ticks are more likely to be accompanied by their disease agents than are introduced mosquitoes or *Culicoides* spp..

Research

Three of four known arboviruses in New Zealand are found in seabirds or seabird ticks. These viruses are found elsewhere in the Pacific and it can be concluded that sea birds and or seabird ticks provide a pathway of entry for the introduction of this sort of agents. Further research is needed to determine if other viruses are present. Ecological studies of vector borne disease in migratory colonial or burrowing birds is being funded by this project.

The research questions identified were:

- Is the tick vectoring disease agents in New Zealand?
- Is the tick part of an entry pathway for vector borne disease?
- What hosts is the tick feeding on?
- Do intercepted ticks have disease agents?

Surveillance

Development of effective surveillance for ticks is needed in order to manage the risks identified. Current surveillance for endemic or possible exotic ticks is minimal. Very few ticks are submitted to New Zealand laboratories for taxonomic identification. Passive surveillance needs to be enhanced so that ticks are submitted and identified.

Tick identification is essential to the management of the risks identified. This is currently done by morphology. New equipment is needed (cold light tables and cold light sources) to ensure specimens remain suitable for agent assays. Current submission and identification methods are not compatible with assays for agents, due to desiccation associated with hot light sources. Intercepted and endemic ticks should be stored and tested for the presence of disease agents at least occasionally.

Other insects (flies, midges, sandflies, blackflies, fleas and lice)

There are 73 known families of Diptera in New Zealand with at least 2310 species. Notably absent is the *Culicoides* genus, which is known to transmit over 50 viruses of significance to humans and livestock, and many other tropical vectors such as Tsetse and Tabanid flies.

Table 3 identified five medium risk species. These being, blackflies (endemic species of *Austrosimulium*), two introduced species of fleas (*Xenopsylla cheopis* and *Ctenocephalides felis*), and two introduced species of lice (*Pediculus humanus capitus* and *Pthirus pubis*) that feed on humans.

Research

Research questions were raised as to what diseases these fleas are vectoring and why murine typhus is an emerging problem.

Surveillance

Fleas and sandflies should be actively collected, identified and tested for disease agents at least occasionally, especially where disease outbreaks are occurring.

The risks associated with *Culicoides* were not considered medium or high by the assessment team, however, surveillance for disease vectored overseas by *Culicoides* spp. remains important for trade reasons. Existing surveillance for important *Culicoides* spp. should be periodically reassessed to ensure that the methodology is appropriate for those species that could be introduced and establish here.

Expertise is required for the identification of fleas, sandflies and *Culicoides* spp., which is done on morphology.

Viruses

There were a large number of arboviruses considered (Table 4). All important genera are listed, but some species may be absent due to very low vector risk in New Zealand. In total, 18 viruses were assessed as being of high importance (all exotic) and 16 as medium importance (three endemic, one introduced, 12 exotic). Flaviviruses, Alphaviruses, and Orbiviruses were identified as the most important genera. Of these 34 viruses, one was identified as having high priority (exotic WNV) and 10 as medium priority (three endemic, one introduced, six exotic). Priority being based on the combination of vector risk and agent importance. Entry pathways associated with the six exotic viruses should be actively managed.

Also identified were the risks associated with endemic arboviruses, Whataroa virus and the three known tick-seabird arboviruses.

Research

There is historical unconfirmed serological evidence of Alphavirus and Flavivirus in livestock and people in New Zealand, although this evidence may be spurious, it may indicate risk associated with unidentified arboviruses. In addition, other seabird tick viruses may be present and this should be investigated.

Surveillance

The type, target and tools needed for agent surveillance are shown in Table 4, where these were identified. The ability to screen for and isolate these genera is essential. Laboratory capability to grow arboviruses in tissue culture, test for alpha and flavivirus antibodies in serum and run PCR on serum or tissues, is required to support surveillance for these agents and related agents, as well as ecological studies.

Haemoparasites

Haemoparasites include the families Haemsporidia (*Plasmodium*, *Haemoproteus, Leucocytozoon*), Piroplasms (*Babesia*), Haemogregarine (*Hepatozoon, Haemogregarina*), Rickettsias (*Aegyptianella, Anaplasma, Ehrlichia, Neorickettsia, Rickettsia, Theileria*), Tryponosomes (*Trypanosoma, Leishmania*), *Mycoplasma*, *Haemobartonella* and *Eperythrozoon*.

Table 5 shows 10 haemoparasites as being of high importance (three endemic, three introduced, four exotic) and 55 as medium importance (four endemic, four introduced, 47 exotic). Of these 65 haemoparasites, three *Plasmodium* species and three *Rickettsia* species were identified as having high priority (all present), and 22 as medium priority (eight present, 14 exotic). Priority being based on the combination of vector risk and agent importance. The assessment identified members of the Haemosporidia, Piroplasm, and Rickettsia families as having risks that should be managed.

Human malaria was not included among those identified, due to its low vector risk in New Zealand. Avian malaria is present and is a high risk to avian wildlife.

The members of the *Rickettsia* family present in New Zealand seems fairly benign in livestock, and their scope may be limited by the relatively poor vector competence of *H. longicornis* compared with some exotic ticks.

In addition to *Plasmodium* spp., New Zealand birds and reptiles are at risk from a number of endemic haemoparasites. The risk is difficult to assess due to the scant attention given to them.

Table 5 shows an additional six bacteria that were considered a medium priority. Priority being based on the combination of vector risk and agent importance.

Research

Research is required to determine the importance of avian malaria and other blood parasites of birds in New Zealand. An ecological study is underway as part of this project to examine these issues.

Plague was once present in New Zealand (238) and the hosts and vectors are still present. This leads onto an important question which needs to be answered, is plague still maintained here?

Borrelia spp. cause Lyme disease and louse borne relapsing fever. Lyme disease may cycle between small rodents and ticks (particularly the deer tick) or it may cycle in seabirds and seabird ticks. Surveillance is required in seabird ticks to determine if it is present on the New Zealand mainland, following its detection in *Ixodes uriae* on Campbell Island.

Surveillance

A recent review of haemoparasites and their surveillance (5), identified the need to strengthen generic detection methods (the making and screening of thick and thin smears) by providing seminars and continuing education of pathologists in New Zealand. We concur and add that incentives are also required to conduct primary screening of slides, as this is a time consuming but essential test, in managing the risk haemoparasites pose in New Zealand.

Surveillance for *Babesia* and *Theileria* species is needed, particularly where disease occurs. The presence or absence of *Yersinia pestis* and *Borrelia* species should be determined by active surveillance supported by laboratory capability in New Zealand.

In addition to generic screening tests, specific tests, such as some PCR tests, are needed to manage the risks associated with these agents and facilitate research into their ecology.

Nematodes

Table 6 shows four nematode species of high importance (all exotic). Of these four species, two species were considered as having high priority (*Dirofilaria immitis* and *Wuchereria bancrofti*) and one as medium priority (*Brugia malayi*). Priority being based on the combination of vector risk and agent importance.

Research and surveillance

Competent vectors are present in New Zealand and entry pathways exist for the agents of canine heartworm and filariasis with the movement of dogs and humans. It is unclear as to why these diseases have not established in New Zealand. The absence of the agents may be due to risk mitigation at the border, climatic factors or vector factors. Current passive clinical surveillance may be sufficient to detect the establishment of these agents.

Discussion

A cross-disciplinary inter-agency review of vectors and vector borne disease is timely. Changes are occurring in the importance and global distribution of some vectors and vector borne diseases. Changes are also occurring in New Zealand in regard to the importance and distribution of some vectors and agents.

This assessment was undertaken in a short time frame and primarily to provide information for those working on the research, surveillance, and laboratory aspects of the CDRP project on vectors and vector borne disease. Hopefully this assessment will allow strategic progress in characterising the unique profile of vector borne disease and risk in New Zealand and in protecting our economic, environmental and health interests.

The absence of many vector borne diseases has resulted in little investment in research into the biology and ecology of our own vectors and agents, leaving us uncertain as to the basic behaviour of some of our mosquitoes, the agents they vector, and possibly ignorant of the tick borne agents in New Zealand bird species.

It is clear, for reasons relating to human health, the environment, and economics, that surveillance systems are needed for the collection, identification, and assay of ticks and mosquitoes in New Zealand. The design of these systems requires both passive and active components and should address the priority agents and risk vectors identified in this assessment in addition to the trade related needs separately identified. Developing the capability to screen at a high level for blood parasites and the important viral genera is an important step in building such a system.

Human health

This review characterises fleas as currently the most important vector of vector borne disease to humans in New Zealand, whereas elsewhere in the world, disease is vectored primarily by mosquitoes and secondarily by ticks. Some important vector borne diseases, such as human malaria and dengue fever are dependant on tropical vectors with little or no likelihood of establishing in New Zealand. The assessment identifies many vectors and agents that are of importance to human health and their exclusion and early detection must be essential components of New Zealand's Biosecurity.

Some important diseases such as West Nile virus have vectors that have already established in New Zealand, and endemic mosquitoes may also be competent vectors of these viruses. Research is needed to determine the vector competence of endemic mosquitoes for agents such as West Nile virus and Ross River virus. The possible introduction of agents (in hosts or vectors) may lead to disease outbreaks in New Zealand. Biosecurity surveillance systems should have the capability to detect these agents.

Some exotic mosquitoes and ticks have the potential to establish in New Zealand. Surveillance is needed to detect introduction and establishment of these vectors.

Economics

This review indicates that currently there are no important vector borne diseases in New Zealand livestock, where as elsewhere in the world, ticks, mosquitoes and *Culicoides* vector diseases with significant impact on livestock and trade. Table 9 shows exotic agents of relevance to trade. Note that for trading reasons it may be necessary to establish or continue surveillance for these organisms, however, most of them were accorded low overall priority, due to a low vector risk in New Zealand.

Many of the diseases that affect trade in animal products (Table 9) are vectored by ticks. The risk of introduction of ticks requires management of potential pathways, and any residual risk should be managed by surveillance for ticks in New Zealand. Surveillance for ticks in New Zealand is currently lacking, and at present the first indication of a recently introduced species may be the occurrence of tick-borne disease.

Environment

New Zealand avian wildlife is less removed from vector borne diseases circulating elsewhere in the world than we might like to think. Limited studies of colonial seabirds and associated ticks have revealed three tick borne arboviruses, and a study of 40 seabird ticks (*Ixodes uriae*) from Campbell Island demonstrated the presence of a Lyme disease agent, *Borrelia garinii*. Blood parasites occurring in penguins may be associated with chick mortality. Their importance needs assessment.

Seabirds remain an entry pathway for vector borne disease, the significance of which grows with the rise in global redistribution of disease agents such as West Nile virus. No comprehensive study of seabird associated vector borne diseases has been made in New Zealand, and this risk should be managed by ecological research into the ticks and other vectors associated with migrating colonial or burrowing seabirds.

Mainland birds are currently at risk from mosquito borne avian malaria. Avian malaria is an emerging problem for conservation interests in New Zealand, and is known to be capable of devastating isolated avian communities overseas and is suspected as the cause of a number of recent population crashes here. Changes in the impact of avian malaria may reflect changes in the composition of mosquito species or changes in the pathogenicity of the *Plasmodium.*

The one confirmed endemic mosquito borne arbovirus cycling in New Zealand wildlife is Whataroa virus. Ecological studies into existing vector borne diseases are essential to the management of their expansion and emergence.

Table 1. Vector risk assessment for mosquitoes

Culicidae Mosquitoes	Hosts	Environment				Disease agents (endemic agents in blue)	Vector risk	Research questions	Vector surveillance
		Larval habitat	Adult Behaviour	Distribution in NZ	Distribution Overseas				
Culex (Culex) pervigilans Bergroth. Endemic.	Birds, humans, occasionally larger mammals (cattle) (1); (2); (3)	All categories of larval habitat except tree holes (4); (3). Found in urban, agricultural, native forest settings (Snell pers ob.; (5), in fresh, polluted and semi-saline water (2); (3); (6)	Nocturnal mosquito (4); (3); (7). Reported serious domestic pest (2). Dispersal unknown.	Most widespread and abundant species, all latitudes of NZ (3); (8); (9)		Alphavirus: Whataroa (10) Orbivirus: Reovirus type 3 (11) Blood parasites: *Plasmodium relictum*? (12); (13)	Abundant, widespread, wide host range, known vector of disease, similar to *Culex pipiens pallens* and *Culex pipiens pipiens* both of which are competent arbovirus vectors. Potentially a high risk vector. High risk.	Is this a competent vector of exotic vector borne diseases of human health significance? Does this vector transmit avian malaria in New Zealand? What are its host preferences?	
Culiseta (Climacura) tonnoiri (Edwards). Endemic.	Humans, cattle, horses, pigs, sheep, poultry, rabbits and possums, penguins (14); (15)	Very slow moving & shaded stream margins, pools among native forests (14)	Dusk & night biter in forest edge and clearing habitats (6); (16); (17). Dispersal unknown.	Northland, Auckland, West coast (3); (9)		Alphavirus: Whataroa (10) Orbivirus: Reovirus type 3 (18) Coxsackie virus: Coxsackie A6 (19); (13)	Abundant (West coast), widespread? Wide host range, known vector of disease. Potentially a high risk vector. High risk.	Is this a competent vector of exotic arboviruses of human health significance? What are its host preferences? What agents is it vectoring?	
Coquillettidia (Coquillettidia) iracunda (Walker). Endemic.	Livestock, humans, dogs (7); (20); (21), possums (Derraik, pers. com.)	Shallow margins of ponds & lakes with vegetation, usually native forest but also adjacent urban, agricultural land (7); (15)	Persistent night biter in vegetated areas, day biter in native forest (4); (21). Dispersal unknown, Suspected to travel up to 500m-1km from breeding site (Snell, pers. obs.).	North Island, West coast of South Island and scattered areas on the South Island (9)		Unknown	Widespread, wide host range? Not a known vector, closely related to *Cq. linealis a* vector of Ross River and Barmah forest in Australia. Could be infected by viraemic travellers and does bite possums. Potentially a high risk vector, especially Ross River virus. High risk.	Is this a competent vector of Ross River or other vector borne diseases of human health significance? What is its host preference? Does it bite birds? What agents is it vectoring?	
Opifex fuscus Hutton. Endemic.	Sea birds, other coastal animals, humans. (22); (23); (7)	Salt water spray zone rock pools. Artificial containers close to sea (4); (24); (25); (3)	Nuisance only, painful bite, bites day and night (4); (7). Autogenous - blood feed only after initial egg batch laid (26). Dispersal unknown.	Spotted coastal distribution on North and South Islands (4); (9)		Alphavirus: Whataroa experimentally (27); (13)	Abundant, widespread spotted coastal distribution, wide host range? Experimental infection with Whataroa virus demonstrated. Coastal location could make it part of a potential entry pathway for tick associated seabird viruses. Medium risk.	Is this a bridging vector for introduction of arbovirus via seabirds ticks? What are its host preferences? What agents is it vectoring?	
Aedes (Ochlerotatus) antipodeus (Edwards). Endemic.	Humans, dogs (28); (3); (29); (21)	Flood water ground pools, especially in shade, mainly in native forest (22); (3). Eggs are laid on mud/slime (2)	Bites humans, generally occurs in low numbers. Mainly winter active but occurs throughout the year (7) . Reported nuisance biter (Cane, pers. com.). Dispersal unknown.	North Island and South Island, all latitudes of NZ (9)		Unknown	Not abundant, widespread disjunct distribution, host range? Not a known vector. Low risk.	What are its host preferences? What agents is it vectoring?	
Aedes (Ochlerotatus) subalbirostris (Klein and Marks). Endemic.	Humans. Attracted to, but not recorded biting livestock.	Ground pools with clean, fresh water (28); (23); (3)	Occurs in low numbers. Rare reports of nuisance biting (Cane, pers. com.). Dispersal unknown.	Southern South Island (3); (25)		Unknown	Not abundant, limited distribution, not a known vector (3); (9). Low risk..	What are its host preferences?	
Maorigoeldia argyropus (Walker). Endemic.	Unknown, suspected not to blood feed (30); (31)	Tree holes etc. artificial containers on edge of native forest (2); (32); (3); (30); (8); (31)	Appears to have no pest significance (30). Dispersal unknown.	Disjunct distribution of North and South Islands (3); (31)		Unknown	Unknown. Low risk.		
Culex (Culex) rotoruae Belkin. Endemic.	Unknown, suspect birds (Snell, pers. com)	Thermal pools (3); (33); (9)	Adult behaviour and dispersal unknown.	Restricted to Taupo Volcanic Zone and Ngawha Springs (3)		Unknown	Not abundant, restricted distribution, not a known vector (3); (9). Low risk.		
Culex (Culex) asteliae Belkin. Endemic.	Unknown, suspect birds (34)	Leaf axils of astelias & bromeliads, artificial containers on edge of native bush (34)	Adult behaviour and dispersal unknown.	Auckland, Northland (3) Wellington (Heath, pers. com)		Unknown	Not abundant, restricted distribution, not a known vector. Low risk.		
Culiseta (Climacura) novaezealandiae (Pillai). Endemic.	Suspect Birds (35)	Coastal broadleaf and flax swamp (35); (16)	Adult behaviour and dispersal unknown.	Tahakopa Scenic Reserve, Southland (35)		Unknown	Not abundant, restricted distribution, not a known vector. Low risk.		
Coquillettidia (Austromansonia) tenuipalpis (Edwards). Endemic.	Unknown, suspect birds (Snell, pers. com.) Unverified reports of biting humans (3)	Herbaceous shallow margins of ponds & lakes in native forest (3)	None recorded. Rare. Dispersal unknown.	Northland, Auckland, Wellington, Fiordland (9)		Unknown	Not abundant, restricted distribution, not a known vector. Low risk.		
Aedes (Nothoskusea) chathamicus (Dumbleton). Endemic.	Unknown, Suspected to bite humans (36)	Saline or brackish rock pools at or just above high tide mark (24); (3)	No known pest significance. Rare. Dispersal unknown.	Chatham Islands (24); (3)		Unknown	Not abundant, restricted distribution, not a known vector. Low risk.		

Culicidae Mosquitoes	Hosts	Environment				Disease agents (endemic agents in blue)	Vector risk	Research questions	Vector surveillance
		Larval habitat	Adult Behaviour	Distribution in NZ	Distribution Overseas				
Culex (Culex) quinquefasciatus Say (southern house or brown mosquito). Introduced.	Birds and mammals: poultry, human, horse, dog, pig, cattle, rabbit, sheep, reptiles (37); (38); (39)	Wide variety of artificial and natural containers. Frequently associated with domestic activity. Prefers organic rich water (38)	A domestic pest in many urban areas, including indoor nocturnal biting (4); (7). Dispersal 0.8-5.6 km (40)	Widespread, especially Northern 2/3rds of NZ, recently located along the Kapiti Coast (9)	Widespread in tropics, sub-tropics & warm temperate parts of the world	Filaroids: *Wuchereria bancrofti, Dirofilaria immitis, Saurofilaria sp., Oswaldofilaria sp. Plasmodium relictum, Plasmodium cathermerium. Hepatozoon breinli.* Lyssavirus: BEF. Alphavirus*:* RRV, EEE, Getah, Sindbis*.* Flavivirus: Alfuy, Kokobera, Kowanyama, Dengue, Edge Hill, JE, Kunjin, MVE, RVF, Stratford, WNV. Orbivirus: *Eubenangee, Corriparta, Reovirus type 3.* Rhabdoviridae: *Almpiwar. Bunyaviridae: Koongal Mapputta, Trubanaman, Wongal.* Myxomatosis*.* Avipox: *Fowlpox. Retrovirus: REV*. (41); (13); (38); (42); (43)	Abundant, widespread, wide host range, known vector of disease. Introduced 1830. Intercepted twice - many possible interceptions but origin uncertain due to local population. High re-introduction and re-establishment risk. Viraemic humans are a potential pathway for entry of vector borne disease. High risk.	What agents is this mosquito vectoring in NZ? What factors make this such a versatile vector?	
Aedes (Finlaya) notoscriptus (Skuse) (domestic container, or striped, or anklebiting mosquito). Introduced.	Arboreal marsupials, cattle, horses, sheep, human, canine, sparrows, rabbit, poultry? (2); (29); (44); (45)	A container breeder. Natural and artificial. Prefers vegetated and/or shaded containers, tree holes (40)	Crepuscular biting pest, but occasionally bites at night also. Bites during day in densely shaded areas. An avid biter that can be a serious pest (4); (3); (29); (7); (17). Travels up to 250-280m from release site (46)	Widespread in North Island and south to Lyttleton (9). Could spread throughout much of South Island (Cane, pers. com.)	Australia, New Guinea, New Caledonia, Indonesia (47)	Filaroids: *Dirofilaria immitis, Onchocerca gibsoni, Wuchereria bancrofti.* Alphavirus: BF, RRV, Whataroa. Flavivirus: Dengue, MVE, RVF. JE. Avipox: Fowlpox. Myxomatosis (48); (42); (48); (50); (49); (13)	Abundant, widespread, wide host range, known vector of disease. Introduced 1918. Viraemic humans a pathway for entry of vector borne disease. Bites possums - a potential reservoir of RRV. Intercepted twice. High re-introduction and establishment risk, High risk, particularly in relation to Australian viruses.	What agents is this mosquito vectoring in NZ? What factors make this such a versatile vector?	
Aedes (Ochlerotatus) camptorhynchus (Thomson) (southern saltmarsh mosquito). Introduced.	Prefers large mammals: marsupials, humans, horses, cattle and birds (44)	Favours brackish and saline marshlands, lake and lagoon edges, ground pools, drainage ditches (but tolerates fresh water inundation) (44); (39)	Serious diurnal biting pest. Vicious biting occurs in open shaded areas during day, dusk and after sunset (39). Disperses widely, can be transported long distances by wind (50). Generally believed to disperse up to 5km.	Eradicated east coast North Island, Mangawhai and Whitford, under eradication at Coromandel, Kaipara and Blenheim. Could become widespread as far south as Christchurch and possibly further south (Cane, pers. com.)	Eastern NSW, Victoria, South Australia, Tasmania, West Australia (42)	*Eperythrozoon ovis. Dirofilaria sp.*; Flavivirus: MVE. Alphavirus: RRV, BF. Myxomatosis. (13)	High abundance and widespread distribution if not controlled, wide host range, known vector of disease, nuisance biter. Introduced in the late 1990's. Intercepted at border. Potential pathway and vector of RRV. Low re-entry risk. High risk.	Has one incursion or multiple incursions occurred and by what pathway? Where found in high abundance, what agents is this mosquito vectoring?	National saltmarsh mosquito surveillance programme. Response surveillance at eradication sites.
Aedes (Halaedes) australis (Erichson) (saltwater mosquito). Introduced.	Unknown, humans, suspect sea birds and mammals (42)	Salt water spray zone rock pools (47), (42) also large tyres and open roadside and field drains (51)	Vicinity of breeding habitat. Nuisance biting in Australia not reported here (42). Not found away from its breeding habitat (50)	Southern South Island (Southland and Otago). Suspect is spreading northward (Cane, pers. com.)	South East Queensland, NSW, Victoria, South Australia (42)	Orbivirus: Reovirus type 3. Coxsackie: A6. Alphavirus: RRV, *Whataroa*. Flavivirus: Dengue. Plasmodia. *Plasmodium relictum? Plasmodium cathemerium.* Laboratory host of *D. immitis*. (13)	Limited distribution, wide host range, known vector of disease. Present since 1961. Could spread Whataroa virus north. Medium re-entry potential. Medium risk (limited distribution).	What agents is this mosquito vectoring in NZ? What factors make this such a versatile vector?	
Aedes (Stegomyia) albopictus (Skuse) (Asian tiger mosquito). Exotic.	Humans, animals, birds, and frogs (52)	Container breeder, natural and artificial – fresh to polluted and even brackish water (52)	Urban environment, biting usually occurs in shaded places during the day, also indoors, occasionally at night (52), (53). Some autogenous egg production. Most disperse up to 180m during lifetime (53), but can up to 800m (54)	Not present. Cold tolerant strain has potential to establish North of Waikato, as low as Hawkes bay if warmer climatic conditions occur (55); (56)	Asia, some Pacific Is, spread to USA, Brazil, Argentina, Europe (56)	Alphavirus: RRV, Chikungunya, EEE, WEE, VEE. Flavivirus: JE, SLE, Dengue, Yellow fever. Bunyaviridae: La Crosse encephalitis. *D.ilmmitis*. (52); (57); (58)	Desiccation resistant eggs laid in containers. Intercepted numerous times. Spread in used tyres. Occurs in many countries with close trading and travel links. Known vector of disease. Intercepted 8 times, high introduction risk, medium establishment risk in the North. High risk.	Potential distribution addressed by Hotspots model.	Port and airport surveillance. Taxonomy on reported cases of nuisance biting.
Aedes (Finlaya) japonicus (Theobald) (Japanese rock pool or Asian bush mosquito). Exotic.	Humans, animals and birds, not reptiles or amphibians.	Container breeder, natural and artificial, fresh to polluted, often small containers. Prefer shaded containers (59). Also in full sun (59). Overwinters as eggs in NE Japan, larvae in SW Japan (71)	Anautogenous. Principally in forested areas, day biters (59). Present in urban, suburban, rural and agricultural settings and bites indoors (70). Dispersal unknown, up to 200m has been suggested.	Not present. Wide potential distribution North Island and Canterbury- tolerant of temperate climates (60); (56)	Native to Japan and SE Asia, spread to USA, Canada, France and USSR (60)	Flavivirus: JE, WNV. Bunyaviridae: La Crosse encephalitis. (61); (56)	Eggs are desiccation resistant. Frequently intercepted at border (6 times). Known vector of disease and a documented pest. Believed to have spread to USA in used tyres (60); (62). High establishment risk, high risk.	Potential distribution addressed by Hotspots model.	Port and airport surveillance. Taxonomy on reported cases of nuisance biting.

Culicidae Mosquitoes	Hosts	Environment				Disease agents (endemic agents in blue)	Vector risk	Research questions	Vector surveillance
		Larval habitat	Adult Behaviour	Distribution in NZ	Distribution Overseas				
Aedes (Ochlerotatus) vigilax (Skuse) (northern saltmarsh mosquito). Exotic.	Humans, animals and birds.	Coastal wetlands and mangroves, saline to brackish pools, occasionally freshwater (50); (42)	Daytime and night biter, particularly the evening. Both indoors and outdoors. Attacks during day near breeding sites e.g. mangroves. Rest in vegetation close to damp soil. Very strong fliers. Found 1.6-96 km from breeding sites. Reported 320 km from the coast in southern Queensland (50). 9 km over water not an effective barrier (63)	Not present. Similar potential distribution to *Ae. camptorhynchus*, North Island and Canterbury (55); (56)	Australia, SE Asia, Indonesia, Melanesia, Fiji (50)	Alphavirus: RRV, BF Flavivirus: MVE, JE, Kunjin. Filaroids: *Dirofilaria immitis*, *Wuchereria bancrofti* (64); (65); (57); (66)	Intercepted at border. Widely distributed in neighbouring countries. Known vector of disease. High introduction and establishment risk. High risk.	Potential distribution addressed by Hotspots model.	Surveillance for *Ae. camptorhynchus*, Port and airport surveillance. Taxonomy on reported cases of nuisance biting.
Culex (Culex) annulirostris (Skuse) (common banded mosquito). Exotic.	Humans, birds, mammals, reptiles, possums (38)	Freshwater mosquito - freshwater, riverine habitats, containers. Brackish and rarely saline, also polluted waters (38); (42); (64)	Vicious evening and pre-dawn biter, also nocturnal and diurnal (38). Will bite in sheltered areas during the day (Snell, pers. obs.). 5-10 km from the emergence site. Some more than 5 km in one day. Up to 12km (67), (68)	Not present. Similar latitudes to *Ae. camptorhynchus* (55); (56)	Australia, Polynesia (38)	Alphavirus: Sindbis, RRV, BF, Flavivirus: Alfuy, Kokobera, Kunjin, MVE, JE. Lyssavirus: BEF Filaroids: *Dirofilaria immitis, Wuchereria bancrofti* (69); (70); (38); (42); (64)	Eggs not desiccation resistant. Intercepted at border, widely distributed in neighbouring countries. Known vector of disease. High introduction and establishment risk. High risk.	Potential distribution addressed by Hotspots model. Is port and airport surveillance adequate or appropriate?	Taxonomy on reported cases of nuisance biting. Suitable habitats are not under surveillance.
Aedes (Stegomyia) aegypti (Linnaeus) (yellow fever mosquito). Exotic.	Humans, animals, birds and reptiles (53)	Container breeder, natural and artificial, preferably large, also subterranean habitats (53)	Urban and forest environments, nuisance biter during day, especially late afternoon to sunset (53). Multiple feeding for single egg batch may occur (53). Dispersal can be up to 800m from emergence site after six days (54)	Not present. One incursion at Port of Auckland where larvae were breeding through on wharf, winter - July 05. Potential distribution restricted by climate (10°C isotherm conditions required). Suspect Northland and Auckland at least (Cane, pers. com.)	Oceania, Australasia, Africa, Americas (53)	Alphavirus: RRV, BF, Chikungungya. Flavivirus: Dengue, MVE, Yellow fever. Potential vector *D. immitis*. (64); (65); (57); (49)	Desiccation resistant eggs are laid in containers and often intercepted at border. Known vector of disease. Medium establishment risk (high introduction risk, however climate prevents establishment in most parts of New Zealand). Known vector of severe disease. Medium risk.	Potential distribution addressed by Hotspots model.	Port and airport surveillance. Taxonomy on reported cases of nuisance biting.
Aedes (Stegomyia) polynesiensis Marks (Polynesian mosquito). Exotic.	Humans (preferred), animals (pigs, dogs, horses, bats) (53)	Container breeder, natural and artificial, can breed in restricted ground water (53)	Urban environment, nuisance daytime biter of humans, usually with shade or cloudy conditions. Biting peaks in early morning and late afternoon. Up to 6 feeds per female (53). Low level autogeny (71). Disperse up to 100m during lifetime (53)	Not present. Potential distribution - Northern coastal areas of North Island, wider if warmer climatic conditions occur (55); (55)	Pacific island countries (63)	Alphavirus: RRV. Flavivirus: Dengue, MVE. Filaroids: *Wuchereria bancrofti* (72); (57); (56)	Desiccation resistant eggs are laid in containers. Occurs in countries with close trading and travel links. Known vector of disease. Limited by climate. Intercepted twice. Known vector of severe disease Medium establishment risk. Medium risk.	Potential distribution addressed by Hotspots model.	Port and airport surveillance. Taxonomy on reported cases of nuisance biting.
Culex (Culex) gelidus Theobald (frosty mosquito). Exotic.	Domestic animals, humans (73)	Freshwater, mosquito - riverine habitats, artificial and natural containers. Temporary and semi-permanent habitats. Sometimes with dirty water or high organic content (74); (38)	Voracious nocturnal biters both inside and outside houses (75), (74). Feeds only on man in absence of other suitable hosts. (76) Dispersal unknown, probably several km (77)	Not present. Believed to have potential to establish North of Waikato, as low as Hawke's bay if warmer climatic conditions occur.	SE Asia, Australia, and PNG (38)	Flavivirus: JE (66) Alphavirus: RRV isolated. Filaroids: *Brugia malaya*; *Wuchereria bancrofti* (78); (38)	Intercepted 2003. High establishment risk. Medium risk.	What is the potential distribution? Is port and airport surveillance adequate or appropriate?	Suitable habitats are not under surveillance.
Culex (Culex) pipiens pallens Coquillett (northern house mosquito). Exotic.	Humans, avian, reptiles. Mammals are secondary hosts.	Artificial containers, subterranean habitats. Prefers polluted water, abundant organic matter.	Dawn & dusk. Primarily a domestic species strongly anthropophilic (79). Readily bites indoors at night with peak biting at pre-dawn and dawn (80). Rests in and around houses (79). Over winters as an adult (80). Short flight range and dispersal remaining around human hosts (79); (81)	Not present. Could establish throughout NZ.	Europe, Asia, North America.	Alphavirus: RRV. Flavivirus: MVE, SLE, WNV. Filaroids: *Wuchereria bancrofti* (82) and probably *Brugia malayi* (79); *Dirofilaria immitis* (83); (84)	Intercepted 2001. Some overwintering females are blooded, allowing possible overwintering of viruses also (85). Short flight range and dispersal remaining around human hosts aggregating filariasis (97); (81). Low introduction risk. High establishment risk. Medium risk.	What is the potential distribution?	Port and airport surveillance. Taxonomy on reported cases of nuisance biting.

Culicidae Mosquitoes	Hosts	Environment				Disease agents (endemic agents in blue)	Vector risk	Research questions	Vector surveillance
		Larval habitat	Adult Behaviour	Distribution in NZ	Distribution Overseas				
Culex (Culex) sitiens Wiedemann (saltmarsh Culex). Exotic.	Humans, animals and birds.	Coastal, brackish waters, typically breeds in brackish pools formed by high tides and rainfall (42); (64). Occasionally found in freshwater pools (78). Natural and artificial containers.	Nocturnal biters with a small peak at sunset (86), feeding both indoors and outdoors. Rest outside during the day. Pest species in summer months in Australia. Specimens caught 20km from breeding site (96)	Not present. Similar distribution potential as *Ae. vigilax.*	East Africa, Oriental region, Indonesia, Australia (see Walter Reed Web site).	Alphavirus: RRV (95) Flavivirus: JE - Lab competence (78); MVE? Filaroids: *Brugia malayi* (naturally infected but suspect secondary role only) (38)	Intercepted four times, last reported interception 2003 ((87)). High introduction and establishment risk. Medium risk.	What is the potential distribution?	Surveillance for *Ae. camptorhynchus*, Port and airport surveillance. Taxonomy on reported cases of nuisance biting.
Aedes (Finlaya) atropalpus Coquillett (rock pool mosquito). Exotic.	Humans and birds.	Rock pools near streams or rivers, and artificial containers (mainly tyres) in areas away from rock pools (88), (94). Diapauses as an egg (89)	Persistent biter close to breeding sites. Bites during the day, Autogenous (88); (90). Doesn't disperse far from breeding site. (88)	Not present. Widespread distribution in eastern coastal US and Canada suggests potential for spread through most of NZ.	North America, Italy (88), (91), France.	Alphavirus: WEE, EEE (88). Bunyaviridae: *La Crosse* encephalitis. Flavivirus: SLE (vertical transmission – (90), WNV (in lab – (92). Shown to transmit avian malaria in lab.	Desiccation resistant eggs laid in containers (89). Never intercepted. Has one of highest WNV vector competency results, but been noted as a reluctant blood feeder. Adapted to breeding in tyres and has become established in Italy via this pathway. Medium establishment risk. Medium risk.	What is the potential distribution?	
Aedes (Ochlerotatus) sierrensis (Ludlow) (western tree hole mosquito). Exotic.	Humans, wide variety of mammals (cattle, dogs), reptiles.	Predominantly tree holes. Also artificial containers with lots of organic matter. Urban and rural areas near woodlands. Diapauses as larvae (93)	Serious nuisance biters of humans and other large mammals (94). Bites anytime of day, including in full sun. Doesn't disperse far from breeding site. Rarely fly under windy conditions (95)	Not present. Widespread distribution in western US and Canada suggests potential for spread through most of NZ.	Western North America, British Colombia (96)	Alphavirus: WEE (in lab); Filaroids: *Dirofilaria immitis* (97) *Setaria yehi* (deer body worm) (98); cited in (93)	Intercepted Dec 2002. Major vector of dog heartworm in parts of U.S. Medium establishment risk. Medium risk.	What is the potential distribution?	
Aedes (Stegomyia) scutellaris species complex of about 16 species (including *Ae. albopictus*). Exotic.	Humans (86)	Natural or artificial containers (99)	Daytime biter (86). Autogenous, feed only in sheltered areas, do not fly in higher wind. Reaches large numbers, attacks man readily and enters dwellings to feed only (100). 500 yards (455m) observed, not more than 800 yards (727m) in dispersal experiments (53); (101)	Believed potential distribution – Northern coastal areas of North Island, wider if warmer climatic conditions occur (Disbury, pers. com). One adult trapped at Auckland port (2007).	India, Indonesia, PNG, Philippines, Australia (53) South east Asia, South Pacific (100), (99)	Flavivirus: Dengue (100); (88). Filaroids: *Brugia malayi* and *Brugia pahangi* (in lab) (102)	Intercepted 1944 (87). Low establishment risk, medium disease risk. Medium risk.	What is the potential distribution?	
Anopheles spp. (Anopheline mosquitoes) 300+ species. Exotic.	Humans	Freshwater mosquito – freshwater, riverine habitats, containers. Nearly all categories of larval habitat (42)	Some species seek blood feeds at night, some at dusk and others at midday. Varies with species. Anopheles gambiae flight range usually less than 1km (103)	Not present. Tropical species excluded by climate, cold tolerant *An. Annulipes* possible in northern New Zealand (104)	Widespread globally (see Walter Reed Web site).	Plasmodia: *P. vivax, P. falciparum, P. berghei, P malariae, P. ovale*. Filaroids: *Wuchereria bancrofti*, *Brugia malayi*, *D. immitis*. Alphavirus: EEE, O'Nyong Nyong. Flavivirus: JE Bunyaviridae: Anopheles A and B. (66)	Eggs laid on water. Adults spread by air transport. Never intercepted. Most species precluded by climate. *An. Annulipes* in Southern Australia a presumed vector of malaria (105). Low establishment risk. Carries severe diseases. Low risk.	Potential distribution addressed by Hotspots model.	Port and airport surveillance. Taxonomy on reported cases of nuisance biting.

Table 2. Vector risk assessment for ticks and mites

Ticks and mites		Hosts	Environment			Disease agents (endemic agents in blue)	Vector risk	Ecological questions	Vector surveillance
			Feeding habits	Distribution NZ	Distribution overseas				
Tick is the common name for the small arachnids, which along with mites, constitute the order *Acarina*. Ticks are ectoparasites, living by hematophagy on the blood of mammals, birds, and occasionally reptiles and amphibians. The major families of tick include the *Ixodidae* or hard ticks, which have thick outer shells made of chitin, and *Argasidae* or soft ticks, which have a membranous outer surface.		Seven of the nine tick species in New Zealand are primarily associated with seabirds, one with landbirds, and one (an introduced species with mammals amd birds.	Ticks require a blood meal to progress to each successive stage in their life cycle.	Throughout, but patchy.	Widespread	Tick-borne viruses are found in six different virus families (*Asfarviridae, Reoviridae, Rhabdoviridae, Orthomyxoviridae, Bunyaviridae, Flaviviridae*) and at least 9 genera. Some as yet unassigned tick-borne viruses may belong to a seventh family, the Arenaviridae. With only one exception (African swine fever virus, family Asfarviridae) all tick-borne viruses (as well as all other arboviruses) are RNA viruses. Some tick-borne viruses pose a significant threat to the health of humans (Tick-borne encephalitis virus, Crimean-Congo haemorrhagic fever virus) or livestock (African swine fever virus, Nairobi sheep disease virus). Ticks are second only to mosquitoes as vectors of human disease, both infectious and toxic. Generally, tick-borne diseases correspond to a specific tick-host combination, and are limited in their geographical extent.			Active collection, taxonomy, and testing of ticks is necessary. No effective passive surveillance occurs.
Argasidae (Soft ticks)	The family Argasidae contains four genera, including *Argas* and *Ornithodoros* (106)	Vertebrates	Soft ticks typically live in crevices, homes, nests resting places of their hosts (107). Emerge briefly to feed.			Medically important soft ticks are in the genus *Ornithodoros* (107). Painful bites. Can sometimes cause tick paralysis. Referred to as 'many-host' or 'multi-host' ticks as many hosts, different species and individuals are fed on during the various stages of the lifecycle (107)	No soft ticks intercepted in New Zealand so far (108); (109)		
	Ornithodoros capensis Neumann.	Sea birds, mainly gulls, terns, penguins but occasionally fowls & man (110); (111). Australasian gannets, white fronted terns (112); (113), spotted shags (114)	Lives in the nest, emerges from substrate to feed (111). Hides in rock crevices.	Coastal. Australasian gannet colony at Cape Kidnappers (112); (113), spotted shag colony at Somes Is, Wellington Harbour, red billed gull and white fronted tern colonies at Kaikoura, Sumner and Karitane (113). East and west coasts of South Island, Kermadec Islands (115)	Transequatorial. Including Oceania and Australia (110)	Flavivirus: Saumarez Reef - NZ (113)& Australia (116); (117), WNV. Quaranfil: Johnston Atoll virus (JAV) - 10 strains from 4000 ticks ex Cape Kidnappers gannets (112); (113); (117) & JAV - Australia 12; 3346; (117), Abal virus (118). Orthobunyavirus: Soldado, unnamed Hughes group virus (113); (118); 3344; (117). Alphavirus: Whataroa survived in the lab (111). Bunyavirus: Aransas Bay, Upolu virus (Australia) (118); (117). Sakhalin: Caspiy. Reovirus: Baku(118). Nyamanini: Hirota, Midway (USA, USSR and Midway Is) (118); (111); (117)	Abundant, widely distributed, known vector of disease. Known pathway for exotic viruses into New Zealand. *O capensis* and arboviruses occur in locations around Australia and the Pacific region that could possibly be a source of ticks and vector borne agents for NZ via migratory birds. Possible pathway for the introduction of West Nile virus. High introduction and re-establishment risk for arbovirus and high disease vector risk. High risk.	Is *O. capensis* carrying exotic or unidentified endemic viruses? Is it a pathway for virus entry into New Zealand? Are colonies, such as those on of spotted shags on Somes Is., carrying virus? Does this tick readily infest land birds in NZ, especially if they frequent seabird colonies?	Active collection and testing of ticks is necessary. No effective passive surveillance occurs.
	Ornithodoros moubata (Murray) (6 species complex) (107)	Mammals including humans (107)	Larvae of this species remain in eggshells and do not bloodfeed (107). Live near hosts in huts, caves, sheds (115)	Absent	Africa (107)	Tick-borne relapsing fever (*Borrelia duttoni*) - only important human disease transmitted by soft ticks (107). Trans-ovarial transmission - infected tick adult female passes spirochetes to eggs, and trans-stadial transmission - infection carried through as e.g. larva develops through the stages to adult tick (107).Transmitted WNV to rodents (119). African swine fever virus (117)	Low introduction risk, disease vector. Low risk.		
	Ornithodoros savignyi (Audouin)	Mammals		Absent	Africa, India, Sri Lanka.		Low introduction risk and low disease vector risk. Low risk.		
	Ornithodoros turicata (Dugès)	Mammals		Absent		Relapsing fever	Low introduction risk. Disease risk. Low risk.		
	Other Ornithodoros. There are 26 other species worldwide.	Mammals (bats, rodents, hares), marine birds (118)	Resting and roosting areas, e.g. nests and caves.	Absent	Worldwide	Several species associated with viruses (118)	Low inducution risk and low disease vector risk. Low risk.		

Ticks and mites		Hosts	Environment			Disease agents (endemic agents in blue)	Vector risk	Ecological questions	Vector surveillance
			Feeding habits	Distribution NZ	Distribution overseas				
	Argas persicus (species group complex)	Poultry, wild birds, domestic birds (ducks, turkey, canaries) (110)	Crevices of poultry houses (108). Repeatedly feed at night.	Absent	South East Asia, Australia (110) and the USA.	Fowl spirochaetosis? (110)	Low introduction and establishment risk and low disease vector risk. Low risk.		
	Argas robertsi (Hoogstraal, Kaiser & Kohls)	Poultry, open-bill stork, heron (118); (110)	Crevices of poultry houses (110). Repeatedly feed at night.	Absent	Australia, Thailand, Taiwan, Ceylon (118); (110)	Fowl spirochaetosis? (110). 2 Dera Ghazi Khan viruses and 1 ungrouped virus (118); (117). Reoviridae: Lake Clarendon virus (Australia) (117)	Low introduction and establishment risk Disease vector risk. Low risk.		
	Other *Argas*. There are a number of other species worldwide.	Birds	Resting and roosting areas, e.g. nests.	Absent	Worldwide	Several species associated with viruses including *A. hermanni, A. cooleyi, A. arboreus, A. streptopelia* (118); (117)			
	Otobius lagophilus (Cooley & Kohls)	Rabbits, hares, rodents, deer, cattle, humans (107)			United States, Canada (107)	Colorado tick fever (CTF) (107)			
Ixodidae (Hard ticks)	The family Ixodidae includes 13 genera, of which *Amblyomma, Dermacentor, Haemophysalis, Rhipicephalus* and *Ixodes* transmit disease (107); (106)	Vertebrates	Hard ticks will attach themselves to the skin of a host for long periods of time (ca. 7 days).	Throughout NZ and offshore islands; patchy on mainland.	Worldwide	Most tick-borne diseases are carried by hard ticks. Hard ticks can transmit human diseases such as relapsing fever, Lyme disease, Rocky Mountain spotted fever, tularemia, equine encephalitis and several forms of ehrlichiosis. Additionally, they are responsible for transmitting livestock diseases, including babesiosis and anaplasmosis.	All intercepted ticks to date were hard ticks (108); (109)		
	Ixodes eudyptidis Maskell	Seabirds including penguins, gannets and gulls (110); (120), pied shags (121); (114). Some land birds in close proximity to seabirds can be affected. Mice - in the lab (111)	Under rocks and plants in colonies	Seabird colonies. Dusky Sound, Nelson (120), Otago, Birdlings Flat (Cant.), Perpendicular Point (West Coast?)(122); (121)	Southern Australia (WA, NSW, Tas., Bass Strait) and NZ only (111); (110); (120)	Flavivirus: Saumarez Reef (6 strains from 120 ticks at a mixed gull and tern colony at Kaikoura) (113) & Australia(116); (117). Causes paralysis (111)	High re-establishment risk and high disease risk. High risk.	What is the host range? Are hosts migratory? What is the distribution?	Active collection and testing of ticks is necessary. No effective passive surveillance occurs.
	Ixodes uriae White	Seabirds - spotted shag (123), many seabird species - penguin, albatross, skua, petrel (110); (120), sooty shearwater (111)	In nest environment (110)	Seabird colonies. Birdlings Flat, Snares Is. (123). Common feeding on albatross on Campbell Island (R. Jakob-Hoff, pers. com.) Otago.	In both hemispheres (110); (120), circumpolar, but no gene transfer between hemispheres, despite transequatorial bird hosts, such as sooty shearwater.	Spirochaetes: Lyme disease (*Borrelia garinii*), Campbell Is. Flavivirus: Tyuleniy, Gadgets Gully (118); (111); (117). 32 viruses of the Great Island virus species group (includes Kemorovo viruses), 8 Sakhalin viruses, 16 Uukuniemi viruses and 3 ungrouped viruses (118); (111); (117). 7 Hughes group viruses (117). No virus isolated from several hundred collected from North Otago coast (near spotted shags). Implicated as vector of *Hepatozoon albatrossi* (124); Jakob-Hoff, RM. 2006, unpublished data).	High re-establishment risk and high disease risk. High risk.	Is this a pathway for the introduction of Lyme disease? What is its host range?	Active collection and testing of ticks is necessary. No effective passive surveillance occurs.
	Aponomma sphenodonti Dumbleton (tuatara tick)	tuatara (111); (123), NZs largest gecko (125)	The tuataras were in burrows associated with seabirds - fairy prions (123), petrels (125). Collected only from on host (125)	On offshore island, Stephen Is (123); (115). Middle Trio Island (125)	NZ only.	Possibly *Haemogregarina tuatarae* (111)	Low (narrow) disease vector risk. Low risk.		
	Ixodes anatis Chilton (kiwi tick)	Land birds, particularly kiwi, but also the grey duck and Canada goose (120); (114); (115)	Possibly kiwi nests.	Widespread, patchy. Little Barrier Is. (122), North Auckland, Ashburton, New Plymoth (120). Widespread on kiwi in Northland (R. Jakob-Hoff, pers. com.).	NZ only.	None known (111). Demonstrated to carry *Babesia kiwiensis* by PCR (R. Jakob-Hoff, unpubl. data).	Low (narrow) disease vector risk. Low risk.	How widespread is this vector in New Zealand? Can it be transmitted to other birds?	Active surveillance
	Ixodes jacksoni Hoogstraal	spotted shag (126), pied shag (121)	In nest environment (126)	Banks Peninsula (126), dead pied shag - New Brighton Beach, Christchurch, pied shag - Lake Forsyth, Birdlings Flat ex pied shag nests (121)	NZ only.	None known(111)	Low disease vector risk. Low risk.	Is it a valid species? No other records since.	

Ticks and mites		Hosts	Environment			Disease agents (endemic agents in blue)	Vector risk	Ecological questions	Vector surveillance
			Feeding habits	Distribution NZ	Distribution overseas				
	Ixodes auritulus zealandicus Dumbleton	Seabirds - dove petrel (121), king penguin, wandering albatross, sooty shearwater, diving petrel, fairy prion (128)	In nest environment, burrows (124)	Seabird colonies. Subantarctic Islands - Snares Is. (122), Stephen Is. (121), Antipodes Is., Macquarie Is., Auckland Is. (120)	This subspecies is NZ, but species is in north and South America.	Lyme disease (*Borrelia burgdorferi*) isolated from Ix. auritulus s.s. (127) None known from this subspecies (111); may cause paralysis.	Possible disease risk to conservation workers. Limited distribution. Low risk.	What bacteria is it vectoring? Needs taxonomic clarification. Does it carry viruses?	
	Ixodes kerguelenensis André & Colas-Belcour	petrel, shearwater	In nest environment, burrows (123)	Seabird colonies. Heard Is, Kergulen Is (120)	sub Antarctic	None known	Low disease vector risk. Low risk.	Does this species carry viruses?	
	Ixodes pterodromae Arthur	Sub Antarctic diving petrel, sooty shearwater (121)	Burrows and immediate environment (121)	Birdlings Flat (121)	sub Antarctic - Ocean Is., Auckland Is., Antipodes Is.? Macquarie Is. (121)	None known (111)	Low risk.		
	Haemaphysalis longicornis Neumann (livestock or cattle tick)	Wide host range although most commonly found on cattle. Deer or cattle often with heavy infestations (128); (110); (109). Domestic animals - cat, dog, goat, pig, rabbit (120), livestock - sheep, horses (120), humans (111) and land birds - magpie, budgerigar (110), North Island Brown Kiwi & banded rail (129), thrush, turkey, duck, sparrow, skylark, pheasant (120)	Each stage feeds on blood for 4-7 days. Nearly 80% of lifecycle off the host in the pasture (128). Can survive unfed for up to 12 months (128)	Occasionally intercepted (108); (109). North Is, Kaitaia, north of Waikanae on west coast and Pirinoa on east coast. North of Hastings and Foxton (120). Golden Bay in South Island. Found as far south as Southland.	Japan, Korea, China, north-eastern USSR, Australia, and western Pacific (110); (120)	An ungrouped Coxsackie A-like virus was isolated in Fiji (118); (111). Bunyaviridae: Khasan virus in USSR (111); (117). Flavivirus: Russian spring-summer encephalitis and Powassan encephalitis were isolated in USSR and Korea respectively (118); (111). Haematozoa shown to be actually or potentially transmitted include *Babesia ovata, B. major* and *B. bigemina*, *Anaplasma phagocytophilum, A. bovis*, *T. sergenti*, *Theileria orientalis* (128); (111), *Rickettsia japonica* and *Coxiella burnetii.* Bovine theileriosis (*Theileria mutans*) in Australia. Rickettsias: experimental vector of Q fever (130); (111). Heavy infestation can cause anaemia (111)	Medium re-introduction risk. Medium disease risk. Important cause of anaemia in some species. Medium risk.	What diseases is it vectoring?	Active collection and testing of ticks is necessary. No effective passive surveillance occurs.
	Rhipicephalus sanguineus (Latreille) (brown dog or kennel tick)	Predominantly dogs, but also ox, cat rat and rabbit in Australia (110); (108)	Inhabits hot regions with a well defined wet season. Sometimes heavy infestations around houses and stables (110)	Most common interception species (46%) (109), often intercepted on inanimate objects, can be many ticks per host (108). Not in NZ. Could establish in New Zealand where dogs present and temperature is suitable, northern North Island or in heated houses (108); (109). Three incursions involving infested houses in NZ.	Widespread throughout the world (110). Warmer parts of Australia, SE Asia, Hawaii, Africa (108)	Babesias: Babesiosis (*Babesia canis*) in dogs (110), *Babesia gibsoni* (109), *Babesia felis.* Ehrlichias: Tropical canine pancytopaenia (*Ehrlichia canis*) (109). Spirochaetes: Lyme disease (*Borrelia burgdorferi*) (117), Rickettsias: Boutonneuse fever (caused by *Rickettsia conori*), experimental vector of Q fever (*Coxiella burnetii*) ((107); (110). Keremovo: Wad Medani (118); (117)	Absent, High introduction and establishment risk. High disease risk. High risk.	Are intercepted ticks infected with agents? Is *R. sanguineus* already in Auckland, Northland?	Active collection and testing of ticks is necessary. No effective passive surveillance occurs.
	Ixodes pacificus Cooley & Kohls (western black-legged tick)	Common on deer and cattle, also humans, dogs (108) birds, mice, cats, sheep.		Occasional interception (5%) (108); (109). Not in NZ. Could establish throughout NZ, wide host range and able to withstand climatic extremes (108)	North America (2462; (108) and Canada (108)	Spirochaetes: Lyme disease (*Borrelia burgdorferi*) (2462). Babesias: *Babesia microti.* Transmits *Francisella tularensis* (108). Bites cause generalised discomfort through slow-healing painful sores (108)	Medium introduction risk. High establishment risk, disease risk high. High risk.		Active collection and testing of ticks is necessary. No effective passive surveillance occurs.
	Ixodes ricinus (Linnaeus) (European sheep or castor bean tick)	Sheep, goats, dogs, cats, horse (120), sometimes humans (107)	Three year lifecycle (107)	Occasionally intercepted (108); (109). One doubtful record of occurrence in New Zealand in 1922 (120). Could establish throughout New Zealand.	Northern Asia and Europe, north Africa (107)	Spirochaetes: Lyme Disease (*Borrelia burgdorferi*), *Anaplasma phagocytophilum, A. marginale.* Babesias: Several species of *Babesia.* Flaviviridae: Russian spring-summer encephalitis (RSSE) or Far Eastern tick borne encephalitis, Central European encephalitis (CEE) or tick-borne encephalitis (TBE) and Louping Ill (LI) (118); (107); (117). 4 Kemerovo viruses & 2 Uukumiemi viruses (118). Eyach virus (117). *Coxiella burnetii.* Bunyaviridae: Crimean-Congo hemorrhagic fever.	Medium introduction risk. High establishment risk, disease risk high. High risk.		Active collection and testing of ticks is necessary. No effective passive surveillance occurs.

Ticks and mites	Hosts	Environment			Disease agents (endemic agents in blue)	Vector risk	Ecological questions	Vector surveillance
		Feeding habits	Distribution NZ	Distribution overseas				
Ixodes holocyclus Neumann (Australian paralysis or Australian scrub tick)	Wide host range, marsupials, (brown bandicoots, echidnas, possums), wallabies, domestic animals, humans, birds (110), occasionally reptiles.	Coastal species (110). Requires moderate temperature and a high moisture level.	Commonly intercepted (24%) (109), mainly intercepted on humans with usually only one tick per host (108). Not in NZ. Could establish in northern New Zealand - Northland, Bay of Plenty, East Coast (108); (109)	eastern Australia (110); (109)	Flaviviridae: Louping Ill. Rickettsias: Queensland Tick typhus or Rickettsial spotted fever (*Rickettsia australis*). Causes paralysis in humans if undetected, can be deadly (108); (109); (131). Potential vector of Q fever.	High introduction risk Medium establishment risk. Disease risk low. Could establish in north of North Island. Medium risk.	Are intercepted ticks infected with agents?	Is this tick established in Northland? Active collection and testing of ticks is necessary. No effective passive surveillance occurs.
Dermacentor variablilis (Say) (American dog tick)	dogs, small rodents, deer humans (109), racoon (118)		Rare interceptions (108); (109). Could establish throughout New Zealand.	Eastern North America (108)	Rickettsias: Rocky Mountain spotted fever (RMSF). Tularaemia: Rabbit fever or deer-fly fever (*Francisella tularensis*). Ehrlichias: *Ehrlichia ewingii*. Reoviridae: Colorado tick fever (107). Spirochaetes: *Anaplasma marginale*. Ungrouped: Sawgrass (SAW) (118); (117)	Common on dogs, Low introduction risk. Medium establishment risk. High disease risk. Medium risk.		Active collection and testing of ticks is necessary. No effective passive surveillance occurs.
Ambylomma cyprium Neumann	pig, cattle, reptiles, dog, horse, buffalo, man.		Intercepted once (108). Not in NZ, unlikely to establish.	Fiji (108), Philippines, China, Indonesia, Timor, PNG.	None reported.	Low introduction risk. Low establishment risk. Low disease risk. Low risk.		
Ambylomma triguttatum C.L. Koch (group of four subspecies) (110); (106)	marsupials, macropods, ox, horse, sheep, dog, pig, dingo and human, lab reared on rabbit (110)		Intercepted three times, twice on humans (108); (109). Not in NZ, unlikely to establish.	Australia (110)	Rickettsias: Q fever (110)	Low introduction risk. Low establishment risk. Low disease risk. Low risk.		
Ambylomma variegatum (Fabricius)	Domestic animals (118)		Not in NZ.	Africa (118)	Bunyaviridae: Crimean-Congo haemorrhagic fever (CCHF) (118). 1 Ganjam, 1 Thogoto and 2 ungrouped viruses (118); (117). Ungrouped: Heartwater disease caused by *Ehrlichia ruminantium*; and Nairobi sheep disease.	Low introduction risk. Low establishment risk. Medium disease risk. Low risk.		
Other *Ambylomma*. There are a number of other species worldwide.	Domestic mammals, woodchuck (118)			Africa, USA, Jamaica (118)	Several species associated with viruses including *A. lepidum, A. americanum, A. cajennense* (1216)	Low introduction risk. Low establishment risk. Low disease risk. Low risk.		
Aponomma hydrosauri (Denny)	Predominantly reptiles, but also ox and horse (110)		Intercepted once (108). Not in NZ.	Australia (110)	Rickettsia: Flinders Island spotted fever (*R. honei*) (139)	Risk unqualified probably low.		
Dermacentor albipictus (Packard)	Moose, deer, horse, humans (109), cattle.		Rare interceptions (108); (109). Could establish throughout New Zealand.	Widespread in North America, Canada (108)	Reoviridae: Colorado tick fever (CTF) (115)	Low introduction risk. Medium establishment risk. Low disease risk. Low risk.		
Haemaphysalis bancrofti (Nuttall & Warburton)	Marsupials and macropods (possums, wallabies, kangaroos), mammals (ox, horse, pig, sheep, dog, human, bat) and birds (110); (108)		Intercepted once (108). Not in NZ. Suitable environmental conditions in New Zealand, although major hosts in short supply (132)	Australia (110)	Theilerias: Experimental vector of bovine theileriosis (*Theileria mutans*) (110)	Low introduction risk. Medium establishment risk. Low disease risk. Low risk.		
Other *Rhipicephalus*. There are a number of other species worldwide.	cattle, goat, sheep, hare, domestic animals, rodents (118)		Not in NZ.	Worldwide	Several species associated with viruses including *R. appendiculatus, R. turanicus, R. rossicus, R. pravus* (116)			
Ixodes persulcatus Schulze (taiga tick)	Humans, small mammals (107)		Not in NZ.	USSR, Siberia, northern Asia, China (107)	Flaviviridae: Russian spring-summer encephalitis (RSSE) or Far Eastern tick borne encephalitis (118). Spirochaetes: Lyme disease (*Borrelia burgdorferi*) (107). Omsk? Haemorrhagic fever and Kemerovo virus (118)	Risk unqualified probably low.		
Ixodes scapularis Say (eastern black-legged tick)	Deer (107)		Not in NZ.	Eastern North America (107)	Spirochaetes: Lyme disease (*Borrelia burgdorferi*) (107). Reoviridae: St Croix River virus (117). Flavivirus: Deer tick virus (117)	Risk unqualified probably low.		
Other *Ixodes*. There are over 220 more *Ixodes* species worldwide.	Mammals, rodents (118)		Not in NZ.	Worldwide	Several species associated with viruses including *I. petauristae, I. cookei, I. granulatus, I. marxi* (118), or Lyme disease e.g. *I. dammini*.	Risk unqualified probably low.		

Ticks and mites		Hosts	Environment			Disease agents (endemic agents in blue)	Vector risk	Ecological questions	Vector surveillance
			Feeding habits	Distribution NZ	Distribution overseas				
	Dermacentro andersoni Stiles (Rocky Mountain wood tick)	Rabbits, hares, rodents, deer, cattle, humans (109)		Not in NZ.	United States, Canada (107)	Reoviridae: Colorado tick fever (CTF) (118); (117), Flaviviridae: Powassan encephalitis (POW) (118). Rickettsias: Rocky mountain spotted fever (RMSF caused by *Rickettsia ricketsi*). Tularaemia: Rabbit fever or deer-fly fever (*Francisella tularensis*) (107)	Risk unqualified probably low.		
	Dermacentor marginatus (Sulzer)			Not in NZ.	Europe, Asia (107)	Flaviviridae: RSSE, Central European encephalitis (CEE). Bunyaviridae: Crimean-Congo haemorrhagic fever (CCHF) (118); (107). Razdan virus (117)	Risk unqualified probably low.		
	Dermacentor silvarum	humans (109)		Intercepted once (109). Could establish throughout New Zealand.		Flaviviridae: Russian spring-summer encephalitis (RSSE) (118)	Risk unqualified probably low.		
	Other *Dermacentor*. There are many other species worldwide.	Mammals (rodents, hares) (118)		Not in NZ.	Worldwide	Several species associated with viruses including *D. reticulatus, D. auratus, D. occidentalis, D. parumapterus* (118); (117). *Dermacentor nitens* vectors *Babesia caballi*.	Risk unqualified probably low.		
	Haemaphysalis concinna Koch	Small mammals, humans (107)		Not in NZ.	Russia, Austria (118)	Flaviviridae: Russian spring-summer encephalitis (RSSE) or Far Eastern tick borne encephalitis (118); (107)	Risk unqualified probably low.		
	Haemaphysalis spinigera Neumann	Monkeys, humans (107)		Not in NZ.	India (1216; (107)	Flaviviridae: Kyasanur Forest disease (KFD) (1216; (107); (117). Kaisodi virus & 1 ungrouped virus (118); (117)	Risk unqualified probably low.		
	Other *Haemaphysalis*. There are a number of other species worldwide.	Domestic animals, rodents, birds, small mammals (118)		Not in NZ.	Worldwide	Several species associated with viruses including *H. punctata, H. leporispalustris, H. inermis, H. wellingtoni* (118)	Risk unqualified probably low.		
	Hyalomma marginatum (species complex) (118); (107)	Birds, domestic animals, cattle (118)		Not in NZ.	Europe, Asia, Africa, Russia (1216; (107)	Flaviviridae: WNV (118). Bunyaviridae: Crimean-Congo haemorrhagic fever (CCHF) (118); (107); (117). Keremovo: Wad Medani (118). 1 Ganjam virus, 2 Dhori viruses and 1 ungrouped virus (118); (117). Matruh virus (117)	Risk unqualified probably low.		
	Other *Hyalomma*. There are a number of other species worldwide.	Camels, cattle, domestic animals.		Not in NZ.	Asia, Africa, Russia (118)	Several species associated with viruses including *H. anatolicum, H. truncatum, H. dromedarii, H. impeltatum* (118)	Risk unqualified probably low.		
Nuttalliellidae	The family Nuttalliellidae includes only 1 genus *Nuttalliella* with one species (107)			Not in NZ.		None reported (107)	Low introduction and establishment risk, low disease risk. Low risk.		
	Nuttalliella namaqua (Bedford)	Rodent, small carnivore (133)	Crevices of granite boulders in Tanzania, semi-arid areas in South Africa (133). Bird nests (141)	Not in NZ.	South Africa, Tanzania (133)	None reported.	Low intorduction and establishment risk. Low disease risk. Low risk.		
Mites	Mites are essentially very small ticks (minus a hypostome), many are non-parasitic. Parasitic mites are divided into burrowing, non-burrowing and follicular mites. Disease in skin caused by mites is called mange. Most mites are host specific, but may survive long enough on other hosts to cause skin lesions. Mites that live in house dust can cause allergies.			NZ has numerous *trombidoidea*, especially on insects.	Worldwide	Some mites are important vectors of rickettsial diseases, such as typhus fever due to *Rickettsia tsutsugamushi* (scrub typhus) and several viral diseases. Mites can present a serious biting nuisance to humans and animals. Many people show allergic reactions to mites or their bites. Certain mites cause a conditions known as scabies and mange and cause a loss of fertility in livestock and loss of quality in wool and hides.			
	Ophionyssus scincorum	Otago skink species (134)				*Hepatozoon lygosomarum* (135)	Risk unqualified.		
	Geckobia species; G. bataviensis and 4 other species.	Geckos, other lizards e.g. skinks in NZ (136)	feed on blood and lymph, other fluid and semi-digested material (107)	Not in NZ except for *G. hoplodactyli* and *G. naultina* (136)	Widespread in pacific, SE Asia and west coast North America.	8 protozoa genera recorded from NZ reptiles, *Haemogregarina sp, Hepatozoon lygosarum, Nyctotherus* sp., *Plasmodium lygosomae.*	Medium introduction risk. Low establishment risk. Disease risk low. Low risk.	We need to know if *G. bataviensis* is a risk to NZ reptiles; around 20% of intercepted geckos have the mite. Do the intercepted mites carry disease?	
	Ophionyssus natricis (snake mite)	Snakes, occasionally lizards, occasionally humans (137)		Not in NZ - has been found on a blue tongue skink (in captivity in NZ) (138); (139).	Widespread, worldwide.	Possibly bacteria, eg *Aeromonas;* blood parasites.	Risk unqualified.		

Ticks and mites		Hosts	Environment			Disease agents (endemic agents in blue)	Vector risk	Ecological questions	Vector surveillance
			Feeding habits	Distribution NZ	Distribution overseas				
	Psoroptes ovis (sheep scab mite)	Sheep, cattle, goats, llamas,a lpacas (140)		Important production limiting disease now eradicated (141)	UK, Europe, South America, Asia, Canada.	Not a biological vector, but is an unwanted organism.	Re-introduction risk is low, impact would be high.		Surveillance required.
	Trombiculid mite spp. (scrub typus mite)	Mammals, reptiles and birds(105)	Feed on lymph, other fluid and semi-digested material (107)	various species but not a danger to humans, 3000 sp of mite, 20 of medical importance (107)	Asia and the Pacific; worldwide (107)	*Rickettsia tsutsugamushi* (scrub typhus) (142); (143); Sindbis virus, Junia virus, haemorrahgic nephrosonephritis.	Risk unqualified.		
	Leptotrombidium (trombicula) akamushi	Mice, humans, rats, moles (107)	Feed on lymph, other fluid and semi-digested material (107)		Tropical, Japan (143), Solomon Islands, Vanuatu (111)	*Rickettsia tsutsugamushi* (scrub typhus)(*Rickettsia = Orientia*) (107) (144); (143) disease limited to eastern and southeastern Asia, India, and northern Australia (107),*Rickettsia akari, Rickettsia orientalis* (145)	Risk unqualified.	Could this mite establish in New Zealand?	
	Geckobiella sp.	Geckos, skinks, lizards.	Feed on blood and lymph, other fluid and semi-digested material (107)	Not in NZ.	Widespread	*Schellackia sp.* and possibly haemogregarines, *Plasmodium mexicanum* (146)	Establishment risk medium, disease risk low.		
	Ornithonyssus bacoti (tropical rat mite)	Rats, man, mice, gerbils (110); (147); (148)		Not in NZ.	Widespread	Lab vector of Hantaan and Seoul virus and may be involved in the transmission of haemorrhagic fever with renal syndrome virus (149); may be reservoir and vector of Rattus-borne Hantavirus (150)	Low risk.		
	Liponyssoides sanguineus (house mouse mite)	Mice, rodents (151) birds, man.	Feeds on blood, lymph, other fluid and semi-digested material (107)	Not in NZ.	Ukraine, South Korea, South Africa, Equatorial Africa.	*Rickettsia akari* (152)	Low introduction and establishment risk. Low disease risk. Low risk.		

Table 3. Vector risk assessment for other insects (Flies Midges, Sandflies, Blackflies, Fleas and Lice)

Other Insects (Flies, Midges, Sandflies, Blackflies, Fleas and Lice		Hosts	Environment				Disease agents (endemic agents in blue)	Vector risk assessment	Research questions	Vector surveillance
			Larval habitat	Adult feeding habits	Distribution NZ	Distribution overseas				
Diptera	Dipterous insects have one pair of wings, the hind wings being represented by halteres. There are 73 families of Diptera in New Zealand with at least 2310 known species, and many others undescribed. Other than the Culicidae (Mosquitoes) and the Simulids (our "sandflies") there are at least 14 species of importance to birds or livestock from four families (1 Muscidae, 5 Hippoboscidae, 3 Calliphoridae, and 5 Oestridae) that are blood feeders, or livestock parasites or bird parasites.									
Ceratopogonidae (Ceratopogonids or biting midges)	Biting midges are flies belonging to the family Ceratopogonidae. There are around 5500 species in more than 60 genera world wide. Members of the genera, *Austroconops, Lasiohelea, Leptoconops*, some species of Forcipomyia and most importantly *Culicoides*, feed on blood of vertebrates including human. Of the approximately 1400 known species of *Culicoides*, roughly 96% are obligate blood feeders, and about 50 are implicated in the transmission of pathogens and parasites. *Culicoides* spp. occupy a wide range of environments from cool to temperate to tropical, and occur on virtually all land masses except Antarctica and New Zealand (153). There are 38 Ceraptogonids recorded in New Zealand - *Leptoconops myersi* Tonnoir is the only known species to feed on blood here.	Vertebrates	Eggs are usually laid on surface of mud or wet soil, especially those with plenty of decaying plant materials, the major food source for the larvae. Biting midge larvae are aquatic or semi-aquatic, and can live in both fresh and salt water. Other breeding sites include saturated soil, tree holes, semi-rotting vegetation and animal dung.	Adults are about 1-4 mm long with dark body colour. They rest in dense vegetation and sometimes shady places. Their flight range varies but is usually a few hundred meters, or less, from their breeding grounds. Dispersal over large distances (transoceanic) by wind is possible. All Culicoides biological functions and activities are closely linked to climate as is therefore, Culicoides borne disease transmission. Different species have specific preferences and tolerances: strong wind (over 2.2 - 3 m/sec, depending on species) and excess or low moisture levels inhibit flying and biting activity, as does low temperature (below 10C for C. variipennis, 18C for C.brevitarsis). Similarly, specific temperature requirements drive both species distribution and abundance. Adults usually emerge in the summer and so it is the period when their nuisances are most serious. Only female adults bite. Biting activity varies among species but they are most active in day time or near sunrise and sunset.	*Culicoides* is absent. If introduced, several temperate species could probably establish in New Zealand. It is not currently known if any *Culicoides* of disease transmission potential could establish in New Zealand.	*Culicoides* widespread.	Collectively *Culicoides* transmit over 50 viruses, significance mostly relates to domestic animals and nuisance biting and allergic skin conditions. To most people, the bites of biting midges cause acute discomfort and irritation. The irritation can last for days, or even weeks. Scratching aggravates the pruritus and may lead to bacterial infection and slow-healing wounds.	Low establishment risk, low disease vector risk, temperate species could establish here.	Periodic reassessment should be undertaken of the establishment risk of any cold tolerant species with disease relevance as some species change their distribution with time. Are there pathways of entry for *Culicoides*.	All non astrosimulium nuisance biting in New Zealand should be investigated and specimens sent for taxonomy.
	Forcipomyia spp.	Not determined.	Not determined.	Not determined. Author queries possibility of Amphibian or Avian hosts.	Not determined.	Genus is widespread.	*Forcipomyia velox* is listed as a vector of the nematode *Icosiella neglecta* to green frogs (154) (other hosts are listed in www articles), and *Forcipomyia townsvillensis* as a lab vector for *Onchocerca gibsoni* to cattle (154)	Disease vector risk low.	Do members of this genus in NZ take blood meals? Is there any disease transmission significance? (neither researched here)	

Other Insects (Flies, Midges, Sandflies, Blackflies, Fleas and Lice		Hosts	Environment				Disease agents (endemic agents in blue)	Vector risk assessment	Research questions	Vector surveillance
			Larval habitat	Adult feeding habits	Distribution NZ	Distribution overseas				
	Leptoconops myersi (Tonnoir)	Probably birds (155), also recorded from humans (156)	Coastal, just above high water mark. Believed to be the moist sand along the margins of brackish stream mouths and brackish estuarine environments (156)	Females take blood meals.	ND, CL, BP, NN ((156)), possibly throughout NZ (A. Heath, pers. com. 2006)	NA - known only from NZ.	*Leptoconops becquaerti* (Kieff.) is implicated as a very poor vector of *Mansonella ozzardi* (157). However, in general Leptoconops (and Styloconops) are either not implicated as vectors or considered not significant.	Disease vector risk low.	Is this species associated with sea-gull ill-health? (query posed by (156))	
	Culicoides species of interest in Australia: *C. actoni, C. brevipalis, C. brevitarsus, C. fulvus, C. pererinus, C. wadai, C. marksii, C. bundyensis, C. molestus, C. ornatus.* *Cuiicoides vectors of Bluetongue virus:* 17 species connected with BTV including *C. imicola* and *C. bolitinos, C. fulvus, C. brevitarsis, C. sonorensis, C. insignis* and *C. pusillus.* *Culicoides imicola* a vector of AHSV.	Horses, cattle, sheep, mammals.	Breeding habitat of many species unknown. *C. brevitarsus* and most disease vectors are dung breeders. *C. molestus* is estuarine.	Attracted to livestock, especially in low wind conditions, swarm half an hour before dark.	Culicoides is absent. If introduced, several temperate species could probably establish in New Zealand. It is not currently known if any Culicoides of disease transmission potential could establish in New Zealand.	The major vector species are *C. imicola* and *C. bolitinos* in Africa, *C. imicola* in Asia, *C. fulvus* and *C. brevitarsis* in Australia, *C. sonorensis* in North America, *C. insignis* and *C. pusillus* in South and Central America. *Culicoides imicola s.l.* is a complex of at least 10 sibling species, with widely differeing biologies and distribution. AHSV is endemic in sub-Saharan Africa but periodically makes brief excursions beyond this area, where it has caused major epizootics extending as far as Pakistan and India in the east, and as far as Morocco, Spain and Portugal in the west.	**Orbivirus:** African horse sickness (AHS) , Bluetongue, epizootic haemorrhagic disease (deer), Palyam, Eubenangee. **Bunyavirus:** Akabane, Oropouche, Simbu. **Lyssavirus:** BEF. **Alphavirus**: Equine encephalosis. **Vesiculovirus:** Vesicular stomatitis. Filaroids: *Dipetalonema (D. perstans, D. streptocerca)*, *Eufilaria* spp., *Splendidofilaria* spp. *Chandlerrella* spp. *Tetrapetalonema* spp. (154), *Mansonella (Mansonella ozzardi)*, *Onchocerca* (in horses, cattle, and possibly monkeys (157) ; Protozoans *Akiba (=Leucocytozoon?)* and *Parahaemoproteus (=Haemoprotues?)* (156), *Haemoprotues* spp., *Leucocytozoon caulleryi, Trypanosoma* spp. (154)	For the majority of species of importance there is a low introduction risk and low establishment risk. The risk of introduction and establishment of disease agents is low. Diseases are important. Various reviews focus on Australian *Culicoides species. C. brevitarsus* was considered likely to be introduced (by wind), but there are mixed views about its likelihood of establishment. *C wadii* was considered likely to establish if introduced, but this is currently doubted. *C onrnatis* and *C molestus* have history of spread around the Pacific, however they are of low or negligible disease significance. Potential risks from other members of this genus for NZ not determined. Fuller risk analysis is required to justify current surveillance. Low risk.	Which species of Culicoides is NZ at risk from? Is there risk pathways for the temperate climate species, and do these present any disease transmission potential, or could they affect NZs quarantine status? (Including - is the range of various important colder tolerant *Culicoides* vectors changing?) *Culicoides* spp. biology and distribution in Australia is now available, as is the range of alternative models. Current assumptions require review.	Annual light trapping in late summer is undertaken in warmer areas of New Zealand. Methods used may not cover the *Culicoides* species of interest.
Chloropidae	*Hippelates insignificans*	Humans, mammals, birds.	The larval habitat of *H. insignificans* is uncertain Overseas *Hippelates* spp. occupy decaying organic matter niches, including in soil and dung, or mine leaves.	Adult *H. insignificans* are attracted to humans skin, ears and eyes. Biting behaviour only recently reported (P. Holder, pers. com.). Overseas species of face fly are known to actively feed on protein rich eye, nasal, and wound secretions, as well as saliva and blood.	Endemic. Known northern coastal distribution. Recently reported at Waitaki valley South Island. Likely to be widespread.	Nil	Not a known vector of disease. Some overseas *Hippelates* spp. (in new world) and *Siphunculina* spp. (in the old world) transmit conjunctivitis (including the bacteria *Moraxella bovis* (pink eye) in cattle), and possibly yaws, and tropical ulcers.	Disease vector risk low. Small fly, which may be confused with *Culicoides.* Not a known vector of disease. Low risk.	What is the association of this species with mammalian hosts (is it taking blood)? Is this species involved in the mechanical transmission of disease? Is this species the casual agent of "Hot water beach itch"? (a rash reported from coastal Coromandel Peninsular, reported to be caused by "small flies")	Surveillance for exotic small biting flies is needed.
Chironomidae. (Chironomids or non biting midges)	There are over 2000 species of Chironomids. They live in water and are imitated by fishermen to catch trout.		Chironomids will live in the larva stage for up to two years before turning into pupa to begin their migration to the surface to hatch into adults. Chironomid hatches occur year round.	They are non biting flies and up until recent reports of Vibrio Cholera have not been associated with disease.	Endemic	Widespread	Recently associated with the **bacterium:** Vibrio cholera in Israel and Africa	Disease vector risk low. Not a known vector or known biter. Low risk.		

Other Insects (Flies, Midges, Sandflies, Blackflies, Fleas and Lice		Hosts	Environment				Disease agents (endemic agents in blue)	Vector risk assessment	Research questions	Vector surveillance
			Larval habitat	Adult feeding habits	Distribution NZ	Distribution overseas				
Simuliidae. (Simulids or Blackflies)	The Simuliidae are a family of small, sturdy-bodied midges with a notorious reputation in some parts of the world as bloodsucking pests. About 1,600 species are currently recognized; however, there are a large number of additional unnamed species. Members of the family are usually called black flies, but in New Zealand they are locally known as sand flies.	Vertebrates	Immature life stages stages are aquatic and virtually confined to running waters. Larvae and pupae are attached to submerged substrates, most often trailing vegetation, stones, or the fixed bedrock of cascades and waterfalls. The larvae are suspension-feeders, collecting material from the running water.	Bloodsucking is not a universal habit, but females of most species feed on warm-blooded vertebrates, often preferring either birds or mammals. Except in the Marquesas, where they can be a severe local scourge, simuliids are rarely more than a minor biting nuisance in the Pacific Islands.	*Austrosimulium* spp. are found only in Australia and New Zealand, where a few species of *Austrosimulium* are serious mammal biters. Other simulid genera are not present in NZ.	Worldwide	There is no evidence that blackflies are involved in any human disease in Australasia or Oceania, but they transmit the **filaroids** *Onchocerca volvulus* (the cause of river blindness in Africa and parts of tropical Central and South America).	The establishment of other Simulids in New Zealand would not really be associated with a disease risk, however they could cause nuisance biting.	What is the risks of introduction of exotic simulids? There have been interceptions from Asia and Australia.	
	Austrosimulium spp. There are 13 species of Austrosimulium in New Zealand. Generally only *Austrosimulium australense* and *A. ungulatum* bite people (our "sandfly"). There are also members of this genus in Australia, including the pestiferous *A. pestilens.*	Vertebrates	As above	Females suck blood.	Genus occurs throughout NZ, including offshore islands. *A. australense* is a minor to major pest biter in the North Island; *A. ungulatum* can be a vicious biting pest in the South Island of New Zealand.	Genus only known in NZ and Australia. *A. pestilens* is a livestock pest that undergoes major periodic outbreaks in Queensland.	*Austrosimulium* spp. are vectors of *Leucocytozoon tawaki* (protozoa) in crested penguins and probably yellow-eyed penguins in New Zealand (191, R. Jacob-Hoff per comm). Experimental infection of *A. ungulatum* has shown that it is not a biological vector of Whataroa virus.	Common, abundant, and the known presence of blood parasites could be of interest. NZ blackfly species may have potential to maintain and transmit exotic filaroids and Protozoa. They may also play a significant role in outbreaks mediated by other arthropods. Possible mechanical vectors of vector borne disease. Medium risk.	What is the role of this vector in blood parasite transmission? Does *Leucocytozoon* spp. occur in other birds in NZ? If introduced, would exotic Filaroids and Protozoa persist and be vectored by the endemic Simuliidae?	Surveillance for exotic small biting flies is needed.
Psychodidae (moth winged flies)	Phlebotominae (true sandflies). There are over 530 species of sandflies. Females of all phlebotomines take a blood meal. Their bite is generally not felt and leaves a small round, reddish bump, which starts itching hours or days later. Some species are important disease vectors. The important genera are *Phlebotomus, Sergentomyia* and *Lutzomyia.*	Vertebrates	Eggs, larvae and pupae occur in the soil, or among leaf litter in forests. The larvae feed on a wide variety of animal and plant material, including faeces. Many species occur in arid areas, however several species, including some disease vectors occur in forest, steep and grassland environments.	Many species of *Phlebotomus* take mammalian blood, including man. Most *Sergentomyia* spp. feed on lizards and other reptiles and may also bite man. Some *Sergentomyia* and *Lutzomyia* sandflies suck blood from birds, but many potentially feed on humans. One species attacks penguins as well. Female sandflies use their mouthparts to create a pool of blood, which is then sucked up.	Phlebotominae is absent from NZ, as well as the rest of Oceania.	Asia, Africa, America, Europe. *Phlebotomus* is the main sandfly genus in the south Palaeartic (including temperate areas up to 48 degrees N), but species also occur in Australia, eastern Africa and parts of Arabia and India. *Sergentomyia* is the dominant genus in the Old World tropics, but is also represented in Australia/ PNG. *Lutzomyia* the most common genus in the New World.	The sandfly is the primary vector of leishmaniasis and sandfly fever. In the new world, leishmaniasis is transmitted by sandflies of the genus *Lutzomyia*. In the old world, the disease is transmitted by sandflies of the genus *Phlebotomus*. The disease is not found in Australia or Oceania. There are at least 30 *Leishmania* pathogens. In dogs: *Leishmania donovani*. In man: *Leishmania infantum, Leishmania tropica, Leishmania braziliensis*. *Plebotomus* spp. also transmit. Bunyavirus: Rift Valley Fever.	Excluded by climate, and/or very low risk of introduction. Low risk.		
Muscidae (Muscid flies)	Muscidae, some of which are commonly known as house flies or stable flies due to their synanthropy, are worldwide in distribution and contain almost 4,000 described species in over 100 genera.	Various	Most species are not synanthropic. Adults can be predaceous, haematophagous, saprophagous, or feed on a number of types of plant and animal exudates. They can be attracted to various substances including sugar, filth, sweat, tears and blood. Larvae occur in various habitats including decaying vegetation, dry and wet soil, nests of insects and birds, fresh water, and carrion.	Adults can be predaceous, haematophagous, saprophagous, or feed on a number of types of plant and animal exudates.	Some species widespread.	Widespread	Adults of many species passively vector pathogens for diseases such as typhoid fever, dysentery, anthrax, and African sleeping sickness.	The establishment of other Muscid flies in New Zealand would not really be associated with a specific disease risk, however they could have an adverse impact in other ways. Low risk.		

Other Insects (Flies, Midges, Sandflies, Blackflies, Fleas and Lice)		Hosts	Environment				Disease agents (endemic agents in blue)	Vector risk assessment	Research questions	Vector surveillance
			Larval habitat	Adult feeding habits	Distribution NZ	Distribution overseas				
	Musca domestica (house fly)	Organic matter	As above	Nectar, protein sources	throughout	throughout	Intermediate host for *Hebronema* nematodes. Otherwise mechanical vector only.	Low risk.		
	Stomoxys calcitrans (stable fly)	Horses, sheep, dogs, humans, cattle.	The female of *Stomoxys calcitrans* usually lays her eggs in decaying vegetable matter, especially if contaminated by urine. Sometimes this fly also lays her eggs in horse manure. A female is capable of laying a total of 800 eggs in batches of 25-50 eggs at a time. Depending on the temperature, the larvae can hatch in 2 to 4 days and mature into adult in 14 to 24 days. Oviposition begins 6 to 9 days after emergence of the female, provided a few meals of blood have been taken.	Bites horses, cattle, dogs, sheep, humans.	Widespread	Widespread	Although *S. calcitrans* is an important nuisance, causing irritation at the area of the bite, its main importance is as a mechanical vector of several diseases although none of these diseases occur in New Zealand. *S. calcitrans* has been found to be a vector of *Trypanosoma evansi* (agent of surra), *T. equinum* (agent of "mal de caderas"), *T. brucei* and *T. vivax* (agent of nagana). Equine infectious anaemia may also be transmitted by *S. calcitrans.* The stable fly can also serve as an intermediary host for *Habronema* nematodes.	Known vector. Present in New Zealand. Mechanical vector, exacerbates rather than causes vector borne disease. Low risk.	Is this a vector of disease in NZ?	
	Haematobia			Haematobia are blood feeding; male cattle more usually	Not in NZ.	India, China, SE Asia, Australia.	Mechanical vector only.	Absent, mechanicla vector only. Low risk.		
	Haematobia irritans (buffalo fly)	Domestic animals	Beneath fresh cattle dung and nearby; 10-14 days egg to adult at 27-30 deg C.	Bloodsucking is not a universal habit, but females of most species feed on warm-blooded vertebrates, often preferring either birds or mammals.			Mechanical vector only. Intermediate host possibly for *Stephanofilaria* sp.	Absent, mechanicla vector only. Low risk.		
Glossinidae (Glosina flies include Tsetse flies)	Large biting flies from Africa	Vertebrates	Tsetse flies have an unusual life cycle. Female tsetse only fertilize one egg at a time and retain each egg within their uterus to have the offspring develop internally during the first larval stages. In the third larval stage, the tsetse larva finally leave the uterus and begin their independent life. The newly independent tsetse larva simply crawls into the ground, forms a hard outer shell called the puparial case in which it completes its morphological transformation into an adult fly.	Female sucks vertebrate blood.	Not in NZ.	Africa	Biological vectors of the African trypanosomiases, deadly diseases which include sleeping sickness in people and nagana (*T. vivax*) in cattle.	Absent. Tropical vector only. Low risk.		
Tabanidae	large , active, persistent flies	Vertebrates	Spread disease in South East Asia. Eggs laid near water. Larvae aquatic and some predatory and some cannibalistic. Pupate in soil.	Both sexes feed on blood.	NZ species feed only on pollen.	Worldwide	Mechanical vectors of Anaplasma in cattle in Australia. *Dirofilaria roemeri* in macropids and possibly a trypanosome. Loa loa and Tulraemia.	Low risk.		
Oestridae	*Gasterophilus haemorrhoidalis (Linneaus, 1758)*	Livestock parasite	Stomach bots; oral cavity and intestine; eggs laid on hairs of host.	Adults don't feed.	Not in NZ.	Worldwide		Low risk.		
	Gasterophilus nasalis (Horse bot fly)	Livestock parasite			Throughout NZ.			Low risk.		

Other Insects (Flies, Midges, Sandflies, Blackflies, Fleas and Lice)		Hosts	Environment: Larval habitat	Adult feeding habits	Distribution NZ	Distribution overseas	Disease agents (endemic agents in blue)	Vector risk assessment	Research questions	Vector surveillance
	Gasterophilus intestinalis (Horse bot fly)	Livestock parasite			Throughout NZ.			Low risk.		
	Oestrus ovis (Nasal bot sheep)	Livestock parasite	Nasal sinuses.	Adult does not feed.	Throughout	Widespread		Low risk.		
	Hypoderma bovis (Warble flies, cattle)	Livestock parasite	Penetrates skin and may move by way of spinal canal to muscles.	Do not feed.	Emerged once from imported cattle.	25 deg to 60 deg N widespread.	No disease associated with these flies.	Major damage to host tissue. Low risk.	Very temperature dependent and seasons may be limiting.	
Calliphoridae	*Calliphora stygia* (brown blowfly)	Livestock parasite		Primary strike fly.			Mechanical vector only.	Low risk.		
	Lucilia cuprina (Weidmann, 1830)	Livestock parasite		Primary strike fly.			Mechanical vector only.	Low risk.		
	Lucilia sericata (green blowfly)	Livestock parasite		Primary strike fly			Mechanical vector only.	Low risk.		
Hippoboscidae	*Ornithoica exilis* (Walker, 1861)	Bird parasite	On host; larva almost immediately pupates.	Both sexes feed on blood.	Unknown; probably throughout.	Widespread	Haemoproteus, Trypanosomes, Dipetalonema. Hippoboscid flies have tested positive for WNV and are likely capable of transmitting the virus mechanically from bird to bird in captive and wild situations. They may have a role in the transmission of other agents in birds in New Zealand.	Low risk.		
	Ornithoica stipituri (Schiner, 1868)	Bird parasite	On host; larva almost immediately pupates.	Both sexes feed on blood.				Low risk.		
	Ornithomya nigricornis Erichson, 1842	Bird parasite	On host; larva almost immediately pupates Not sure what authority is being used for this species. Why is *O. avicularia* missing?	Both sexes feed on blood.				Low risk.		
	Ornithomya variegata Bigot, 1885	Bird parasite	On host; larva almost immediately pupates.	Both sexes feed on blood.				Low risk.		
	Melophagus ovinus (Sheep ked)	Livestock parasite	On host	Feeds on blood.	Once throughout, now rare.	Worldwide	Trypanosome	Low risk.		
Fleas	There are at least 1800 species of fleas, which are laterally flattened wingless insects whose adults suck blood from birds or mammals.	Vertebrates, mammals and birds.	Larvae feed mainly on organic matter in host environment; e.g. nest material and blood exuded from adults.	Adults spend their time between the host and the environment in between blood meals.	Some are widespread, others restricted to sub Antarctic islands.	7 cosmopolitan species and 1 European, 2 Australian.	The most famous flea borne disease is the bubonic plague caused by *Yersinia pestis*. They are the intermediate host of the filaroid nematode *Dipetalonema reconditum* and the cestode *Dipylidium caninum*, also *Rickettsia prowazekii*.			
	Xenopsylla cheopis	*Rattus rattus*, mice.			Common	Cosmopolitan	*Yersinia pestis*, *Rickettsia typhi* (158) ? Same as *R. prowazekii*.	Plague was present in early 20th century (238). High vector disease risk. Absence of maintenance hosts. Medium risk.	Plague was present in early 20th century (238). Is it still here?	
	Ctenocephalides felis	Cats, dogs, rat, hedgehog nest.			Common, widespread.	Cosmopolitan	*Rickettsia felis, Bartonella henselae, Bartonella clarridgeiae, Dipetalonema reconditum.*	Companion animal disease and zoonosis. Medium risk.		
	Xenopsylla vexabilis	*Rattus exulans*			Rare, offshore islands.	Australia, SE Asia, Hawaii.		Low risk.		
	Ctenocephalides canis	Dog, cat , man.			Common	Cosmopolitan	*Dipetalonema reconditum*	Low risk.		
	Ceratophyllus gallinae	Chickens and wild birds, man.			Common	European		Low risk.		
	Pulex irritans	Man, pig, dog, rat.			Common, but not from pig.	Cosmopolitan	*Dipetalonema reconditum*	Low risk.		
	Echidnophaga gallinacea	Chicken, pigeons, ducks, dogs, cats, horses, rabbits.				Australia		Low risk.	Are seabird fleas a pathway for the entry of exotic agents?	
	Sea bird fleas	Seabirds			Common, sub Antarctic islands, around 8 species.	Some circumpolar	None known	Low risk.		

Other Insects (Flies, Midges, Sandflies, Blackflies, Fleas and Lice		Hosts	Environment				Disease agents (endemic agents in blue)	Vector risk assessment	Research questions	Vector surveillance
			Larval habitat	Adult feeding habits	Distribution NZ	Distribution overseas				
	Nosopsyllus fasciatus	Rats, mustelids, mice, some birds			Common, widespread.	Cosmopolitan	*Yersinia pestis?*	Low risk.		
	Leptopsylla segnis	Mouse, rat.			Common, widespread.	Cosmopolitan		Low risk.		
	Pygiopsila hoplia	Rats, marsupials.			Offshore islands only.	Australia and PNG.		Low risk.		
	Spilopsyllus cuniculi	Rabbit			Absent	Australia	Vector for myxomatosis.	Low introduction risk. High estabblishment risk. Low risk.		
Lice	Lice are dorsoventrally flattened wingless insects, which feed on birds and mammals. They are divided into sucking lice, which feed on blood and lymph, and biting lice, which feed on epidermis and secretions. Only biting lice occur on birds.		Lice have nymphs, not larvae and all stages are on the host.				Some lice are intermediate hosts of the Cestode Dipylidium caninum, others mechanically transmit disease, such as typhus in humans, trench fever.	Generally the disease risks associated with lice are low.		
	Pediculus humanus capitus	Human		Sucking	Common	Cosmopolitan	*Borrelia*	Human disease. High introduction risk. Low establishment risk. Medium risk.		
	Pthirus pubis	Human		Sucking	Common	Cosmopolitan	*Rickettsia quintana; Borrelia recurrentis* (LBRF)	Human disease. High introduction risk. Low establishment risk. Medium risk.		
	Pediculus humanus corporis	Human		Sucking	Rare	Cosmopolitan	*Rickettsia prowazekii*	Human disease medium introduction risk. Low establishment risk. Low risk.		
	Menopon gallinae	Chicken		Biting	Common	Cosmopolitan		Low risk.		
	Menacanthus stramineus	Chicken		Biting		Cosmopolitan				
	Menacanthus pallidulus	chicken		Chewing		Cosmopolitan				
	Goniodes gigas	Chicken		Biting	Not in NZ	Cosmopolitan				
	Goniocotes gallinae	Chicken		Biting		Cosmopolitan				
	Goniocotes dissimilis	chicken		Chewing		Cosmopolitan				
	Lipeurus caponis	Chicken		Biting		Cosmopolitan				
	Chelopistes meleagridis	Turkey		Biting	Common	Cosmopolitan				
	Anaticola anseris	domestic goose				Cosmopolitan				
	Ciconiphilus pectiniventris	domestic goose				Cosmopolitan				
	Bovicola bovis	Ox		Biting	Common	Cosmopolitan				
	Bovicola ovis	Sheep		Biting	Common	Cosmopolitan				
	Bovicola equi	Horse		Biting	Common	Cosmopolitan				
	Bovicola limbatus	Goat				Cosmopolitan				
	Bovicola caprae	Goat		Biting	Common	Cosmopolitan				
	Bovicola longicornis	Deer		Biting		Cosmopolitan				
	Bovicola breviceps	Llama			Common	?				
	Trichodectes canis	Dog		Biting	Common	Cosmopolitan				
	Felicola subrostratus	Cat		Biting	Common	Cosmopolitan				
	Columbicola columbae	Pigeon		Biting	Common	Cosmopolitan				
	Linognathus ovillus	Sheep		Sucking	Rare	Cosmopolitan				
	Linognathus vituli	Ox		Sucking	Common	Cosmopolitan				
	Linognathus pedalis	Sheep		Sucking	Uncommon	Cosmopolitan				
	Linognathus stenopsis	Goat		Sucking	Common	Cosmopolitan				

Other Insects (Flies, Midges, Sandflies, Blackflies, Fleas and Lice		Hosts	Environment				Disease agents (endemic agents in blue)	Vector risk assessment	Research questions	Vector surveillance
			Larval habitat	Adult feeding habits	Distribution NZ	Distribution overseas				
	Linognathus setosus	Dog		Sucking	Common	Cosmopolitan				
	Solenopotes burmeisteri	Deer		Sucking		Cosmopolitan				
	Solenopotes capillatus	Ox		Sucking	Rare	Cosmopolitan				
	Haematopinus asini	Horse		Sucking	Common	Cosmopolitan				
	Haematopinus eurysternus	Ox		Sucking	Uncommon	Cosmopolitan				
	Haematopinus suis	Pig		Sucking	Very common	Cosmopolitan				
Cimicidae (bed bugs)	Bed bugs are small, brownish, flattened insects, which feed solely on the blood of animals. The common bed bug, *Cimex lectularius* Linnaeus, is the species most adapted to living with humans. It has done so since ancient times.									
	Cimex lectularius (bed bug)	Prefers feeding on humans, it will also bite other warm-blooded animals, including birds, rodents, bats, and pets.	Female bed bugs lay from one to twelve eggs per day, and the eggs are deposited on rough surfaces or in crack and crevices. The eggs are coated with a sticky substance so they adhere to the substrate. Eggs hatch in 6 to 17 days, and nymphs can immediately begin to feed. They require a blood meal in order to molt. Bed bugs reach maturity after five molts. Developmental time (egg to adult) is affected by temperature and takes about 21 days at 86° F to 120 days at 65° F. The nymphal period is greatly prolonged when food is scarce. Nymphs and adults can live for several months without food. The adult's lifespan may encompass 12-18 months. Three or more generations can occur each year.	Bed bugs are active mainly at night. During the daytime, they prefer to hide close to where people sleep. Their flattened bodies enable them to fit into tiny crevices - especially those associated with mattresses, box springs, bed frames, and headboards. Bed bugs do not have nests like ants or bees, but do tend to congregate in habitual hiding places. They feed by piercing the skin with an elongated beak through which they withdraw blood. Engorgement takes about three to 10 minutes, yet the person seldom knows they are being bitten. Symptoms thereafter vary with the individual. Many people develop an itchy red welt or localized swelling, which sometimes appears a day or so after the bite. Others have little or no reaction. Unlike fleabites, which occur mainly around the ankles, bed bugs feed on any bare skin exposed while sleeping (face, neck, shoulders, arms, hands, etc.). The welts and itching are often attributed to other causes such as mosquitoes.	Bed bugs (*Cimex lectularius*) are found throughout the world and are becoming more common in New Zealand.	Most frequently found in the northern temperate climates of North America, Europe, and Central Asia, although it occurs sporadically in southern temperate regions.	A common concern with bed bugs is whether they transmit diseases. Although bed bugs can harbour pathogens in their bodies, transmission to humans is highly unlikely. For this reason, they are not considered a serious disease threat. Their medical significance is mainly limited to the itching and inflammation from their bites. Claims that bed bugs can transmit Leprosy, Q fever and Brucellosis. Australia is suffering a bed-bug epidemic with the tourism industry losing an estimated $108 million a year because of the blood-sucking insects, according to a new entomology study.	High re-introduction risk. High re-establishment risk. Important economic cost. Disease risk low. Low risk.		
	Cimex hemipterus (tropical bed bug)					In the United States, *C. hemipterus* occurs in Florida.		Low introduction risk. Low establishment risk. Important economic cost. Disease risk low. Low risk.		

Table 4. Arbovirus importance and priority

Agent			Vectors	Disease agent hosts	Location	Agent importance	Agent priority assessment (vector risk and agent importance)	Research questions	Agent surveillance
Family	Genus	Disease agent	NZ vectors in blue text, shading indicates summary of vector risk	(NZ in blue)					(NZ in blue)
Virus									
Reoviridae	Orbivirus	Reovirus type 3	Mosquitoes. *Culex pervigilans, Culiseta tonnoiri, Culex quinquefasciatus, Aedes notoscriptus, Aedes australis.*	Humans	NZ	Mechanical vector only.	Low priority.		
		Palyam group - at least 15 viruses (159, 160)	*Culicoides* spp., isolated from ticks in Africa and mosquitoes in India (159)	Cattle, neutralizing antibody has also been found in sheep and goats (159)	Australia Africa and Asia (159)	Minor disease of livestock. Medium importance for exports.	Low priority.		**Type:** An arbovirus and *Culicoides* surveillance programme has been operating in New Zealand since 1991 (161) sentinel cattle, light traps. **Target:** Cattle serum. **Tool:** Serology (AGID).
		Bluetongue	*Culicoides*: 17 species connected with bluetongue virus transmission. The major vector species are *C. imicola* and *C. bolitinos* in Africa, *C. imicola* in Asia, *C. fulvus* and *C. brevitarsis* in Australia, *C. sonorensis* in North America, *C. insignis* and *C. pusillus* in South and Central America.	Cattle, sheep, goats, deer, ruminants.	Worldwide- north of latitude 34°S and south of latitude 50°N. Known to be expanding range in northern hemisphere.	High importance for exports. Disease affecting livestock and trade.	Low priority.	Climate change means periodic reassessment is needed of the risk of establishment.	**Type:** Sentinel cattle serology, passive surveillance in sheep. **Target:** Cattle serum, clinical sheep. **Tool:** Serology (AGID), virus isolation, PCR Australia.
		Epizootic haemorrhagic disease	*Culicoides*	Deer, cattle.	Worldwide	High importance for exports. Disease affecting livestock and trade.	Low priority.		**Type:** Sentinel surveillance. **Target:** Cattle serum. **Tool:** Serology (AGID).
		African Horse sickness	*Culicoides imicola.* Occasionally mosquitoes and ticks mechanically transmit disease.	Equidae, dogs.	AHS is limited to geographical areas where the vector *C. imicola* is present. A few outbreaks have occurred outside Africa, such as in the Near and Middle East (1959-63), in Spain (1966, 1987-90) and in Portugal (1989)	Disease affecting horses. High importance for exports No entry pathway.	Low priority.		
		Eubenangee viruses	*Culicoides*, mosquitoes, *Culex quinquefasciatus.*			Disease of cattle. Cattle viraemic for up to 8 weeks. Main vector not present. Low importance.	Low priority.		**Type:** Screening *Culex quinquefasciatus*: **Target:** Cattle serum. **Tool:** Serology.
		Corriparta	Mosquitoes. *Culex quinquefasciatus.*			Vector present.. Importance not assessed. Probably low.	Low priority.		Screening *Culex quinquefasciatus*.
		Equine encephalosis	*Culicoides imicola*	H Horses	South Africa	Disease affecting horses. . Medium importance for exports. No entry pathway.	Low priority.		
	?	Baku	*Ornithodoros capensis*		Uzbekistan	Vector present. Importance not assessed. Probably low.	Low priority.	Is this agent present?	Screening *Ornithodorus capensis.*
Bunyaviridae	Orthobunyavirus	Oropouche,	*Culicoides paraenesis* and mosquitoes, *Aedes serratus*	Humans, sloths.	Amazon, caribean, Pnanama.	Diseasea affecting people similar to dengue fever. Low introdcution risk. Medium importance.	Low priority.		
		Tahyna virus	*Aedes* spp.	Humans	Moravia	Affects people. Low intridcution risk. Low establishment risk. Low importance.	Low priority.		
		Thimiri	?	Humans	India	Affects people. Low intridcution risk. Low establishment risk. Low importance.	Low priority.		

Agent			Vectors	Disease agent hosts	Location	Agent importance	Agent priority assessment (vector risk and agent importance)	Research questions	Agent surveillance
Family	Genus	Disease agent	NZ vectors in blue text, shading indicates summary of vector risk	(NZ in blue)					(NZ in blue)
		Koogal	Mosquitoes. *Culex quinquefasciatus.*			Vector present. Importance not assessed.	Low priority.	Is this agent present?	
		Wongal	Mosquitoes. *Culex quinquefasciatus.*			Vector present. Importance not assessed.	Low priority.	Is this agent present?	
	Simbu group	Simbu viruses (162). The group includes viruses such as Akabane disease virus, Aino, Tinaroo, Peaton and Cache valley viruses, which cause similar syndromes.	Australia: *Culicoides brevitarsis, C. wadii.* Japan: *C. oxystoma, Aedes vexans, Culex trieeniorhynchus.* Africa: *C. imicola, C. milnei.* Kenya: *Anopheles funestus.*	Cattle and other ruminants including sheep (163); (162) and goats.	Viruses in the Simbu-group occur endemically in large areas of Africa, Asia, the Middle East and Australia (163); (164); (162) and the related Cache Valley virus occurs in Texas (165); (166). No reference was found to the occurrence of the virus in Canada or the European Union.	The virus could only be introduced into New Zealand by animals that are in the incubation period or viraemic at the time of introduction. Since the incubation period is 1-6 days (162)and the viraemic period is from 3-4 days (162) The likelihood of introducing a viraemic animal is low but non- negligible. No vector in NZ, Climate not really suitable for vector. The virus has also been isolated from mosquitoes and there is no work that confirms that New Zealand mosquitoes are non-competent vectors, the likelihood that the virus could be transmitted by mosquitoes is non-negligible. Medium importance for exports.	Low priority.		Type: Sentinel cattle serology, passive surveillance in calves and lambs. **Target:** Cattle serum. **Tool:** Serology (SNT), virus isolation. There are competitive ELISAs for detection of Akabane specific and Simbu-group specific antibodies (169)
		Douglas	*Culicoides*			No vector in NZ, Climate not really suitable for vector.	Low priority.		Type: Sentinel cattle serology. Target: Cattle serum. Tool: Serology (SNT).
	Unassigned	Maputta	Mosquitoes. *Culex quinquefasciatus.*			Vector present. Risk difficult to assess. Importance low.	Low priority.		
		Trubanaman	Mosquitoes. *Culex quinquefasciatus.*			Vector present. Risk difficult to assess. Importance low.	Low priority.		
		Khasan	Tick. *H. longicornis.*			Vector present. Risk difficult to assess. Importance low.	Low priority.		
		Aransus	Tick. *Ornithodoros capensis.*			Vector present. Risk difficult to assess. Importance low.	Low priority.		
	Nairovirus	unclassified Hughes group virus	Tick. *Ornithodoros capensis.*	Gannets (Cape Kidnappers), red billed gulls, white fronted terns (Kaikoura, Sumner, Karitane).	Hughes group viruses are found in North Pacific and coast of Peru.	Agent and vector present. No known impacts here.	Low priority.	What species of virus is present?	**Type:** Active surveys. **Target:** *O. capensis*, other bird ticks, colonial bird serum. **Tool:** Serology, virus isolation, PCR.
		Nairobi sheep disease virus	Tick: *R. appendiculatus, Amblyomma variegatum, Rhipicephalus* spp.	Sheep and goats.	Africa	Disease affecting livestock. High importance for exports No entry pathway.	Low priority.		
		Crimean-Congo haemorrhagic fever virus	Tick: *Hyalomma, Rhipicephalus*, and *Dermacentor* spp.	Humans and ruminants, smaller animals (hares).	Africa Asia Middle ease and Eastern Europe.	Severe human disease Africa, Asia, the Middle East and Eastern Europe (159). High importance for exports No entry pathway.	Low priority.		**Tool:** Elisa PCR Virus isolation.
	Upolo group	Upolo	Tick. *Ornithodoros capensis.*			Importance not assessed.	Low priority.	Is this agent present?	

Agent			Vectors	Disease agent hosts	Location	Agent importance	Agent priority assessment (vector risk and agent importance)	Research questions	Agent surveillance
Family	Genus	Disease agent	NZ vectors in blue text, shading indicates summary of vector risk	(NZ in blue)					(NZ in blue)
	Phlebovirus	Rift valley fever	Primary vector: *Aedes* spp. Of the Neomelanconium group.Secondary vector: *Culex, Anophales, Aedes* (stegomyia), *Mansonia, Eretmopodites* spp.Mechanical (some) *Culicoides Stomoxys* and tabanids. *Glossinia* and other biting flies.	Mammals, humans, cattle, buffalo, sheep, goats, camels.	Africa	Severe human and wildlife disease. Major vectors excluded by climate, two minor vectors present, requires high rainfall and high density of vectors. High importance for exports No entry pathway.	Low priority.		
	La cross encephalitis	*La cross* vuirus	*Aedes atropalpus*			Important human disease. Risk of introduction and establishment low.	Low priority.		
Lyssaviruses		Bovine Ephemeral fever virus	*Culicoides*, mosquitoes: *Culex annulirostris. Culex quinquefasciatus.*	Cattle, buffaloes.	Africa Asia, Australia.	Disease affecting livestock. Medium importance for exports Entry pathway and low competence vector present.	Medium priority.		Type: Screening *Culex quinquefasciatus.*
Togaviridae	Alphavirus	Ross river	Isolated from at least 30 species of mosquitoes and transmission has been demonstrated from at least 13 species(174) Mosquito: (in order of importance) *Aedes vigilax, Culex annulirostris, Aedes camptorhynchus* (167), *Coquillettidia linealis, Aedes notoscriptus, Aedes polynesiensis, Aedes aegypti, Aedes albopictus, Aedes australis, Culex quinquefasciatus*. Medium vecotr risk while SSM is under eradication. High if eradication attempt ceases.	People, marsupials, sheep, horses, rats, sheep.	Australia, Papua New Guinea, Solomons, Outbreak in Fiji (168); (166); (169)	High impact human disease. Main vectors not present, minor vectors present, hosts present, entry pathway described, outbreak in Fiji seems to have been started by a single traveller from Australia infecting mosquitoes in Fiji (168); (170). Possible reservoir hosts are wallabies which occur in some areas and possums (167) (171)	Medium priority (High if SSM is not eradicated).	Are native species competent vectors?	Type: Human clinical and laboratory surveillance, clinical surveillance horses, exotic mosquito surveillance. Target: Human serum, mosquitoes, animal serum. Tool: PCR NSP1 all alpha viruses, serology IgM, IgG (ELISA antibody test).
		Whataroa virus	Natural: *Culex pervigilans, Culiseta tonnoiri*. Laboratory: *Opifex fuscus, Aedes notoscriptus, Aedes australis, Ornithodoros capensis.*	Birds: Thrush, blackbird, silver-eye, red poll, chaffinch, hedge sparrow, bellbird, tui.		Probably a minor human and wildlife disease. Vector, host and agent present. Some vectors expanding distribution.	Medium priority.	Is this agent still present? What is its distribution?	**Type:** Screening mosquitoes and birds. **Target:** Mosquitoes, bird serum. **Tool:** PCR NSP1 all alpha viruses.
		Unidentified Group A virus?	Endemic mosquitoes?	Chickens, humans.	Auckland, Hamilton, Carterton.	If this agent exists it is probably a minor human disease. Sera from 5 human cases of encephalitis inhibited haemagglutination of SFV Auckland 1959.	Medium priority.	What was this agent?	Type: Screening mosquitoes and birds. **Target:** Mosquitoes, bird serum. **Tool:** PCR NSP1 all alpha viruses.
		Sinbis	Mosquitoes, *Culex annulirostris, Culex quinquefasciatus.*	Birds, vertebrates.		Human and wildlife disease.	Medium priority.		Type: Screening mosquitoes and birds. **Target:** Mosquitoes, bird serum. **Tool:** PCR NSP1 all alpha viruses.
		Chikungunya	*Culex pipiens pallens, Aedes polynesiensis, Aedes albopictus, Aedes aegypti.*	Humans		Human disease. Medium importacne. Low introduction and establishment risk. Vectors absent.	Low priority.		Type: Screening mosquitoes and birds. **Target:** Mosquitoes, bird serum. **Tool:** PCR NSP1 all alpha viruses

Agent			Vectors	Disease agent hosts	Location	Agent importance	Agent priority assessment (vector risk and agent importance)	Research questions	Agent surveillance
Family	Genus	Disease agent	NZ vectors in blue text, shading indicates summary of vector risk	(NZ in blue)					(NZ in blue)
		Barmah forest	*Aedes vigilax, Culex annulirostris, Aedes aegypti, Coquillettidia linealis, Aedes notoscriptus, Aedes camptorhynchus,* Midges.	Humans, marsupials, cattle, horses (unknown vertebrate hosts).	Australia	Much unknown, human disease, minor vector present, possibly a similar risk to Ross River.	Medium priority.	Are native species competent vectors?	**Type:** Human Laboratory surveillance. **Target:** Human serum. **Tool:** Serology, virus isolation, PCR.
		Semliki Forest virus	Not assessed			Not assessed.	Presumed low priority.		**Tool:** PCR NSP1 all alpha viruses.
		Getah virus	*Culex tritaeniorynchus, Aedes vexans nipponi, Culex quinquefasciatus,* and others.	Horses, neonatal pigs, mammals and birds.	Malaysia, NE and SE Asia, Japan.	Vector present. Animal disease.	Low priority.		**Tool:** PCR NSP1 all alpha viruses.
		Eastern equine encephalomyelitis	*Culiseta meanura, Culicoides, Aedes alpbopictus, Culex quinquefasciatus.*	Equidae, humans, poultry, pigs.	South America, eastern side of US, Canada, and Mexico.	Livestock, wildlife and human disease. High importance for exports.	Low priority.		Passive surveillance post arrival quarantine. **Tool:** PCR NSP1 all alpha viruses.
		Venezuelan equine encephalomyelitis	*Aedes albopictus, Culex* spp.	Equidae, humans, cattle, swine, dogs.	Colombia, Ecador, Peru, Venezuela, Guatemala, Costa Rica, Mexico.	Livestock disease and zoonoses. High importance for exports No entry pathway.	Low priority.		**Tool:** PCR NSP1 all alpha viruses
		Western equine encephalomyelitis	*Culex tarsalis, Aedes albopictus.*	Equidae, humans, poultry.	South America, western US, southwestern Canada.	Livestock disease and zoonoses. High importance for exports.	Low priority.		Passive surveillance post arrival quarantine. **Tool:** PCR NSP1 all alpha viruses.
Flaviviridae	Flavivirus	Saumarez Reef virus	Ticks: *O. capensis, I. eudyptidis.*	Mixed gull and tern colony Kaikoura.	Australia , Tasmania.	Present. Importance unknown.	Low priority.		**Type:** Active surveillance. **Target:** Bird ticks, colonial bird serum. **Tool:** Generic serology, virus isolation, PCR.
		Japanese encephalitis	Mosquitoes (28 species). *Culex tretaenorhynchus, Aedes japonicus, Aedes vigilax, Culex annulirostris, Aedes albopictus, Culex gelidus, Culex quinquefasciatus.*	People, pigs, horses, water birds.	Japan, Taiwan, SE Asia, Northern Australia, China.	Livestock disease and zoonoses. Major vectors absent, birds may introduce virus. High importance for exports.	Low priority.		
		Kunjin	*Culex annulirostris, Culex quinquefasciatus* a poor vector.	Vertebrates, (water birds), humans.	Australia, Indonesia.	Human disease. No competent vector in NZ. Extrinsic incubation period long in colder climates.	Low priority.		
		Dengue 1 to 4	*Aedes aegypti, Aedes albopictus, Aedes polynesiensis, Aedes vigilax, Culex annulirostris, Culex quinquefasciatus, Aedes notoscriptus, Aedes australis.*	Humans	46 countries, Spread from Asia to Pacific and Americas during the war.	Severe human disease. Major vectors not present, but two could establish, known interceptions, Human cases introduced regularly. Tropical or sub tropical only. Extrinsic incubation period too long in colder climates.	Low priority.		**Type:** Human clinical and serological surveillance. Surveillance for exotic mosquitoes. **Tools:** IgM Capture, Indirect IgG (ELISA antibody tests) MAT for confirmation?
		West Nile virus	8 genera mosquitoes, 6 genera ticks, *Culex quinquefasciatus, Ornithodorus capensis, Aedes japonicus.*	Vertebrates	Europe, Asia, Africa, North America.	Severe human, wildlife, and livestock disease. Wide range of vectors and vertebrate hosts. Dramatic spread throughout the world. One known competent vector present, endemic *Culex pervigilans* possible vector. Possible entry pathway through seabird tick *O. capensis*. High importance for exports. Entry pathway.	High priority.	Are native species competent vectors? Could *C. quinquefasciatus* become infected from introduced ticks?	**Type:** Avian: live bird sentinels, wild bird mortality investigation. Screening posssible cases. **Target:** Equidae: cerebrospinal fluid, post mortem. Human, mosquito/tick. **Tools:** Isolation of infectious virus. Specific RNA detection by reverse transcription-polymerase chain reaction (RTPCR) can be developed.

Agent			Vectors	Disease agent hosts	Location	Agent importance	Agent priority assessment (vector risk and agent importance)	Research questions	Agent surveillance
Family	Genus	Disease agent	NZ vectors in blue text, shading indicates summary of vector risk	(NZ in blue)					(NZ in blue)
		Yellow Fever virus	*Aedes aegypti* mosquitoes South America forests - *Haemogogus* (sylvan mosquitoes) East Africa - *Aedes africanus* (monkeys) *Aedes bromeliae* (*Ae. simpsoni*) (monkey to humans) West Africa - *Ae. furcifer-taylori, Ae. luteocephalus* (monkeys to humans).	Humans, monkeys, possibly other vertebrates.	Africa, Asia, South America.	Highly important disease of humans in the tropics. Vectors absent. Pathway exists in humans for agent.	Medium priority. High if competent vector establishes.		
		MVE	*Aedes aegypti, Aedes vigilax, Culex annulirostris, Culex quinquefasciatus* a poor vector, *Aedes notoscriptus, Aedes camptorhynchus.*	Vertebrates, (waterbirds), humans.	Australia, Papua New Guinea.	Human disease. No competent vector in NZ. Not widespread in Australia. Extrinsic incubation long in colder climates.	Medium priority. High if competent vector establishes.		
		Unidentified Group B virus?	Endemic mosquitoes?	humans chickens, birds horses.	Tauranga, Westland.	Human disease. Not isolated. 101/232 (44%) of fowl tested in Westland 1959 inhibited haemagglutination of JEV. 32 at 1:40, 27 at 1:80, 11 at 1:160. Serology tests on tissue culture indicated the virus was closer to JEV than MVE or St Louis virus. Between Dec 1962 and February 1963 a number of human cases were seen in South Westland which gave serological evidence of a group B virus. Also positive were some human sera from Tauranga.	Medium priority.	What Flavivirus is this?	
		Tick borne encephalitis viruses The viruses causing tick borne encephalitis (172) are a closely related group of viruses belonging to Genus: Flavivirus. The tick borne encephalitis viruses include the agents of: Louping ill, Central European TBE , Far Eastern TBE, Omsk haemorrhagic fever in Siberia, Kyasanur Forest disease in the Indian subcontinent, Langat in Malaysia, Negishi in Japan, Powassan in North America and parts of the former USSR and four viruses from Asia that have no known veterinary or medical significance (159)	At least 32 vertebrate species and a wide variety of ticks can be infected. New Zealand cattle tick is not a known vector of the viruses but the virus may be transmitted.	Humans	Widespread	Diseases of humans.	Low priority.		Tools: HI test CFT serodiagnosis only of relevance to humans. Virus isolation.
		Louping ill	Ticks: *Ixodes ricinus, I. holocyclus, R. appendiculatus, Ixodes persulcatus.*	Sheep, goats pigs other vertebrates	United Kingdom, Central and East Europe.	Livestock disease. High importance for exports. No trade entry pathway.	Low priority.		Covered by Transmissible Spongiform Encephalopathy (TSE) surveillance.
		Powassan encephalitis	Ticks: *H. longicornis.*		North America	Vector present. Importance not assessed.	Low priority.		
		Russian spring-summer encephalitis virus	Ticks: *Ixodes ricinus, H. longicornis*, others.	humans, rodents	Russia	Human disease. Low introduction risk.	Low priority.		

Agent			Vectors	Disease agent hosts	Location	Agent importance	Agent priority assessment (vector risk and agent importance)	Research questions	Agent surveillance
Family	Genus	Disease agent	NZ vectors in blue text, shading indicates summary of vector risk	(NZ in blue)					(NZ in blue)
		Alfuy	*Culex annulirostris*, *Culex quinquefasciatus.*			Vector present. Importance not assessed.	Low priority.	Is this agent present?	
		Stratford	Not assessed			Importance not assessed.	Low priority.		
		Edge hill	*Culex quinquefasciatus.*			Vector present. Importance not assessed.	Low priority.	Is this agent present?	
		Kokobera	*Culex annulirostris*, *Culex quinquefasciatus.*			Vector present. Importance not assessed.	Low priority.	Is this agent present?	
		Kowanyama	*Culex quinquefasciatus*			Vector present. Importance not assessed.	Low priority.	Is this agent present?	
Rhabdoviridae	Vesiculovirus	Vesicular stomatitis virus	*Aedes* spp., sand flies (Lutzomyia, shannoni) which are the most likely vectors). *Culicoides* spp. are also possible vectors and have been infected experimentally Blackflies (*Simulium* spp.) have also been incriminated in the transmission of the disease. In the US disease is limited by first frost.	horses, cattle and pigs and more rarely sheep and goats Maintenance hosts of the virus have not yet been conclusively established but deer and raccoon and the cotton rat (Sigmodon hispidus) Antibody production has been described in pigs, white tailed deer, raccoon, skunk, bobtail, kinkajou, two and three toed sloths, night monkeys, marmosets, agoutis and rabbits.	Brazil (Piry), Iran (Isfahan), India (Chandipura), Outbreaks in France and South Africa eradicated. Endemic in Central and South America and thousands of outbreaks occur each year from southern Mexico to northern South America. In the USA the disease occurs sporadically in some southern states but is endemic in at least one location in Georgia. In some seasons the disease spreads northward along riverbeds into northern locations in the USA and even as far as Canada.	Tropical livestock disease, possible vectors present. High importance for exports.	Low priority.		**Type:** Passive surveillance of clinical horses. **Tool:** OIE recommended serological test CF(IgM) SVN(IgG). IgG/IgM Immunofluorescence. Real-time PCR and antigen ELISA.
	Unassigned	Almpiwar	*Culex quinquefasciatus*			Vector present. Importance not assessed.	Low priority.	Is this agent present?	
Unassigned	Quaranfil	Johnston Atoll virus	Tick: *Ornithodoros capensis.*	Jannets Cape Kidnappers	Northern Pacific, Gt Barrier reef, NZ.	Wildlife disease.	Medium priority.	Is this agent still present? What is its distribution?	**Type:** Active surveillance. **Target:** O capensis, bird serum. **Tools:** Serology, virus isolation, PCR.
		Abal	Tick: *Ornithodoros capensis.*			Vector present. Importance not assessed.	Low priority.	Is this agent present?	
Picornoviridae		Human coxsackievirus A6	*Aedes australis*			Vector present. Importance not assessed.	Low priority.	Is this agent present?	
		Coxsackie A like	Tick: *H. longicornis*			Vector present. Importance not assessed.	Low priority.	Is this agent present?	

Agent			Vectors	Disease agent hosts	Location	Agent importance	Agent priority assessment (vector risk and agent importance)	Research questions	Agent surveillance
Family	Genus	Disease agent	NZ vectors in blue text, shading indicates summary of vector risk	(NZ in blue)					(NZ in blue)
Poxviridae	Avipox	Fowlpox is widespread, especially in the northern parts of New Zealand. Bolte et al. reviewed the avian species reported as infected with avipoxviruses and included 232 species from 23 orders in their list. The true number of species that are vulnerable to infection with avipoxviruses must be very large.As with other poxviruses, avipoxviruses are generally considered to be host specific or to have a narrow host range. Reports in the literature, however, provide examples where avipoxviruses appear to have host ranges of varying scope.	*Culex quinquefasciatus, Aedes notoscriptus, Aedes albopictus*. Lice hibboscid flies, house and feather mites.			Agent and vector present. Mechanical transmission.	Low priority.	How many of these agents are present?	Tools: Histology, virus isolation. EM (electron microscopy examination), PCR.
Retroviridae	*Gammaretrovirus*	Avian reticuloendotheliosis virus	The main route for infection of birds with REVs appears to be transovarial vertical transmission. Horizontal transmission appears to play some role in the epidemiology of the organism and this may be assisted by mechanical transfer by insects. *Culex quinquefasciatus.*			Mechanical transmission. Bird disease – low importance.	Low priority.		Tools: Virus isolation PCR.
	Lenti group	Equine infectious anaemia	Tabanid flies *Tabanus* spp. *Hybomitra* spp. *Chyropsis* spp. *Stomoxys calcitrans.* Mechanical transmission.	Horses		Not a biological vector borne disease. High importance for exports. Entry pathway.	Low priority.		Type: Investigation of anaemic horses.
Asfarviridae	*Asfivirus*	African swine fever virus	Agasid tick: *Ornithodorus moubata, O. erraticus, Stomoxys calcitrans?* Mechanical transmission.	Pigs		Livestock disease. Restricted to Africa and Iberia, eradicated in South America. High importance for exports. No entry pathway.	Low priority.		
?	Sachalin	Caspiy	Tick: *Ornithodoros capensis.*	Seabirds		Wildlife disease. Vector present. Importance not assessed.	Low priority.	Is this agent present?	
?	Nyamanini	Midway	Tick: *Ornithodoros capensis.*	Seabirds		Wildlife disease. Vector present. Importance not assessed.	Low priority.	Is this agent present?	

Table 5. Haemoparasite importance and priority

Agent			Vector	Disease agent hosts	Location	Agent importance	Agent priority assessment (vector risk and agent importance)	Research questions	Agent surveillance
Family	Genus	Disease agent	(NZ in blue)	(NZ in blue)	(NZ in blue)				(NZ in blue)
Haemoparasites									
Haemosporidia	Plasmodium	*Plasmodium relictum*	Mosquito (173); (174). *Culex quinquefasciatus, Culex pervigilans* (175) , *Aedes australis*? (13)	Birds (173); (174). Yellow eyed penguin, Fiordland crested penguin, blue penguin, song thrush, blackbird, pipit, skylark, grey duck, house sparrow, shining cuckoo, New Zealand dotterel, chaffinch, starling, greenfinch, saddleback, weka (176); (177); (178); (175)	Worldwide distribution (except Antarctic) (173); (174), all latitudes of New Zealand (recent spread and increase in prevalence, may be ongoing) (178)	High importance wildlife disease. Agent present, may be expanding distribution and increasing prevalence. Pathogenic effects known.	High Priority.	What species vector *Plasmodium* in New Zealand? What are their host preferences? Is range and prevalence increasing? What are the impacts?	**Type:** Clinical surveillance, active surveys. **Target:** Clinical serum, *Culex quinquefasciatus, Culex pervigilans, Aedes australis* . **Tools:** Thin blood smears, Immunoblot technique for Plasmodium, PCR testing and sequencing.
		Plasmodium cathemerium	Mosquito (159); (174)	Birds (173); (174). Canary, house sparrow, finches (179)	Worldwide distribution (except Antarctic) (173); (174), Whangarei (single incident) (179)	Wildlife disease. Persistent presence of agent unknown. Pathogenic effects known.	High Priority.	Is there a persistent presence of this species?	**Type:** Clinical. **Target:** serum, *Culex quinquefasciatus, Culex pervigilans, Aedes australis*. **Tools:** Thin blood smears, Immunoblot technique for Plasmodium, PCR testing and sequencing.
		Plasmodium elongatum	Mosquito. *Culex* spp. (173); (174)	Birds (173); (115). New Zealand dotterel (176); (177)	Worldwide distribution (except Antarctic) (173); (174). Auckland Zoo and Otorohanga Kiwi House (single linked incident - only record in Australian zoogeographical region) (176); (177)	Wildlife disease. Persistent presence of agent unknown. Pathogenic effects known.	Low priority.	Is there a persistent presence of this species?	**Type:** Active surveys. **Target:** Blood. **Tools:** Thin blood smears, Immunoblot technique for *Plasmodium*, PCR testing and sequencing.
		Plasmodium lygosomae	Mosquito	Green tree skink, Copper-tailed skink, Scaly-toed geko [(180)] Moko skink (139)	Solomons (180), New Zealand (139)	Wildlife disease. Agent present. Pathogenic effects unknown.	Low priority.	What is the host/geographic range of this species?	**Type:** Active surveys. **Target:** Blood. **Tools:** Thin blood smears, Immunoblot technique for *Plasmodium*, PCR testing and sequencing.
		Plasmodium spp.	Mosquito	Australasian gannet, skylark, mohua (176); (177); (178)	Mohua at Orana Park, Christchurch (178). Others unknown.	Wildlife disease. Unconfirmed species.	High Priority.	Species identities?	**Type:** Active surveys. **Target:** Blood. **Tools:** Thin blood smears, Immunoblot technique for *Plasmodium*, PCR testing and sequencing.
		Plasmodium vaughani	Mosquito. *Culex pipiens, Culiseta morsitans* (173); (174)	Birds (173); (174)	Worldwide distribution (except Antarctic) (173); (174)	Wildlife disease. Agent absent. Vector absent, although *Culex* spp. and *Culiseta* spp. present. Potential pathway for entry.	Low priority.		**Tools:** Thin blood smears, PCR testing and sequencing.
		Plasmodium circumflexum	Mosquito. *Culiseta* spp.(173); (174)	Birds (173); (174)	Worldwide distribution (except Antarctic) (173); (171)	Wildlife disease. Agent absent. Vector absent, although *Culiseta* sp present. Potential pathway for entry.	Low priority.		**Tools:** Thin blood smears, PCR testing and sequencing.
		Plasmodium egerniae	Mosquito	Reptiles. Land mullet (180)	Queensland, Australia (180)	Wildlife disease. Agent absent. Potential vectors present. Limited pathway for entry.	Low priority.		

Agent			Vector	Disease agent hosts	Location	Agent importance	Agent priority assessment (vector risk and agent importance)	Research questions	Agent surveillance
Family	Genus	Disease agent	(NZ in blue)	(NZ in blue)	(NZ in blue)				(NZ in blue)
		Plasmodium giganteum australis	Mosquito	Reptiles. Bartagame (180)	Queensland, Australia (180)	Wildlife disease. Agent absent. Potential vectors present. Limited pathway for entry.	Low priority.		
		Plasmodium falciparum, vivax, ovale, malariae	Mosquito. *Anopheles* spp. (181)	People	Asia, Africa, Central and South America, Oceania, and certain Caribbean islands.	Severe human disease. Agent absent. Vector tropical and absent. Human pathway of entry present.	Low priority.		Type: Clinical surveillance. Target: Blood. Tools: Thick smears, ICT (immunochromatographic test).
		Plasmodium berghei, vinckei, chabaudi, yoelli	Mosquito. *Anopheles* spp.	Rodents	Central Africa	Agent absent. Vector absent. No entry pathway.	Low priority.		Type: Active surveys. Target: Blood. Tools: Thick smears.
		Plasmodium lutzi, giovannolai, griffithsi, tejerai, coturnixi, lophurae, durae, pedioecetae, pinottii, formosanum, gundersi, anasum, garnhami, hegneri, octamerium, gabaldoni, leanucleus, columbae, subpraecox, matutinum, gallinaceum, polare, rouxi, fallax, hexamerium, nucleophilum, paranucleophilum, bertii, kempi, juxtanucleare, huffi, hermani	Mosquito (173); (174)	Birds (179); (174)	Highly localised, or not present in Australian zoogeographical region (173); (170)	Wildlife disease. Agents absent. Potential vectors present. Potential pathway for entry.	Low priority.		Tools: Thin blood smears, PCR testing and sequencing.
		Plasmodium spp.	Mosquito	Reptiles (182)	Not present in Australian zoogeographical region (180)	Wildlife disease. Agents absent. Potential vectors present. Limited pathway for entry.	Low priority.		Target: Thin blood smears. Tools: PCR testing and sequencing.
	Haemoproteus	*Haemoproteus* spp.	Biting midges or sand flies (Diptera: Ceratoponidae) and hippoboscid flies (Hippoboscidae) (183); (184); (185); (174)	Wide range of birds and reptiles (174); (186). Among birds, especially common among waterfowl and seabirds (186) (176) . Generally specific to bird families, but exceptions do occur (187); (174). In NZ recorded in blackbird, song thrush, skylark, and North Island robin (188), (189), (176)	Worldwide distribution (174); (186). In NZ recorded in South Auckland and Tiritiri Matangi Island (162)	Wildlife disease. Agents present Generally of low clinical significance, but exceptions do occur (173); (174). Hippoboscid flies, Ornithoica stiptiuri, common on red-crowned parakeets on Tiritiri Matangi may be vector for Haemoproteus found there in a NI robin.	Medium priority.	What is the clinical significance in red-crowned parakeets and North Island robins?	Type: Active surveys. Target: Blood. Tools: Thin blood smears, PCR testing and sequencing.
	Leucocytozoon	*Leucocytozoon tawaki*	Simulid flies (Diptera: Simuliidae). *Australosimulium ungulatum* (190), *A. australense, A. dumbletoni* (Diptera: Simulidae) (174)	Little Blue penguin, Jackass penguin (174), Fiordland crested penguin (191); (192); (176); (115)	South Africa (174) and New Zealand (Kaikoura & South Westland) (191); (192); (176)	Wildlife disease. Agent present. Low risk. Can be pathogenic, but relatively high host specificity. Possible role in mortality of Yellow eyed penguin chicks, Stewart Island.	Medium priority.	What is the clinical significance in Fiordland crested penguins and yellow eyed penguins?	Type: Active surveys . Target: Blood, *Australosimulium*. Tools: Thin blood smears, PCR testing and sequencing.

Agent			Vector	Disease agent hosts	Location	Agent importance	Agent priority assessment (vector risk and agent importance)	Research questions	Agent surveillance
Family	Genus	Disease agent	(NZ in blue)	(NZ in blue)	(NZ in blue)				(NZ in blue)
		Leucocytozoon fringillinarum	Simulid flies (Diptera: Simuliidae) (174)	Birds (174) . Far less host-specific than normal for Leucocytozoon (over 200 host species). Chaffinches (188)	Worldwide distribution (except Antarctic) (174). Wellington (188)	Wildlife disease. Agent present. Low risk. Although low host-specificity, generally of low clinical significance.	Low priority.	What is the host/geographic range of this species in New Zealand?	Type: Active surveys . Target: Blood. Tools: Thin blood smears, PCR testing and sequencing.
		Leucocytozoon spp.	Simulid flies (Diptera: Simuliidae) (174)	Yellow-eyed penguin.	Stewart Island.	Wildlife disease. Agent present. Can be pathogenic. Unconfirmed species.	Medium priority.	Species identity?	Type: Active surveys . Target: Blood; Tissue (post mortem). . Tools: Thin blood smears, PCR testing and sequencing.
		Leucocytozoon spp.	Simulid flies (Diptera: Simuliidae) and (for one species) biting midges (family Ceratopogonidae) (174)	Birds (173); (193); (194); (174). Generally specific to host genera, but exceptions do occur (174)	Highly localised, or not present in Australian zoogeographical region, or highly host specific (173); (174)	Wildlife disease. Agents absent. Low risk. Potential vectors present. Can be pathogenic, but generally specific to host genera.	Low priority.		Target: Blood. Tools: Thin blood smears, PCR testing and sequencing.
Piroplasms	Babesia	*Babesia kiwiensis*	Ticks: *Ixodes anatis* (identified in ticks from kiwi by PCR - R. Jakob-Hoff, pers. comm.).	North Island brown kiwi (195); (194); (196)	New Zealand	Wildlife disease. Agent present. Considered to be a significant pathogen in chicks.	Medium priority.	Are other species of kiwi affected?	Type: Active surveys, clinical surveillance. Target: Blood, serum. Tools: Thin stained smears, serology, PCR.
		Babesia argentina	*Boophilus microplus* in central and south America, and *B. microplus* and *B. australis* in Australia.	Cattle	Central and South America, Australia.	Livestock disease. Vector and agent absent.	Low priority.		
		Babesia caballi	Ticks: *Dermancentor nitens, D. albipictus, D. variabilis, Hyalomma, Rhipicephalus* spp., *Rhipicephalus sanguineus.*	Equines	Tropics, subtropics and some temperate countries.	Livestock disease. Agent absent, Vectors absent, horse movements provide an entry pathway.	Low priority.		Type: Export serology, clinical surveillance. . Target: Blood, serum. Tools: Thick smears, serology IFAT, ELISA, PCR.
		Babesia divergens	*Ixodes ricinus, Haemaphysalis punctata.*	Cattle, man, gerbils.	Europe, and perhaps Asia.	Livestock and human disease. Agent and vector absent.	Low priority.		Type: Clinical surveillance. Target: Blood, serum. Tools: Thick smears, serology, PCR.
		Babesia microti	*Ixodes scapularis*	Rodents, dogs, man.	America	Human disease. Vector and agent absent. Human and canine entry pathway.	Low priority.		Type: Clinical surveillance . Target: Blood, serum. Tools: Thick smears, serology, PCR.
		Babesia bovis	*Boophilus microplus, B. annulatus.*	Cattle	North and South America, Southern Europe, Africa, Asia, Australia.	Livestock disease. Vector and agent absent.	Low priority.		Type: Clinical surveillance . Target: Blood, serum. Tools: Thick smears, serology, PCR.
		Babesia jakimovi	*Ixodes ricinus*	Cattle	Japan, Siberia.	Livestock disease. Vector and agent absent.	Low priority.		Type: Clinical surveillance . Target: Blood, serum. Tools: Thick smears, serology, PCR.
		Babesia bigemina	Boophilus ticks: *B. annulatus, B. decoloratus, B. geigyi, B. microplus. Rhipicephalus evertsi.* Possibly *Haemaphysalis longicornis* (197)	Cattle	North and South America, Southern Europe, Africa, Asia, Australia.	Livestock disease. Agent absent, potential vector present.	Medium priority.		Type: Clinical surveillance . Target: Blood, serum. Tools: Thick smears, serology, PCR.

Agent			Vector	Disease agent hosts	Location	Agent importance	Agent priority assessment (vector risk and agent importance)	Research questions	Agent surveillance
Family	Genus	Disease agent	(NZ in blue)	(NZ in blue)	(NZ in blue)				(NZ in blue)
		Babesia gibsoni	Ticks: *Rhipicephalus sanguineus, Haemaphysalis longicornis* (135); (197), *H. bispinosa.*	Dogs (135)	Australia, North Africa, Far east.	Companion animal disease. Agent absent, a vector present, pathway (live dogs) present.	Medium priority.		Type: Clinical surveillance. Target: Blood, serum. Tools: Thick smears, serology, PCR.
		Babesia trautmanni	*Rhicephalus sanguineus, boophilus, Hyalomma, Demacentor.*	Pigs	Europe, Asia, Africa, Central and South America.	Livestock disease. Vector and agent absent. Human and canine entry pathway (rare event).	Low priority.		Type: Clinical surveillance. Target: Blood, serum. Tools: Thick smears, serology, PCR.
		Babesia perroncitoi	Unknown ticks	Pigs	Africa	Livestock disease. Agent absent. Pathway absent.	Low priority.		Type: Clinical surveillance . Target: Blood, serum. Tools: Thick smears, serology, PCR.
		Babesia ovata	*Haemaphysalis longicornis* (198) ; (197)	Cattle	Japan, China.	Livestock disease. Agent absent, vector present. Pathway absent. (based on current imports).	Medium priority.		Type: Clinical surveillance . Target: Blood, serum Tools: Thick smears, serology, PCR.
		Babesia major	*Boophilus calcaratus, Haemaphysalis punctata, H. longicornis* (197)	Cattle	USA, North Africa, Europe, Former Soviet Union.	Livestock disease. Vector present, agent absent. Limited pathway for entry.	Medium priority.		Type: Clinical surveillance . Target: Blood, serum. Tools: Thick smears, serology, PCR.
		Babesia ovis	*Ixodes persulcatus, Rhipicephalus bursa, R. tiranicus, R. evertsi, Hyalomma anatolicum, Haemaphysalis longicornis* (199); (196)	Sheep and goats.	Southern Europe, central Asia, north Africa.	Livestock disease. Agent absent. Vector present. Pathway absent. (based on current imports).	Medium priority.		Type: Clinical surveillance . Target: Blood, serum. Tools: Thick smears, serology, PCR.
		Babesia motasi	*Haemaphysallis punctata, Rhipicephalus bursa* (199)	Sheep and goats.	Europe Middle east Soviet union, SE Asia, Africa.	Livestock disease. Potential vector present, agent absent. Pathway absent. (based on current imports).	Low priority.		Type: Clinical surveillance . Target: Blood, serum. Tools: Thick smears, serology, PCR.
		Babesia vogeli	*Rhicephalus sanguineus*	Domestic dog.	Asia, Africa.	Companion animal disease. Agent absent. Vector absent.	Low priority.		
		Babesia pantherae	Unknown ticks	Leopard	Kenya	Panther disease. Agent absent. Pathway absent.	Low priority.		
		Babesia canis	Ticks, *Rhipicephalus sanguineus* (200)	Dogs (200)	USA	Companion animal disease. Agent absent. Vector absent.	Low priority.		Type: Clinical surveillance . Target: Blood, serum. Tools: Thick smears, serology, PCR.
		Babesia herpailuri	Unknown ticks	Cats	South America, Africa.	Companion animal disease. Agent absent. Pathway absent.	Low priority.		
		Babesia cati	Unknown ticks	Domestic cat and Indian wildcat.	India	Companion animal disease. Agent absent. Pathway absent.	Low priority.		
		Babesia shortti	Ixodid tick suspected (176)	Falcons (201)	Africa, Middle East, Sicily (201)	Wildlife disease. Vector unknown. Potential host present (NZ falcon). The most pathogenic of the avian Babesia. Has been recorded in captive falcons in England and USA. (84)	Medium priority.		Type: Clinical surveillance . Target: Blood, serum . Tools: Thick smears, PCR.
		Babesia felis	Unknown ticks	Domestic cat, Sudanese wildcat, puma, leopard.	Sudan, South Africa.	Companion animal disease. Vector absent, pathway absent.	Low priority.		Type: Clinical surveillance . Target: Blood, serum Thick smears, serology, PCR.
		Babesia pierci	Ixodid ticks (201)	Penguins. Jackass penguin, Little blue penguin (201)	South Africa, Southern Australia (207)	Wildlife disease. Potential vectors present. Pathway present.	Medium priority.	Is this pathogen already in NZ penguins?	Type: Active surveys, clinical surveillance. . Target: Blood, serum. Tools: Thin stained smears, serology, PCR.

Agent			Vector	Disease agent hosts	Location	Agent importance	Agent priority assessment (vector risk and agent importance)	Research questions	Agent surveillance
Family	Genus	Disease agent	(NZ in blue)	(NZ in blue)	(NZ in blue)				(NZ in blue)
		Babesia spp.	Ixodid ticks. Also possibly Argasid ticks of the genus *Alectorobius* (201) ; (199)	Birds. Wide range of hosts (201); (195)	Africa, Europe, Asia, North America, central Pacific, Australasia (201); (199)	Wildlife disease. Agents absent. Potential vectors present. Limited pathway for entry e.g. imported infected cattle from Australia. Bird infections only acquired vertically at the nest (201)	Low priority.		
Haemogregarine	Hepatozoon	*Hepatozoon kiwii*	Most likely the tick *Ixodes anatus* (194)	North Island brown kiwi (194)	New Zealand(194)	Wildlife disease. Present, not considered clinically significant (83)	Low priority.	Is the pathogen clinically significant? Is *Ixodes anatus* the vector?	Type: Clinical surveillance . Target: blood. Tools: Thin smears.
		Hepatozoon lygosomarum	Mite: *Ophionyssus scincorum* (202)	Grand skink, Otago skink, McCann's skink, Common skink, Moko skink (136); (139); (202)	New Zealand - Wellington, South Canterbury, Otago (136); (139); (202)	Wildlife disease. Present, not considered clinically significant (136)	Low priority.	Is the pathogen clinically significant?	
		Hepatozoon musculi	Unknown arthropod	Mouse (203)	New Zealand	Agent present.	Low priority.		
		Hepatozoon cuniculi	Unknown arthropod	Rabbit (203)	New Zealand	Agent present.	Low priority.		
		Hepatozoon breinli	*Culex quinquefasciatus, C. fatigans* (204)	Lizards	Australia, North Africa, Far east.	Wildlife disease. Agent absent. Vector present. Limited pathway. Not considered clinically significant.	Low priority.		Type: Active surveys, Target: Blood, *Cx.. quinquefasciatus*? Tools: Thin smears.
		Hepatozoon spp.	Lice, fleas, triatomid bugs, flies, mosquitoes, sandflies, tsetse flies, ticks, mites (204)	Birds, snakes, lizards, amphibians, mammals (188); (205); (203); (206); (207)	Worldwide	Wildlife disease. Agents absent. Vectors likely present. Limited pathway. Not considered clinically significant.	Low priority.		
	Haemogregarina	*Haemogregarina tuatarae*	Arthropods	Tuatara (208)	Stephens and Little Trios Islands, Cook Strait.	Wild life disease. Present. Not considered clinically significant.	Low priority.	What is the vector? Is the pathogen clinically significant?	Type: Active surveys Target: Blood, vectors?
		Haemogregarina spp.	Arthropods	Common gecko, Duvauvel's gecko, Pacific gecko, common skink, speckled skink, spotted skink (121)	Wellington region	Wildlife disease. Present. Not considered clinically significant.	Low priority.	What species are present? What are the vectors?	
		Haemogregarina spp., *Hemolivia* spp., *Karyolysus* spp.	Arthropods	Reptiles (Haemogregarina, Hemolivia and Karyolysus), Amphibians (Hemolivia), Turtles (Haemogregarina) (207)	Worldwide	Wildlife disease. Agents absent. Vectors likely present. Limited pathway. Not considered clinically significant.	Low priority.		
Rickettsias	Aegyptianella	*Aegyptianella* spp.	Argasid ticks (176). Potentially *Ornithodores capensis* on a large number of seabirds in NZ (209)	Wide range of birds ((210); unconfirmed reports in a Princess parrot (211), red-fronted parakeet (176)) and North Island brown kiwi (194) in New Zealand.	Primarily found in tropics and sub-tropics. No records in Australia.((212). One species found in frogs in Ontario, Canada (213)	Wildlife disease. Agent present.	Low priority.	What species are present? What is the vector?	Type: Active surveillance Target: Clinical blood, argasid ticks . Tools: Thin smears, PCR?

Agent			Vector	Disease agent hosts	Location	Agent importance	Agent priority assessment (vector risk and agent importance)	Research questions	Agent surveillance
Family	Genus	Disease agent	(NZ in blue)	(NZ in blue)	(NZ in blue)				(NZ in blue)
	Anaplasma	*Anaplasma marginale*	*Boophilus microplus*, other *Argas, Boophilus, Dermacentor, Ixodes, Rhipicephalus* ticks. (214); (197); (215); (216)	Ruminants	Australia, Worldwide	Livestock disease. Vector and agent absent. Pathogenic but not a major cause of economic loss. *H. longicornis* not a vector (197). Important for trade.	Low priority.		Target: Blood smears, serology. Tools: Nested PCR for *Anaplasma, Ehrlichia,* and *Trypanosoma*.
		Anaplasma centrale	Ticks	Cattle, deer, people.	Australia, South Africa.	Livestock disease. Non pathogenic vaccine for A marginale. Agent absent. Potential vector present (*H. longicornis*).	Low priority.		
		Anaplasma ovis	Ticks	Sheep, goats.	South and East Asia, Africa.	Livestock disease. Agent absent. Potential vector present (*H. longicornis*).	Low priority.		
		Anaplasma platys (formerly *Ehrlichia platys*)	*Rhipicephalus sanguineus*	Dogs	USA, Japan, Venezuala, Thailand, Europe, Taiwan, Greece.	Companion animal disease. Agent absent, could be introduced with imported dogs. Potential vector present (*H. longicornis*).	Low priority.		
		Anaplasma bovis (formerly *Ehrlichia bovis*)	Ticks	Cattle, deer, people.	Japan	Livestock disease. Agent absent. Potential vector present (H. longicornis). Important for trade.	Low priority.		Target: Blood smears, serology. Tools: Nested PCR for *Anaplasma, Ehrlichia,* and *Trypanosoma*.
		Anaplasma phagocytophila (formerly *Ehrlichia equi, E. phagocytophila,* human granulocytic ehrlichiosis)	Ticks. *I. ricinus, I hexagonus, I. scapularis*	Humans, dogs, cats, sheep, deer, rodents, elk, horses, llamas, sheep, cattle, bison.	USA, UK, Europe.	Human and livestock disease. Agent absent but can be transported in ticks on migratory birds (217). Potential vector present (*H. longicornis*). Important for trade.	Low priority.	Is the agent present in ticks carried by migratory birds?	Type: Active surveillance Target: *H. longicornis* and *Ixodes* spp. on migratory birds(1), animal blood smears Blood smears. Tools: serology. Nested PCR for *Anaplasma, Ehrlichia,* and *Trypanosoma*.
		Anaplasma sp unidentified	Ticks	cattle, deer, pig, possum.	New Zealand? (203). Originally reported in 1951 but no follow-up report.	Livestock disease. Agent present.	Medium priority.	What species is present? What ticks vector it?	Tools: Nested PCR for Anaplasma, Ehrlichia, and Trypanosoma.
	Ehrlichia (215); (216)	*Ehrlichia ruminatum* (formerly *Cowdria ruminantium*) (heartwater)	*Amblyomma* spp. ticks	Cattle, sheep, goat (218)	Africa, Caribbean.	Livestock disease. Agent absent, vector absent.. Important for trade. No entry pathway.	Low priority.		Tools: Nested PCR for *Anaplasma, Ehrlichia,* and *Trypanosoma*.
		Ehrlichia ewingii	*Amblyomma* spp. ticks	Dogs, white-tailed deer, humans.	USA	Livestock disease. Agent absent, vector absent. Entry pathway.	Low priority.		
		Ehrlichia chaffeensis	*Amblyomma* spp. ticks	White-tailed deer, dogs, humans.	USA, Africa, Europe, South and Central America.	Livestock disease. Agent absent, vector absent.	Low priority.		Tools: Nested PCR for *Anaplasma, Ehrlichia,* and *Trypanosoma*.
		Ehrlichia muris	*Haemaphysallis* spp.	Rodents	Japan	Agent absent. Potential vector present (*H. longicornis*).	Low priority.		
		Ehrlichia canis	*Rhipicephalus sanguineus*	Dogs, wolves, jackals.	Worldwide in many tropical and subtropical areas.	Companion animal disease. Agent absent, vector absent.. Entry pathway. Important for movemetn of pet dogs.	Low priority.		Tools: Nested PCR for *Anaplasma, Ehrlichia,* and *Trypanosoma*.

Agent			Vector	Disease agent hosts	Location	Agent importance	Agent priority assessment (vector risk and agent importance)	Research questions	Agent surveillance
Family	Genus	Disease agent	(NZ in blue)	(NZ in blue)	(NZ in blue)				(NZ in blue)
	Neorickettsia (215); (216)	*Neorickettsia risticii* (formerly *Ehrlichia risticii*)	Trematode in snails, aquatic insects.	Horse	USA	Livestock disease. Agent absent, vector absent.	Low priority.		**Tools:** Nested PCR for Anaplasma, Ehrlichia, and Trypanosoma.
		Neorickettsia helminthoeca	*Nanophyetus salmincola* (fluke) in fish.	Dogs	USA	Companion animal disease. Agent absent, vector absent.	Low priority.		
		Neorickettsia sennetsu (formerly *Ehrlichia sennetsu*)	Trematode in fish	Human	Japan, Malaysia.	Human disease. Agent absent, vector absent.	Low priority.		**Tools:** Nested PCR for *Anaplasma, Ehrlichia,* and *Trypanosoma*.
		"SF Agent"	*Stellantochasmus falcatus* (fluke) in fish.	Humans	Japan	Human disease. Agent absent, vector absent.	Low priority.		
	Rickettsia (219)	*Rickettsia conorii*	*Rhipicephalus sanguineus*	Humans	Mediterranean countries, Africa, India, Southwest Asia.	Human disease. Agent absent, vector absent.	Low priority.		PCR, serology.
		Rickettsia felis	Fleas. *Ctenocephalides felis*	Cats, humans (220); (221)	Worldwide, North Island of New Zealand.	Human and companion animal disease. Present, clinical signs not pathogonomic.	Medium priority.	Is the distribution expanding and incidence increasing?	**Type:** Clinical cases in cats and humans, surveys **Target:** Blood, fleas. **Tools:** Bacterial culture, serology, PCR.
		Rickettsia typhi (murine typhus)	Fleas. *Xenopsylla cheopis*	Rats, humans (222); (221)	Worldwide. Auckland.	Human and companion animal disease. Agent emerging since 1989.	High Priority.	Is the distribution expanding and incidence increasing?	**Tools:** PCR, serology.
		Rickettsia australis	Tick: *Ixodes holocyclus*	Humans, mice.	Queensland, Australia (223)	Human disease. Agent absent, vector absent.	Low priority.		
		Rickettsia honei	Tick: *Aponomma hydrosauri*	Humans	Australia (224)	Human disease. Spreading in Australia (224)	Low priority.		
		Rickettsia japonica	Ticks. *H. longicornis* (197)	Humans	Japan	Human disease. Agent absent, vector present.	Medium priority.		**Tools:** PCR
		Rickettsia tsutsugamushi (scrub typhus)	Mites: Trombiculid mites, *H. longicornis* (197)	Humans	Asia, northern Australia, Pacific Islands (225)	Human disease. Agent absent, vector present.	Medium priority.		
		Rickettsia spp.	Ticks, mites, lice, fleas.	Wide variety of animals.	Worldwide	Agent absent.	Medium priority.		
		Coxiella burnetii (Q fever)	Ticks may be involved. *H. longicornis* (197)	Humans, wide variety of animals and birds (211)	Worldwide, not New Zealand.	Multispecies disease. Agent absent. Entry pathway via live animal and bovine semen imports. High importance for trade.	Medium priority.		**Type:** Many surveys have failed to find this agent.. Clinical surveillance.
		Bartonella henselae	Fleas. *Ctenocephalides felis*	Cats, humans (220); (221)	Worldwide, North Island of New Zealand.	Present, clinical signs not pathogonomic.	High Priority.	Is the distribution expanding and incidence increasing?	**Type:** Clinical cases in cats and humans, surveys. **Target:** Blood, fleas. **Tools:** Bacterial culture, serology, PCR.
		Bartonella clarridgeiae	Fleas. *Ctenocephalides felis*	Cats, humans (220); (221)	Worldwide, North Island of New Zealand.	Present, clinical signs not pathogonomic.	High Priority.	Is the distribution expanding and incidence increasing?	**Type:** Clinical cases in cats and humans, surveys. **Target:** Blood, fleas. **Tools:** Bacterial culture, serology, PCR.
		Bartonella spp.	Fleas and ticks	Wide range of mammals (231)	Worldwide	Human and companion animal disease. Agents absent, potential vectors present.	Medium priority.		
	Theileria	*Theileria orientalis*	Ticks, *Haemaphysalis longicornis* (197)	Cattle (203)	Asia, Australia, New Zealand.	Livestock disease. Present. Considered only mildly pathogenic.	Medium priority.		

Agent			Vector	Disease agent hosts	Location	Agent importance	Agent priority assessment (vector risk and agent importance)	Research questions	Agent surveillance
Family	Genus	Disease agent	(NZ in blue)	(NZ in blue)	(NZ in blue)				(NZ in blue)
		Theileria sp.	Ticks	Deer (unconfirmed) (222)	New Zealand? (unconfirmed)	Livestock disease. Present? (unconfirmed).	Medium priority.		
		Theileria sergenti	Ticks. *Haemaphysalis longicornis* (197)	Cattle	Asia, Australia	Livestock disease. Agent absent, vector present. Entry pathway via imported cattle from Australia.	Medium priority.		
		Theileria buffeli	Ticks. *Haemaphysalis longicornis* (197)	Cattle, buffaloes.	USA, Asia, Australia	Livestock disease. Agent absent, vector present. Entry pathway via imported cattle from Australia.	Medium priority.		
		Theileria equi (formerly *Babesia equi*) (226)	Ticks: *Dermancentor, Hyalomma, Rhipicephalus* spp., *Rhipicephalus sanguineus.*	Equines	Tropics, subtropics and some temperate countries.	Livestock disease. Agent absent, vector absent, horse movements provide an entry pathway.	Low priority.		Type: Export serology, clinical surveillance. Target: Blood, serum. Tools: Thick smears, serology IFAT, ELISA, PCR.
		Theileria annae	*Ixodes hexagonus*	Dogs	Spain	Companion animal disease.	Low priority.		
		Theileria cervi	Ticks: *Amblyomma*	Deer	USA	Livestock disease.	Low priority.		
		Theileria spp.	Ticks: *Rhipicephalus, Amblyomma, Hyalomma*	Cattle, buffaloes.	Worldwide	Livestock disease. Agent absent, vector absent. Pathogenic species are of high importanvce to trade.	Low priority.		
Tyrpanosomtida Trypanosomes	Trypanosoma	*Trypanosoma lewisi*	Fleas	Norway rat	New Zealand (203) 1951	Importance low.	Low priority.		Blood smears, serology. Tools: Nested PCR for *Anaplasma, Ehrlichia,* and *Trypanosoma*.
		Trypanosoma eudyptulae	Vector unknown	Little blue penguin.	Tasmania (227)	Wildlife disease. Presence in New Zealand not determined.	Low priority.	Are NZ penguins already infected?	
		Trypanosoma evansi (surra)	Biting flies, *Atoylotus, Lyperosia. Stomoxys calcitrans.*	Horses, deer, camels, llamas, dogs, cats, cattle.	*T. evansi* reported to have occurred in Australia? (228); (229)	Livestock disease. Some vectors present, agent absent. High importance for trade. No entry pathway.	Low priority.	Is this agent able to establish in New Zealand?	Type: Clinical surveillance Target: Blood films, *Stomoxys calcitrans*. Tools: Nested PCR for *Anaplasma, Ehrlichia,* and *Trypanosoma*; stained blood smears.
		Trypanosoma spp.	Tsetse flies, triatomid bugs, tabanid flies, *Stomoxys calcitrans*, mites, Culicoides, hippoboscid flies, *Culex pipiens* (228); (229); (212); (230); (231); (232); (233)	Wide host range in birds and mammals ((234); (212); (235)	Primarily tropics.	Livestock disease. Agent absent, main vectors absent.	Low priority.		
	Leishmania	*Leishmania* spp.	Phlebotomids, (Sandflies).	Hyraxes, canids, rodents humans, dogs.	Worldwide, except Oceania.	Vectors and agent absent. High importance to dog movements.	Low priority.		
Mycoplasma	Mycoplasma (236); (237)	*Mycoplasma ovis comb. Nov (Eperythrozoon ovis)*	Mosquitoes, midges, ticks.	Sheep and goats (203)	Worldwide, including New Zealand.	Livestock disease. Present.	Low priority.	What is the vector?	
		Mycoplasma wenyoni (Eperythrozoon wenyoni)	Ticks, likely *Haemaphysalis longicornis* in NZ.	Cattle (203)	Worldwide, including New Zealand.	Livestock disease. Present 1974 1977 1984.	Low priority.	What is the vector?	
		Mycoplasma parvum (Eperythrozoon parvum / Eperythrozoon suis)	Biting and sucking insects.	Pigs (209)	Worldwide, including New Zealand.	Livestock disease. Present.	Low priority.	What is the vector?	

Agent			Vector	Disease agent hosts	Location	Agent importance	Agent priority assessment (vector risk and agent importance)	Research questions	Agent surveillance
Family	Genus	Disease agent	(NZ in blue)	(NZ in blue)	(NZ in blue)				(NZ in blue)
		Mycoplasma haemofelis (Haemobartonella felis)	Fleas and ticks. *Ctenocephalides felis.*	Cats (187)	Worldwide, including New Zealand.	Companion animal disease. Present, clinical signs not pathogonomic, can cause severe anaemia.	Low priority.	Is the distribution expanding and incidence increasing?	
		Mycoplasma haemocanis (Haemobartonella canis)	Fleas and ticks.	Dogs (199)	Worldwide, including New Zealand.	Companion animal disease. Present - infrequent - non pathogenic.	Low priority.	Is the distribution expanding and incidence increasing?	
		Mycoplasma coccoides (Eperythrozoon coccoides)	Biting insects.	Mice	Worldwide, not NZ.	Agent absent.	Low priority.		
OTHER		*Vibrio cholerae*	Chironomids - egg masses just an environmental reservoir, not a vector therefore should not be included.			Absent	Low priority.		
		Myxomatosis	Mosquitoes, fleas, *Spilopsyllus cuniculi, Culex quinquefasciatus, Aedes notoscriptus, Aedes camptorhynchus.*	Rabbits	South America, Europe, Australia.	Main vectors absent, agent absent. OIE listed, exotic, required by some importing countries, but trade in rabbits is minimal and the disease could be negotiated out of import requirements so it can be classified as 'not important'. Entry pathway.	Low priority.		
		Yersinia pestis	Fleas. *Xenophylla cheopis.*	Mammals.Maintained in small mammals. Kills rats.	All continents except Australia, Antarctica. Maintenance hosts probably absent in New Zealand. Incursions possible.	Severe human disease, vector present, host present, agent present in early 20th century. Exotic, required by some importing countries, but trade in small mammals is minimal so for trade purposes it is 'not important' Entry pathway.	Medium priority.	Is this agent still present in New Zealand?	Tools: Isolation, serology.
		Francisella tularensis	Tick: *Dermacentor variabilis, Amblyomma americanum, Demacentor andersoni.*	Humans, rabbits, hares	North America, Europe, Asia.	Human disease. . Agent absent, vector absent. OIE listed, exotic, required by some importing countries, but trade in small mammals is minimal so for trade purposes it is 'not important'. No entry pathway.	Low priority.		
	Spirochete	*Borrelia burgdorferi* (Lyme disease) Also *Borrelia garinii, afzelii, japonica*	Ticks: *Ornithodorus turicata, Rhipicephalus sanguineus, Ixodes ricinus, I. hexagonus, I. scapularis,* Sea bird ticks, *Ixodes uriae.*	Humans, dogs, cats, birds (300+ species) (211)	America, Europe, UK.	Human disease. Possible entry pathway with seabird ticks, imported cats and dogs, travellers, main tick vectors absent. Evidence for *Borrelia garinii* on Campbell island associated with *I. uriae*.	Medium priority.	Is this agent able to establish in New Zealand?	Type: Surveys, clinical surveillance Target: Serum. Tools: Serology and PCR.
		Borrelia anserina	Argasid ticks (198)	Chickens, turkeys, pheasants, geese, ducks (156)	Tropics	Wildlife disease. Agent absent, vector absent.	Low priority.		
		Borrelia recurrentis (louse-borne relapsing fever)	Lice: *Pedicus humanis*	Human	Worldwide, not NZ.	Human disease. Agent absent, vector present.	Medium priority.	Is this agent able to establish in New Zealand?	
		Borrelia spp. (tick borne relapsing fever - 15 species)	Ticks: *Ornithodorus*	Human, rodents, insectivores, wild and domestic pigs, bats.	Worldwide, not NZ.	Human disease. Agent absent, vector absent.	Low priority.		

Table 6. Nematode importance and priority

Agent			Vectors	Disease agent hosts	Location	Agent importance	Agent priority	Research questions	Agent surveillance
Family	Genus	Agents							
Nematodes	Filarial parasites (filaroids) are long hair-like tissue-dwelling nematodes. All except the Guinea worm *Dracunculus medinensis* (which uses a copepod) employ insects as intermediate hosts. They all have a similar life cycle, which includes an obligatory maturation stage in a blood-sucking insect or a copepod and a reproductive stage in the tissues or blood of a definitive host. Adult male and female worms live in the lymphatics, skin, or other tissues. Microfilariae (which are specialised embryos not larvae) are produced by the female worm, circulate in the blood, or invade the skin, and are ingested by the vector where larval development, but not multiplication, occurs. The infective L3 stage migrates to the proboscis of the vector and is transmitted to the new host during feeding. The infective stage is deposited onto the skin whilst the mosquito is feeding and find their own way through the skin, usually via the puncture made by the mosquito. Lymphatic filariasis is a mosquito-borne parasitic disease, which is caused by three species of tissue dwelling filaroids: *Wuchereria bancrofti* is responsible for 90% of cases and is found throughout the tropics and in some sub-tropical areas world-wide. *Brugia malayi* is confined to Southeast and Eastern Asia. *B. malayi* is also found in monkeys, cats and other small animals but it is not known how important this is in the epidemiology of human disease. *B timori* is found in Timor								
	Filaroid	*Dirofilaria immitis*	Mosquito: *Aedes vigilax, Aedes notoscriptus, Culex quinquefasciatus, Aedes camptorhynchus, Aedes vigilax, Aedes albopictus, Culex annulirostris, Anopheles, Aedes sierrensis, Culex pipiens pipiens.*	Dog	Australia	Dog heartworm is a high impact animal disease. Pathway for introduction exists with incoming dogs. Vectors and hosts present in abundance. No importance for exports.	High Priority.		Type: Clinical surveillance, active surveys. Target: Blood, heart examination. Tools: Smears, Knott's test, serology.
		Wuchereria bancrofti	*Anopheles punctulatus, Aedes polynesiensis, Culex quinquefasciatus, Aedes notoscriptus.*	People	Southeast Asia, Melanesia, Pacific, tropics and sub tropics worldwide.	Cause 90% of lymphatic filariasis. Pathway for introduction in humans, *Culex quinquefasciatus* present, Considered a major risk if *Aedes polynesiensis* establishes.	High Priority.	Why is this absent: Climate or vector?	Clinical surveillance.
		Onchocerca gibsoni	Simulids, *Aedes notoscriptus, Forcipomyia.*	Cattle			Not prioritised.		
		Saurofilaria sp.	*Culex quinquefasciatus*		Vector is present.		Not prioritised.		
		Oswaldofilaria sp.	*Culex quinquefasciatus*		Vector is present.		Not prioritised.		
		Setaria yehi	*Aedes sierrensis*	Deer			Not prioritised.		
		Brugia malayi	Mosquito	People	Southeast and eastern Asia.	Important human disease. Uncertain of vector status.	Medium priority.		
		Icosiella neglecta	*Culex sitiens, Culex pipiens palens, Culex gelidus, Anopheles.*				Not prioritised.		
		Wucheriua loaloa		People			Not prioritised.		
		Dipetelonema reconditum	Fleas: *Ctenocephalidies canis, C. felis, Pulex irritans.*	Dogs	Agent present infrequent.	Low clinical importance. Present.	Low priority.		
		Dirofilaria repens	?		Japan		Not prioritised.		
		Dipetelonema perstans	*Culicoides*				Not prioritised.		
		Eufilaria spp.	*Culicoides*				Not prioritised.		
		Chandlerrella spp.	*Culicoides*				Not prioritised.		
		Tetrapetalonema spp.	*Culicoides*				Not prioritised.		
		Dipetelonema streptocerca	*Culicoides*				Not prioritised.		
		Mansonella ozzardi	*Culicoides* or Simulid fly				Not prioritised.		
		Brugia timori	Mosquito	People	Timor	Important disease of people.	Low priority.		
		Mansonella perstans	Midges				Not prioritised.		
		Mansonella streptocerca	*Culicoides*				Not prioritised.		
		Onchocerca volvulus	Simulids	Human			Not prioritised.		
		Parafilaria bovicola	*Musca autumnalis, M. xanthomela, M. lusoria, M. nevilli, M. vitripennis.*	Cattle, buffalo.	All continents except Australia and America.		Not prioritised.		
	Spiruroid	*Habronema*	Muscidae: *Musca domestica, Stomoxys calcitrans.*	Horses	Vector is present.		Not prioritised.		

Table 7. Summary table of medium risk and high risk vectors

Vector type	Present in New Zealand	Absent from New Zealand
Mosquitoes	*Culex (Culex) pervigilans* Bergroth	*Aedes (Stegomyia) albopictus* (Skuse) (Asian tiger mosquito).
	Culiseta (Climacura) tonnoiri (Edwards)	*Aedes (Finlaya) japonicus* (Theobald) (Japanese rock pool or Asian bush mosquito).
	Coquillettidia (Coquillettidia) iracunda (Walker)	*Aedes (Ochlerotatus) vigilax* (Skuse) (northern saltmarsh mosquito).
	Culex (Culex) quinquefasciatus Say (southern house or brown mosquito). Introduced.	*Culex (Culex) annulirostris* (Skuse) (common banded mosquito).
	Aedes (Finlaya) notoscriptus (Skuse) (domestic container, or striped, or anklebiting mosquito). Introduced.	*Aedes (Stegomyia) aegypti* (Linnaeus) (yellow fever mosquito).
	Aedes (Ochlerotatus) camptorhynchus (Thomson). Introduced.	*Aedes (Stegomyia) polynesiensis* Marks (Polynesian mosquito).
	Aedes (Halaedes) australis (Erichson) (saltwater mosquito). Introduced.	*Culex (Culex) gelidus* Theobald (frosty mosquito).
	Opifex fuscus Hutton	*Culex (Culex) pipiens pallens* Coquillett (northern house mosquito).
		Culex (Culex) sitiens Wiedemann (saltmarsh Culex).
		Aedes (Finlaya) atropalpus Coquillett (rock pool mosquito).
		Aedes (Ochlerotatus) sierrensis (Ludlow) (western tree hole mosquito).
		Aedes (Stegomyia) scutellaris species complex
Ticks	*Ornithodoros capensis* Neumann	*Rhipicephalus sanguineus* (Latreille) (brown dog or kennel tick).
	Ixodes eudyptidis Maskell	*Ixodes pacificus* Cooley & Kohls (western black-legged tick).
	Ixodes uriae White	*Ixodes ricinus* (Linnaeus) (European sheep or castor bean tick).
	Haemaphysalis longicornis Neumann (livestock or cattle tick). Introduced.	*Ixodes holocyclus* Neumann (Australian paralysis or Australian scrub tick).
		Dermacentor variablilis (Say) (American dog tick).
Blackflies	*Austrosimulium australense* and *A. ungulatum* (our "sandfly").	
Fleas	*Xenopsylla cheopis.* Introduced.	
	Ctenocephalides felis. Introduced.	
Lice	*Pediculus humanus capitus.* Introduced.	
	Pthirus pubis. Introduced.	

High risk vectors are in light blue shading.
Medium risk vectors are in light yellow shading.

Table 8. Summary table of medium and high priority agents

Agent type		Present in New Zealand	Absent from New Zealand
Virus	Flavivirus	Unidentified Group B virus?	West Nile virus
			Yellow Fever virus
			Murray valley encephalitis virus
	Alphavirus	Whataroa virus	Ross river virus
		Unidentified Group A virus?	Sinbis virus
			Barmah forest virus
	Quaranfil	Johnston Atoll virus. Introduced.	
	Lyssavirus		Bovine Ephemeral fever virus
Haemosporidia	Plasmodium	*Plasmodium relictum*	
		P. cathemerium	
		P. spp.	
	Haemoproteus	*Haemoproteus* spp.	
	Leucocytozoon	*Leucocytozoon tawaki*	
		Leucocytozoon spp.	
Piroplasms	Babesia	*Babesia kiwiensis*	*Babesia bigemina*
			Babesia gibsoni
			Babesia ovata
			Babesia major
			Babesia ovis
			Babesia shortti
			Babesia pierci
Rickettsias	Anaplasma	*Anaplasma* sp. unidentified. Introduced.	
	Rickettsia	*Rickettsia typhi* (murine typhus). Introduced.	*Rickettsia japonica*
		Bartonella henselae. Introduced.	*Rickettsia tsutsugamushi* (scrub typhus).
		Bartonella clarridgeiae. Introduced.	*Rickettsia spp.*
		Rickettsia felis. Introduced.	*Coxiella burnetii* (Q fever).
			Bartonella spp.
	Theileria	*Theileria orientalis.* Introduced.	*Theileria sergenti*
		Theileria sp. Introduced.	*Theileria buffeli*
Bacteria	Yersinia		*Yersinia pestis*
	Spirochete	*Borrrelia garinii?* Introduced.	*Borrelia burgdorferi* (Lyme disease), also *B. afzelii, B. japonica*
			Borrelia recurrentis (louse-borne relapsing fever).
Nematodes	Filaroid		*Dirofilaria immitis*
			Wuchereria bancrofti
			Brugia malayi

Medium priority agents are shaded yellow. High priority agents are shaded light blue.

Table 9. Importance of exotic vector borne diseases to New Zealand's market access

Agent type	An Office International des Épizooties (OIE) listed disease agent that is not present in New Zealand (exotic) and is a requirement for country freedom certification by most importing countries	A disease agent that is not present in New Zealand (exotic) but is not listed by the OIE and is a requirement for country freedom by a very small number of importing countries
Virus	West Nile virus	Bovine ephemeral virus
	African horse sickness	Equine encephalosis
	African swine fever virus	Palyam group
	Bluetongue virus	Simbu viruses
	Crimean-Congo haemorrhagic fever virus	
	Eastern equine encephalomyelitis	
	Epizootic Haemorrhagic Disease	
	Japanese encephalitis	
	Louping ill virus	
	Nairobi sheep disease virus	
	Rift Valley fever	
	Venezuelan equine encephalomyelitis	
	Vesicular stomatitis virus	
	Western equine encephalomyelitis	
Blood parasites and bacteria		*Anaplasma* (ruminants, pigs horses, dogs, cats)
		Babesia spp. (ruminants, pigs horses, dogs, cats)
		Pathogenic *Theileria* (cattle, deer, horses)
		Coxiella burnetii
		Ehrlichia (ruminants, dogs)
		Leishmania (dogs)
		Trypanosoma evansi (ruminants, horses, dogs, cats)
		Francisella tularensis

Shading indicates the priority accorded the agent in the assessment, based on the vector risk and the importance of the agent.

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