



**North Australian
Indigenous Land &
Sea Management
Alliance**

**Indigenous Communities are Ideally Located to Monitor and
Reduce the Biosecurity Risks Associated with Illegal Foreign
Fishing and Climate Change in Northern Australia**

This discussion paper has been prepared to support the NAILSMA Board

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Abstract

Australia is currently free from numerous diseases, pests and weeds that are endemic in many countries around the world. This is due to Australia's high standard of living, relative isolation, and stringent quarantine laws. However, the increased illegal fishing and unauthorised land incursions taking place in northern Australia, and the change in regional distribution of pathogens and vectors due to global change all pose serious biosecurity threats to Australia. The main risks to Australian public health are the introduction of exotic vectors and the further distribution throughout Australia of those vectors already present, which are capable of transmitting diseases such as dengue fever, Ross River fever, Japanese encephalitis, malaria and Leishmaniasis. There is also a risk of illegal fishers introducing highly pathogenic avian influenza to Australia, via the chickens that they carry onboard their vessels. The location of remote Indigenous communities within northern Australia and Indigenous land and sea management practices places Indigenous peoples in a crucial position that enables them to detect illegal foreign fishers, and identify notifiable diseases and invasive alien species at an early stage. Therefore, a successful, integrated approach to maintain Australia's biosecurity requires Indigenous communities to be centrally involved in biosecurity strategies in northern Australia.

NAILSMA

The North Australian Indigenous Land and Sea Management Alliance (NAILSMA) is a northern Australian bioregional forum for Indigenous land and sea managers, which was established in 2001. NAILSMA's strategic goal is to assist Indigenous managers to sustainably care for the wet/dry tropics of northern Australia by supporting economic development opportunities based on Indigenous land and sea management (Armstrong et al., 2006). A sustainable 'culture based economy' should also improve the socioeconomic status of Indigenous peoples of northern Australia, while valuing and enhancing cultural practices that have evolved over millennia. NAILSMA aims to support capacity building and transfer of customary knowledge and practices within; increase communication, trust and the sharing of indigenous knowledge between; and advocate for the rights and interests of; Indigenous land and sea managers (Armstrong et al., 2006). To achieve this, NAILSMA aims to be the peak Indigenous leader in research for projects that are pertinent to the whole of northern Australia, and develop a network that involves communities and organisations that are involved in Indigenous land and sea management (Armstrong et al., 2006). This alliance is to be broad and inclusive, with the strategic decisions and focus of NAILSMA being determined by an annual forum that informs the NAILSMA Board and Executive. Recently, Indigenous managers of sea country have voiced their desires to have NAILSMA advocate on their behalf in relation to the management of marine resources across northern Australia. This paper provides an important source of information for both Traditional Owners about their role, either realised or ignored, and other potential sources of resources in the increasingly important role that TO's are and will play in the future management of our northern coastline.

Introduction

Australia is currently free from numerous diseases, pests and weeds that are endemic in many countries around the world. This is due to Australia's high standard of living and relative isolation, the strict human quarantine regulations carried out during colonisation (Maglen, 2005), and the current stringent quarantine laws that were introduced in 1908 (Commonwealth of Australia, 1908). However, the increased illegal fishing and unauthorised land incursions occurring in northern Australia, the change in regional distribution of pathogens due to the movement of people and animals eastwards within Indonesia, and the alteration in the global distribution of arthropod vectors that carry pathogens, are all of concern. These changes can facilitate the spread of infectious diseases to regions presently free of them and pose a biosecurity threat to Australia. If introduced to Australia, these invasive exotic species could cause considerable morbidity and mortality to humans, animals and plants, and result in significant economic cost and job losses.

Biosecurity covers a broad range of issues and includes strategies that assess and manage the risk of infectious disease, quarantined pests, genetically modified organisms, bioterrorism, and agricultural terrorism (Meyerson and Reaser, 2002). An important aspect of maintaining Australia's biosecurity is surveillance. Australian quarantine procedures mainly focus on border control, but also cover pre-border quarantine (NAQS, 2004). Australia, Papua New Guinea (PNG) and Indonesia are members of a Tripartite Committee on Agricultural Health and Quarantine (TCAHQ). Australia also has separate Memorandum of Understandings with East Timor, PNG and Indonesia on quarantine matters. These initiatives represent a major aspect of Australia's pre-border quarantine by helping to stop the spread of diseases within these countries by capacity building (Thompson et al., 2003).

The other crucial component of Australian quarantine is border and post-border control. The location of remote Indigenous communities within northern Australia and Indigenous land and sea management practices places Indigenous peoples in a critical position that enables them to detect illegal foreign fishers (IFF) and identify notifiable diseases, pests and weeds at an early stage (Armstrong, 2004). Therefore, a successful, integrated approach to maintain Australia's biosecurity requires Indigenous communities to be centrally involved in biosecurity strategies in northern Australia. This report will review 1) the main biosecurity risks to Australia as a result of illegal fishing and climate change, focusing on the public health risks, 2) the diseases that could be introduced by illegal fishing or affected by climate change, which cause public health risks to Australia, and 3) the current surveillance that occurs in northern Australia. Finally, this report will discuss why Indigenous communities in the north should become more involved in monitoring and reducing these biosecurity risks to Australia.

Biosecurity risks to Australia from illegal foreign fishing

Although there are no reliable figures for the number of illegal foreign fishing vessels (IFFV) inside the Australian exclusive economic zone, Coastwatch, the division of Australian Customs that provides civil maritime surveillance and response service, has recently confirmed that 13,018 sightings of foreign vessels took place in 2005, which had risen from 9,639 in 2004 (Sydney Morning Herald, 2006). As these are aerial sightings, vessels can be counted more than once, while others may be missed. This increase coincides with increased apprehensions of IFFV. Even if only 10% are in fact IFFV, then greater than 85% are escaping detection, as only 100 IFFV were intercepted in the six months to June 2005 (AFMA, 2004-05), with 1,485 IFFV being detained in 2004-05 (DIMIA, 2004-05). Over 90% of these are from Indonesia, who target shark fin, reef fish, trochus and trepang (sea cucumber) (AFMA, 2004-05). Twenty-nine IFFV were apprehended in a two week period as a result of *Operation Clearwater* (AFMA, 2004-05). This was a major logistical task, as the legislative authority for Australian maritime areas lies with numerous Commonwealth and State agencies, and requires effective inter-agency coordination for surveillance to be efficiently carried out (Woolner, 2001). Coastwatch does not have the resources to maintain this level of operation (Woolner, 2001). Hence, most of the IFFV go undetected.

There are several biosecurity risks associated with the presence of IFFV near Australia's shore and the unauthorised landings of IFF to Australian public health and to Australia's environment. The public health risks to Australians can arise after direct transmission of communicable disease, such as tuberculosis, from the IFF. After IFF have been detained, the Department of Health and Aging assesses their health. They are held at Broome (Western Australia), Darwin (Northern Territory), and Thursday Island (Queensland) and are usually screened within 24 hours for fitness to fly and presence of communicable diseases (Krause, 2006). Health authorities have detected high incidents of tuberculosis¹ and some sexually transmitted infections. The influx of Indonesian IFF has also resulted in an increase in the rate of malaria notified in Western Australia (Liu et al., 2005).

While the IFFV do not contain ballast water, which is a source of invading foreign species of marine and plant life, the larger IFFV contain large amounts of ice and water. As these boats originate from areas with large numbers and great diversity in mosquito species, it is highly likely that the boats also carry mosquitoes from Indonesia. While the Australian Federal government has not released information on the presence of mosquitoes on the IFFV, the detection of the vector for dengue virus (*Aedes aegypti*) on Indonesian IFFV has been reported (Beebe et al., 2005). Furthermore these mosquitoes are likely to carry the viruses and parasites that are endemic in South-East Asia and cause diseases such as dengue fever, Japanese encephalitis and malaria. The IFFV also carry live cats, chickens, dogs and rats (DAFF, 2005), which can carry pathogens that cause disease in humans, such as *Toxoplasma gondii*, avian influenza virus, *Leishmania* and *Schistosoma japonicum*, respectively.

Threats to the environment come from the food (e.g. fruit potentially infested with fruit fly) and plant materials (eg banana leaves potentially infected with black sigatoka) carried onboard (DAFF, 2005), and from the possible introduction of feral animals (ie cats and dogs) to the mainland. Other risks include termites and wood borers, which commonly infest wooden IFFV (DAFF, 2005). To minimise the quarantine risk, once intercepted, IFFV are kept 1.5 nautical miles offshore, which is thought to be too far for arthropods to fly to shore. Any water found onboard is chlorinated and tipped overboard, while food is double bagged and then destroyed. Divers inspect the boats for marine pests, particularly the Asian muscle. The boats are fumigated, deratted and then burnt, as they are still considered to be a quarantine risk.

¹ During 1999 – 2001, 4.6% and 78.2% of Indonesian inmates in Darwin had active and latent tuberculosis, respectively (Zweck et al., 2003). The latter have a 20% life-time risk of developing active tuberculosis.

Increased human health risks caused by climate change

The world's eco-system is currently undergoing massive global change, which incorporates climatic change, changes in atmospheric composition, land use and land cover change, the spread of exotic invasive species, and changes in biodiversity (Sutherst, 2001). Computer models suggest that anthropogenic induced climate change will result in an increase in mean global temperature of 1.4 – 5.8°C by 2100, relative to baseline 1990 levels (Figure 1A), depending on final atmospheric CO₂ concentration (IPCC, 2001a). Global warming is expected to cause more extreme climatic events such as heatwaves, floods, droughts and cyclones; regional changes in precipitation (Figure 1B); and rising sea levels (Kovats et al., 2003). This will have serious impacts on human health around the world, and change the geographical distribution of arthropod vectors, and pattern of transmission of vector-borne (eg dengue fever), water-borne (eg giardiasis) and food-borne (eg salmonellosis) diseases (Figure 2). For example, in temperate countries, prolonged heatwaves increases the number of deaths from cardiovascular and respiratory diseases (Kovats et al., 2003). Rainfall can also affect the dispersal of microbial pathogens such as *Cryptosporidia* and *Giardia* (Patz and Kovats, 2002). Changes in the risk of diseases transmitted by mosquitoes also occurs in some areas during the El Niño-Southern Oscillation (ENSO) phenomenon (Patz and Kovats, 2002, WHO, 2006b). These have all been recently reviewed by the World Health Organization (Kovats et al., 2003).

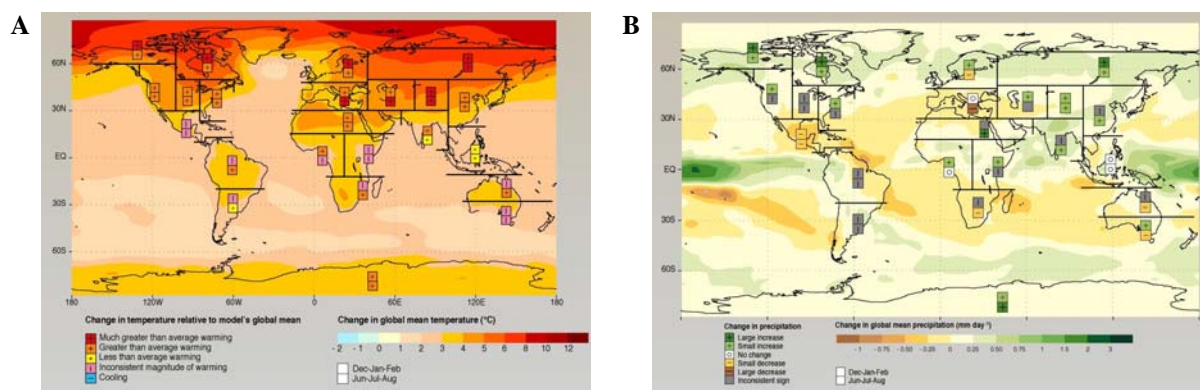


Figure 1. Change in temperature (A) and precipitation (B) as estimated by the HadCM3 model under the A2 (provincial enterprise) Standardised Reference Emission Scenario (SRES). Obtained from (IPCC, 2001b).

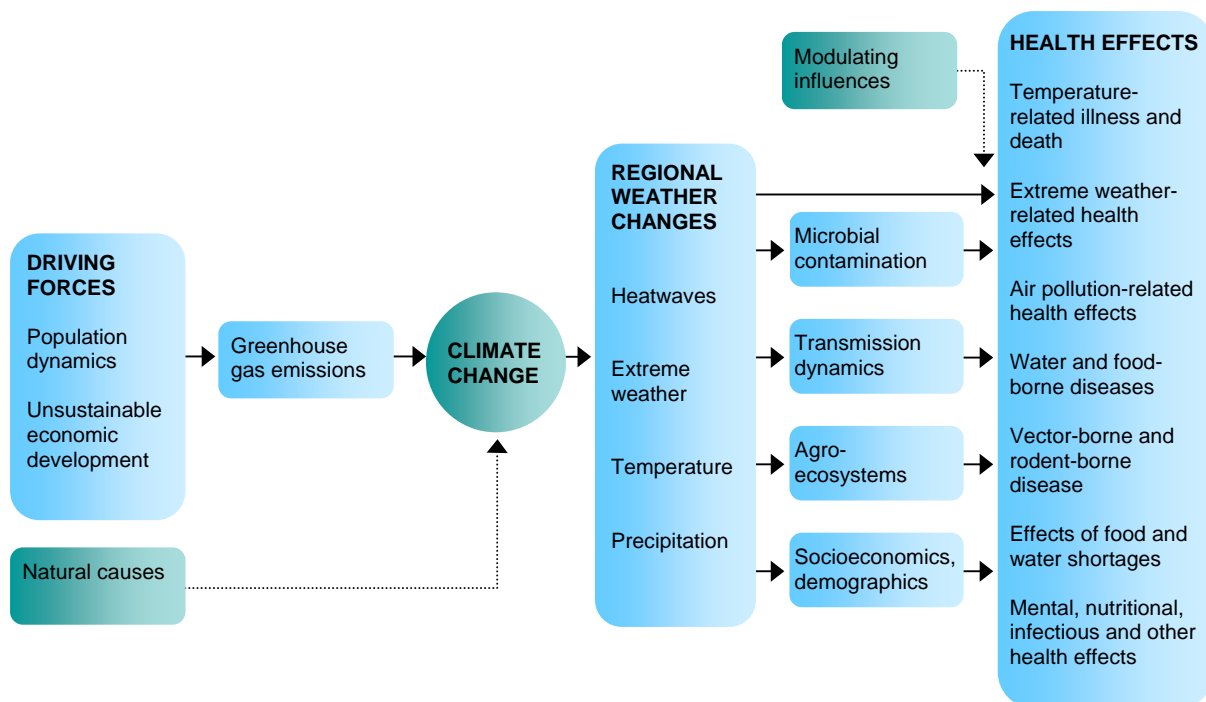


Figure 2. Pathways by which climate change affects human health. Modified from (Kovats et al., 2003).

Pathogen and Arthropod Vector Ecology and Global Change

Diseases caused by viruses (eg dengue fever) and parasites (eg malaria) carried by arthropod vectors (eg mosquitoes, sandflies, ticks) are causing increasing problems around the world. Although the reasons for this have not been clearly elucidated, global climate change is likely to be a major contributor, as arthropod growth is highly sensitive to the climatic variations of temperature, humidity and rainfall (Kovats et al., 2003, Kuhn et al., 2005, Sutherst, 2001, Woodruff et al., 2005). Pathogens are also temperature sensitive. For example, *Plasmodium falciparum* and Japanese encephalitis virus cannot complete their development below 18°C and 20°C, respectively (Kuhn et al., 2005). Increases in temperatures above these thresholds, but within their tolerance ranges, will decrease development time, which will increase the reproduction rates of the pathogens (Kuhn et al., 2005), increasing disease transmission rates.

Temperature and humidity affect arthropod vector metabolic rates, egg production and frequency of blood feeds (Kovats et al., 2003, Kuhn et al., 2005). Accelerated vector development rates and longer growing seasons increase their abundance, altering the seasonal timings of arthropod lifecycles and amplify the number of generations each year (Sutherst, 2001). This means that arthropods could appear not just earlier in the season but also earlier in the year. Shorter and milder winters will also increase the survival rates of pathogens and the transmitting arthropods, especially in subtropical areas. These can all result in higher disease transmission rates, which can lead to epidemics. Climate change is expected to produce greater extremes of wetness and dryness, leading to more variable numbers of arthropods (Sutherst, 2001). This will make it more difficult to predict disease outbreaks before they occur.

As CO₂ levels continue to rise, plant biomass will increase, providing more shelter for the free-living stages of vectors such as ticks, and more favourable micro-climates for longer each year, thus increasing their survival rate (Sutherst, 2001). Furthermore, changes in land use, such as the increased production of maize crops in Africa, can also affect arthropod population growth rates. Maize pollen is highly nutritious to the larvae of the mosquito *Anopheles arabiensis*, which is the major vector of malaria in Africa (Sutherst, 2001). Eradication of arthropod vectors may also result in the appearance of vacant niches, which can be filled by other species of disease vectors. This can cause further problems if the new species prove to be resistant to the chemicals that were used to control the original vector population (Sutherst, 2001).

As pathogen and vector development have optimum climatic conditions, climate change can result in unfavourable as well as favourable conditions for pathogen and vector development. An important consideration is that different vector populations will be differentially affected, depending on where the population resides (Sutherst, 2001). Populations on the edge of ideal environmental conditions are more likely to be affected by climatic variation than those populations in the core of the species' climatic envelope (Sutherst, 2001). Therefore even small changes in climate can affect the distribution and abundance of disease vectors, and thus disease. This could result in areas that are currently endemic becoming unable to support vector development, while other presently unsuitable places could be able to sustain disease transmission, potentially affecting new human populations that lack immunity to the pathogen (Kovats et al., 2003). The processes that drive pathogen and vector population dynamics are complex (Figure 3) and are not fully understood, and suggest that an integrated, holistic approach is required to manage them (Kovats et al., 2003, Sutherst, 2001).

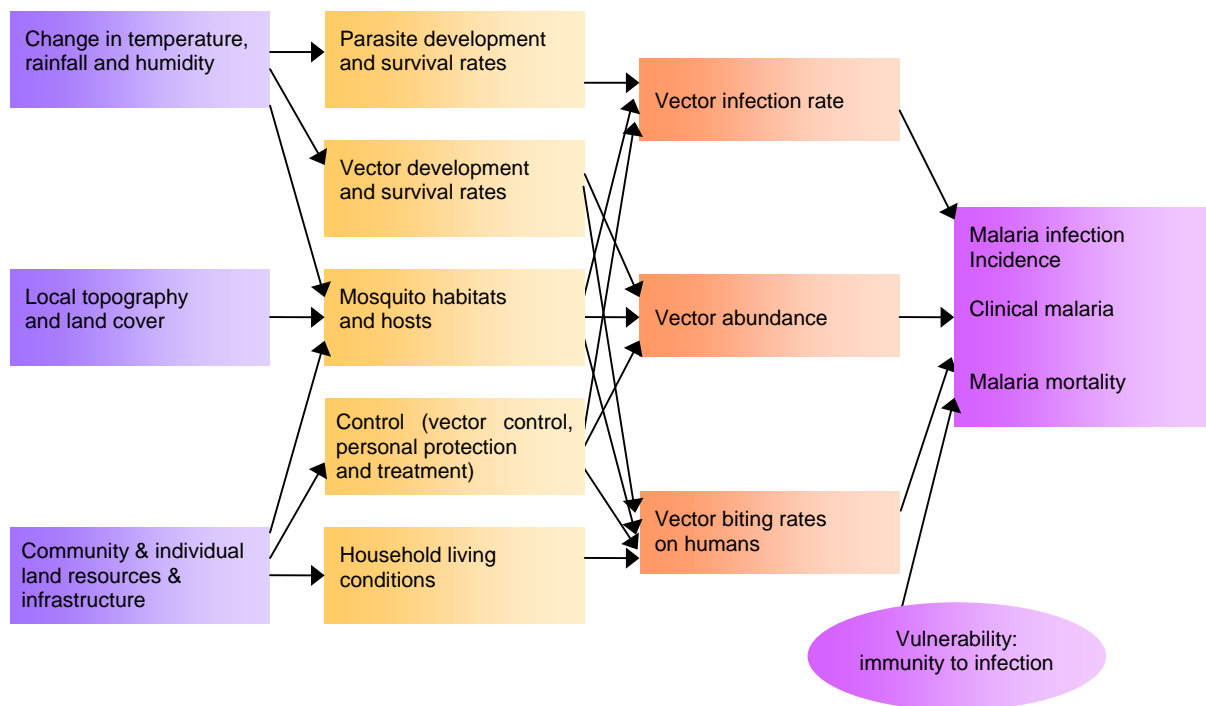


Figure 3. Causal web for the associations between climate and one vector-borne disease (malaria). Modified from (Kovats et al., 2003).

Vector and Disease Mapping

To enhance detection and prevention of vector-borne disease, there needs to be site-specific early-warning systems, linked with effective intervention. This requires the establishment, maintenance and improvement of long-term disease and vector surveillance, particularly in suspected hotspots of climate change and increased health risks (Patz and Kovats, 2002). For mosquitoes, monitoring has traditionally been carried out using light traps baited with dry ice (CO₂). The trapped mosquitoes are then transferred to laboratories, morphologically assessed, and the mosquito species and the pathogens they carry are then detected using molecular biological techniques.

Long distance mosquito dispersal can occur naturally, primarily by wind action, and by human movement by sea, land, and air transportation (Beebe and Cooper, 2002). However, it is more likely that short-distance dispersal is responsible for the spread of mosquitoes in a region, through the establishment of unobserved intermediate populations near the area. This usually only occurs when the vicinity no longer supports the mosquito population (Beebe and Cooper, 2002). An inconclusive study by Sved and coworkers (2003) tried to establish how long-range dispersal of pest species occurs in quarantine zones using genetic drift and gene frequency. Another study by Beebe and coworkers (2005), investigated where the mosquito vector of dengue virus (*Ae. aegypti*) that appeared in Tenant Creek originated from. They identified Cairns as the source, by using mitochondrial DNA sequencing.

As the trapping of mosquitoes is extremely laborious, scientists are starting to incorporate computer models to predict the location of specific species of mosquitoes. The aim is to reduce the number of traps required to generate accurate maps (Hales and Hearnden, 1999). This is now possible due to the increased understanding of the interactions between climatic factors and disease, and advances in technology that has increased the accuracy and lead-times of weather forecasts and climate predictions. This has led to the development of quantitative spatial models of the relationships between climatic factors and disease, which predict geographical changes in the incidence of epidemic-prone infectious diseases (eg malaria) (Kuhn et al., 2005). These models incorporate current and predicted temperature, altitude, human population densities and epidemiological data to determine vector index growth and distribution, and projected health risks. They are designed to give early warnings of potential epidemics to help epidemic preparedness and possibly prevention. The information generated from the various models available can help authorities prevent future outbreaks, by directing where control measures should be applied. The value of these models obviously depends upon their accuracy. Further research comparing actual versus predicted mosquito populations is required to produce useful, accurate models.

Human Disease Risks due to Climate Change in Australia

According to a recent report by the Australian government, climate change is predicted to result in an increase in average temperatures of between 0.4° – 2°C by 2030 and 1° – 6°C by 2070 (Allen Consulting Group, 2005), with a rise in the average rainfall across northern Australia and decreases in eastern and southern Australia, which has already started to happen (McMichael et al., 2002, Woodruff et al., 2005). Climate change is expected to increase the intensity, frequency, and distribution of vector- and water-borne diseases in Australia, and could result in the establishment of disease transmission cycles by exotic pathogens (McMichael et al., 2002, Woodruff et al., 2005). These diseases include dengue fever, Ross River fever, malaria, Leishmania and Japanese encephalitis, and diarrhoea caused by the parasites *Cryptosporidium* and *Giardia*, which are prevalent in Indigenous communities. Reduction of total greenhouse gas emissions is considered to be a primary preventative health strategy (McMichael et al., 2002, Woodruff et al., 2005).

Diseases that could be introduced by illegal fishing or affected by climate change and cause increased Australian public health risks

Dengue Fever

Dengue is usually a mild but debilitating viral fever, caused by four serotypes of dengue viruses. Symptoms can include fever, muscle and joint pain, headache and rash. However, subsequent infection by different serotypes increases the risk of development of dengue haemorrhagic fever, which is characterised by a breakdown in the blood-clotting mechanism with internal bleeding, and can be fatal (Kuhn et al., 2005). Dengue viruses are the most widespread arboviruses² found in the tropics (WHO, 2006c). The main vector is the mosquito *Aedes aegypti*, but dengue viruses can also be transmitted by *Ae. albopictus* (WHO, 2006c). The distribution of *Ae. aegypti* in tropical areas has spread dramatically, possibly due to climate change. While the virus normally circulates in endemic cycles, it can cause acute, widespread epidemics, affecting up to 70-80% of the population (Kuhn et al., 2005, WHO, 2006c). Outbreaks are generally associated with elevated temperature and humidity, and the direct and indirect effects of high rainfall, on the biology of the virus and vector (Kuhn et al., 2005).

Ae. aegypti and dengue virus serotypes 2 and 4 are present in northern Queensland. Models suggest that even if substantial efforts are made to reduce greenhouse gas emissions, dengue virus transmission zones will spread further along the coast, southwest to Carnarvon and southeast to Rockhampton by 2100 (McMichael et al., 2002, Woodruff et al., 2005). However, uncontrolled emissions are likely to result in the transmission zones expanding into the hinterlands and covering coastal areas across northern Australia from Carnarvon in the west, to Sydney in the southeast. Good mosquito control programs will be essential to prevent the establishment of the secondary dengue vector *Ae. albopictus* in Australia, and to reduce disease outbreaks. *Ae. albopictus* is common in South-East Asia and PNG, has been detected by AQIS at Australian ports (McMichael et al., 2002), and could potentially be introduced into Australia via IFFV. It has a higher cold tolerance than *Ae. aegypti* and is spreading around the world. If introduced into Australia, *Ae. albopictus* could colonise populous southern areas, potentially extending the dengue transmission zones to the large southern cities, which would prove a significant public health threat (McMichael et al., 2002).

Ross River Fever

Ross River fever is an enzootic³ arthritic infection transmitted by *Aedes* and *Culex* mosquitoes that can also infect humans (Kuhn et al., 2005). This is currently the most significant arbovirus in Australia, and is predicted to spread due to climate change. The correlation between climate variables (rainfall and humidity) and disease incidence has led to the development of regional early-warning models that are based on rainfall levels in south-eastern Australia (Kuhn et al., 2005). Changing rainfall patterns and rising temperatures are likely to affect the distribution pattern of Ross River virus. However, at present there is insufficient information to accurately predict the potential consequences of climate change on the distribution of the virus (McMichael et al., 2002). It is likely that increased rainfall as well as a rise in temperature is required for the spread of Ross River virus in Australia (McMichael et al., 2002). This will not necessarily result in increased symptomatic disease in the long-term, as the increased incidence of disease is likely to cause infections to occur during childhood, which are asymptomatic and provide lifelong immunity (IPCC, 1998). More research into the ecology of the virus, its vector and host are required.

Malaria

Malaria is a potentially life-threatening disease common in many tropical and sub-tropical areas, and is caused by four related species of the protozoan parasite *Plasmodium*, which are transmitted by *Anopheles* mosquitoes (WHO, 2006b). This is one of the most serious health problems facing developing countries, with approximately 40% of the world's population at risk and up to 1 million deaths each year caused by *P. falciparum* (Bradley, 2005, WHO, 2006b). One bite from an infected mosquito is sufficient to cause disease. Clinical symptoms can include fever, chills, headache, muscular aching and weakness, vomiting, cough, diarrhoea and abdominal pain, acute renal failure, generalised convulsions, and circulatory collapse followed by coma and death (Kuhn et al., 2005, WHO, 2006b). After a mosquito bites a person infected with *Plasmodium* parasites, it takes 10 – 14 days for the malaria parasites to replicate in the mosquito and to travel to the mosquito's salivary glands, where they lie for up to 59 days (Bradley, 2005). Initial maturation of the *Plasmodium* parasite in humans takes 6 – 16 days,

² Arboviruses are viruses that are transmitted by arthropod vectors.

³ Enzootic diseases are diseases that are endemic in animal populations. In the case of Ross River virus, this is typically marsupials.

which is followed every 48 – 72 hours by the classical malarial symptoms of acute febrile episodes and rigours (WHO, 2006b).

While malaria is no longer endemic in Australia (it was officially eradicated in 1981), the number of cases of malaria diagnosed in Australia is increasing. This is not just due to travellers and visitors getting infected overseas, but also a result of local transmission of malaria parasites from individuals infected overseas (Hanna et al., 2004). The mosquito *An. farauti sensu lato*, which is a vector of *Plasmodium* parasites, is present in Australia north of latitude 21°S (McMichael et al., 2002).

A multivariate climate model of *P. falciparum* suggests that global climate change will not dramatically alter the distribution of malaria around the world, including Australia (Rogers and Randolph, 2000). Although this model provides more accurate predictions of the present situation than univariate models do, it is still only 78% accurate (Rogers and Randolph, 2000). Additionally, as the central statistical equation of this study was based on inaccurate maps of current malaria distribution, it is uncertain how useful this model really is (McMichael et al., 2002). This model shows that currently there is a probability of greater than 0.65 that coastal, northern Australia is at risk of *P. falciparum* malaria (Rogers and Randolph, 2000), which is in the malaria-receptive zone, but failed to predict the Queensland coastal strip from Cairns down to Mackay (McMichael et al., 2002).

Other models, however, suggest that climate change will result in expansion of the vector range, and suggest where malaria *could* be found. The empirical-statistical CLIMEX model predicted that by 2030 the malaria-receptive zone could extend down the Queensland coast to Gladstone (Bryan et al., 1996, McMichael et al., 2002). Another model (MIASMA) used biological information to estimate where *P. falciparum* could occur (Martens et al., 1999). This model suggests that malarial transmission around Cairns could happen year round, while transmission around Darwin and down the east coast to just north of Sydney could occur 7 – 11 months of the year. While this models historical geographical vector distribution, it is unlikely that malaria will establish itself in these areas, as in contrast to the CLIMEX model, the MIASMA model does not take into account vector control measures and environmental modifications that affect vector distribution (McMichael et al., 2002). None of these models mapped the potential future distribution of malaria caused by the milder species *P. vivax*. This has been responsible for the locally acquired outbreaks that have occurred in far north Queensland (Hanna et al., 2004).

A revision of the CLIMEX model incorporates the projected increased global warming and more extreme changes in rainfall (IPCC, 2001a), the overall climatic suitability of an area for the development of *An. farauti s. l.* growth, and the survival of *P. falciparum* and *P. vivax* (McMichael et al., 2002). Both *Plasmodium* species are predicted to be able to propagate for several months in the summer in most parts of Australia, conditional on the presence of suitable vectors. An increase in temperature of 3°C will move this distribution southwards, further decreasing the suitability of the north-west and inland areas (McMichael et al., 2002). This model also suggests that the malaria-receptive zone could expand southward to Rockhampton, Gladstone and Bundaberg, if adequate control measures are not carried out.

Although Australia remains vulnerable to malaria implantation (Bryan et al., 1996, Martens et al., 1999, McMichael et al., 2002, Rogers and Randolph, 2000), it is likely that local transmission will remain low for several reasons. These include the use of insect screens and repellents resulting in a low proportion of blood meals taken from humans; the restricted, unaided flight-range of 1 – 2 km, and short lifespan (10 – 14 days) of *Anopheles* mosquitoes that prevents parasite development in greater than 95% of mosquitoes in Darwin; and the low mosquito-to-human density in northern Australia (Bryan et al., 1996). However, rising sea-levels could result in the introduction of malarious refugees from low-lying areas in the Asia-Pacific region to Australia, potentially providing a large reservoir of infection (Bryan et al., 1996). Continued surveillance of vector distribution and screening of immigrants, therefore, is important in preventing malaria from being reintroduced to Australia. Again, additional vectors (*Anopheles*) could be introduced by unauthorised landings of IFF, and pose a potential biosecurity threat to Australia.

Leishmaniasis

Leishmaniasis is caused by the protozoan parasite *Leishmania*, and is transmitted by the bite of female phlebotomine sandflies (Kuhn et al., 2005). It is a major, chronic human disease, with approximately 1.5 – 2 million documented cases each year with 10% or more fatalities, and 350 million people at risk (WHO, 2006b). Cutaneous leishmaniasis affects the skin and is characterised by ulcerative skin lesions, while visceral leishmaniasis can result in anaemia, enlarged spleen and liver, fever, and weight loss. This is another zoonotic disease where humans are accidental hosts. The animal reservoirs are dogs, rodents and other mammals (Rose et al., 2004, WHO, 2006b). Leishmaniasis is on the increase around the world, with anecdotal reports of expansion of vector distribution (Kuhn et al., 2005, Sutherst, 2001). Climatic factors such as high rainfall can increase sandfly breeding, while environmental changes (eg deforestation, dam building) can affect zoonotic reservoirs.

These factors and population movements are all associated with disease outbreaks (Kuhn et al., 2005, WHO, 2006b).

Locally acquired Leishmaniasis has recently been detected in the skin lesions of red kangaroos in Australia, with local sandflies presumed to be the vector (Rose et al., 2004). This finding has led Biosecurity Australia to review procedures for the quarantine of imported dogs into Australia (DAFF, 2006). While it is currently unknown if this potentially novel *Leishmania* species is capable of infecting humans, it is possible that there are undiagnosed human cases in northern Australia (Rose et al., 2004). This disease is endemic in Indonesia, and the dogs carried on the IFFV may be infected. Unauthorised landings by IFF and their dogs may lead to the introduction of exotic *Leishmania* species that are known to infect humans, into Australia. If *Leishmania* was introduced into Indigenous communities, which have large numbers of dogs, it would not be easily eradicated. More research is needed to elucidate the vector-host-parasite transmission cycle of the *Leishmania* species found in Australia.

Avian Influenza

Avian influenza is a highly contagious disease that primarily infects birds, but also occasionally infects pigs and more rarely humans (WHO, 2006a). While the relatively rare infection of people by avian H5N1 via birds is of concern to health officials around the world, the major fear is the risk of this virus mutating to become easily transmitted by people and causing a human influenza pandemic.

Although wild waterfowl are considered to be the natural reservoir of avian influenza A viruses, disease can also occur in domestic poultry, which commonly consists of mild symptoms, such as a drop in egg number and ruffled feathers (WHO, 2006a). However, domestic and wild birds can also be infected with extremely pathogenic variants that are highly infectious, cause disease that affects multiple organs and can result in up to 100% mortality within 48 hours of infection (WHO, 2006a). Avian influenza outbreaks, especially in South-East Asia, are not an unusual event, as 1 – 20% of all ducks are infected with influenza viruses (Normile, 2005). However, the current outbreaks of avian influenza with the H5N1 subtype, which started in 2003, have been the most severe and longest epidemic on record (WHO, 2006a). Since 2003 avian H5N1 outbreaks in birds have been mainly reported in Asia, but within 2 years have spread around the world and have appeared in Central Asia, Europe, the Middle East and Africa (OIE, 2006). Avian H5N1 is also considered to be endemic in many parts of Indonesia and Vietnam, and in some parts of Cambodia, China, and Thailand (WHO, 2006a).

The risk of avian influenza spreading to Australia is low compared to other countries. This is because wild waterfowl, the natural viral reservoir, do not normally migrate to Australia, and the migratory waders and shore birds that do arrive, are less likely to be infected with the highly virulent avian H5N1 subtype (Conkey, 2006a). Wild bird surveillance programs, carried out by the Australian Quarantine and Inspection Service's (AQIS) Northern Australia Quarantine Strategy (NAQS), have not detected avian H5N1 in Australia (Conkey, 2006b). Highly pathogenic H5N1 has also not been detected in West Papua or PNG. For transmission to commercial poultry, infected migratory birds would first have to infect native nomadic wild birds, which would then need to infect domestic poultry. The presence of chickens onboard the IFFV (which originate from Indonesia, where avian H5N1 outbreaks have occurred) increases the risk of avian H5N1 being introduced to Australia. If it was introduced to Australia the greatest risk would be transmission of the virus to production birds and not humans, as there are few backyard flocks in Australia.

Japanese encephalitis

Japanese encephalitis, the leading cause of viral encephalitis (inflammation of the brain) in Asia, is transmitted by *Culex* mosquitoes. It can cause severe rigours, fever, headache and malaise that last from 1 – 6 days. Infection of the nervous system can result in deafness, personality changes, mental retardation, coma and death (Kuhn et al., 2005). While Japanese encephalitis virus is a zoonotic virus that mainly exists in a transmission cycle between pigs, water birds, mosquitoes and/or water, it also causes highly seasonal and severe human epidemics during the monsoon season, when temperatures exceed 30°C (Kuhn et al., 2005, WHO, 2006c). In India transmission peaks as rainfall and temperature increase, and the spread of Japanese encephalitis to new areas has been correlated with intensive rice cultivation (Kuhn et al., 2005, WHO, 2006c). Japanese encephalitis is endemic in rural areas of Indonesia.

Japanese encephalitis virus has recently spread, undetected, 3,000 km from Bali to northern Australia, and probably reached the Torres Strait by island hopping (Mackenzie, 2005). There have been outbreaks of Japanese encephalitis in pigs and humans on Badu Island in the Torres Strait since 1995. In 1998 virus activity spread to the Northern Peninsula Area (NPA) and western Cape York Peninsula (van Den Hurk et al., 2003). Despite these outbreaks, Japanese encephalitis has so far not established itself in mainland Australia (Liu et al., 2005). A recent study has demonstrated that local *Culex* mosquitoes preferentially bite marsupials, with less than 10% of bloodmeals taken from birds and pigs each, on mainland northern Australia (van Den Hurk et al., 2003). In

contrast, between 1995 and 1998, greater than 30% of bloodmeals were taken from pigs on Badu Island and Baa's Yard in NPA, where domestic pigs were kept at high densities and close to human habitation (van Den Hurk et al., 2003). Pigs are considered to be essential for virus amplification in most areas, and removal of domestic pigs from human habitation on Badu Island has limited the contact between the main vector *Cx. Annulirostris*, the amplifying hosts and humans (van Den Hurk et al., 2003). These data suggest that as long as pigs (wild or domestic) are kept from human habitation, and without the introduction of exotic mosquito species from South-East Asia that are likely to predominately feed on pigs (eg *Cx. Tritaeniorhynchus* Giles on board IFFV), it is unlikely that Japanese encephalitis virus will establish natural transmission cycles in northern Australia.

Water- and food-borne diseases

Diarrhoeal diseases (eg those caused by *Cryptosporidium*, *Escherichia coli*, *Giardia*, *Salmonella*, and *Shigella*) can be transmitted by water, food, contact between humans, or insects. Many diarrhoeal diseases peak in numbers during the hottest months of the year, as temperature and humidity directly influence the replication rate of pathogens and their survival in the environment (Kovats et al., 2003, Patz and Kovats, 2002). Additionally, heavy rainfall and runoff can alter the transport and distribution of microbial pathogens. For example, some Australian water supplies may be at risk of faecal contamination from farm animals after high-intensity rainfalls (McMichael et al., 2002). It has been predicted that climate change will result in an increase of 5-18% by 2050 in diarrhoeal hospital admissions by Indigenous children (McMichael et al., 2002). Generally, Indigenous communities have poorer quality water supplies and sewage disposal, than mainstream communities, and are most at risk of contracting water- and food-borne infections (IPCC, 1998).

Indigenous Health

Indigenous Australians have three times the illness and mortality rates of non-Indigenous Australians (ABS, 2006a), which is in contrast to the significant improvements in the health of Indigenous peoples in New Zealand (NZ) and North America (Ring and Elston, 1999). Prior to European settlement Indigenous Australians had good environmental health management and health practices (Jardine-Orr et al., 2003). However, since then, Indigenous housing and environmental health have become inextricably linked, as inadequate housing has contributed to poor health (Jardine-Orr et al., 2003, urbis keys young, 2002). The diseases mentioned above are exacerbated by poverty and poor health. Furthermore, Indigenous Australians are socially marginalised from access to services, including health care. Therefore, these diseases, if introduced, will have a much bigger impact on Indigenous populations in northern Australia than on non-indigenous populations.

Monitoring biosecurity risks in northern Australia

Surveys, ranging from two to eight days, are carried out by NAQS across northern Australia (Figure 4A) for the early detection of exotic diseases and pests, such as Japanese encephalitis, surra, fruit flies, the screw-worm fly, bluetongue virus, avian influenza, and other pests and weeds (DAFF, 2005). These surveys check the health of feral (pigs and buffalo) and sentinel (pigs and cattle located in areas of high risk) animals; look for plant pests, plant diseases and weeds; and train Indigenous Ranger groups. The feral pig surveillance and Ranger training programs have helped Adjumarllarl rangers to be able to collect and send good quality post-mortem tissue and blood samples from pigs to NAQS (DAFF, 2003). If sick animals are reported to NAQS then extra surveys are carried out to determine the nature of the illness. Other NAQS activities include setting up light trapping for midges on a monthly basis, while local people in remote locations clear and maintain fruit fly traps. The arthropods are sent to quarantine entomologists for identification (DAFF, 2003). During the 2004–05 season, Japanese encephalitis and Asian papaya fruit flies, which are serious horticultural pests, have been detected in the Torres Strait, while bluetongue virus⁴ was found in the Cape York Peninsula (Bamaga) (DAFF, 2005).

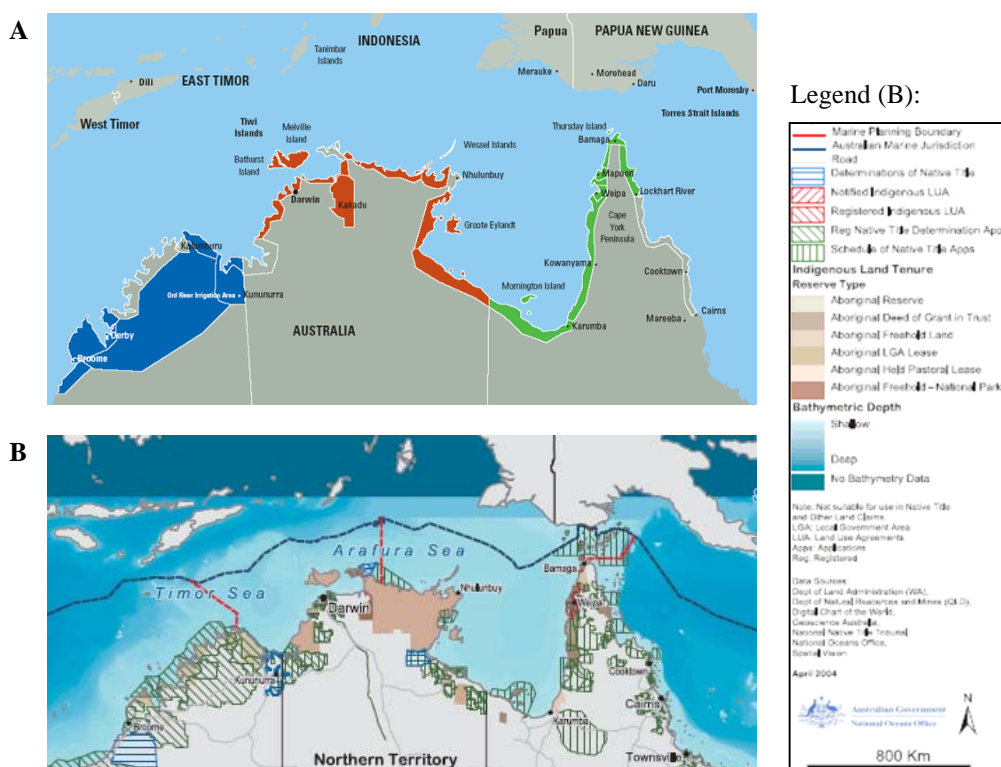


Figure 4. Map showing (A) the NAQS survey zones (obtained from (DAFF, 2005)) and (B) the Native Title and Conservation status of Northern Australia at April 2004 (obtained from (Neptune, 2004)). During the 2004-05 season 38 NAQS surveys were carried out across northern Australia, of which 75% is Indigenous owned (DAFF, 2000).

Indigenous communities are ideally placed to monitor and reduce biosecurity risks

While Indigenous land ownership is extremely dynamic, making it difficult to assess, it is estimated that up to 18% of Australia is owned, controlled or managed by Indigenous people (Pollack, 2001). Most Indigenous land is located in remote rangelands, with up to 43% of the Northern Territory being Indigenous owned (Pollack, 2001). At 30 June 2001, the estimated Indigenous resident population was 2.4% of the total estimated resident population of Australia, with approximately 29% of Northern Territory residents identified as Indigenous (ABS, 2002b). In contrast with non-Indigenous populations, most of Australia's Indigenous people live outside the major urban centres (69%), with one in four living in remote locations, compared to one in fifty non-Indigenous residents (Figure 5) (ABS, 2006a). This includes areas that are vulnerable to invasion by exotic species and incursion by IFFV, which are monitored by NAQS. Effective surveillance of this land, of which 75% is

⁴ Bluetongue is an arthropod-borne viral disease, which affects cattle.

Indigenous owned (Figure 4B), is only possible due to the assistance and vigilance of local residents (DAFF, 2000). Indigenous communities are, therefore, ideally placed to monitor and reduce biosecurity risks in northern Australia, and should become more involved in border protection and post-border quarantine surveillance. Any involvement of Indigenous communities will require adequate training and once training has been completed, payment at industry award rates. This could be done by expanding the Indigenous ranger programs as successful natural resource management (NRM) programs have been established using Indigenous Rangers.

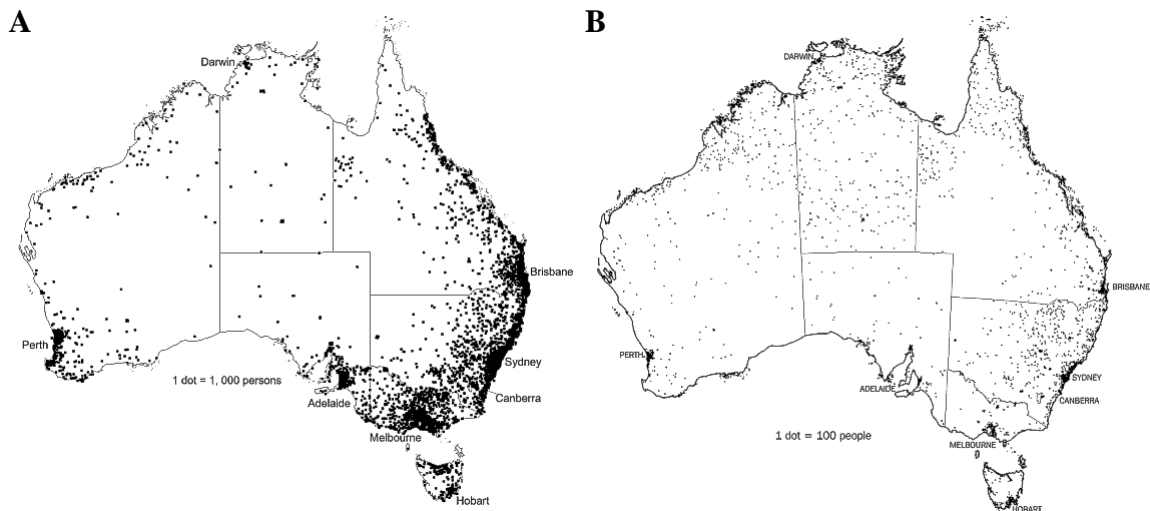


Figure 5. Map of the estimated (A) total Australian (1 dot represents 1,000 persons) and (B) Indigenous (1 dot represents 100 persons) population distribution at 30 June 2001. Obtained from (ABS, 2006b).

The Indigenous Sea Rangers Program

The Northern Territory employs about 37 Indigenous Sea Rangers (ABC News, 2006a), who protect their cultural interests and help safeguard Australia's biosecurity. Indigenous people in northern Australia have detailed local knowledge of the tides, location of fish stocks, and are able to spot hidden IFFV along the coast, which are difficult to detect, even by conventional radar, in the complex river systems and dense mangroves (ABC News, 2005c, ABC News, 2006a). Indigenous Rangers have found IFFV in estuarine rivers and empty camps, made by IFF, on their traditional land (ABC News, 2006a). Once Indigenous Rangers discover IFFV they notify Customs (ABC News, 2005b). As Customs does not have the resources to intercept all of the IFFV that approach Australia's coastline, the most cost effective approach would be to employ Indigenous Sea Rangers (ABC News, 2006a). Complete border control would require expansion of the Indigenous Sea Ranger program, to cover the whole of northern Australia, and not just the Northern Territory. With sufficient resources it has been claimed that Indigenous Sea Ranges would be able to locate all unauthorised landings by IFF (The Age, 2006).

In the recent 2006-07 Federal Budget, \$389 million over four years, has been allocated to combat illegal fishing in Australia's northern waters. Included in this is \$6.9 million for Indigenous community engagement for assistance in monitoring the biosecurity risks from IFFV, which will be reviewed after 12 months (The Commonwealth Treasurer, 2006). While there is uncertain at present on exactly what this program will entail, with some of the money going directly to AQIS for quarantine inspections (ABC News, 2006b), this is a good start.

Indigenous Land Ranger Programs

Indigenous people are also vastly familiar with the flora and fauna found on their traditional lands, know their land well, and with extra training and collaboration with existing land management programs, would be able to detect invading species (Gardener, 2005). The Strategic Weed Management Plan for Top End Aboriginal Land was set up by the National Heritage Trust and the Indigenous Land Corporation, with the dual objectives of managing and eradicating the weed mimosa and building Indigenous community capacity in weed management (Gardener, 2005). This program is viewed as being successful as there is greater community engagement, with knowledge being exchanged between rangers, their families and traditional owners, and the generation of external contracts for the rangers. These contracts include government and private weed spraying, fencing and mustering, AQIS and Customs surveillance, harvesting feral animals for human and pet consumption, pastoralism and tourism, and mine site rehabilitation (Gardener, 2005). Other services that Indigenous communities could provide include biodiversity conservation, controlling feral animal numbers, generating carbon credits through the management of savanna burning, and sustainable use of wildlife products and bush

foods (Armstrong et al., 2006, Gardener, 2005). This work is relevant to Indigenous people as contemporary land management practices are similar to traditional ones and provides them with a chance to get back onto their country (Gardener, 2005).

The Northern Land Council and AQIS have formed a partnership to provide quarantine surveillance on Indigenous Lands in the Northern Territory (The University of Melbourne, 2001). This could be expanded. As part of post-boarder quarantine control, members of Indigenous communities could set up mosquito traps, and trap migratory birds using nets and collect blood and cloacal swabs for analysis of influenza viruses, in addition to the screw-worm fly and papaya fruit fly trapping they are already involved in (DAFF, 2000). Further development of the animal disease awareness training programs carried out by NAQS, and training in autopsy techniques, could allow gross disease to be detected early, with samples sent onto NAQS for testing. Field tests for the pathogens of concern would help make on the ground assessment easier, as many parasite infections are asymptomatic (Thompson et al., 2003), which is important if the meat is to be used for human or pet consumption.

Indigenous Employment in Remote Locations

Indigenous Australians are marginalised from the dominant market system and have the lowest economic status of all Australians (Altman, 2000). This is mainly due to historical exclusion from state support, including provision of services that mainstream towns of a similar size receive; Indigenous population structure and the remote location of Indigenous communities; cultural factors such as the absence of labour migration and differing priorities; and discrimination (Altman, 2000). The high level of formal Indigenous unemployment, especially in remote areas, is hidden by the Community Development Employment Projects (CDEP) scheme, which is a work-for-the-dole scheme. Instead of receiving the dole, CDEP participants work for four hours a day and are considered to be employed. In remote areas CDEP accounts for 60% of jobs, while in non-remote locations 90% of Indigenous workers are in mainstream employment (ABS, 2002a). CDEP is the current paradigm for employment in Indigenous communities and is based on the premise that unemployment is short-term, and that Indigenous Australian's will soon move into the dominant market system (Altman, 2000, Gardener, 2005). However, this is highly unlikely, as mainstream employment opportunities are largely absent in these rural and remote Indigenous communities. In very remote areas, 40.6% of participants have been on CDEP for over 5 years (Altman et al., 2005). If extra hours are worked, participants can receive CDEP top-up, which can double the amount received. CDEP is generally viewed as a cost-effective program that provides participants with positive training, employment and economic outcomes, enhanced individual wellbeing and community development (Altman et al., 2005). CDEP can also allow participation in customary activities, such as traditional land and sea management, as well as paid work.

In 2004 across the Top End of the Northern Territory there were 30 community-based NRM programs involving 300 rangers. Although these programs targeted Indigenous land, they also benefited neighbouring lands, including national parks, by preventing the spread of weeds from Indigenous land, for example (Gardener, 2005). While mainstream town councils use rates generated from residents and businesses to pay for their employees, Indigenous communities rarely have a cash economy, have no rate monies to draw from, and other funding is sporadic and often difficult to obtain, meaning that they cannot pay for the equivalent council workers (Gardener, 2005). Therefore, these programs all relied on payment via CDEP, with a top-up component, giving a maximum income of \$21,000 per annum (Gardener, 2005). There was a high turn over of rangers, which has been linked to the low pay and lack of a real job opportunity, even though there were higher expectations of rangers compared to other CDEP participants (Gardener, 2005). Even senior rangers, who often work independently, received CDEP plus top-up payments, while the coordinators, who were non-Indigenous, received industry award wages (Gardener, 2005). This raises the question of how equitable is it for Indigenous workers that are carrying out "real" and important jobs, to be paid significantly less than their non-Indigenous counterparts, and removes the incentive to achieve (Gardener, 2005).

The sea ranger program is also paid for by CDEP. The Rangers, however, want equivalent wages to Customs and AQIS employees (ABC News, 2006a). The federal opposition has proposed employing Aboriginal rangers within a proposed Australian Coast Guard on a full-time basis (ABC News, 2005a). This would involve training them to help prevent animals and diseases reaching Australia. Furthermore, this would also formally acknowledge the important role that Indigenous rangers have in maintaining Australia's biosecurity.

Current funding for the important work carried out by Indigenous rangers is inadequate. Indigenous people living on country generate environmental, economic and social benefits at national as well as local and regional levels (Altman, 2003). However, when compared to neighbouring national parks and other reserved lands, Indigenous land is not equitably resourced (Altman, 2003). There needs to be a whole of government approach for these multi-outcome projects, with core funding coming from various State and Federal government sources, including Health, Employment and Workplace Relations, Defence, Fisheries, Customs, and Family and Community Services Departments (Gardener, 2005). The human and natural resources on Indigenous land can be used in a sustainable way to develop regional economies, restore Indigenous capacity and empowerment. These programs can produce meaningful employment for Indigenous people in remote locations at the same time as helping to maintain Australia's biosecurity.

Conclusions

The increased incursions of IFFV near Australia's shore and unauthorised landings, in addition to the spread of pathogens and vectors due to global change, all pose serious biosecurity threats to Australia. These include the possible introduction of feral animals, exotic pests, diseases and weeds to the mainland, and a change in distribution of diseases already present in Australia, which could cause considerable economic, environmental and health costs. The main public health risks come from the potential spread of dengue, Ross River and Japanese encephalitis viruses throughout Australia, and the introduction of avian influenza to Australia. IFFV that approach Australia's coastline could introduce exotic disease vectors that have the potential to change the distribution pattern of pathogens already present in Australia. Of particular concern, is the possible introduction of *Ae. albopictus*, which could spread dengue virus to Australia's southern populous cities, which would cause a considerable public health threat. The effects of climate change on the biology of pathogens and vectors are very complex. While climate change could increase the occurrence of some diseases, such as dengue fever, it could at the same time reduce the overall incidence of symptomatic disease in other instances (eg Ross River fever). At present there is great uncertainty as to what effect climate change will have on global vector and pathogen distribution, other than that change will occur. More research and surveillance is required to generate accurate and useful models.

Fortunately, most of the biosecurity risks from IFFV and climate change are currently minimised as most of the diseases of concern are very vector and host specific, and are likely to be introduced in remote locations with small human populations. This makes it unlikely that malaria and Japanese encephalitis will take hold in northern Australia. However, tourism is growing across northern Australia, increasing the risk of infection and of these diseases becoming established. Vigilance is of the upmost importance to make sure that this does not happen. However, government agencies, such as Customs and AQIS, do not have the resources to intercept all of the IFFV that approach Australia's northern coastline, or to completely monitor this area for the introduction of exotic diseases, pests and weeds. The coastal area most at risk is 75% Indigenous owned. Indigenous people in northern Australia know their land well, are vastly familiar with the flora and fauna found on their traditional lands, have detailed local knowledge of the tides, location of fish stocks, and are able to spot hidden IFFV along the coast in the complex river systems and dense mangroves. Indigenous communities are, therefore, ideally placed to monitor and reduce biosecurity risks in northern Australia. Therefore, a successful, integrated approach requires Indigenous communities to be centrally involved in biosecurity strategies in northern Australia. The most cost effective approach, therefore, would be to employ Indigenous Land and Sea Rangers. Payment at the same rate that Customs and AQIS employees receive, would formally acknowledge this important role, which Indigenous rangers have in helping to maintain Australia's biosecurity.

Acronyms and Abbreviations

AQIS	Australian Quarantine Inspection Service
CDEP	Community Development Employment Projects
CO ₂	carbon dioxide
DAFF	The Department of Agriculture, Fisheries and Forestry
DIMIA	The Department of Immigration, Multicultural and Indigenous Affairs
ENSO	El Niño-Southern Oscillation
IFF	illegal foreign fishers
IFFV	illegal foreign fishing vessels
IPCC	Intergovernmental Panel on Climate Change
NAQS	Northern Australia Quarantine Strategy
NPA	Northern Peninsula Area
NRM	natural resource management
PNG	Papua New Guinea
SRES	Standardised Reference Emission Scenario
TCAHQ	Tripartite Committee on Agricultural Health and Quarantine
WHO	World Health Organization

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