Australian Government

Inspector-General of Biosecurity

Review of Department of Agriculture and Water Resources management of biosecurity risks posed by invasive vector mosquitoes

Review report

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Contents

Summary

Australia's geographic isolation and lack of shared borders provide a degree of natural protection from exotic threats. Our national biosecurity system also helps prevent the introduction of pests that can harm people, agricultural industries and the environment.

Invasive mosquitoes and vector-borne diseases present a re-emerging problem to many countries, including Australia. Several factors including increased international travel and trade, increased urbanisation and changing climate have increased the risk and distribution of vectors—virus-carrying insects such as mosquitoes and midges—and the viruses they carry globally and within Australia.

Australia is largely maintaining freedom from the invasive vector mosquitoes *Aedes aegypti* and *Ae. albopictus,* which can carry and spread yellow fever, dengue, chikungunya and Zika viruses, thus saving our population from a huge potential disease burden. Endemic *Ae. aegypti,* which used to support dengue outbreaks in south-eastern Queensland, is now confined to parts of tropical north Queensland, and *Ae. albopictus* is restricted to some Torres Strait islands, due to effective programs implemented by Australian Government and state/territory health departments over many years.

Prevention of new incursions and establishment of these mosquitoes is being achieved by adaptive application of proven mosquito control measures outlined in the World Health Organization's International Health Regulations (2005) (IHRs). These vector control obligations apply to aircraft and vessels and must also be applied within a minimum of 400 metres of points of entry of travellers, aircraft, vessels, containers, cargo and postal parcels.

Biosecurity officers from the Department of Agriculture and Water Resources oversee pre-border vector control on ships, aircraft and cargo by industry, and carry out border vector monitoring, surveillance and response measures under policies determined by the Department of Health's Director of Human Biosecurity, with necessary powers under the *Biosecurity Act 2015.* There has been a fairly smooth transition from the previous *Quarantine Act 1908*, although some minor amendments to the *Biosecurity Act 2015* are planned to clarify powers between the Department of Health and the Department of Agriculture and Water Resources.

Pre-border aircraft disinsection by insecticide treatment must be carried out by airlines in accordance with the Schedule of aircraft disinsection procedures for flights into Australia and New Zealand. The Department of Agriculture and Water Resources enters into Approved Arrangements with most major airlines to manage this. Biosecurity officers verify that required treatment has been carried out, largely by checking the information in an Aircraft Disinsection Information database and documents presented on arrival. If a biosecurity officer deems necessary, the airline or ground handlers will treat the aircraft cabin and baggage holds under supervision of the biosecurity officer.

All ships from international ports must arrive at designated first points of entry where they are inspected by a biosecurity officer for compliance with the international Ship Sanitation Scheme. This includes ensuring decks, cabins or break bulk cargo have no containers or pools of stagnant water, or evidence of past pooling and drying out, where mosquitoes could have been breeding during the voyage. The Department of Agriculture and Water Resources' new Maritime Arrivals Reporting System (MARS) allows pre-arrival reporting by ships' captains to ensure the biosecurity risk of each vessel entering Australian waters is assessed and all biosecurity risks posed by vessels, including the risk of mosquito importation, are adequately managed. The balance between biosecurity officers simply checking documents and databases and physically inspecting ships will need to be kept under review, in terms of effective risk management.

At international airports and seaports which are first points of entry, and in designated permanent monitoring zones around them, biosecurity officers work with state/territory health departments and port authorities to ensure these ports are rendered as unreceptive as possible to any mosquitoes that may arrive, by removing or treating any possible breeding sites. This is particularly difficult at tropical ports with high seasonal rainfall. In most cases there appears to be good cooperation with port authorities but extra attention is needed when there is new construction at and around busy ports, and particularly when new facilities are designed.

Monitoring for the presence of exotic mosquitoes in and around first points of entry is carried out by Department of Agriculture and Water Resources' vector control staff in consultation with medical entomologists from state/territory health departments. These biosecurity officers deploy different types of mosquito traps targeted at collecting the different life stages (eggs, larvae and adults) of mosquitoes that may emerge from aircraft cabins or baggage holds, or that fly off vessels or the cargo on them. Traps are cleared weekly, mosquito larvae are grown out to a stage where they can be identified, and any suspect mosquitoes are submitted to state/territory medical entomologists for confirmatory identification.

Ae. aegypti and *Ae. albopictus* detected at first points of entry are now being sent for genotyping to determine their country or area of origin and this should be done wherever possible. Detected mosquitoes are also being tested for genetic mutations that can indicate resistance to the standard insecticides used worldwide for many years.

Improvements can be made in providing field biosecurity officers with uniform and well-designed traps, instructions for correct installation, training and technical support. Although many of the local vector officers are very experienced and know their ports of entry and mosquito risk management intimately, issues such as lack of current site maps of trap locations across first points of entry (so that rotating staff can find them) need addressing. The Department of Agriculture and Water Resources' Surveillance Information Management System (under development) should address this. The servicing of traps at remote ports was also noted as being difficult and resource-intensive. The suggestion that routine trapping at some of these remote ports should be discontinued and replaced by periodic surveys merits consideration and advice on this should be sought from the National Arbovirus and Malaria Advisory Committee (NAMAC).

The pattern of exotic mosquito detections is changing markedly. Before 2014 most detections were in northern Australia, associated with seaports or cargo. In contrast, in 2014, 2015 and 2016, mosquito detections increased significantly overall and especially at southern airports (Sydney, Melbourne, Adelaide and Perth), with the majority of detections being *Ae. aegypti* recorded in Perth.

These increased detection rates may reflect an increased carriage rate of mosquitoes from certain airports in recent years, whether due to increasing travel from high-risk countries, changed practices at overseas ports, mosquitoes developing insecticide resistance, or inadequate aircraft disinsection in some circumstances. The increased detection rate may also be partly due to increased surveillance activities undertaken at airports and the use of newer and more efficient Biogents traps by Department of Agriculture and Water Resources.

For example, a number of recent airport *Ae. aegypti* detections were shown by genotyping to originate from a single origin in South East Asia. This led to detailed analysis of possible risks along the pathway and ways that they could be mitigated, such as extra spraying of aircraft baggage holds with residual and/or fast knockdown insecticides. Such measures may have been responsible for a significant reduction in mosquito detections at international airports in December 2016/January 2017 compared with the same period the year before. The ability of the system to identify and respond to such emerging risks is commendable.

Any confirmed detection of *Ae. aegypti* or *Ae. albopictus* at a first point of entry triggers an emergency response that must be carried out quickly to prevent new populations of these mosquitoes establishing or spreading further. These responses may be major, expensive and disruptive, especially at busy airports, because they may require complete fogging of passenger terminals with insecticides, spraying of baggage receival and sorting area walls with residual insecticides, and the setting of extra traps, tactically placed according to detections, that are cleared daily rather than weekly until no more mosquitoes are detected.

Responsibilities for exotic mosquito responses at Australian first points of entry are shared between Australian Government and state/territory health departments, Department of Agriculture and Water Resources and port authorities and their neighbours including local governments. The Department of Health, in close cooperation with Department of Agriculture and Water Resources, is developing new national guidelines for these responses. These guidelines are needed to clarify lines of authority and action, funding responsibilities, and hopefully will allow for locally managed quick responses, when required.

Apart from the national response guidelines, consideration should be given at each major first point of entry to reinstating local Memoranda of Understanding (MoUs) or setting up local consultative committees between Department of Agriculture and Water Resources, port authorities and their tenants and neighbours, and local and state/territory health departments and government representatives, who meet at least annually, so that all parties understand their roles and responsibilities both for routine mosquito monitoring and in the event of an emergency response.

The Department of Health and the Department of Agriculture and Water Resources should maintain a watching brief and support for further strategic and tactical research into better surveillance and control of mosquito vectors and the diseases they transmit. For example, a notable program called “Eliminate Dengue” led by Monash University researchers with Gates Foundation funding, is showing huge potential to prevent *Ae. aegypti* from transmitting dengue and possibly other diseases. This appears to have greatly reduced the incidence of locally acquired dengue in Cairns and may eliminate it. If further validated by international trials, this program could in future be deployed to reduce the burden of dengue fever in neighbouring countries, thereby also reducing biosecurity risks to Australia.

Purpose

The purpose of this review was to examine the effectiveness of vector monitoring and controls at Australia’s points of entry undertaken by the Department of Agriculture and Water Resources to manage biosecurity risks associated with invasive vector mosquitoes, especially *Aedes* spp., entering or establishing in Australia.

Review objectives and scope

This review aimed to assess how the Department of Agriculture and Water Resources:

- manages biosecurity risks and disease threats posed by invasive vector mosquitoes entering into Australia through various pathways especially via aircraft, vessels and imported cargo
- coordinates its management and delivery of monitoring, surveillance for early detection and reporting mechanisms, prevention, eradication measures and scale back processes with the Australian Government Department of Health, state/territory health departments and key industry stakeholders at points of entry (airports, seaports) and approved premises
- cooperates, communicates and shares information with these stakeholders in monitoring and managing mosquito breeding areas and delivering collaborative or complementary action for mosquito management services.

The scope of this review covered operational policy and activities that are the responsibility of the Australian Government Department of Agriculture and Water Resources. It did not examine policy and activities that are the responsibility of Australian Government and state/territory health departments.

Potential risks

Potential risks that were considered as part of this review include:

- risk-based and sampling methodologies (to detect, identify, control and eradicate pests) are inadequate or not used correctly
- the Department of Agriculture and Water Resources is not provided with appropriate or timely information by other stakeholders to allow it to carry out its responsibilities
- stakeholders do not receive appropriate or timely information from the Department of Agriculture and Water Resources to allow them to carry out their responsibilities
- capacity and capability are inadequate to identify new or emerging risks from exotic mosquito species
- vector management obligations for conveyances and points of entry are either inadequate or not complied with by relevant stakeholders
- insufficient Department of Agriculture and Water Resources' resources or capabilities are available to address relevant biosecurity risks.

Review methodology

During the course of this review, the IGB undertook:

- a review of relevant scientific literature, reports and Department of Agriculture and Water Resources policies and procedures
- fieldwork at airports and sea ports in Sydney, Brisbane, Cairns, Perth and Darwin, viewing firsthand the practicalities of regular mosquito surveillance and reduction of mosquito receptivity

- visits to regional offices in Brisbane, Cairns, Perth and Darwin for discussions with:
    - Department of Agriculture and Water Resources inspectorate staff (including biosecurity officers, regional vector coordinator, national vector coordinator and entomologists)
    - state/territory health department staff (including medical entomologists)
- key stakeholder discussions focused on Department of Agriculture and Water Resources operational policy and risk management activities, including:
    - the department’s implementation of invasive vector mosquito entry prevention and detection before and at first points of entry from aircraft, vessels and imported cargo
    - the department’s coordination of and communication processes about exotic vector mosquito monitoring, surveillance for early detection and reporting mechanisms, eradication measures and scale back processes with the Australian Government Department of Health, state/territory agencies and industry stakeholders at airports and seaports.

Review team

Dr Naveen Bhatia assisted the Inspector-General in this review.

Recommendations

The full department response to the recommendations is at Appendix A.

Recommendation 1

The department should continue efforts to develop improved testing methods for residual insecticide on aircraft and implement any suitable test as soon as it is validated.

Department's response: Agreed

Recommendation 2

The department should communicate with seaport and airport authorities and be included in the planning and design stages of new developments, to educate them about the importance of designing and maintaining port sanitation to keep ports, including construction sites, clear of water containers and areas where water could stagnate and mosquitoes could breed. This should also be part of ongoing monitoring and surveillance activities undertaken by staff involved in vector activities in states/territories.

Department's response: Agreed

Recommendation 3

The department should clearly map the boundaries of 400-metre monitoring zones around all first points of entry, and at priority ports, formalise vector monitoring arrangements with all private and public key stakeholders, and set up regular local communication arrangements to ensure these arrangements remain current and well understood.

Department's response: Agreed

Recommendation 4

The department should ensure that, for efficient vector monitoring at all ports, regions have access to operationally appropriate traps, instructions for correct installation, training and technical support.

Department's response: Agreed

Recommendation 5

The department should review, in consultation with the Department of Health and the National Arbovirus and Malaria Advisory Committee, routine mosquito surveillance at remote ports and assess the feasibility of replacing it with occasional strategically timed surveys.

Department's response: Agreed

Recommendation 6

The department, together with the Department of Health, should continue to update airlines (and port authorities in presumed countries of origin) about exotic vector mosquito detections at Australian ports, and provide management options and assistance (where appropriate) to minimise biosecurity risks.

Department's response: Agreed

Recommendation 7

The department should continue to submit as many exotic mosquito isolates as possible for both geographic origin and insecticide resistance characterisation, and, in cooperation with neighbouring countries and the Department of Health, publish the results regularly.

Department's response: Agreed

Recommendation 8

Until the successful launch of the Surveillance Information Management System (SIMS), the department should implement an interim communication strategy with the Department of Health for rapidly communicating exotic mosquito detections at first points of entry to state and territory health medical entomologists and department's regional vector coordinators across Australia.

Department's response: Agreed

Recommendation 9

The department should consider reinstating Memoranda of Understanding or setting up local consultative committees with local public and private stakeholders around each first port of entry, to regularly review contact lists and contingency plans defining all parties' roles and responsibilities in case of an incursion.

Department's response: Agreed

Recommendation 10

The department, in consultation with the Department of Health and the National Arbovirus and Malaria Advisory Committee, should consider establishing improved local arrangements and appropriate delegations to local coordinators enabling state and territory health officials to get quick advice on coordination of exotic vector mosquito responses.

Department's response: Agreed

Recommendation 11

The department should ensure that staff conducting vector monitoring at the border are well trained, aware of biosecurity risks associated with exotic vector mosquitoes and adhere to standard operating procedures. The department should also update work instructions to ensure up-to-date information is available to vector officers.

Department's response: Agreed

Dr Helen Scott-Orr
Inspector-General of Biosecurity

11 May 2017

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1 The mosquito threat

Mosquitoes arguably cause more human suffering than any other organism, with over one million people worldwide dying from mosquito-borne diseases every year. They transmit a range of severe human diseases including malaria, yellow fever, dengue, chikungunya and Zika. None of these diseases are endemic in Australia and their establishment would have a significant impact on morbidity and mortality within the community. All except malaria are or may be transmitted by *Aedes aegypti* and *Ae. albopictus* mosquitoes. These mosquito species recently carried chikungunya to the Caribbean—the first cases of this debilitating disease seen in the Americas (WHO 2014)—and since 2014 have transmitted the explosive Zika epidemic in South America, then Central America, and most recently North America.

In the 1940s the discovery of synthetic insecticides was a major breakthrough in the control of vector-borne diseases. Large-scale indoor spraying programs during the 1950s and 1960s succeeded in bringing many of the major vector-borne diseases under control. By the late 1960s many of these diseases—except for malaria in Africa—were no longer considered to be of primary public health importance. Development of an effective vaccine for yellow fever also reduced the emphasis on vector control.

However, within the past two decades many important vector-borne diseases have re-emerged or spread to new parts of the world. Traditionally regarded as a problem for tropical countries, vector-borne diseases pose an increasingly wider threat to global public health, both in the number of people affected and their geographical spread.

Environmental changes and increasing human population densities are causing an increase in the number and spread of many vector-borne diseases worldwide. Dengue in particular is emerging as a serious public health concern threatening more than 2.5 billion people in over 100 countries, causing an estimated 50–100 million cases annually in the tropics. Costs have increased 30-fold over the past 50 years, with staggering human and economic impacts, and with increasing geographic spread and severity of outbreaks. The emergence of chikungunya since the 1950s and the recent re-emergence of severe outbreaks of yellow fever are further major indicators of future risks.

The importation of mosquito vectors from countries where certain diseases are endemic into countries where they are not causes major public health consequences. This may include:

- if the mosquitoes are infected they may transmit disease in the country of arrival
- an imported infected mosquito may establish infection and transmission by a local mosquito population
- introduced mosquitoes may become established in new countries potentially introducing disease risks that previously were not present (for example, the risk of dengue transmission in southern Australia if *Ae. aegypti* or *Ae. albopictus* was to become established)
- the introduction and establishment of an imported vector may necessitate a costly control program, as occurred with *Ae. albopictus* in the United States and Italy (Gratz et al. 2000).

The threat of Zika virus

- Zika virus, a flavivirus related to West Nile, yellow fever, St Louis encephalitis and the equine encephalitides, has emerged from its origins in central Africa and has rapidly spread to the South Pacific and Western Hemisphere. Since its discovery in 2014 off the coast of South America, Zika cases have been found in 35 countries in the Americas.
- Zika is usually transmitted through the bite of an infected *Ae. aegypti* mosquito. The illness is usually quite mild, with fever, rash, conjunctivitis and joint pain lasting a few days to several weeks or months—for up to 80 per cent of sub-clinical and unreported cases. However, infection during pregnancy may lead to babies with microcephaly, a congenital defect of cranium and brain size resulting in profound neurological defects that is often fatal or leads to lifelong mental impairment.
- Semen of men who have been infected with Zika virus may remain infectious for up to six months. Cases of sexual transmission have been recorded in a number of European countries and the United States.
- There is a continuing risk of Zika virus being imported into Australia by travellers from affected countries, with the risk of local transmission in areas of central and north Queensland where the mosquito vector is present. According to the Department of Health's Zika virus web page, at least 58 confirmed cases have been reported in Australia, all infected overseas.
- Zika virus infection is nationally notifiable. The disease has no vaccine or treatment. Prevention by avoiding mosquito bites is the best course of action.

Vector-borne disease outbreaks in Australia

Australia has a number of serious human diseases transmitted by endemic mosquitoes, which necessitate local control and hygiene to prevent export of these diseases and vectors. For example, annual notifications of selected mosquito-borne diseases in Queensland between 2000 and 2009 are presented in Table 1.

Table 1 Annual notifications of selected mosquito-borne diseases in Queensland, 2000 to 2009

Mosquito transmitted disease	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Barmah Forest virus infection	345	601	387	869	583	680	955	826	1,245	797
Dengue	85	42	81	725	275	117	78	120	233	1,033
Japanese encephalitis	0	0	0	1	1	0	0	0	0	0
Kunjin virus disease	0	0	0	6	5	1	1	0	1	1
Murray Valley encephalitis	0	1	0	0	0	1	0	0	0	1
Ross River virus infection	1,481	1,568	885	2,514	2,005	1,179	2,611	2,137	2,846	2,149
Total	1,911	2,212	1,353	4,115	2,869	2,253	3,645	3,083	4,325	3,981

Source: Queensland Government (2010)

Most of these diseases, except for dengue and Japanese encephalitis, are endemic to parts of Australia and are transmitted by various endemic disease species. Dengue and Japanese encephalitis are not endemic in Australia but are regularly reintroduced by means of infected travellers. As in other parts of the world, dengue outbreaks in Australia were becoming more frequent in tropical north Queensland. The most recent large outbreak occurred in 2009 in Cairns and resulted in over 1,000 reported cases (Table 1). Until very recently, there was no cure or vaccine for dengue and control was targeted at reducing the abundance of mosquito vectors. Until the validation and widespread application of a new vaccine against one strain of dengue, and the innovative Eliminate Dengue Program (discussed in Section 8 of this report), vector mosquito control will remain the mainstay of dengue risk reduction.

Aedes mosquitoes

Some *Aedes* mosquitoes have successfully evolved to live and breed near humans and feed specifically on human blood, making them an abundant vehicle for the transmission of serious diseases. They are container breeders, laying their eggs in and on the edges of water-filled containers such as pot plant bases, hollows in plants, tyres, buckets, or pools in drains, and on ground, tarpaulins or machinery.

These *Aedes* mosquitoes have high invasive potential, as their eggs, laid singly on damp substrates, can withstand long transportation and desiccation for many months by entering diapause (a period of suspended growth). Due to human commerce and travel they have successfully spread from their native tropical forests of Asia to every continent except Antarctica.

In Australia, dengue virus is almost exclusively transmitted by the highly domestic *Ae. aegypti* mosquito, which is currently only prevalent in north coastal Queensland communities. It was previously recorded as far south as the New South Wales/Victoria border in the east and south of Perth in the west. The move from rainwater tanks to reticulated urban water schemes saw *Ae. aegypti* and dengue cases disappear from some of these areas. Recent changes in domestic water storage practices could allow re-establishment of *Ae. aegypti* populations and, along with imported cases of Zika, dengue, chikungunya and yellow fever among returning and international travellers in Australia, contribute to the risk of outbreaks of these diseases. In other parts of Australia, *Ae. aegypti* is now considered exotic, but many areas such as Brisbane, Darwin, Perth and Sydney would support its re-establishment.

The Asian tiger mosquito, *Ae. albopictus,* has emerged in recent decades as an increased disease vector threat overseas, known as the 'barbecue stopper' because of its aggressive daytime biting behaviour. It is primarily a forest species that has become adapted to rural, suburban and urban human environments, showing potential to move from Asia into more temperate climates in Africa, the Americas and Europe. This is notably aided by the international trade in used tyres, in which mosquitoes lay eggs when they contain rainwater. *Ae. albopictus* was the vector responsible for an outbreak of chikungunya in Italy in 2007 with 130 cases and one death. In Australia, *Ae. albopictus* is currently confined to the Torres Strait Islands and presents a constant risk of introduction to the mainland.

Flight range studies suggest that most female *Ae. aegypti* may spend their lifetime in or around the houses where they emerge as adults and they rarely fly further than 400 metres. This means that people and conveyances, rather than mosquitoes, are more likely to be responsible for their rapid distribution between communities and places. Both *Ae aegypti* and *Ae albopictus* transmit viruses that cause tropical fevers such as yellow fever, dengue, chikungunya and Zika. They are also considered possible vectors of West Nile, Japanese encephalitis, Rift Valley fever and equine encephalitis viruses, as well as filarial nematodes, which can cause elephantiasis in people.

The viruses are passed on to humans through the bites of an infective female mosquito, which mainly acquires a virus while feeding on the blood of an infected person. Within the mosquito, the virus incubates and spreads to the salivary glands in 8 to 12 days. It can then be transmitted to humans during subsequent probing or feeding.

Both mosquito species lay eggs on the surface of water, on surfaces adjacent to water like the damp area above the actual water line of a rock pool, or on drying-out muddy areas that may not be covered again by water for weeks or months. Those laid on the water surface will usually hatch within three days; those laid elsewhere are resistant to drying and will not hatch until actually immersed by a rising water level or inundation. A phenomenon of delayed hatching means that not all eggs hatch at the first immersion. Eggs hatch to larvae that are fully dependent on water and will die if the water evaporates before the adult stage is reached. Adults emerge from the pupae at the surface of the water, usually in 7 to 10 days after the eggs hatch. Adults usually mate near breeding grounds within the first day after emergence. The males, which do not suck blood, are short-lived while the females seek one or more blood meals, needed for the maturation of their eggs.

The lifespan of a female mosquito depends on satisfactory conditions of humidity and temperature. Nevertheless, females are quite capable of several blood feeds, laying eggs after each. They may even take blood more frequently than is required for egg maturation if opportunities for feeding are readily available. An adult may live for several weeks, not merely a few days, if it can avoid adverse environmental conditions.

Ae. aegypti and *Ae. albopictus* will feed day or night when a potential host comes within their limited flight ranges. *Ae. aegypti* tends to enter and stay within houses if conditions are proper. This species is exceedingly skittish, often leaving its host prior to taking a full blood meal when the host moves. Both mosquitoes also seem to prefer feeding on the host’s lower extremities. The primary means of controlling both species is to eliminate their oviposition habitats by removing water bearing containers or emptying them and scrubbing the insides to remove eggs deposited above the waterline.

2 Invasive mosquito risk management responsibilities

International

The World Health Organization (WHO) has created the International Health Regulations (IHR) (2005) to prevent, protect against, control and respond to the spread of serious infectious human diseases. Annex 5 of the IHR (WHO 2005) deals with specific measures for vector-borne diseases and outlines the obligations of signatories to implement vector control measures from identified sources of risk (Appendix B). These vector control obligations apply to aircraft and vessels and must also be applied within a minimum of 400 metres of points of entry of travellers, aircraft, vessels, containers, cargo and postal parcels.

National

The Australian Government, through the Department of Health, is responsible for implementing the IHR. The Department of Agriculture and Water Resources assists in the implementation as it relates to communicable disease control at the border. Relevant legislative frameworks incorporate these international obligations into domestic law. Industry is responsible for complying with domestic law, and domestic law implements obligations under the IHR.

Pre-border and border activities include risk assessment, establishing conditions of entry, pre-clearance checks, inspection and compliance activities. Post-border activities include surveillance, monitoring, risk assessment, emergency preparedness and response planning. Responsibilities along the biosecurity continuum are shown in Figure 1.

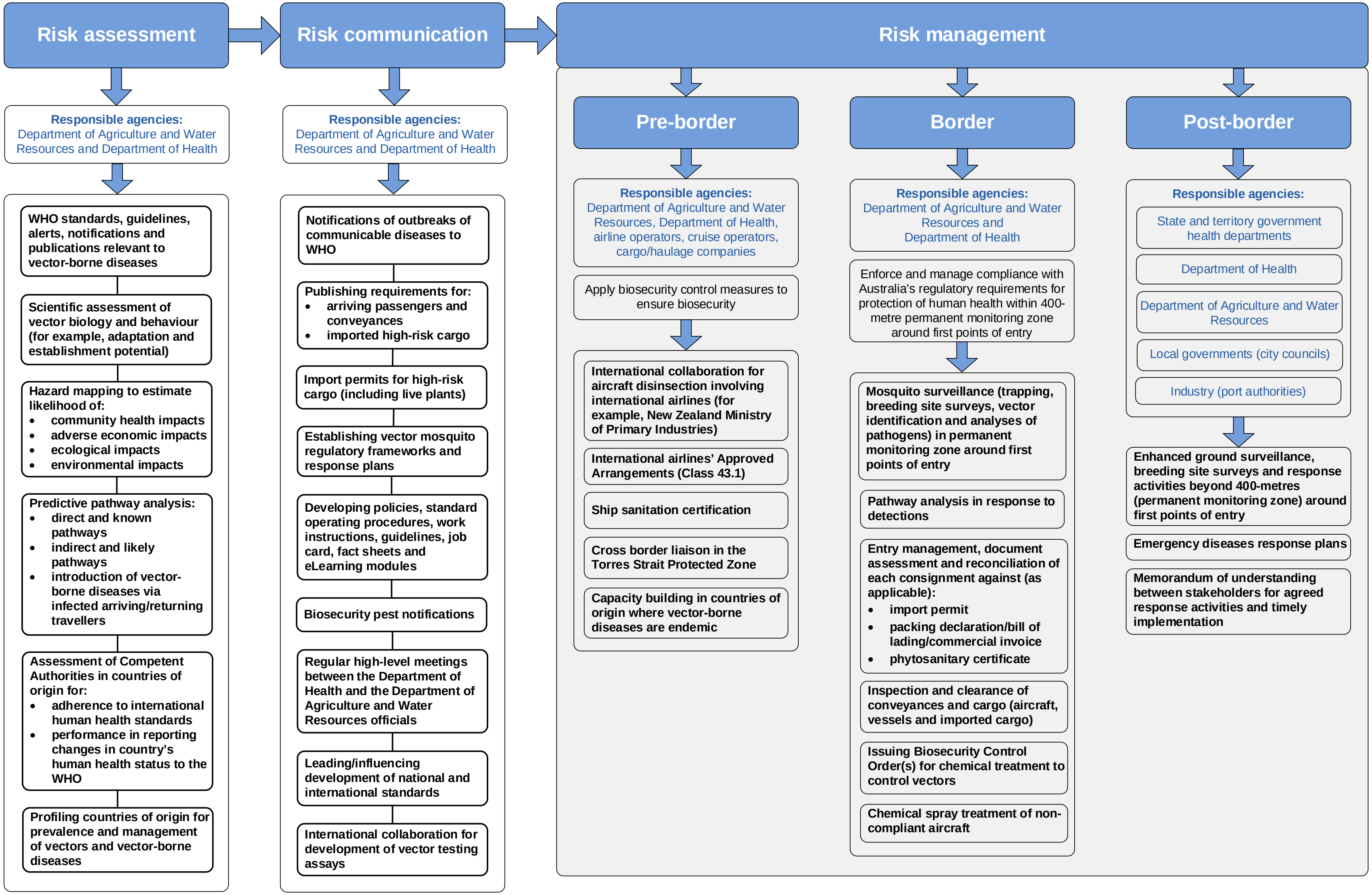
Department of Health

At the national level, the Department of Health develops policies for exercising human biosecurity powers pre-border, at the border and post-border, including risk prevention and mitigation activities addressing vector-borne transmission of Listed Human Diseases. It also coordinates communicable disease control activities and health emergency responses across the country. Australia's Chief Medical Officer is also the Director of Human Biosecurity under the *Biosecurity Act 2015* and oversees the Office of Health Protection, which provides policy direction and guidance to the Department of Agriculture and Water Resources and state and territory health department communicable disease representatives (Chief Human Biosecurity Officers) to support the implementation of human biosecurity powers.

The Department of Health—through its National Arbovirus and Malaria Advisory Committee—is developing national guidelines for exotic mosquito monitoring and control at Australia's points of entry. These guidelines aim to ensure consistency in response protocols across states and territories following an exotic mosquito detection. They will articulate roles and responsibilities of key stakeholders, including funding arrangements, requirements for inspection and surveillance (regular and enhanced), treatment methods, scale back processes, reporting requirements, communication pathways and legislative foundations.

These guidelines should, among other things, address the concerns of Russell (2015) about treatment and intervention activities at ports, by formalising responsibilities (including financial responsibilities) for vector control responses when incursions do occur.

Figure 1 Control measures for management of biosecurity risks posed by invasive vector mosquitoes, especially *Aedes* spp., entering or establishing in Australia



Department of Agriculture and Water Resources

The *Biosecurity Act 2015* provides the Director of Biosecurity (Secretary of the Department of Agriculture and Water Resources) with specified powers relating to human biosecurity measures at the border. The department carries out operational pre-border and border activities to prevent the entry and establishment of exotic mosquitoes. Those prescribed in the *Biosecurity (Human Health) Regulation 2016* are:

- setting requirements for aircraft disinsection for all arriving international aircraft
- implementing a ship sanitation scheme consistent with the IHR, including complete vector deck inspections of all international vessels

Other vector mosquito control activities carried out by the department include:

- ensuring import conditions are met for imported cargo posing a vector risk (for example, tyres and other break bulk cargo), including mitigation activities such as mandatory treatments and inspections
- vector monitoring (mosquito trapping and surveillance for receptivity) at international first ports and permanent monitoring zones
- notifying Department of Health and other stakeholders of reportable mosquito species and breeding sites detected in the international first port zone.

The Department of Agriculture and Water Resources' exotic vector mosquito control responsibilities are jointly managed by four divisions (Appendix C). The department's Service Delivery and Compliance Divisions carry out most mosquito vector monitoring and control management, Biosecurity Plant Division staff manage import conditions for plants that may introduce vectors, and Biosecurity Animal Division manages import conditions for animals that may introduce vectors and controls the importation of exotic mosquitoes for research purposes.

State and territory governments

Health departments

State/territory health departments have primary responsibility for:

- human communicable disease prevention and control programs
- responses to notifications of all notifiable diseases, including vector borne diseases
- confirmatory identification of exotic mosquitoes
- developing and prescribing response plans to mosquito detections/incursions at ports (in collaboration with the Department of Agriculture and Water Resources)
- post-border vector control activities including:
    - surveillance and responses to incursions
    - systematic control or eradication plans for specific mosquito vector populations in their jurisdiction
    - providing access to specialists for identifications as required
    - communicating details of exotic incursions to all principal stakeholders in a timely manner.

Local governments

Councils play an important role in protecting residents from vector mosquitoes by monitoring and treating all mosquito breeding sites on public land throughout their jurisdiction, including roadsides, drains and parks, under authority and direction from their state/territory health department. This reduces risks from endemic mosquitoes and the diseases they carry, and from any exotic mosquito incursions.

Industry

Conveyance (aircraft and ship) owners and captains, and break bulk cargo shippers

Airlines must carry out required disinsection; vessels must comply with ship sanitation; break bulk cargo shippers must comply with specific import requirements.

Seaport and airport authorities (or corporations)

Seaport and airport authorities are critical in the fight against entry and establishment of exotic vectors in and around first points of entry. They must:

- facilitate access to necessary sites for mosquito surveillance, monitoring and control
- implement any vector control measures required by the Department of Agriculture and Water Resources and the Department of Health, including employing accredited contractors to carry out required insecticide treatments
- communicate health, safety and environmental issues relevant to mosquito vector management to all tenants on their premises
- liaise with their tenants about the control of mosquito vectors of import/export significance on their land, including preventative measures to eliminate mosquito breeding sites.

3 Vector mosquito risk management

Arrival mechanisms for mosquitoes

Mosquitoes can enter Australia with aircraft, in passenger cabins or baggage compartments, or with imported goods and the conveyances carrying them. The pathway of arrival may vary based on the life stage of the mosquito. Live adult mosquitoes will most likely arrive in Australia on aircraft. Other life stages of mosquitoes may arrive via water imported intentionally or unintentionally into Australia. Examples of this include pooled rainwater on decks, machinery, other exposed cargo and unsealed water storage containers on ships. Eggs of *Aedes* mosquitoes are able to survive for extended periods until exposed to water, at which stage they hatch and commence their life cycle.

There are many instances of exotic vectors having been introduced into and established in countries where they had not previously been found. How a mosquito may have been introduced is difficult to verify unless the species is detected in or immediately around an international airport or seaport (Gratz et al. 2000).

Intelligence and forecasting of new and emerging risks and high-risk countries

Trade and passenger movements from countries with vector-borne diseases can pose serious risk of entry and establishment of the vector mosquitoes *Ae. aegypti* and *Ae. albopictus* and of pathogenic viruses in Australia if effective pre-border and at border biosecurity risk control measures are not implemented satisfactorily. The WHO regularly publishes lists of areas from which arriving conveyances (ship and aircraft) should be required to undertake disinsection and other vector control measures.

The department takes a proactive approach (through use of intelligence from WHO notifications of outbreaks and emergencies, ProMED and International Biosecurity Intelligence System) to monitor the incidence and severity of vector-borne diseases around the world so that targeted measures can be undertaken as needed. Given the high prevalence of serious mosquito-borne diseases in neighbouring South-East Asian and South Pacific countries, and the high levels of cargo trade and passenger movements from them, these countries present the highest risk.

Traditionally, shipping and seaports have been regarded as the highest risk pathways of entry of mosquitoes, due to the ease with which their eggs may survive long periods of dessication after being laid in small rainwater pools on decks or breakbulk cargo, only to hatch after these pools are replenished by rain at or near the port. *Ae. aegypti* detections at first points of entry in Northern Territory coincided with arrivals of vessels carrying break bulk cargo from South-East Asian ports (NT Department of Health Medical Entomology Annual Report 2014/15).

However, aircraft can also provide a quick pathway for dissemination of vectors of communicable diseases as they can transport vectors from a risk port to an Australian port within a few hours. In recent years, increasing numbers of detections/interceptions of *Ae. aegypti* have been reported from airports around Australia that receive direct flights originating in South-East Asian countries.

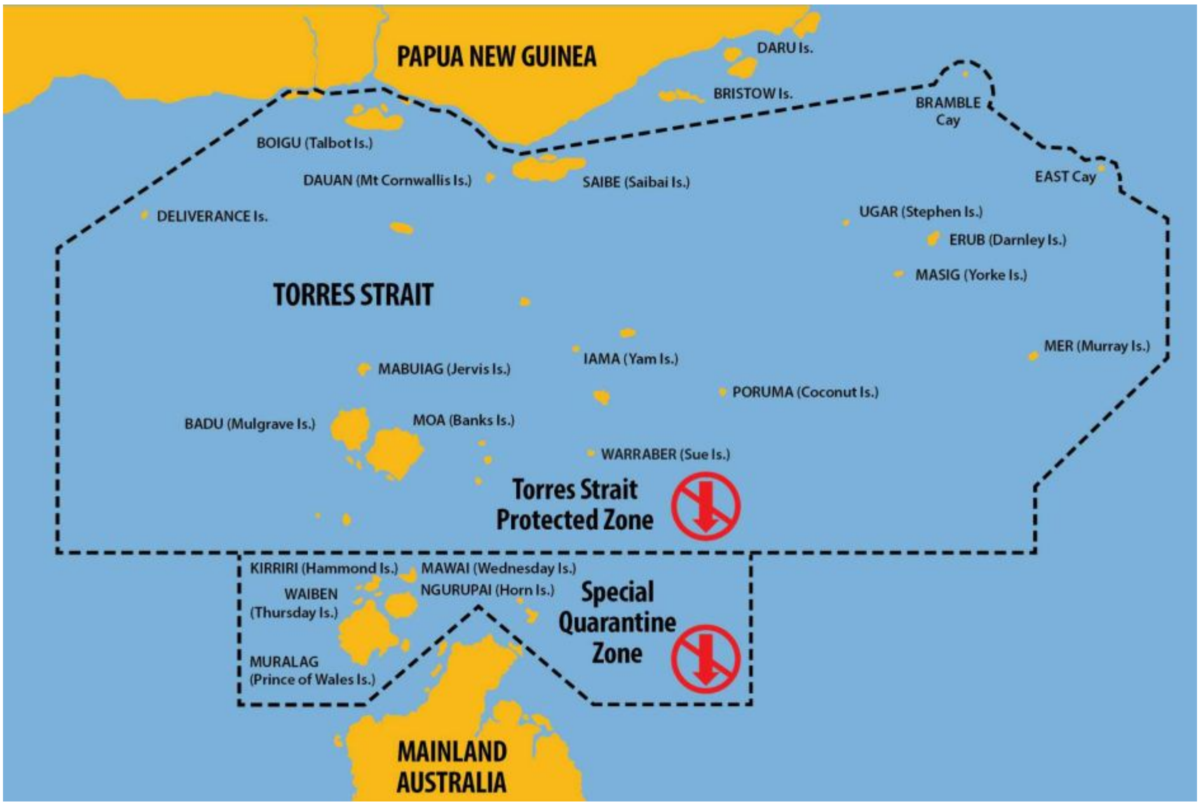
Torres Strait Protected Zone

The proximity of the Torres Strait Islands to Australia's near northern neighbours, such as Papua New Guinea (PNG), is one of the region's key biosecurity concerns. Less than five kilometres separates the northern-most island, Saibai, from the PNG coastline, with the remaining islands and reefs scattered throughout the region, forming stepping stones that provide an ideal route for the entry of harmful diseases or pests (Map 1).

The Torres Strait Treaty—an international agreement between Australia and PNG—allows free movement (without passports or visas) between Australia and PNG for traditional activities in the Torres Strait Protected Zone (TSPZ) and nearby areas. The Australian Government supports the effective delivery of two-way information and data sharing with PNG pertaining to communicable disease and other health issues which may arise from these cross border movements.

Mosquito-borne diseases and the vectors which transmit them are rampant in PNG and the Australian Government (through the Department of Health) provides funding to the Queensland Government to support the control of Asian tiger mosquitoes in the Torres Strait, to prevent this mosquito from invading and establishing in mainland Australia. The implementation plan for *Ae. albopictus* prevention and control in the Torres Strait program—executed under the National Partnership Agreement on Health Services—assists in the control of *Ae. albopictus* mosquito within the Torres Strait and attempts to eliminate it from an area if detected. In 2014–15, 3,900 inspections across 650 premises in the Torres Strait identified and treated thousands of potential mosquito breeding sites. The funding also provides for continuation of strong reporting practices between the Australian Government, Queensland Government and PNG.

Map 1 Torres Strait quarantine zones



Source: Department of Agriculture and Water Resources

Northern Australia Quarantine Strategy

The Northern Australia Quarantine Strategy (NAQS) was established by the Department of Agriculture and Water Resources in 1989 to provide an early warning system for exotic pest, weed and disease detections across northern Australia. NAQS is responsible for identifying and evaluating risks, and providing early warning of biosecurity pests (including vector mosquitoes) through a program of monitoring, surveillance and public awareness across northern Australia and in neighbouring Indonesia, East Timor and Papua New Guinea. NAQS activities are delivered via a network of scientific and operational staff based in Broome, Darwin, Nhulunbuy (Gove), Weipa, Bamaga, Cairns and throughout the Torres Strait.

Managing risks of mosquito arrival by air

Aircraft disinsection for mosquito control

The WHO recommends an international framework of aircraft disinsection to reduce the risks of vector transport around the world (WHO 2012). WHO's Guidelines for testing the efficacy of insecticide products used in aircraft currently recommend three methods for aircraft disinsection: blocks away; pre-flight and top-of-descent spraying; and residual treatment. This involves, in practice, four techniques:

- Pre-flight spraying—an aerosol containing an insecticide with rapid action and limited residual action is applied by ground staff to the flight deck, passenger cabin including toilet areas, open overhead and side-wall lockers, coat lockers and crew rest areas. The spray is applied before the passengers board the aircraft but not more than one hour before the doors are closed. A two per cent permethrin cis:trans (25:75) formulation is currently recommended for this application, at a target dose of 35 grams of formulation per 100 cubic metre to various types of aircraft, with a droplet size of 10–15 microns. Pre-flight spraying is followed by a further in-flight spray, that is top-of-descent as the aircraft starts its descent to the arrival airport.
- Blocks away spraying—is carried out by crew members when the passengers are on board, after closure of the cabin door and before the flight takes off. An aerosol containing an insecticide for rapid action is used. The air-conditioning system should be switched off during cabin spraying. The flight deck is sprayed before the pilot boards (when no passengers are on board). The doors of overhead luggage racks should be closed only after spraying has been completed. An aerosol containing two per cent D-phenothrin is currently recommended by WHO and should be applied at a rate of 35 grams of formulation per 100 cubic metre. Cargo holds should also be disinsected.
- Top-of-descent spraying—is carried out as the aircraft starts its descent to the arrival airport. An aerosol containing two per cent D-phenothrin is applied with the air recirculation system set at from high to normal flow. The amounts applied are based on a standard spray rate of one gram per second and 35 grams of the formulation per 100 cubic metre.
- Residual treatment—the internal surfaces of the passenger cabin and cargo hold, excluding food preparation areas, are sprayed with a compression sprayer that has a constant flow valve and flat fan nozzle. Permethrin 25:75 (cis:trans) emulsifiable concentrate at a target dose of 0.2 grams per square metre is applied at intervals not exceeding two months. The emulsion is applied at 10 ml per square metre to avoid run

> off. Residual sprays are applied by professional pest control operators and are intended for long-term residual activity on aircraft interior surfaces. In electrically sensitive areas, it may be necessary to use an aerosol instead of a compression sprayer. After treatment is completed, air-conditioning packs should be run for at least 1 hour before the crew and passengers embark to clear the air of the volatile components of the spray. Areas that undergo substantial cleaning between treatments require supplementary 'touch-up' spraying. (WHO, 1995).

The only products currently approved for use within Australia for aircraft disinsection are those recommended by WHO.

WHO has also published a risk assessment model that can be used to ensure products and methods used for disinsection do not give rise to unacceptable health effects in passengers (including children), aircrew or ground staff from aircraft disinsection insecticides.

The *Biosecurity Act 2015* provides for all aircraft entering Australia to be treated in a manner approved by the Director of Human Biosecurity. The Department of Agriculture and Water Resources administers disinsection requirements on behalf of the Department of Health according to WHO recommendations and partners with NZ Ministry for Primary Industries to develop and regulate joint aircraft disinsection requirements.

Pre-embarkation as per the Schedule for Aircraft Disinsection is not a WHO recommended method of aircraft disinsection. Following 2016 ad-hoc advisory group meetings WHO is considering including this method, which is exclusively used by Australia and New Zealand.

All aircraft entering Australia are required to undergo disinsection. Other countries determine disinsection requirements based on country of origin. WHO has recommended that state parties consider disinsection following Zika.

The Department of Agriculture and Water Resources has published Guidelines for airline and aircraft operators arriving in Australian territory, which include pre-arrival reporting requirements, pratique, approval to land aircraft in Australia, the mandatory in-flight announcement, aircraft disinsection and management of biosecurity waste.

Approved Arrangements

Approved Arrangements are voluntary arrangements with the Department of Agriculture and Water Resources entered into by private sector operators, and are described in detail on the department's website. These arrangements allow operators to manage biosecurity risks in accordance with departmental requirements, using their own premises, facilities, equipment and people, without constant supervision by the department but with occasional compliance monitoring or auditing.

Most major airlines flying into Australia and New Zealand have or will be developing a formal Approved Arrangement Class 43.1: Disinsection treatment with the department. This allows airline operators to manage treatment of international aircraft by disinsection according to the Schedule of aircraft disinsection procedures for flights into Australia and New Zealand.

The Approved Arrangements scheme came into effect when the *Biosecurity Act 2015* was enacted in mid 2016. Before this, most international airlines were covered by compliance agreements under the *Quarantine Act 1908*. Transitional arrangements apply until their registration under the old scheme expires. At the time of writing this report, three airlines were on a Class 43.1 Approved Arrangement and the remaining 57 were on transitional arrangements.

Aircraft Disinsection Information database

The Department of Agriculture and Water Resources uses its Aircraft Disinsection Information (ADI) database to collect up-to-date information on the status of residual and pre-embarkation disinsection of international aircraft arriving into Australia for airlines subject to an Approved Arrangement. To conform to the Australian cabin and hold disinsection requirements, airline operators can choose either:

- residual treatment—internal surfaces of an aircraft are sprayed at regular intervals, no greater than eight weeks, with a residual insecticide
- pre-embarkation treatment—the internal surfaces of an aircraft are sprayed at the last overseas port. The treatment lasts for the duration of the single flight sector.

Airlines must hold a Department of Agriculture and Water Resources disinsection Approved Arrangement or an arrangement with New Zealand Ministry of Primary Industries for one of these disinsection treatment methods. If an aircraft arriving into Australia has not had its residual or pre-embarkation treatment performed as per its Approved Arrangement, the aircraft must use either the pre-flight and top-of-descent or on-arrival disinsection methods. The pre-flight and top-of-descent method will involve both cargo hold spraying and cabin spraying.

Verification of aircraft disinsection

The Department of Agriculture and Water Resources is responsible for the biosecurity clearance of all incoming international aircraft, aircraft waste, goods, live animals and passengers' accompanied baggage. The operator of an incoming aircraft is required to report before landing to biosecurity officers if the prescribed disinsection measures for the aircraft have not or will not have been taken before the aircraft first lands in Australian territory.

The Department of Agriculture and Water Resources does not have a formal verification or audit scheme in place for aircraft disinsection Approved Arrangements. However, each airline with an Approved Arrangement is monitored for compliance through checking the ADI database. This database is used by airlines to update their disinsection information for each aircraft, based on the aircraft registration number. If the database is not updated before the aircraft's arrival in Australia, biosecurity officers meet the aircraft on arrival. A list of airlines with an Approved Arrangement is kept on an internal departmental team site. Biosecurity officers access this list before checking the information contained in ADI. Airlines that do not have an Approved Arrangement do not have access to ADI; on arrival biosecurity officers meet the aircraft to check their proof of disinsection treatment.

When an aircraft is met on arrival, the cabin crew must provide the biosecurity officer their completed certificate and used disinsection cans. If these are not provided, a respray of the aircraft is required and is completed under supervision of the biosecurity officer. An Airport Incident Notification (AIN) is completed whenever a respray of an aircraft is required, or in any other instances of non-compliance, and these notifications are received by Department of Agriculture and Water Resources's Compliance Division in Canberra.

The Compliance Division uses these notifications to determine any issues, non-compliance trends and areas for improvement. When required, it may seek further information from the attending biosecurity officer, the supervisor or airport manager as well as the airline. This may also involve an informal desktop review of documentation. When a biosecurity officer detects a non-compliance, several methods may be used to address it, including educating the airline staff about the requirements and how they are to be performed, and escalating more significant issues for consideration for suspension of their Approved Arrangement. Proposed further non-compliance action is also discussed with the NZ Ministry of Primary Industries.

Some of the department’s airport locations undertake random verification by attending aircraft to collect used disinsection cans and certificates, even if the ADI has been updated correctly. Where non-compliance is identified, a decision to respray under supervision is made by the biosecurity officer in attendance and an AIN is completed.

Extra risk-based treatment measures may be deployed in response to seasonal detections of mosquitoes from specific overseas airports. Our Australian summer coincides with the wet season in several of our tropical neighbours, when mosquito breeding is intense. For example, following numerous detections of *Ae. aegypti* originating from a single origin in South East Asia at several Australian airports in the 2015–16 summer, extra requirements to respray cargo holds were put in place at all international airports for the 2016–17 summer. Table 2 provides a snapshot of this extra activity plus routine verification measures undertaken during January 2017. As discussed in Chapter 6 ‘Exotic mosquito detection and response process’, may have contributed to reduced numbers of new mosquito detections at the targeted airports this summer.

Table 2 Disinsection of international aircraft arriving at Australian first points of entry, January 2017

First point of entry	Number of cargo holds resprayed for aircraft arriving from ‘Risk Source’ as per additional disinsection measures put in place	Number of flights attended for top-of-descent verification and checking of cans for airlines not on an Approved Arrangement	Number of airlines on an Approved Arrangement with ADI-related issues[a]	Number of non-compliant flights[b]
Adelaide	39	2	2	–
Brisbane	67	52	3	25
Cairns	16	9	3	3
Canberra	*	4	–	–
Darwin	49	23	–	13
Gold Coast	*	141	–	–
Melbourne	92	224	2	3
Perth	226	152	3	–
Townsville	14	9	–	–
Sydney	118	311	85	54
Total	554	927	98	98

Risk Source is the single South East Asian origin where the exotic *Aedes* mosquitoes detected at Australian international airports originated from. ***These first points of entry do not receive flights arriving from the ‘Risk Source’. **ADI** Aircraft Disinsection Information database. **a** ADI-related issues include not updating the ADI or validity of residual certificate. **b** Airlines that have been non-complaint and require a re-spray and those airlines that have not signed onto an Approved Arrangement and have chosen the ‘on arrival’ method.

Source: Department of Agriculture and Water Resources

The department conducts informal disinsection education activities with airlines as required. Where minor non-compliance issues are identified, the department will work with the airline to ensure they understand the disinsection requirements and apply treatments correctly.

Repeated non-compliance, could lead to the suspension of an airline's Approved Arrangement. This would result in the airline having to perform pre-flight and top of descent or on arrival treatments until the department is confident in their ability to comply with disinsection requirements. The department has suspended Approved Arrangements with airlines for disinsection on several occasions.

Technology development for testing for residual insecticide on aircraft

Apart from checking aircraft self-reporting of disinsection on the ADI database, the department is exploring methods of testing for insecticide residues in arriving aircraft. This would allow inspection staff to take on-the-spot quantitative measurements of residue levels to determine compliance with disinsection requirements.

The NZ Ministry of Primary Industries uses live fly bio-assays to test insecticide efficacy on all airlines arriving directly into New Zealand from tropical ports, and shares these results with the department. These are difficult to implement at airports with busy schedules and quick flight turn-around times and hence are not used in Australia.

As a pilot, the Department of Agriculture and Water Resources trialled the verification of minimum pesticide residue levels via enzyme-linked immunosorbent assay (ELISA) test kits. Although those tests provided quantitative results, they are time-consuming, costly, require specialist laboratory testing and do not provide timely results to enable quick remedial action if inadequate concentrations of pesticide are detected. High pressure liquid chromatography, the current gold standard for residue testing, was not trialled because of its even higher cost, greater time delay before results become available and the need to engage external laboratories for the testing.

For this reason, the Department of Agriculture and Water Resources has teamed up with the Australian Government Department of Industry, Innovation and Science to invite innovators to develop on-the-spot measurement technology to determine whether pyrethroid residues on interior aircraft surfaces are high enough to kill mosquitoes and other insects. This world-first Australian initiative is commendable as no such technology currently exists.

Recommendation 1

The department should continue efforts to develop improved testing methods for residual insecticide on aircraft and implement any suitable test as soon as it is validated.

Department's response: Agreed

The department is investigating new innovative methods for monitoring insecticide residues on-board international aircraft as part of the Department of Industry, Innovation and Science sponsored Business Research and Innovation Initiative (BRII). Methods utilising rapid on-the-spot technologies are currently being investigated with the intention of adopting the successful method at the end of the BRII process.

Managing risks of mosquito arrival by sea

Ship Sanitation Certification scheme

WHO's Ship Sanitation Certification (SSC) scheme aims to control the international spread of human diseases by proposing minimum standards of cleanliness and sanitation. This is achieved by inspecting for and controlling animal vectors (rodents and mosquitoes), preventing the discharge of untreated ballast water, checking certification of potable water and sewage, and biosecurity measures for human carriers of disease.

Ship sanitation control exemption and control certificates are internationally recognised and issued in accordance with Article 39 of the IHR. They are required for all vessels on international voyages that call at a port of a state that is a party to the IHR.

The Department of Agriculture and Water Resources administers ship sanitation certification requirements on behalf of the Department of Health. Each vessel is assessed for ship sanitation compliance prior to arrival at a designated first point of entry. Biosecurity officer on-board verification of compliance of a vessel includes sighting the original sanitation certificate and verifying that the vessel continues to comply with the ship sanitation standards. The certificate must be issued by an appropriate authority in the country of origin and, regardless of the language of issue, must be identifiable as to what it certifies and any specified conditions. Any vessel that arrives at a port without a valid certificate is subjected to additional conditions.

Depending on the biosecurity risk, the biosecurity officer issues either:

- A *Ship Sanitation Control Exemption Certificate* when, at the time of inspection, there are no signs of rodent or mosquito vectors, vector reservoirs (risk of mosquitoes), no measures are required to control vectors, and the relevant certification of vessel facilities is in order; or
- A *Ship Sanitation Control Certificate* when, at the time of inspection, there are signs or evidence of rodent or mosquito vectors or vector reservoirs, subsequent measures are applied to control them, or relevant certification of vessel facilities is invalid, out of date and/or out of order.

Not all first points of entry are ports for the Ship Sanitation Certification scheme. Ship sanitation inspections and issuing of certificates (including issuing of extensions to certificates) can only occur at ports declared by the Director of Human Biosecurity, where the Department of Agriculture and Water Resources can safely, reliably and regularly perform the service. These ports are listed in the department's Import Industry Advice Notice (50/2016) and referred to the WHO IHR, through the Department of Health, for publishing on the IHR website Ship Sanitation Ports List.

Routine vessel inspections

All vessels entering Australian territory from international waters are assessed, for arrival at first points of entry, by biosecurity officers to ensure that biosecurity risks, including the presence of exotic mosquitoes or pooled water that could harbour mosquito eggs, are identified and treated accordingly.

A vessel's risk level is determined by an assessment of its past inspection history and the information provided to the Department of Agriculture and Water Resources in pre-arrival reporting by the vessel's master or agent. A routine vessel inspection includes the inspection of all galleys, pantries, provision stores, management of the vessel's waste facilities, ballast water verification, cabins and inspection of any other areas of the vessel deemed appropriate by the biosecurity officer.

All vessels are initially considered high risk until information, from a Pre-arrival report (PAR), is provided about the vessel's arrival and its compliance assessed. Vessel compliance history and assessed risk will inform the need for intervention by a biosecurity officer to verify compliance and manage residual biosecurity risks.

Russell (2015) reported that:

> It seems to be becoming increasingly difficult to gain full access and carry out comprehensive inspections for both aircraft and ships, and to undertake appropriately sited surveillance at ports. At seaports it appears that relatively fewer vessels and on board cargoes are being inspected than previously, with more vessels being cleared on documentation.

Maritime Arrivals Reporting System

The IGB noted that the Department of Agriculture and Water Resources has adopted a comprehensive Vessel Compliance Scheme and implemented the Maritime Arrivals Reporting System (MARS), which provides enhanced capability to undertake consistent and thorough risk assessments for all vessels before their arrival into Australian ports. In addition, the educational material published as part of the MARS release (in November 2016) is believed to have increased the biosecurity awareness among the regulated entities (shipping companies and ships' masters)—enabling them to understand and comply with Australian requirements.

The MARS is an online portal for commercial vessel masters and shipping agents of all international vessels, seeking Australian biosecurity clearance, to submit required pre-arrival information about the biosecurity status of a vessel; request Department of Agriculture and Water Resources' services such as sanitation certification; and view directions and certificates issued by the department along with compliance outcomes, after the vessel is inspected.

Pre-arrival reporting using MARS ensures that the biosecurity risk of each vessel entering Australian waters is assessed and all biosecurity risk posed by vessels, including the risk of mosquito importation, is adequately managed.

Where a vessel inspection does not meet the department's standards, additional directions or corrective actions are issued by a biosecurity officer. As well, demerit points will be issued that require a more stringent (and more expensive) inspection regime for a future period until satisfactory compliance is demonstrated. The MARS makes this information available to other biosecurity officers as well as the vessel's captain.

Vessel Compliance Scheme

The Department of Agriculture and Water Resources' Vessel Compliance Scheme (VCS) is aimed at improving the transparency of the risks biosecurity officers focus on as part of the inspections, and the consequences of non-compliance. This ensures vessel masters and crew are able to better prepare the vessel to reduce the likelihood of non-compliance, thereby improving their chances of qualifying as 'compliant' entities to take advantage of reduced intervention and associated benefits.

The Vessel Compliance Scheme operates through MARS. Once on the scheme, vessels will receive reduced physical inspections over a defined voyage cycle. Vessels that qualify as compliant vessels receive 40 per cent inspection over a defined voyage cycle. Other vessels receive 100 per cent. Irrespective of the compliance history, the department undertakes risk assessments that may result in targeted inspections being carried out to manage risks. All non-compliant vessels (based on their compliance history) are inspected on arrival.

To qualify for the VCS, commercial vessel operators must meet these requirements for reduced intervention:

- a minimum of three voyages to Australia in a 12-month period
- below the individual inspection threshold of 10 points for a voyage
- below the collective threshold of 20 points over three voyages.

This demerit action list and associated points (available on Department of Agriculture and Water Resources' website) determine vessel eligibility for the VCS. For biosecurity risks associated with vector mosquitoes on board international vessels, these demerits apply:

- minor vector demerit—where shallow standing water is present in receptacles or ship structures but there is no evidence of mosquitoes or larvae
- major vector demerit—where deep standing water is present in receptacles or ship structures that is unable to drain naturally (for example, buckets, containers, tyres) with no evidence of mosquitoes or larvae.

To manage potential biosecurity risks associated with exotic vector mosquitoes, biosecurity officers would require the crew of vessels with vector demerits detected to empty the receptacles on the deck to dry naturally or that water be treated with chlorine.

Departmental data indicate that between July and December 2016, 5300 vessels arrived on Australian shores. Of those, 3700 vessels were inspected by biosecurity officers, including Routine Vessel Inspections and Ship Sanitation Certificates. The remaining vessels were cleared on documents. For biosecurity risks associated with exotic vector mosquitoes, 58 (approximately 1.5 per cent) vessels received a minor vector demerit and 18 (approximately 0.5 per cent) vessels received a major vector demerit.

Managing risks of mosquito arrival by cargo

High-risk cargo such as used tyres, machinery and other break bulk cargo, and live plants (especially lucky bamboo, if imported in water as a substrate) may provide optimal spaces for water to stagnate, which is used by mosquitoes to breed.

Import permits may be required for importation of high-risk cargo. The department's Biosecurity Import Conditions system (BICON) sets out import requirements for used tyres, machinery and live plants. The import permit establishes a level of assurance based on the department's risk assessment (for pests) for each pathway. The permit is a directive to the importer, stipulating conditions that each consignment must meet to allow entry into Australia, which may include mandatory treatments.

Cargo arriving in Australia can often be cleared by the department using accompanying declarations and information provided by the importer. If an importer fails to provide requisite documentation, an imported cargo is opened and inspected by a biosecurity officer. After document assessment, the biosecurity officer issues the importer with a directive that goods are released from biosecurity control or that actions are required—for example, inspection, treatment, isolation, hold pending further information or insect identification.

4 Vector surveillance and monitoring program at ports

The Department of Agriculture and Water Resources performs vector monitoring activities at proclaimed first points of entry around Australia. These first points comprise international airports and seaports except for those ports where the department does not have a permanent presence and are specified under the *Biosecurity Act 2015*. In these locations, third parties (such as the Department of Immigration and Border Protection, state government officials and/or port operators) perform these functions wherever possible.

The program performs two main tasks: vector monitoring and port surveillance. Specific activities depend on the risk category of the port as determined by the review performed by Russell (2015). Higher risk ports involve greater monitoring and surveillance activities.

The Department of Agriculture and Water Resources vector monitoring network is a group of biosecurity officers involved in vector monitoring and includes vector officers, regional vector coordinators, the national vector coordinator and operational science entomologists. Roles and responsibilities of staff involved in surveillance, monitoring and management of exotic vector mosquitoes in Australia are in Appendix D.

Vector monitoring activities at international defence ports are performed by Defence personnel or contractors, with the exception of military bases, that are co-located within commercial proclaimed first ports, where Department of Agriculture and Water Resources typically performs vector monitoring activities. All costs of routine vector monitoring at first ports of entry are covered by the Department of Agriculture and Water Resources, with the exception of defence ports serviced by defence personnel/contractors.

Vulnerability and receptivity of first points of entry

There are 93 first points of entry into Australia (Map 2). These include both seaports and airports. A point of entry may be determined with regard to its vulnerability to exotic vector mosquito entry (the likelihood that a site may host a vessel or aircraft from a high-risk area carrying a mosquito vector) and its receptivity to exotic vector mosquito establishment (the potential of a site to host mosquito larvae). The vulnerability of first points continuously changes with changes in the origins of vessels and cargoes. Receptivity of ports is partly climatically determined but can largely be managed by maintaining sanitary conditions (Russell 2015).

In 1998 the then Australian Quarantine and Inspection Service (AQIS) commissioned the first review and risk assessment of vector monitoring at Australia's first points of entry (Russell 1998). In 2015 the Department of Health commissioned a second review (Russell 2015). As part of these reviews the vulnerability and receptivity risks of all first points of entry were assessed and a risk category rating was assigned. Map 2 shows the risk categories as determined from the 1998 review. A similar map depicting the port risk categories from the 2015 review is currently not available.

Map 2 Australia's first points of entry and their mosquito vector introduction risk as determined in Russell 1998

Source: Department of Agriculture and Water Resources

Russell (2015) concluded that:

> While the ‘vulnerability’ of first ports will continue to change with changes in vessels and cargoes, ‘receptivity’ of ports can be managed by maintaining sanitary conditions and, in this regard, these Australian ports are generally in a very good condition. The highest risk ports remain as Cairns, Darwin and Townsville Seaports as Category 1, with Brisbane Seaport, Darwin Airport (including the RAAF Base), Townsville Airport (including the RAAF Base), Thursday Island Seaport, Horn Island Airport, and the Christmas and Cocos Islands Sea- and Airports all close behind.

In the current IGB review, staff at several ports of entry noted the excellent cooperation they received from airport and port corporation management in maintaining or improving port sanitation, to reduce mosquito receptivity. Simple design and maintenance processes included removing receptacles that could contain standing water, replanting landscape gardens with plants that do not have crevices able to trap water, and capping drain sumps and other potential stagnant water holders.

Tyres within the port environment (used as pneumatic or boat fenders) are high-risk breeding sites (Figure 2) and should be removed if possible. Otherwise, they must be checked to ensure they are kept free of water or have holes drilled in them by the relevant authority so they do not hold water. If this is impractical and they are required for port operations, they should be treated with larvicide regularly, and included as dipping sites in the port’s vector monitoring program.

Figure 2 Tyres within the port environment

Risks of poor sanitation increase during any airport or seaport construction processes. For example, for several months while a new international terminal was being built at Perth international airport, construction activities provided opportunities for water stagnation on site and consequent mosquito breeding risks.

Plastic bollards used for temporary traffic management are filled with water and may remain on building sites for several weeks or months. If uncapped, they present major breeding grounds for mosquitoes—as demonstrated by presence of exotic mosquito larvae in samples collected from bollard water in some states/territories. This is a major concern for both Department of Agriculture and Water Resources and state/territory health department officials as it could potentially lead to the establishment of exotic vectors.

Recommendation 2

The department should communicate with seaport and airport authorities and be included in the planning and design stages of new developments, to educate them about the importance of designing and maintaining port sanitation to keep ports, including construction sites, clear of water containers and areas where water could stagnate and mosquitoes could breed. This should also be part of ongoing monitoring and surveillance activities undertaken by staff involved in vector activities in states/territories.

Department's response: Agreed

The department is actively involved in the planning and design of new developments of airport and seaports which includes negotiating appropriate infrastructure to mitigate a range of biosecurity risks including vectors of human health.

In consultation with industry, the department is developing a set of standards to guide first point operators in meeting the first point requirements under the First Point of Entry Determinations. The standards cover such things as infrastructure and facilities which enable and support effective risk assessment and management activities; management of hazards and risks in the port/airport surrounds to minimize the receptivity of the environment to pest and disease incursions including site sanitation and source reduction.

Officers from the department involved in surveillance activities at first points of entry currently do and will continue to be involved in monitoring of the environment to minimise potential breeding sites.

Permanent biosecurity monitoring zones

In the case of first points of entry, the permanent biosecurity monitoring zone (PBMZ) is all of the area within the boundary of the first point and extends out including all of the area within a 400-metre perimeter of the first point boundary. Within the PBMZ around first point of entry, biosecurity officers can perform a range of functions, including identifying areas (by putting up notices), setting traps etc. Biosecurity officers may enter private land within a PBMZ to set traps but must do so with the permission of the occupier unless a biosecurity monitoring zone warrant is issued. The port operators should maintain a sanitary area within the first point boundary including not leaving receptacles around that could harbour mosquitoes and encourage breeding.

During fieldwork, it was noted that some key stakeholders are confused about clear boundary delineation of the 400-metre permanent monitoring zone around several first points of entry. The Department of Agriculture and Water Resources staff can access land and facilities within port boundaries, but at some ports the 400-metre distance from a potential vector entry point may extend beyond the port to neighbouring public or private land. Access to this land for vector monitoring and surveillance activities may be difficult to arrange and in some instances—for example, in railway corridors near ports—may have WHS and security implications.

Confusion over vector monitoring and control responsibilities close to the boundaries of first points of entry can also occur, which may fall to local councils acting under state/territory health department authority. For example, up to three local councils bordering an international port in Western Australia are responsible for monitoring beyond the 400-metre monitoring zone. Given the high-risk rating of the port (Russell 2015), state health officials feared that this could lead to gaps in vector monitoring and response activities outside the first point of entry. It is hoped that the National Guidelines for Exotic Mosquito Detections at Australian First Points of Entry (see Section 2: Invasive mosquito risk management responsibilities), being developed by the Department of Health, will help clarify roles and responsibilities within and beyond permanent biosecurity monitoring zones.

Recommendation 3

The department should clearly map the boundaries of 400-metre monitoring zones around all first points of entry, and at priority ports, formalise vector monitoring arrangements with all private and public key stakeholders, and set up regular local communication arrangements to ensure these arrangements remain current and well understood.

Department’s response: Agreed

The department is investigating mapping opportunities for all first points of entry to depict port boundaries, biosecurity monitoring zones and among other things, the 400m vector monitoring zone. Furthermore the National Guidelines for Exotic Mosquito Detections at Australian First Points of Entry, which is in the final stages of development by the Department of Health, articulates a clear definition of the 400m zone in relation to vector monitoring at first points of entry and details the roles and responsibilities of key stakeholders within and outside this area.

The formalising of vector monitoring arrangements with all private and public key stakeholders and regular local communication arrangements within and to the extent of the 400m zone around first points of entry would be resource prohibitive. The department does, however have a number of other mechanisms by which it would be able to communicate with relevant stakeholders. These include:

- Through the department's National Border Surveillance (NBS) program, the department undertakes surveillance and engagement activities around first points of entry for a range of biosecurity risk pests and diseases. Opportunity exists to leverage this activity to support stakeholder engagement on mosquito vector issues.
- The National Guidelines for Exotic Mosquito Detections at Australian First Points of Entry is under development and is intended to be the mechanism to promote key stakeholder engagement and collaboration. The national guidelines will support the establishment of local stakeholder consultative groups to support preparedness activities in response to possible exotic mosquito detections. The guidelines detail the roles and responsibilities of key stakeholders when responding to exotic mosquito detections as well as include action plans and response procedures. Contact lists for the key stakeholder will be maintained using the template in the guideline and updated during stakeholder meetings.

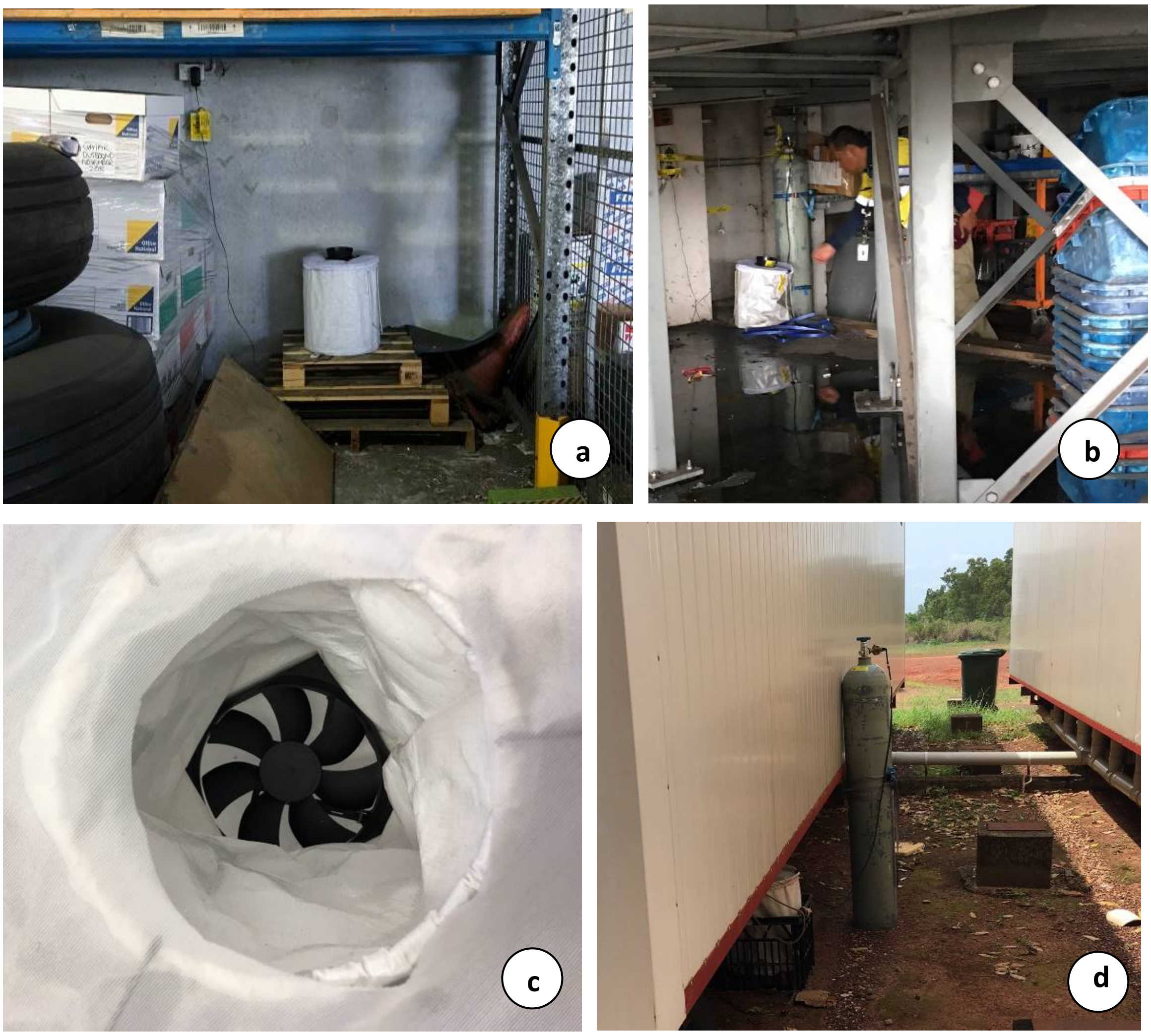
5 Exotic mosquito trapping

Vector monitoring involves setting various mosquito monitoring traps, as well as sampling standing bodies of water and receptacles by dipping, and identifying the species of mosquitoes collected. The Department of Agriculture and Water Resources vector monitoring program uses three main types of traps for detecting exotic *Aedes* spp. mosquitoes.

Biogents (BG) Sentinel traps

BG-Sentinel traps are the preferred method for long distance (20 metres) adult *Aedes* mosquito trapping (Figure 3a, b). They were initially developed to monitor the dengue mosquito (*Ae. aegypti*) and the Asian tiger mosquito (*Ae. albopictus*) and are a better method of targeting these species than the previously used carbon dioxide (CO_2) light traps. However, the BG trap is also attractive to many other mosquito species especially when used with CO_2.

Figure 3 Biogents-Sentinel trap for adult mosquito trapping



The BG-Sentinel mosquito trap is essentially a collapsible, fabric container with a white lid with holes covering its opening (Figure 3c). BG-Sentinel traps can be 'baited' with CO_2 to attract mosquitoes from a greater distance, or used 'unbaited', as the black and white contrast of the trap attracts mosquitoes. In the middle of the gauze cover, air is sucked into the trap through a black catch pipe by an electrical fan, drawing approaching mosquitoes into a catch bag. The air then exits the trap through the white gauze, generating ascending currents that resemble convection currents produced by a human host and, if a special 'BG-Lure' is added, also resemble human body odour.

While these traps are highly effective, they require an electricity supply and preferably an associated CO_2 cylinder (Figure 3d) and so are not suited for remote area monitoring. They require servicing at least weekly to change the collection bag and replace the CO_2 cylinders (if required). In some regions, the department has agreements with third-party service providers to replace cylinders at regular intervals (before they run out of gas).

Tyre traps for larval trapping

Tyres are an ideal habitat for container breeding mosquitoes (*Aedes* spp.) due to their darkness, sheltered interior, and ability to hold relatively large water volumes that become contaminated with organic matter and attract egg-laying females. Used tyres can be made into mosquito breeding traps, with water set to a standard depth. Depending on the ambient conditions at the location (especially in summer), each week the water is drained from the tyre trap and any mosquito larvae are grown out in the laboratory for identification. The water is replaced exactly at the same level and position in the tyre to ensure that any eggs laid at the water's edge are flooded and hatch. The tyre's position may be maintained by a metal support, or the level position may be indicated by paint marks.

For collecting larval mosquito vectors through sentinel tyre traps, the Department of Agriculture and Water Resources' work instruction clearly states correct installation of tyre traps. However, variations in tyre trap installation were noted across the regions. In one region, all sentinel tyre traps were installed as per the work instruction and mounted on a permanent metal frame (Figure 4a). Such installation provided sturdy support and enabled staff to reset the tyre to the same position after draining (allowing eggs previously laid to be submerged and subsequently hatch). Another region had sentinel tyre traps affixed loosely with a metal chain to a fence and placed on the floor (Figure 4b), with markings across the tyre face indicating the correct position of the trap (white line markings on the tyre face must remain parallel to the ground after draining).

In some instances, tyre traps were incorrectly installed:

- Figure 5 shows a sentinel tyre trap that was not mounted on a permanent structure and had rolled over due to wind or other factors.
- Some traps had no water in them. The vector coordinator in each region must ensure water level in traps are maintained optimally (depending on the weather conditions).
- In one region, tyre traps had a wire mesh installed to prevent birds and other animals from drinking water from them. In contrast, in other regions, no wire mesh was installed.

Recommendation 4

The department should ensure that, for efficient vector monitoring at all ports, regions have access to operationally appropriate traps, instructions for correct installation, training and technical support.

Department's response: Agreed

The department uses a suite of mosquito surveillance traps which were assessed as part of Russell, RC 2015, *Vector monitoring risk assessment of Australia's first ports of entry* as being appropriate for detection of exotic Aedes species. The department will conduct an audit to ensure that each region has access to operationally appropriate traps.

Detailed work instructions and a comprehensive eLearning training package, as well as on the job training is available and assessable to all staff involved with vector monitoring. To ensure consistent, best practice procedures are conducted, the Mosquito Vector Monitoring Work Instruction is currently being reviewed and updated.

The national vector coordinator will also undertake periodic assessments nationally to ensure equipment and procedures are appropriate and being deployed correctly to bring an added focus on nationally consistency.

Ovitraps for mosquito egg collection

Ovitraps are designed to monitor the presence of container breeding mosquitoes, in particular *Ae. aegypti* and *Ae. albopictus*, by collecting eggs (Figure 6). A number of ovitrap designs and procedures are in use across Australia; however, the overall concept of the trap is the same. Important points to consider during construction and installation of ovitraps include:

- containers must be black to provide a dark habitat to encourage mosquitoes to lay eggs
- a rough egg laying surface, facing out towards the middle of the container, must be provided (masonite paddles or wooden tongue depressors are best)
- the inside of the container must be smooth and kept clean to discourage egg laying on the side of the container
- the container must be filled with aged water containing organic material to encourage mosquitoes to the trap.

These traps are monitored by collecting the wooden paddles for laboratory inspection for eggs and growing out of larvae for identification, removing the water in the trap and inspecting for larvae, replacing the paddles and topping up the water as needed. Regular servicing of these traps is necessary for them to be effective. During fieldwork, in some ovitraps water (solution) did not appear to have been replaced for a few weeks as there was an evidence of algal build up in containers.

Figure 4 Tyre traps installed in permanent monitoring zones around first points of entry for mosquito larval collection

Figure 5 Incorrect installation of sentinel tyre trap at an international port

Figure 6 Ovitrap for collection of mosquito eggs

Dipping of stagnant water for larval collection

Dipping of pooled or stagnant water in natural water habitats and artificial receptacles is undertaken at each port on a regular basis, dependent on its risk category (Russell 2015), as part of the mosquito vector monitoring program. Dipping provides a representative larval sample to determine species present in the port area and indicate its natural receptivity for mosquito breeding. Dipping sites identified during ground surveys are water holders that cannot readily be removed such as blocked drains and other sites that are continually refilled with rainwater and leaf litter. High-risk dipping sites are treated with the insect growth regulator s-methoprene as this will arrest mosquito development at the larval stage and prevent adults emerging between dips (Figure 7).

Figure 7 Treatment of a drain holding stagnant water with a methoprene briquette

Carbon dioxide light traps

Carbon dioxide light traps were widely used for adult mosquito trapping before the BG-Sentinel trap was developed and proven to be more effective at catching *Aedes* mosquitoes. Light traps are made up of an esky, light, trap, fan, battery and a catchment net. On the day the trap is set, dry ice is placed into the esky. As the ice melts, it releases carbon dioxide gas, attracting mosquitoes that mistake the gas as potential food sources such as people or animals. The battery operated light also attracts mosquitoes while the fan draws mosquitoes into the trap. Once the mosquitoes enter the trap they are unable to escape. The light traps are set up overnight at specific sites and collected the following morning. They are still used to monitor certain endemic mosquitoes for surveillance for export risk management, as well as other exotic non-*Aedes* mosquitoes.

Mosquito larval culture

Rearing mosquito larvae trapped via routine vector monitoring through to adults is not an accepted practice. Mosquito larvae are reared to the fourth larvae instar stage for identification to reduce the risk of exotic mosquitoes emerging as adults and escaping. When a potentially exotic species needs to be reared to adulthood, this occurs within a quarantine-approved insectary to prevent accidental escape of adult mosquitoes once they emerge and is conducted in consultation with a Department of Agriculture and Water Resources' Operational Science Support (OSS) entomologist.

The vector monitoring officers in their regions service the vector monitoring traps (usually every week) and all larval mosquitoes within the traps or collected through dipping are placed into marked vials (identifying individual source traps) and taken back to the local Department of Agriculture and Water Resources office for identification or rearing if required. Adult mosquito specimens remain in the traps collection bag/container and placed into a freezer to kill the mosquitoes to enable identification.

OSS entomologists ensure any specimens taken from international vessels or imported cargo are only reared in a quarantine insectary. The culture containers are secured in a designated area where they will not be disturbed and marked with signage 'Larval rearing–Do not disturb'. No insecticides are applied in this area.

Fast development of larvae relies on warm temperatures (ideally temperatures should be around 25 °C to 28 °C). If larvae are not identified immediately, larvae are submersed in hot water (70 °C to 80 °C) for 1 to 2 minutes to cure them before storage in ethanol or are placed directly into ethanol.

Placement of mosquito traps for point of entry monitoring

Considerable skill and experience is needed in placing the different types of mosquito traps at and around airports and seaports. A good understanding of mosquito life cycle and behaviour, as well as the way the traps work, is essential. During this review it was noted that state health department medical entomologists work closely with the Department of Agriculture and Water Resources vector control staff to place the traps optimally, and that many of the Department of Agriculture and Water Resources staff servicing them are very experienced. However, some less experienced staff were encountered, and continued attention to junior staff training, mentoring and supervision is needed. The IGB concurs with Russell (2015) that the current surveillance suite of ovi-, tyre- and adult-trapping technologies is still appropriate for detection of exotic species at ports.

Remote vector monitoring locations

In northern Australia, some vector monitoring sites are located in very remote places (up to 2,000 kilometres from Perth). Inspection of such sites and servicing of traps is very difficult, as they are occasionally serviced once a week. Similarly, it is often difficult to deliver dry ice or CO_2 gas cylinders for these traps on a regular basis.

The IGB concurs with Russell (2015) that:

> There needs to be further consideration of the most practical methods for surveillance at the substantial number of more or less remote ports that do not have resident Department of Agriculture and Water Resources staff to maintain vector surveillance, and where the resident traps cannot be serviced appropriately. It could be argued that surveillance at these ports should be discontinued but, possibly, occasional strategically timed surveys could replace the routine trapping that is currently problematic.

Recommendation 5

The department should review, in consultation with the Department of Health and the National Arbovirus and Malaria Advisory Committee, routine mosquito surveillance at remote ports and assess the feasibility of replacing it with occasional strategically timed surveys.

Department's response: Agreed

The department will consult with the Department of Health and seek advice from the National Arbovirus and Malaria Advisory Committee to investigate alternatives to routine mosquito surveillance at low risk remote ports including strategically timed surveys.

The periodic use of new exotic mosquito surveillance initiatives such as Rapid Surveillance for Vector Presence (RSVP) and Environmental DNA (eDNA) testing of water samples will also be considered.

Rapid Surveillance for Vector Presence system

Australian researchers are developing a world-first Rapid Surveillance for Vector Presence (RSVP) system to expedite presence/absence surveillance of invasive peri-domestic mosquito species (such as *Ae. aegypti* and *Ae. albopictus*) by integrating ovitraps, automated egg quantification and molecular diagnostics. This involves deploying standard mosquito ovitraps (water-bearing containers) designed to encourage female mosquitoes to deposit eggs on cloth strips inserted in the traps. The traps are deployed for a period of two weeks and the strips are then submitted to a laboratory for analysis. A specialised test conducted at the laboratory can detect a single *Ae. aegypti* amongst a background of common local species.

Once developed, the RSVP system is anticipated to support flexibility in ovitrap design and provide a sensitive, cost-effective, user-friendly and rapid laboratory process (36 hours) for high volumes of samples.

Development and validation of environmental DNA (eDNA) markers for detection of exotic mosquitoes

Mosquitoes require water to complete their life cycle, with all larval stages residing in water. Mosquitoes leave traces of their DNA in water through skin cells shed as they moult. This genetic material can persist in the environment even after the mosquito has moved. Powerful new genetic techniques can detect this environmental DNA (eDNA) and identify the species of mosquito that left it behind.

Cesar, a company based in Melbourne, has developed an eDNA quantitative PCR test for *Ae. aegypti* and *Ae. albopictus* that allows potential water breeding sites to be tested for the presence of DNA from both target species. Testing has shown that the DNA of both species is detectable up to 6 weeks after the larvae have left the water (larvae are typically only present in water for approximately 1 week). Due to the cryptic breeding habits of some exotic species such as *Ae. aegypti*, localised breeding can be difficult to identify using traditional larval surveys. The eDNA assay can be used to determine whether exotic mosquitoes detected at first points of entry are breeding in the local port environment, providing a new monitoring method for preventing establishment of exotic mosquitoes in Australia.

6 Exotic mosquito detection and response process

Detections of exotic mosquitoes

Surveillance data provided by the Department of Agriculture and Water Resources (Table 3) show the numbers of *Ae. aegypti* and *Ae. albopictus* species captured using a variety of mosquito traps in monitoring zones around international airports and seaports.

Table 3 Exotic mosquito detections at first points of entry in Australia, 2006 to 2016

Exotic mosquito detections	Unit	2006 to 2013[a]	2014 to 2016[a]
Total exotic mosquito detections	no.	38	131
Detections in Queensland, Northern Territory and northern Western Australia	%	89.5 (34 detections)	15 (20 detections)
Detections at airports	%	2.5 (1 detection)	94 (123 detections)
Detections at seaports and cargo facilities	%	97.5 (37 detections)	6 (8 detections)
Detections from surveillance traps	%	50 (19 detections)	85.5 (112 detections)

[a]Percentage values within a column overlap and represent exotic mosquito detections across states/territories, airports, sea ports, cargo facilities and design/type of traps used.

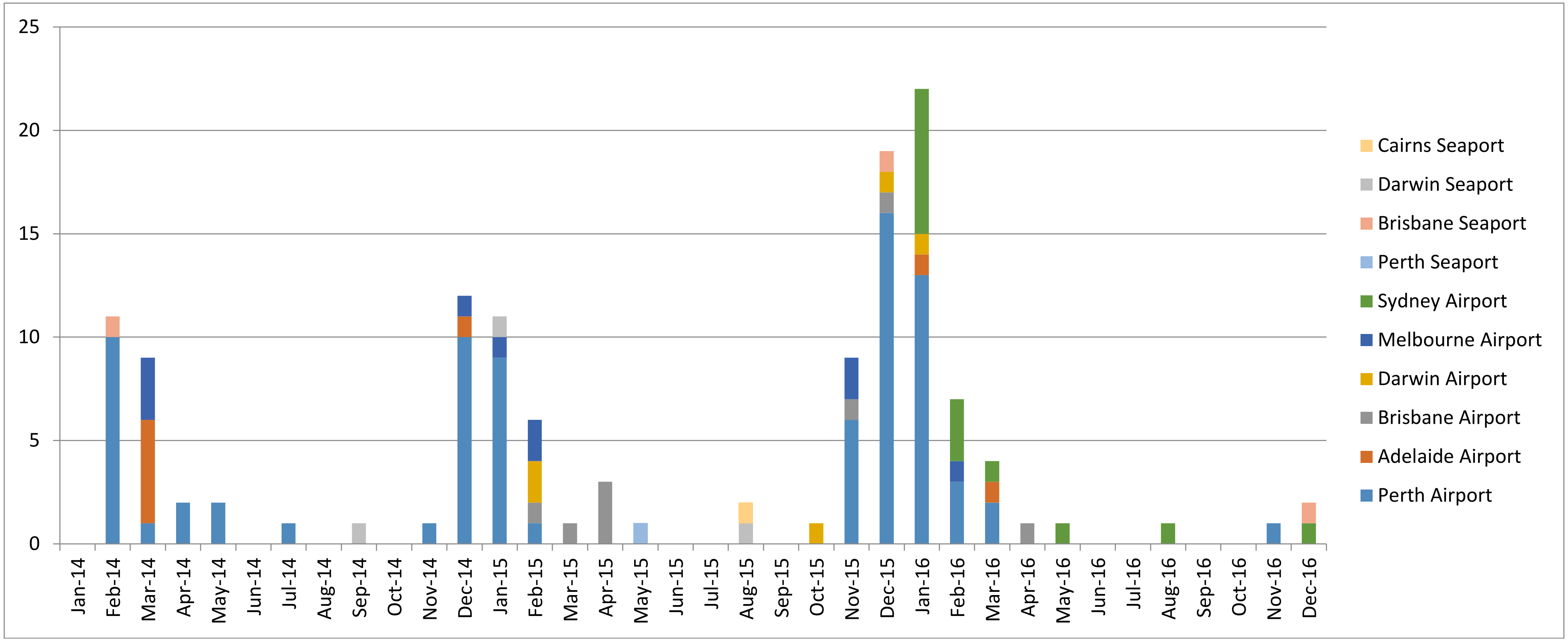
Before 2014 the majority of exotic mosquito detections appear to have occurred in the northern parts of Australia with more than 97 per cent of detections being in a seaport or cargo environment. In contrast, the past three years have seen a significant increase in the numbers of mosquitoes being detected at airports in southern parts of Australia (Sydney, Melbourne, Adelaide and Perth). Between 2014 and 2016 the highest numbers of exotic mosquitoes (in particular, *Ae. aegypti*), at all different life cycle stages, were recorded in Perth (Figure 8).

It is postulated that the increase in exotic *Ae. aegypti* detections at Australia's international airports may be due to one or more of the following:

- increased surveillance activities undertaken within airport environments and particularly due to the department's use of BG traps. BG traps are relatively new and have a more efficient design than the previously used CO_2 light traps. Before 2014 surveillance for mosquitoes may have been less targeted with less sensitive methods being utilised
- an increased carriage rate of mosquitoes from certain airports in recent years, whether due to increasing travel from high-risk countries or changed practices at overseas ports
- mosquitoes developing insecticide resistance or inadequate aircraft disinsection in some circumstances
- changes in infrastructure at a likely 'risk source' in South East Asia.

Increased cargo hold spraying and other disinsection activities appear to have been successful in managing this extra risk posed by flights from the punative 'risk source' with a reduction in the number of exotic mosquito detections observed during the 2016/17 period compared to the previous two years (Figure 8).

Figure 8 Exotic mosquito detections at the Australian first points of entry between 2014 and 2016



Source: Department of Agriculture and Water Resources

Recommendation 6

The department, together with the Department of Health, should continue to update airlines (and port authorities in presumed countries of origin) about exotic vector mosquito detections at Australian ports, and provide management options and assistance (where appropriate) to minimise biosecurity risks.

Department's response: Agreed

The department will continue to update airlines and relevant authorities in source countries about exotic mosquito detections at Australian ports where origins or risk pathways are identified.

Diagnostic capability in Australia

Access to expertise and resources for diagnostics is through relationships with the state/territory health departments and National Arbovirus and Malaria Advisory Committee (NAMAC). NAMAC oversights diagnostic standards and medical entomologists in state/territory health departments assist with diagnostic confirmation of exotic mosquitoes. A list of laboratories and research institutions with diagnostic capability is in Appendix E.

Characterisation of exotic mosquitoes detected by Department of Agriculture and Water Resources

When *Ae. aegypti* or *Ae. albopictus* mosquitoes are detected in the Department of Agriculture and Water Resources monitoring program, the relevant state/territory health department is notified and a medical entomologist confirms the identification—usually within 24 hours of collection—from the vector monitoring trap. There are instances where identification and confirmation can take up to a week following collection due to the poor state of the specimens or if larval rearing is required to conduct morphological diagnosis. DNA testing may be undertaken when either:

- morphological identification is not possible to confirm the identification
- the specimens were collected as an early instar mosquito larvae and require further culturing to the fourth larval instar to allow for identification.

With the advent of more sophisticated DNA genotyping and other techniques, an increasing number of isolates are now being forwarded to specialist laboratories for further characterisation of two important features:

- The geographic origin of the mosquito can now be established with a high degree of confidence. This provides invaluable information for analysis of the pathway by which it reached Australia or, in the case of *Ae. aegypti*, whether it is indeed an exotic mosquito or has spread from a domestic population in north Queensland to some other part of Australia. It may allow feedback to particular airlines, shipping lines, or ports of origin, and increased surveillance and verification of disinsection or port sanitation. This is turn will allow further targeted risk reduction as discussed in Section 3.
- Mosquitoes can be tested to identify potential resistance to synthetic pyrethroids including those used for aircraft disinsection and in response treatments to exotic mosquito detections. As insecticide resistance is an emerging problem worldwide in many insect species, this contingency must be monitored. Results from genotyping showed that all airport detections at international passenger terminals carried

mutations associated with synthetic pyrethroid resistance, inferring possible knockdown resistance providing a possible mechanism for the increases in detections over the past several years.

Concerns about responsibility for surveillance and intervention in ports where it is difficult to determine whether *Ae. aegypti* and *Ae. albopictus* have arrived on international versus domestic transport (Russell 2015) should be clarified in the National Guidelines.

Recommendation 7

The department should continue to submit as many exotic mosquito isolates as possible for both geographic origin and insecticide resistance characterisation, and, in cooperation with neighbouring countries and the Department of Health, publish the results regularly.

Department's response: Agreed

Identifying the origin of exotic mosquitoes is crucial for identifying pathway risks and to that extent the department has commissioned a research project with an Australian researcher to develop a spatial DNA library for *Aedes aegypti* and *Aedes albopictus* using a highly sensitive next generation sequencing technique. As part of this project all exotic *Aedes aegypti* and *Aedes albopictus* detected at first points of entry are currently being tested to determine their geographical origins.

The department will publish these results, in cooperation with the Department of Health, in a form and timing that supports both department's ongoing activities to prevent the arrival of mosquitoes into Australia. As part of this process, source countries will be notified prior to the publication of data relating to their country.

Enhancing capacity for pathways analysis

The regional vector coordinators receive notification of all exotic mosquito detections through the Department of Agriculture and Water Resources internal Biosecurity Pest Notification process, usually within 24 hours of the detection being confirmed. All exotic detections are recorded in the Incidents database, and details of all exotic mosquito detections are also provided to the Department of Health and to the NAMAC Secretariat for information and dissemination. However, the IGB was informed that pathway analysis for exotic vector mosquitoes would be enhanced by the use of a centralised database for recording detections at first points of entry across the country. This should be achieved by the proposed Surveillance Information Management System (SIMS).

The IGB was informed that a specific vector monitoring and surveillance module is being developed by the Department of Agriculture and Water Resources as part of a wider departmental SIMS. The SIMS will provide an electronic workflow for planning, organising and conducting vector monitoring and surveillance activities as well as streamlined reporting functionality providing a more efficient and controlled method for undertaking these activities.

The SIMS is aimed at addressing:

- inefficient, mostly manual entry and transfer of surveillance data
- insufficient support of mobility, multimedia formats, spatial (GPS) data and data mapping
- inefficient data exchange with laboratory information management systems

- insufficient support of collaboration and data sharing with other surveillance data repositories.

Once the SIMS is introduced, the program will negate the need for raw data sheets and timely manual data entry by using mobile devices to collect data in real time, ensuring better data quality. The program will include spatial mapping capabilities, which will enable maps of first points of entry to be created showing the locations of all trapping and surveillance sites. With real-time data entry through the SIMS, better auditing, quality assurance of vector monitoring activities and timely reporting of vector monitoring results to key stakeholders will also be possible.

Recommendation 8

Until the successful launch of the Surveillance Information Management System (SIMS), the department should implement an interim communication strategy with the Department of Health for rapidly communicating exotic mosquito detections at first points of entry to state and territory health medical entomologists and department's regional vector coordinators across Australia.

Department's response: Agreed

The department will continue to work with the Department of Health to develop and implement a communication strategy to ensure details of all exotic mosquito detections at first points of entry are provided to state and territory health jurisdictions.

The department's regional vector coordinators across Australia are already informed of all exotic mosquito detections at first points of entry through the department's internal Biosecurity Pest and Disease Notification (BPDN) process. BPDNs are typically produced and distributed within 24 hours of the exotic mosquito detection being confirmed and contain specific details of when, where and how the detection occurred and the response actions that have and will be undertaken.

Response process

In Australia, response arrangements following exotic mosquito detection at a port are a joint responsibility of the Department of Agriculture and Water Resources, the relevant state/territory health department and the port operator. The typical process and the roles and responsibilities for responding to exotic mosquito detections is shown in (Table 4). Table 4 outlines steps in the current process for notifying relevant external stakeholders of exotic mosquito detections.

When an exotic mosquito is detected at a port or airport, state health officials then conduct a risk assessment in consultation with the Department of Agriculture and Water Resources to determine what insecticide treatment response is required. The state/territory health department notifies the port operator of these treatment requirements. Treatment requirements include knockdown fogging treatments, residual surface spraying, harbourage spraying and treatments of drains, receptacles and other water sources that may present a mosquito breeding risk. The mix of treatments is determined on a case-by-case basis based on the circumstances surrounding the detection and risk of dispersal. In most instances a fogging treatment is conducted when an exotic mosquito is detected in a vector monitoring trap. If the ports do not undertake the treatments being requested, the *Biosecurity Act 2015* (Act) gives

Table 4 Exotic mosquito detection and response process at first points of entry

Step	Activity	Responsible agency/stakeholder
1	Routine vector monitoring	DAWR
2	Identification of suspect exotic mosquitoes	DAWR
3	Confirmation of exotic mosquito ID by medical entomologist	STHD
4	Risk assessment and determination of response activities (treatments)	DAWR, STHD
5a	Port advised of the detection and treatment requirements (treatments likely to include adult fogging treatment, residual surface spray, larval treatments, source reduction)	STHD
5b	DoH advised of the detection and treatments being requested	DAWR
6	Port organises treatments to be conducted with treatment provider	Port
7	Requested treatments undertaken (preferably within 24 hours from detection)	TP
8	DAWR deploys additional vector surveillance traps (traps serviced daily for 10 days post treatment, then every second day for one week, then weekly for 2 to 4 weeks. Process starts again if further exotic mosquitoes are detected)	DAWR
9	Ground surveillance/breeding site surveys undertaken	DAWR, STHD
10	Pathway analysis conducted	DAWR
11	Reassessment of situation and expand efforts if necessary	DAWR, STHD
12	Deployment of surveillance traps considered for outside 400 metre precinct	STHD
13	Stakeholder communication	
	• daily updates of enhanced surveillance results to all stakeholders	DAWR
	• confirmation of timing and completion of treatments	Port, TP
	• media/public communication strategy, if required	DAWR, STHD, DoH, Port
	• key stakeholder meetings, as required	DAWR, STHD, Port
14	Joint decision made to stand down and cease enhanced surveillance activities. Routine vector monitoring activities continue (step 1)	DAWR, STHD, Port

DAWR Australian Government Department of Agriculture and Water Resources. **STHD** State/territory health department. **DoH** Australian Government Department of Health. **Port** Port authority. **TP** Treatment provider.

Source: Department of Agriculture and Water Resources

provisions for a Biosecurity Control Order (BCO) to be issued. Currently only a Biosecurity Officer can issue a BCO but an amendment to the Act is being put through to also give the states and territories the power to issue BCOs.

Owing to the department's good working relationship with key stakeholders, it prefers to have dialogues directly with stakeholders (such as port authorities and tenants) rather than issuing BCOs for treatment of premises. However, it is suggested that, whenever needed, the department should issue formal BCOs for stakeholders to act quickly and in a timely fashion, minimising the risk of delay in treatments.

Port operators are responsible for arranging and paying for the required treatments, and they normally hire approved third-party service providers for these treatments. Similarly, for aircraft disinsection, airlines pay for the additional hold treatments being conducted on flights originating from any identified risk source. Treatments for vector mosquitoes are very specialised and only a handful of service providers are suitably skilled to provide these treatments. Depending on the local arrangement at the time, either department staff or the state health department oversee satisfactory implementation of the treatments.

Following any exotic mosquito detection, biosecurity officers conduct enhanced vector surveillance through deployment of additional mosquito traps within the port area to monitor the effectiveness of the response treatments. Servicing/clearing of these traps is also increased from weekly to daily trap clearances for 10 days following the detection and application of knockdown treatments. The frequency is reduced to 2 to 3 times during the following week, and then to weekly, if no further exotic mosquitoes are detected. The additional vector monitoring traps remain in place for the duration of the response period and are removed when the state health department and the Department of Agriculture and Water Resources agree response is no longer required (4 to 6 weeks following the exotic mosquito detection). Routine vector monitoring then recommences.

During fieldwork, the IGB was informed that a cargo handling company's premises within the 400-metre monitoring zone in one state were treated by the council following an exotic mosquito detection at no cost to the company. However, the same company's premises in another state was charged for conducting a response treatment following an exotic detection. While the department has no role in the funding arrangements between the port operator and the treatment provider, this issue highlights the need for an overarching national policy that identifies roles and responsibilities, including funding, of all key stakeholders, and provides transparency.

Integrating stakeholder action at first points of entry

To achieve effective management and control of exotic vector mosquitoes, between 1997 and 2006 the Department of Agriculture and Water Resources signed a series of local Memoranda of Understanding (MoUs) for key first points of entry with key stakeholders such as state/territory health departments, city councils, airport and seaport authorities and neighbouring property owners. Under each MoU, the roles and responsibilities of each organisation were defined. Regular meetings were held with signatories to ensure these roles and responsibilities were understood and that each party was prepared for possible responses to mosquito detections.

These MoUs were made redundant after 2006 and, since then, vector monitoring and response activities have been undertaken on goodwill by the key stakeholders. The National Guidelines for Exotic Mosquito Detections at Australian First Points of Entry, which are currently being developed, will provide a framework for responding to exotic mosquito detections and are aimed at promoting key stakeholder engagement and collaboration.

Recommendation 9

The department should consider reinstating Memoranda of Understanding or setting up local consultative committees with local public and private stakeholders around major first points of entry, to regularly review contact lists and contingency plans defining all parties' roles and responsibilities in case of an incursion.

Department's response: Agreed

Once implemented, the department will use the National Guidelines for Exotic Mosquito Detections at Australian First Points of Entry as the mechanism to promote key stakeholder engagement and collaboration. The national guidelines will be used to establish local stakeholder consultative groups where stakeholder meetings will be held to establish preparedness to possible exotic mosquito detections. The guidelines detail the roles and responsibilities of key stakeholders when responding to exotic mosquito detections as well as include action plans and response procedures. Contact lists for the key stakeholder will be maintained using the template in the guideline and updated during stakeholder meetings.

Communication with key stakeholders

Across Australia, preventing entry and establishment of exotic vector mosquitoes at first points of entry is jointly managed by the department's national and regional vector coordinators, state/territory health departments and port authorities. In discussions with various stakeholders the IGB noted that the department maintains an excellent working relationship with all key stakeholders; however, communication between these stakeholders could be improved, to ensure more effective information sharing.

During fieldwork, several stakeholders expressed concerns about the timely coordination of responses to vector detections. The feedback received was:

- state/territory health officials engaged in vector management often need timely response, particularly in instances of an exotic detection or management response coordination. In particular, for Western Australia, which is in a different time zone, the state health authorities suggested availability of a coordinator from the Department of Agriculture and Water Resources 24/7, and allowances for different time zones (including public holiday periods) would be quite useful in facilitating dissemination of information to other stakeholders and seeking advice from regional and national vector coordinators. This will also facilitate a collaborative approach between local Department of Agriculture and Water Resources officers and state health departments in determining treatment requirements and other management requirements in the event of a detection
- it would be useful to clarify roles of coordinators in each organisation for quick distribution of information, preferably through the use of generic email inboxes. Furthermore, as the department is transitioning from *Quarantine Act 1908* to *Biosecurity Act 2015*, generic email inboxes can also be used for dissemination of changes in arrangements related to *Biosecurity Act 2015* to all key stakeholders.

Recommendation 10

The department, in consultation with the Department of Health and the National Arbovirus and Malaria Advisory Committee, should consider establishing improved local arrangements and appropriate delegations to local coordinators enabling state and territory health officials to get quick advice on coordination of exotic vector mosquito responses.

Department's response: Agreed

Decisions on response activities to a mosquito interception at a first point of entry are managed at a regional level, and in the event that treatment is required e.g. fogging, are carried out by the relevant state and territory health officials in consultation with the Department of Health. Officers of the department do not exercise any delegations in these situations.

Once implemented, the National Guidelines for Exotic Mosquito Detections at Australian First Points of Entry will set out best practice processes and procedures for responding to exotic mosquito detections at first points of entry. These guidelines promote stakeholder engagement whereby improved local arrangements will be established through key stakeholder groups to incorporate and address any local site specific issues identified. This includes communication strategies for informing key stakeholders on activities and enhanced surveillance results during exotic mosquito responses.

7 Department of Agriculture and Water Resources staff training in vector monitoring and control

Biosecurity officers involved in vector monitoring are required to successfully complete eLearning comprised of five modules. These modules provide important background information on vector mosquitoes and disease risks, biological factors that aid in targeted vector monitoring, and vector monitoring traps and methods of using them.

- Module 1: The Mosquito Threat—covers mosquitoes as vectors, the diseases they can transmit and mosquitoes as invasive species.
- Module 2: Managing the Risk—covers international obligations, managing the vector risk (for example, introduction to disinsection, vessel inspections, cargo inspections and vector monitoring) and port risks.
- Module 3: Biological Profiles of Target Mosquito Species—covers mosquito biology, biological cues and habits used to target mosquitoes, habitat profiles and target mosquito species.
- Module 4: Monitoring for Mosquito Vectors Part 1—covers dipping, how and why this activity is conducted.
- Module 5: Monitoring for Mosquito Vectors Part 2—covers trapping, how and why different traps are used, critical control points associated with each trap type, culturing mosquito larvae for identification and data recording.

After completion of module-based training, staff undergo on-the-job learning. Competency is assessed through knowledge-based questions. The department has developed a number of work instructions, standard operating procedure, guidelines, fact sheets, policies and other relevant material (Appendix F) to help biosecurity officers obtain the knowledge required to undertake vector monitoring.

Staff responsible for conducting mosquito identification undertake face-to-face training with regional vector coordinators and/medical entomologists.

Vector officers and regional vector coordinators also attend vector training courses run by state health departments. Two such courses are:

- WA Health Mosquito Management Course
- NSW Health Mosquito Management Course.

Compliance with instructional material

During fieldwork, the IGB noted that states and territories across the country largely use nationally consistent methods of vector monitoring and surveillance, risk assessment, vector control, case detection and outbreak response. The harmonisation of methods for entomological surveillance facilitates the exchange and management of data. The use of agreed methods by states and territories also enables better coordination in planning action to prevent the spread of invasive mosquitoes into newer areas and the transmission of diseases, and to prepare for the control of cross-border outbreaks.

However, during fieldwork, the IGB noted some discrepancy in vector monitoring and surveillance activities undertaken by regional coordinators and field biosecurity officers across states/territories. For example, the IGB noted that a vector officer in one of the regions did not know why Sentinel tyre traps must be installed in a particular way, casting doubts about his skills in reinstalling traps after drainage (collection of substrate for laboratory analysis). It is important to have experienced and well-trained biosecurity officers to avoid any mishaps.

Russell (2015) noted that:

> Unfortunately, as an unfunded program, vector surveillance is not afforded a high priority by local managers and the program suffers from a lack of interest by some managers with regard to the allocation of sufficient staff and time.

However, at the high-risk tropical ports visited by the IGB, most of the field staff seemed experienced and enthusiastic despite their vector monitoring work being very routine.

The IGB also noted that work instruction ‘Mosquito vector monitoring’ is under revision. Given that the new legislation came into effect in June 2016, it is appropriate for the department to update the work instruction as soon as possible.

The Department of Agriculture and Water Resources needs to be proactive; vector monitoring requires constant oversight and efficient strategies to address deficiencies. The department should periodically check the quality of service at the front line of defence, and continue to provide training and refresher courses to vector officers to meet technical and operational requirements of vector monitoring program in a timely manner.

Recommendation 11

The department should ensure that staff conducting vector monitoring at the border are well trained, aware of biosecurity risks associated with exotic vector mosquitoes and adhere to standard operating procedures. The department should also update work instructions to ensure up-to-date information is available to vector officers.

Department’s response: Agreed

To ensure a consistent, best practice approach to vector monitoring is undertaken by departmental staff, the department is currently reviewing and updating its Mosquito Vector Monitoring Work Instruction.

Furthermore the department has a vector monitoring eLearning training package which details the risks associated with exotic mosquitoes including pathway risks, mosquito surveillance methods and critical control points associated with each trap type used by the department.

The national vector coordinator will also undertake periodic assessments nationally to ensure equipment and procedures are appropriate and being deployed correctly to bring an added focus on nationally consistency.

The department also encourages staff involved in vector monitoring to attend external training courses run by state and territory health departments with departmental staff previously attending course run by WA Health, NSW Health and QLD Health.

8 Preventing future mosquito-borne diseases in Australia

The importance of border vector control in preventing entry and establishment of exotic mosquitoes will remain high for the foreseeable future. Despite the success of programs to date, several developments affect whether Australia will be able to maintain its enviable record of freedom from endemic dengue fever and other serious mosquito-borne diseases. There are challenges such as emerging insecticide resistance in some mosquito populations, as well as opportunities for improved control of mosquitoes should they penetrate our borders and become endemic.

Insecticide resistance

Because no specific treatment and efficient vaccine is yet available, vector control against *Ae. aegypti* remains the most effective solution to prevent dengue transmission. Environmental management, educational programs and mechanical elimination of the breeding habitats are continuously implemented, but currently the use of chemical and biological agents are the main methods for reducing the incidence of the disease.

Unfortunately, vector control programs in Australia's north are facing operational challenges with the emergence and development of insecticide resistance in dengue vectors, especially *Ae. aegypti*. Resistance to organophosphates and pyrethroids has been reported in many parts of the world (Marcombe et al. 2012), and this resistance has recently been shown to be negatively impacting on the efficacy of vector control interventions. To date Australian populations of *Ae. aegypti* are not known to have developed resistance against pyrethroids and other insecticides.

The massive use of a few insecticide families for vector control since the 1950s may have contributed to insecticide resistance in mosquitoes. Space spraying treatments with vehicle-mounted or portable thermal fogger (aerial or inside application, respectively) are implemented during periods when high entomological indexes are reported and during outbreaks to rapidly kill infected adult mosquitoes.

To monitor for the introduction of insecticide resistant strains into Australia, the Department of Agriculture and Water Resources is submitting samples of *Ae. aegypti* that have been collected in vector monitoring traps at first points of entry in North Queensland (Cairns and Townsville, in particular) to an external laboratory for insecticide resistance testing (voltage-sensitive sodium channel gene mutations inferring possible knockdown resistance[kdr]). This testing is not only used to monitor for the introduction of possible insecticide resistance genes, but it is also used to confirm that *Ae. aegypti* mosquitoes detected within the Department of Agriculture and Water Resources' vector traps in North Queensland are from local populations and are not exotic mosquitoes arriving through international pathways.

Sterile insect technique

Sterile insect technique (SIT) is a form of pest control that uses ionising radiation to sterilise male insect pests that are mass-produced in special rearing facilities. It has been successfully used worldwide for over 50 years for various agricultural insect pests, such as fruit flies, tsetse flies, screw worms and moths. Its deployment against disease-transmitting mosquitoes, such as the carrier of the Zika, chikungunya and dengue viruses, is ongoing. Some pilots have been successfully completed and others show promising results.

In SIT, sterile males are released systematically from the ground or by air over the targeted areas, where they mate with wild females, which then do not produce offspring. As a result, when applied in combination with other control methods, this technique can suppress populations of insect pests. The SIT is among the safest and most environmentally friendly, and therefore sustainable, control methods available, and is usually applied in integrated campaigns to suppress insect pest populations. The International Atomic Energy Agency, in partnership with the Food and Agriculture Organization of the United Nations, is spearheading global research in the development and application of SIT.

The 'Eliminate Dengue Program'

The Eliminate Dengue Program is a large multi-institution research program involving Australia, Indonesia, Vietnam, Brazil and Colombia and led by Monash University. Its aim is to control dengue by using the naturally occurring obligate intracellular insect bacterium, *Wolbachia pipientis*, to suppress transmission of dengue viruses by *Ae. aegypti* (Moreira et al. 2009). This important discovery has the potential to transform the fight against life-threatening and vector-borne viral diseases. Current progress with the research is found on the Eliminate Dengue Program website. If further validated by international trials, this program could in future be deployed to reduce the burden of dengue fever in neighbouring countries, thereby also reducing biosecurity risks to Australia.

Import of exotic mosquitoes

Researchers working on programs such as the Eliminate Dengue Program may need different strains of exotic mosquitoes from overseas. The Department of Agriculture and Water Resources' Biosecurity Import Conditions system (BICON) sets out import requirements for viable mosquito eggs. An import permit gives conditions for each consignment. Biosecurity officers at the border inspect the consignment, which is then forwarded directly to a nominated Approved Arrangement site. Transfer of adult, pupal and larval life stages of the mosquitoes is not permitted between the listed Approved Arrangement sites (specific to each import permit) unless specific written approval has been obtained from the Department of Agriculture and Water Resources.

Since 2006 the department has issued 47 import permits for live mosquitoes/eggs. On 31 December 2016, six import permits were valid for the import of mosquito eggs. Of these, five are for *Ae. aegypti* eggs and one for *Anopheles stephensi* eggs.

Appendix A: Agency response

Australian Government
Department of Agriculture and Water Resources

SECRETARY

Ref: 2016-17/01

Dr Helen Scott-Orr
Inspector General of Biosecurity
1 Crewe Place
ROSEBERY NSW 2018

Dear ~~Dr Scott-Orr~~ Helen

Thank you for providing your report on the *Review of Department of Agriculture and Water Resources management of biosecurity risks posed by invasive vector mosquitoes* for formal management comments on the findings and recommendations.

Firstly I would like to congratulate you on the completion of your first review as Australia's Inspector General of Biosecurity. It is a comprehensive and thoroughly researched report and provides a range of recommendations that will support the department's policy and operations over the coming years.

I am informed that you undertook extensive fieldwork in compiling this report, which is shown in the detailed exploration of the issues surrounding invasive vector mosquitoes, and that you and your team worked closely with officers in the department throughout the development of the report.

The department's management response to the recommendations in your report are at Attachment A. The department has agreed with the eleven recommendations contained in your review.

The department has assessed the report and does not consider any information contained in the report to be prejudicial to the public interest.

Yours sincerely

Daryl Quinlivan

5 May 2017

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ATTACHMENT A

Recommendation 1 – Agreed

The department should continue efforts to develop improved testing methods for residual insecticide on aircraft and implement any suitable test as soon as it is validated.

Departmental response:
The department is investigating new innovative methods for monitoring insecticide residues on-board international aircraft as part of the Department of Industry, Innovation and Science sponsored Business Research and Innovation Initiative (BRII). Methods utilising rapid on-the-spot technologies are currently being investigated with the intention of adopting the successful method at the end of the BRII process.

Recommendation 2 - Agreed

The department should communicate with seaport and airport authorities and be included in the planning and design stages of new developments, to educate them about the importance of designing and maintaining port sanitation to keep ports, including construction sites, clear of water containers and areas where water could stagnate and mosquitoes could breed. This should also be part of ongoing monitoring and surveillance activities undertaken by staff involved in vector activities in states/territories.

Departmental response:
The department is actively involved in the planning and design of new developments of airport and seaports which includes negotiating appropriate infrastructure to mitigate a range of biosecurity risks including vectors of human health.

In consultation with industry, the department is developing a set of standards to guide first point operators in meeting the first point requirements under the First Point of Entry Determinations. The standards cover such things as infrastructure and facilities which enable and support effective risk assessment and management activities; management of hazards and risks in the port/airport surrounds to minimize the receptivity of the environment to pest and disease incursions including site sanitation and source reduction.

Officers from the department involved in surveillance activities at first points of entry currently do and will continue to be involved in monitoring of the environment to minimise potential breeding sites.

Recommendation 3 – Agreed

The department should clearly map the boundaries of 400-metre monitoring zones around all first points of entry, and at priority ports, formalise vector monitoring arrangements with all private and public key stakeholders, and set up regular local communication arrangements to ensure these arrangements remain current and well understood.

Departmental response:
The department is investigating mapping opportunities for all first points of entry to depict port boundaries, biosecurity monitoring zones and among other things, the 400m vector monitoring zone. Furthermore the National Guidelines for Exotic Mosquito Detections at Australian First

Points of Entry, which is in the final stages of development by the Department of Health, articulates a clear definition of the 400m zone in relation to vector monitoring at first points of entry and details the roles and responsibilities of key stakeholders within and outside this area.

The formalising of vector monitoring arrangements with all private and public key stakeholders and regular local communication arrangements within and to the extent of the 400m zone around first points of entry would be resource prohibitive. The department does, however have a number of other mechanisms by which it would be able to communicate with relevant stakeholders. These include:

- Through the department's National Border Surveillance (NBS) program, the department undertakes surveillance and engagement activities around first points of entry for a range of biosecurity risk pests and diseases. Opportunity exists to leverage this activity to support stakeholder engagement on mosquito vector issues.
- The National Guidelines for Exotic Mosquito Detections at Australian First Points of Entry is under development and is intended to be the mechanism to promote key stakeholder engagement and collaboration. The national guidelines will support the establishment of local stakeholder consultative groups to support preparedness activities in response to possible exotic mosquito detections. The guidelines detail the roles and responsibilities of key stakeholders when responding to exotic mosquito detections as well as include action plans and response procedures. Contact lists for the key stakeholder will be maintained using the template in the guideline and updated during stakeholder meetings.

Recommendation 4 - Agreed

The department should ensure that, for efficient vector monitoring at all ports, regions have access to operationally appropriate traps, instructions for correct installation, training and technical support.

Departmental response:
The department uses a suite of mosquito surveillance traps which were assessed as part of Russell, RC 2015, *Vector monitoring risk assessment of Australia's first ports of entry* as being appropriate for detection of exotic *Aedes* species. The department will conduct an audit to ensure that each region has access to operationally appropriate traps.

Detailed work instructions and a comprehensive eLearning training package, as well as on the job training is available and assessable to all staff involved with vector monitoring. To ensure consistent, best practice procedures are conducted, the Mosquito Vector Monitoring Work Instruction is currently being reviewed and updated.

The national vector coordinator will also undertake periodic assessments nationally to ensure equipment and procedures are appropriate and being deployed correctly to bring an added focus on nationally consistency.

Recommendation 5 - Agreed

The department should review, in consultation with the Department of Health and the National Arbovirus and Malaria Advisory Committee, routine mosquito surveillance at remote ports and assess the feasibility of replacing it with occasional strategically timed surveys.

Departmental response:
The department will consult with the Department of Health and seek advice from the National Arbovirus and Malaria Advisory Committee to investigate alternatives to routine mosquito surveillance at low risk remote ports including strategically timed surveys.

The periodic use of new exotic mosquito surveillance initiatives such as Rapid Surveillance for Vector Presence (RSVP) and Environmental DNA (eDNA) testing of water samples will also be considered.

Recommendation 6 - Agreed

The department, together with the Department of Health, should continue to update airlines (and port authorities in presumed countries of origin) about exotic vector mosquito detections at Australian ports, and provide management options and assistance (where appropriate) to minimise biosecurity risks.

Departmental response:
The department will continue to update airlines and relevant authorities in source countries about exotic mosquito detections at Australian ports where origins or risk pathways are identified.

Recommendation 7 – Agreed

The department should continue to submit as many exotic mosquito isolates as possible for both geographic origin and insecticide resistance characterisation, and, in cooperation with neighbouring countries and the Department of Health, publish the results regularly.

Departmental response:
Identifying the origin of exotic mosquitoes is crucial for identifying pathway risks and to that extent the department has commissioned a research project with an Australian researcher to develop a spatial DNA library for *Aedes aegypti* and *Aedes albopictus* using a highly sensitive next generation sequencing technique. As part of this project all exotic *Aedes aegypti* and *Aedes albopictus* detected at first points of entry are currently being tested to determine their geographical origins.

The department will publish these results, in cooperation with the Department of Health, in a form and timing that supports both department's ongoing activities to prevent the arrival of mosquitoes into Australia. As part of this process, source countries will be notified prior to the publication of data relating to their country.

Recommendation 8 – Agreed

Until the successful launch of the Surveillance Information Management System (SIMS), the department should implement an interim communication strategy with the Department of Health for rapidly communicating exotic mosquito detections at first points of entry to state and territory health medical entomologists and department's regional vector coordinators across Australia.

Departmental response:
The department will continue to work with the Department of Health to develop and implement a communication strategy to ensure details of all exotic mosquito detections at first points of entry are provided to state and territory health jurisdictions.

The department's regional vector coordinators across Australia are already informed of all exotic mosquito detections at first points of entry through the department's internal Biosecurity Pest and Disease Notification (BPDN) process. BPDNs are typically produced and distributed within 24 hours of the exotic mosquito detection being confirmed and contain specific details of when, where and how the detection occurred and the response actions that have and will be undertaken.

Recommendation 9 – Agreed

The department should consider reinstating Memoranda of Understanding or setting up local consultative committees with local public and private stakeholders around each first port of entry, to regularly review contact lists and contingency plans defining all parties' roles and responsibilities in case of an incursion.

Departmental response:
Once implemented, the department will use the National Guidelines for Exotic Mosquito Detections at Australian First Points of Entry as the mechanism to promote key stakeholder engagement and collaboration. The national guidelines will be used to establish local stakeholder consultative groups where stakeholder meetings will be held to establish preparedness to possible exotic mosquito detections. The guidelines detail the roles and responsibilities of key stakeholders when responding to exotic mosquito detections as well as include action plans and response procedures. Contact lists for the key stakeholder will be maintained using the template in the guideline and updated during stakeholder meetings.

Recommendation 10 – Agreed

The department, in consultation with the Department of Health and the National Arbovirus and Malaria Advisory Committee, should consider establishing improved local arrangements and appropriate delegations to local coordinators enabling state and territory health officials to get quick advice on coordination of exotic vector mosquito responses.

Departmental response:
Decisions on response activities to a mosquito interception at a first point of entry are managed at a regional level, and in the event that treatment is required e.g. fogging, are carried out by the relevant state and territory health officials in consultation with the Department of Health. Officers of the department do not exercise any delegations in these situations.

Once implemented, the National Guidelines for Exotic Mosquito Detections at Australian First Points of Entry will set out best practice processes and procedures for responding to exotic mosquito detections at first points of entry. These guidelines promote stakeholder engagement whereby improved local arrangements will be established through key stakeholder groups to incorporate and address any local site specific issues identified. This includes communication strategies for informing key stakeholders on activities and enhanced surveillance results during exotic mosquito responses.

Recommendation 11 – Agreed

The department should ensure that staff conducting vector monitoring at the border are well trained, aware of biosecurity risks associated with exotic vector mosquitoes and adhere to standard operating procedures. The department should also update work instructions to ensure up-to-date information is available to vector officers.

Departmental response:
To ensure a consistent, best practice approach to vector monitoring is undertaken by departmental staff, the department is currently reviewing and updating its Mosquito Vector Monitoring Work Instruction.

Furthermore the department has a vector monitoring eLearning training package which details the risks associated with exotic mosquitoes including pathway risks, mosquito surveillance methods and critical control points associated with each trap type used by the department.

The national vector coordinator will also undertake periodic assessments nationally to ensure equipment and procedures are appropriate and being deployed correctly to bring an added focus on nationally consistency.

The department also encourages staff involved in vector monitoring to attend external training courses run by state and territory health departments with departmental staff previously attending course run by WA Health, NSW Health and QLD Health.

Appendix B: World Health Organization's International Health Regulations Annex 5—Specific measures for vector-borne diseases

1. World Health Organization shall publish, on a regular basis, a list of areas where disinsection or other vector control measures are recommended for conveyances arriving from these areas. Determination of such areas shall be made pursuant to the procedures regarding temporary or standing recommendations, as appropriate.
2. Every conveyance leaving a point of entry situated in an area where vector control is recommended should be disinsected and kept free of vectors. When there are methods and materials advised by the Organization for these procedures, these should be employed. The presence of vectors on board conveyances and the control measures used to eradicate them shall be included:
   (a) in the case of aircraft, in the Health Part of the Aircraft General Declaration, unless this part of the Declaration is waived by the competent authority at the airport of arrival;
   (b) in the case of ships, on the ship sanitation control certificates; and
   (c) in the case of other conveyances, on a written proof of treatment issued to the consignor, consignee, carrier, the person in charge of the conveyance or their agent, respectively.
3. States Parties should accept disinsecting, deratting and other control measures for conveyances applied by other States if methods and materials advised by the Organization have been applied.
4. States Parties shall establish programs to control vectors that may transport an infectious agent that constitutes a public health risk to a minimum distance of 400 metres from those areas of point of entry facilities that are used for operations involving travellers, conveyances, containers, cargo and postal parcels, with extension of the minimum distance if vectors with a greater range are present.
5. If a follow-up inspection is required to determine the success of the vector control measures applied, the competent authorities for the next known port or airport of call with a capacity to make such an inspection shall be informed of this requirement in advance by the competent authority advising such follow-up. In the case of ships, this shall be noted on the ship sanitation control certificate.
6. A conveyance may be regarded as suspect and should be inspected for vectors and reservoirs if:
   (a) it has a possible case of vector-borne disease on board;
   (b) a possible case of vector-borne disease has occurred on board during an international voyage; or
   (c) it has left an affected area within a period of time where on-board vectors could still carry disease.

Appendix C: Department of Agriculture and Water Resources national and regional responsibilities

Compliance Division

Pathway Compliance Branch

- Enables deployment of biosecurity risk mitigation measures to achieve compliance with biosecurity requirement
- Detects, identifies and responds to non-compliance by deploying surveillance and verification tools and capabilities such as operational science support
- Sets operational policy for the biosecurity clearance of all air and sea cargo, passengers, crew and international shipping vessels
- Provides support through the development, maintenance and improvement of training and electronic systems

Pathway Surveillance and Operational Science

National Vector Coordinator
Responsible for national coordination and consistent vector monitoring and exotic mosquito response processes

Travellers and Vessels

Responsible for operational policies and procedures relating to the regulation of international conveyances including aircraft disinsection and ship sanitation certification

Cargo and Mail

Responsible for policies and procedures relating to the entry and inspection of imported cargo (excluding plant and animal related goods)

Service Delivery Division

Inspection Services

Vector Officers, Regional Vector Coordinators, Inspectors
Responsible for conducting vector monitoring activities, coordinating vector monitoring activities across a designated area and/or conducting inspections of international conveyances and imported cargo

Scientific Services

Operational Science Entomologists
Entomologists provide technical diagnostic support

Regional Vector Coordinators (RVCs)
RVCs coordinate vector monitoring activities across a designated area and conduct vector monitoring activities

First points of entry (international ports)

Vector monitoring officers at first points of entry manage compliance with Australia's regulatory requirements for human health protection by conducting inspections of international conveyances and imported cargo. Their activities specifically relate to preventing the entry and establishment of exotic vector mosquitoes through:

- requesting and maintaining equipment and materials required for vector duties
- surveillance of the port area
- setting and collection of traps
- preparation and identification of specimens
- collection, recording and storage of data
- preparation and distribution of post-surveillance reports

Biosecurity Plant Division

Plant Biosecurity

Undertakes risk assessment/analysis and develops policies relating to import of:

- live plants that may harbour exotic mosquitoes in substrate
- plant products including commodities that pose mosquito vector risks

Plant Import Operations

- Assesses applications for import of plants that may harbour exotic mosquitoes in substrate, into Australia (for example, lucky bamboo)
- Issues import permits for import of plants

Biosecurity Animal Division

Animal Biosecurity

Undertakes risk assessment/analysis and develops policies relating to import of :

- live exotic mosquitoes for research purposes
- animal products including commodities that pose mosquito vector risks

Animals and Biological Import Assessments

- Assesses applications for import of live exotic mosquitoes into Australia (for research purposes)
- Issues import permits for live mosquito import

Appendix D: Roles and responsibilities of staff

Position	Responsibilities
National vector coordinator	• coordination, communication and periodic reporting of exotic mosquito detections with the Australian Government Department of Health and state and territory health departments • informing the department's Operational Science Support (OSS) National Program Manager, program managers, regional managers, regional vector coordinators (RVCs) and other Department of Agriculture and Water Resources management on exotic mosquito detections • coordination and communication with RVCs • organising with department's OSS entomologists for the delivery of the National Vector Training conference on an annual basis • reviewing and updating standard operating procedures and work instructions, as required • administrative and support duties for the vector monitoring data templates • ensuring periodic reporting is provided to department's program managers and OSS entomologists, Australian Government Department of Health and external stakeholders, as required
Regional vector coordinator	• providing technical vector advice (including vector awareness training) to biosecurity officers • maintaining regular contact with vector officers and key stakeholders within their region and act as central contact for relevant department's staff (including biosecurity officers), the National Defence Force vector personnel, state health department, and OSS within their region in respect to any issues relating to notification or other vector responsibilities • ensuring each port prepares a consolidated vector 'toolbox' consisting of: o aerial maps of their ports, with trap locations o description of each trap type, its location, and timeframe in which each trap must be serviced o copies of all vector-related work instructions (monitoring, surveillance and response strategy) o ensuring they remain current with the department's Instructional Material Library o copy of the department's Mosquito Vector Monitoring Workbook/Handy References o copies of raw data worksheets o list of vector contacts at state health department, and department's regional and national level o relevant MoUs with local authorities o mosquito notification procedures Regional vector coordinators must ensure that the 'toolbox' and the documents within are reviewed and updated on an annual basis to ensure maps, trap locations and contacts remain current and work instructions are the same as the ones on Instructional Material Library. • standardising laboratory/field equipment (as agreed by Vector Network) and review supply and maintenance of necessary equipment within their region • coordinating the collection of regional vector data for their region • preparing and distributing the quarterly vector report and data to the National Vector Coordinator for national consolidation and distribution to the department's program/branch managers and the Department of Health • participating (where possible) in periodic ground surveillance surveys as detailed in the Vector Monitoring Regime for each port within the region • conducting/arranging annual refresher training courses and verification/ proficiency testing for all staff undertaking vector monitoring in their region where required

	• undertaking an annual review of vector monitoring activities in their region to identify current issues, staffing constraints, training needs and other requirements to ensure vector monitoring arrangements are fulfilled • assisting in the development of MOUs between the department and other stakeholders (in conjunction with the National Vector Coordinator and key programs) • performing identifications of specimens and carry out vector monitoring activities (where the regional RVC position entails) at international ports in their region according to the requirements under the risk category • ensuring that monitoring and ground surveillance activities for all ports in their region are fulfilled as per the risk category requirements. Identified issues/constraints must be reported to the National Vector Coordinator and to the relevant management in the region • coordinating/performing additional vector monitoring and surveillance activities during emergency response/exotic detections • performing other activities as determined by the region where capacity and capability exists
Vector monitoring officer	• requesting and maintaining equipment and materials required for vector duties • surveillance of the port area • setting and collection of traps • preparation and identification of specimens as required by their position • collection, recording and storage of data • preparation and distribution of weekly, monthly, annual and post-surveillance reports, as required • ensuring familiarity with, and understanding of, this work instruction and other related documents including those listed in the cross-reference materials
Managers and supervisors	• ensuring mosquito vector monitoring requirements are fully met for individual ports (as outlined in Russell (1998), Russell et al. (2004) and Russell (2015)) • ensuring adequate contingency plans are in place to address the absence of vector monitoring officers (for example, covering for officers on leave) • day-to-day activities at the port and distribution of information during incursion and remediation activities • ensuring staff are allocated sufficient time to conduct essential vector duties
Operational science support entomologists	• assisting in the delivery of national vector training • providing technical guidance to the vector network as required and identifying specimens unknown to the Vector Monitoring Officer or Regional Vector Coordinator • positive identification of exotic species
Medical entomologists	• provides confirmatory identification of exotic mosquitoes • provide advice and carry out surveillance, monitoring and control of insects and related animals that affect human health. They primarily perform a public health function with the aim of reducing the impact of insects of medical importance on the health and wellbeing of the people in respective states and territories. Medical entomologists are employed by universities, private industries and federal, state and local government agencies

Appendix E: Australian diagnostic laboratories for vector mosquitoes

Laboratory/research institution (location)	Description of services offered
Cesar (Melbourne)	• DNA testing to determine species identification • DNA testing of *Ae. aegypti* and *Ae. albopictus* to identify likely origins using next generation sequencing techniques • Testing for insecticide resistance markers in exotic mosquitoes • Developing a geographical spatial DNA database for *Ae. aegypti* and *Ae. albopictus* for faster identification of origins • eDNA testing of water samples for the presence of *Ae. aegypti* and *Ae. albopictus* DNA
Queensland Health Forensic Science Services (Brisbane)	• DNA testing to determine species identification
Queensland Institute of Medical Research (Brisbane)	• The only research facility in Australia that has a laboratory colony of *Ae. albopictus* • Also has laboratory colonies of *Ae. aegypti* including a strain that is insecticide resistant • Validation of the use of ELISA testing for monitoring aircraft disinsection
School of Biological Sciences, University of Queensland (Brisbane)	• DNA testing of *Ae. aegypti* and *Ae. albopictus* to identify likely origins using microsatellite sequencing techniques
Victorian Infectious Disease Reference Laboratory (Melbourne)	• Undertakes virus testing of exotic mosquitoes where requested by state/territory health departments

Appendix F: Department of Agriculture and Water Resources work instruction and guidelines

The department has a number of policy documents, standard operating procedures, work instructions, references and guidelines to help biosecurity officers with verification inspection and clearance of conveyances, travellers and cargo:

- Cargo compliance verification inspection work instruction
- Inspecting high risk pathway sea cargo work instruction
- Inspecting machinery work instruction
- Inspecting used vehicles processed by approved offshore treatment providers work instruction
- Inspection of aircraft cargo holds work instruction
- Inspection of aircraft cabin and galley areas work instruction
- Inspection of non-commercial vessels instruction and guideline
- Mosquito vector monitoring work instruction
- Mosquito vector surveillance work instruction
- On arrival disinsection direction
- Roles and responsibilities of regional vector coordinators
- Routine vessel inspections standard operating procedure
- Ship sanitation certificate inspection work instruction
- Treating imported goods work instruction
- Verification of aircraft disinsection guideline
- Vessel areas and associated quarantine pests and diseases reference.

Glossary

Term	Definition
Container breeder	Mosquitoes that have evolved to breed in small quantities of fresh water, includes *Aedes aegypti* and *Ae. albopictus*
Dipping	Surveillance method used to monitor the receptivity of the port. It involves visiting known sites (established during ground surveillance), observing their condition, and collecting larvae if present
Instar	Stage of larval growth. It is not until the fourth instar that the mosquito larvae can be identified
Light trap	Trap used to collect the adult stage of the mosquito. This type of trap uses a small light and CO_2 to attract mosquitoes
Monitoring	Regular activity undertaken to ascertain the presence of mosquitoes at the port and the ports receptivity
Ovitrap	Trap used to collect the egg stage of the mosquito
Receptivity	Likelihood exotic mosquito species would find the local environment suitable (considering habitat and host preferences and climate factors for principal target species), and the quality of the port sanitation
Sentinel tyre	Trap used to collect the larval stage of the mosquito
Surveillance	Inspection of port facilities and/or vessels taking notes of possible sources of receptivity
Trapping	Means of monitoring mosquitoes inhabiting a port
Vector	Mosquito capable of carrying human and animal diseases
Vulnerability	Likelihood exotic mosquito species could be imported from areas where they were known to be established (considering the nature of arriving vessel and aircraft pathways and imported cargo), and the quality of the port surveillance program

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