BIOSECURITY THREATS TO INDIGENOUS BIODIVERSITY IN NEW ZEALAND

An Analysis of Key Issues and Future Options

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GLOSSARY

Alien species	A species, sub-species, or lower taxon occurring outside of its natural range (past or present) and dispersal potential (i.e. outside the range it occupies naturally due to direct or indirect introduction or care by humans). (From IUCN Guidelines 2000[1].)
Alien invasive species	An alien species which becomes established in natural or semi-natural ecosystems or habitats, is an agent of change, and threatens native biological diversity.[2]
CBD	Convention on Biological Diversity
DOC	Department of Conservation
ERMA	Environment Risk Management Authority
GISP	Global Invasive Species Programme
HSNO Act	Hazardous Substances and New Organisms Act
ICES	International Council for the Exploration of the Seas
IGBP	International Geosphere – Biosphere Programme
IMO	International Maritime Organisation
Incursion	An occurrence of an organism not previously known to be established in New Zealand and does not include interceptions. (definition of the Biosecurity Technical Forum)
Interception	A detection of an organism in a transitional facility or a biosecurity control area, on or in risk goods. (definition Of the Biosecurity Technical Forum)
IPPC	International Plant Protection Convention
IUCN	World Conservation Union
MAF	Ministry of Agriculture and Forestry
MQS	Ministry of Agriculture and Forestry Quarantine Service
NIWA	National Institute of Water & Atmospheric Research
Semi-natural ecosystem	An ecosystem which has been altered by human actions, but which still retains significant native elements.[3]
SPREP	South Pacific Regional Environment Programme
SPS	Agreement on the Application of Sanitary and Phytosanitary Measures
WTO	World Trade Organisation

INTRODUCTION

"Introduced invasive species pose the single largest threat to the survival of many of New Zealand's threatened species and ecosystems. Better assessment and management of the biosecurity risks to native flora and fauna is needed if we are to arrest the current decline of New Zealands's unique biodiversity."

Department of Conservation Briefing to Biosecurity Minister , Dec. 1999[4]

People started bringing species from other countries into New Zealand hundreds of years ago, but in large numbers only after European colonisation in the nineteenth century. Many of these alien species have been beneficial, indeed essential to the development and prosperity of the nation. Unfortunately, numerous species have not. The detrimental introductions, or alien invasive species (see Glossary for definitions), have cost the country billions of dollars. A recent estimate[5] put the economic losses from pests, weeds and pathogens at $440 million and private and public sector pest control costs at $400 million annually. Excluded from this figure were intangible costs of pest damage to public conservation lands. Over-hunting, over-fishing and extensive destruction of habitats, coupled with the ongoing impacts of invasive species, have had devastating impacts on New Zealand's biodiversity.[6]

This paper looks briefly at the global situation as it influences our efforts to prevent further declines in our unique biological diversity.[7] It then examines current and emerging threats to biodiversity (excluding threats to primary production systems) from marine, plant and animal invasives. The paper also comments on current management practices and strategies, and then comments on system needs against future threats from invasive species.

1. SETTING THE SCENE – THE GLOBAL CONTEXT

1.1 Global Environmental Impacts

Alien invasive species have caused extinctions and degraded ecosystems on every major landmass and particularly on island countries. The flora and fauna of islands, after million of years of geographical isolation and speciation, often have lower competitive attributes than more aggressive plants and animals from continental areas. Island bird species, in particular, were woefully unprepared for the arrival of predators such as cats, rats, stoats, ferrets and foxes.[8] Thanks to human migration and commerce, the number of alien species that have established in new ranges "has increased by orders of magnitude in the past 500 years and especially in the past 200 years".[9]

Six years of international research into global change (Global Change and Terrestrial Ecosystems Project of the IGBP) came to the consensus that the main cause of future biodiversity loss at a global scale will be land change, mainly from habitat loss and fragmentation of landscapes. The next most important global factor that researchers identified was invasion by alien species.[10] Scientists expect alien invasives to have even greater impacts in the future, given (1) the globalisation of economies and, hence, the greater movements of people and materials; and (2) the susceptibility of disturbed ecosystems to invasive species.[11]

Given the extent and impacts of invasive species it is both surprising and alarming how little work has been done to estimate the costs of bioinvasions on economies at national and global levels.[12] Surprising, because the direct economic costs are substantial from losses to crops, forestry, fisheries, and grazing capacity. Alarming, because it indicates the low political and public understanding of inextricable links between nature and economies. A recent effort by United States ecologists to calculate the annual costs of all alien invasives in the United States concluded that invasive weeds cost US agriculture about $27 billion per year (10% of the potential crop value). The total costs to the USA of all non-indigenous species (plants, animals, microorganisms) were estimated at over $138 billion per year.

The fact that invasive species have caused hundreds of extinctions and reduced populations of many other species is well documented. One of the difficulties of getting a better political understanding of the significance of these impacts is the problem of clearly demonstrating the economic impacts and consequences of biodiversity loss. This is a critical area of work where more interaction between ecological and economic disciplines is needed. A start has been made,[13] but much still remains to be done.

1.2 Challenges for Invasives Research

A much better understanding of the economics of invasive species and more cost-benefit analyses when assessing species for importation have been called for.[14] One major review paper[15] has suggested that if a cost-benefit analysis had been applied to

many of the deliberately introduced invaders it would have clearly shown that costs would swamp any realised or perceived benefits.

While this is often true for known invasives, there are major difficulties in predicting which alien species will become invasive at a later time, and which will not. Efforts to identify general features of future invasive species have not been very successful. The epidemiology of invasions needs to be better understood as do invasive pathways. There is also a need to recognise and research microorganisms as important invasive species and examine their impacts on wildlife. Emerging infectious diseases are increasingly recognised as major causes of death in marine habitats,[16] in terrestrial communities,[17] and have been strongly linked to the alarming global declines of amphibian species.[18] The role of humans in unwittingly spreading wildlife diseases, including wildlife managers involved in re-introduction projects, needs far more research.[19]

Belatedly, international scientific initiatives are now underway that seek to better understand invasive problems and promote the application of appropriate responses. One initiative involving New Zealand scientists is the Global Invasive Species Programme (GISP). It is working to synthesise the existing knowledge base on invasive species (including their current status, ecology, human dimensions, impacts on global change, invasive pathways) and to develop new tools to deal with them (early warning systems, global databases, economics of invasives, risk analysis approaches, legal and institutional aspects, control and management, education).[20]

1.3 Global Political Initiatives

The limited understanding of the impacts of invasive species has inhibited policy development, slowed international political initiatives and limited proactive efforts to address the underlying causes of invasive species. Few countries have a legislative framework as comprehensive as New Zealand's for dealing with invasive species. If the global efforts were greater and more effective, however, then New Zealand would benefit in a number of ways.

First, there should be a more favourable political climate to address the tensions between 'free trade' practices and 'safe trade' proponents. Current WTO rules can make it difficult to exclude invasive species, ruling that such bans are unlawful or protectionist trade barriers.[21] Second, international cooperation to constrict pathways for 'hitchhiker' alien species at point of export should improve, as should agreements on pre-export inspections. Third, the development of smarter 'anti-invasive' technologies for moving goods and commodities around the globe would benefit considerably from international cooperation. This has particular relevance to problems with ballast water and shipping containers. Fourth, support for efforts to research invasive issues and share knowledge globally should be easier to obtain.

The current political climate in many countries means that most of the action against invasive species is reactive and concentrates on killing the most damaging invaders. "System management, rather than species management, ought to be the focus."[22] As long as the simplistic 'kill pests' approach persists in other countries the more

vulnerable they are likely to be to further invasives. When these are neighbouring countries, or our major trading partners, New Zealand's biosecurity is also more at risk.

Given the dominance of the USA in global trade it is encouraging to note the current initiatives underway at the US Federal level on invasive species. In February 1999, President Clinton signed Executive Order 13112 Invasive Species. The intent is "…to prevent the introduction of invasive species and provide for their control and to minimise the economic, ecological, and human health impacts that invasive species cause." The Executive Order establishes an Invasive Species Council,[23] charged with 'providing national leadership regarding invasive species' including the production of a National Invasive Species Management Plan. The membership of the Invasives Species Council goes well beyond the limited number of biosecurity interests currently on the New Zealand Biosecurity Council. The first draft of the Council's Management Plan was circulated for comment in mid-2000.

1.4 International Agreements

There are at least 16 international legal instruments with programmes or activities that are relevant to invasive species. In addition, there are about 25 regional conventions or treaties that include reference to invasives. Three of the regional treaties apply to the South Pacific.[24] Finally, there are several codes of conduct and guidelines (such as the IUCN Guidelines)[25] or resolutions from international organisations that address different invasive species issues. An example of the latter is the 1997 Assembly Resolution of the International Maritime Organisation that adopts guidelines on measures to reduce the spread of marine invasive organisms and pathogens.

These various instruments divide roughly into two groups. There are measures to prevent the opportunity for potentially invasive species to enter new ranges (quarantine), or efforts to limit the spread and impact of invasives once they are established in a new range. The key instruments relating to border control are the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS) and the International Plant Protection Convention (IPPC). Under the SPS members of the WTO can restrict movements of species that may pose a threat to human, animal, or plant life, but any such measures must be based on internationally agreed guidelines. The IPPC is concerned with quarantine against plant and plant product pests. The focus is on agricultural pests. These instruments will be discussed further in Section 2.2.

The main convention relating to limiting and managing invasives is the Convention on Biological Diversity (CBD). Article 8 promotes in-situ conservation of biological diversity and 8(h) calls on Parties to the Convention "…as far as possible and as appropriate" to "Prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species." The Secretariat of the CBD was requested at the 2000 meeting of the Parties to the Convention to look at "all options for future work on alien invasive species" to provide practical support to implement Article 8 (h).

Marine invasives are addressed by the UN Convention of the Law of the Sea (UNCLOS). Article 25 requires all Parties to take all measures to prevent, reduce and control intentional or accidental introductions of species "alien or new" which may cause significant harmful changes to the marine environment. It provides a legal basis for stronger inter-governmental action on the major problem of ballast water (see Section 2.6).

1.5 Regional Developments

New Zealand is a member of the South Pacific Regional Environment Programme (SPREP), the inter-governmental agency dealing with regional environmental issues. SPREP has recently developed a regional invasive species strategy. It identifies major shortfalls in technical capacity, inadequate quarantine and risk assessment, inadequate legislation, difficulties in accessing basic information, low public awareness. The strategy identifies needs in: information, awareness, infrastructure, protocols, legislation, funding and linkages. Such regional initiatives offer the opportunity to develop and coordinate programmes between neighbouring countries, improve management capacity and share information and research findings. Similar initiatives have been in place for many years to guard against potential pathogens and pests of agricultural crops, for example, keeping out fruit fly, but the risks to indigenous biodiversity have not been treated as seriously.

1.6 Opportunities

It has been stated that effective border control for New Zealand is the first line of defence against invasive species. There is a growing recognition that this is in fact the second line of defence, that more can and should be done to reduce the threats off-shore through a wide range of initiatives.[26] These could include initiatives to influence the rules whereby the WTO resolves environment-related trade disputes and the widening of quarantine and border controls to add biosecurity threats to agricultural and human health concerns. Unfortunately, recent amendments to the IPPC have been seen by some commentators as weakening the Convention's ability to take on the protection of native flora from trade related pests.

The Biodiversity Convention offers a range of opportunities to promote work on invasive species issues and raise political awareness of the nature and extent of the problems. Likewise, there are regional initiatives in the South Pacific at a number of levels that would improve regional awareness and response capacity which, in turn, assists New Zealand's interests.

2. OFF-SHORE THREATS – CURRENT AND EMERGING

2.1 Trading Patterns and Trade Growth

Since European colonisation, New Zealand has relied heavily on trade. Up until 1915, 90% of trade was with the United Kingdom and Australia. The percentage of trade with the United Kingdom started declining in the 1950s and today the UK receives about 10% of New Zealand's total exports. New Zealand now trades with a far wider range of countries and with much larger volumes of goods and commodities. The diversification has been with other European countries, Japan, other Asian countries and members of the Asian Pacific Economic Co-operation Group (APEC) which includes the USA, Canada and Chile. More than half of New Zealand's overseas trade is now with Australia and Asia.[27] Since unintentional introductions ('hitchhikers') arrive in association with traded commodities or visitors, new trading initiatives also create new opportunities and new pathways for alien and invasive species.

A case in point is the current Government initiative to increase markets with Chile, a country (and region) with traditionally low trading volumes with New Zealand. Expanded trade with Chile may, for example, increase the risk of arrival of temperate forest pathogens and insect pests of beech species (Genus *Nothofagus).*[28] New Zealand is linked biogeographically with Australia, South America and Africa and these countries are the most likely source of insect pest threats and devastating pathogens. Fortunately, there are no records of invasion of temperate forest pathogens and forest pests between the Northern and Southern Hemispheres because of the distinctive floristic histories and biogeography of the northern and southern continents.

Trade volumes have been rising steadily for our major ports for a number of years. These volumes are increasing faster than the rate of increase in expenditure for port and airport quarantine, surveillance and monitoring operations. Consequently, inspections at entry points inevitably decline as a percentage of total imports, although targeting of 'high risk' goods may be increased following risk analysis studies. Recent social and infrastructure breakdowns in the Solomon Islands will have disrupted their quarantine systems and increased their biosecurity risks, both internally and within the region.

2.2 Trade Rules

There is a tension between free trade laws and countries wishing to tighten their quarantine regulations. The formation of the World Trade Organisation in 1995 had, as a fundamental principle, the dismantling of tariffs by WTO members. It is a concern within the WTO that countries will use their quarantine laws as surrogate tariffs to protect uncompetitive industries. For example, a country wanting to protect its flower industry could ban imported flowers by exaggerating the pest risks on flower imports. The mechanism used to prevent this is the WTO's Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement). These

measures must be based on international standards, guidelines or recommendations. Members of the WTO may set higher levels of protection 'if there is scientific justification' but at the same time they are required to 'take into account the objective of minimising negative trade effects'.

This is often seen as erring on the side of trade, not on the side of caution, or the precautionary principle as it seen by those interested in the threat of invasive species. Frequently, it would seem, environmental concerns clash with politico-economic interests.[29]

Some commentators suggest the WTO operates on the reverse of the precautionary principle with respect to potential invasive species. Trade must be allowed to continue until comprehensive scientific evidence of risk indicates otherwise. As was indicated in Section 1.2 this can be very difficult to justify, given the unpredictable behaviour of so many species in new ranges.[30] A precautionary approach to risk assessment means that there are likely to be many "false positives" identified as potential invasives. Therefore to counter the pressures for liberal movements of plants and animals the predictive power of any risk assessment needs to be very high.[31]

2.3 Exotic Arrivals via Visitors

When New Zealand achieved new highs of 1.7 million visitors per annum there was no related media coverage of the 'hitchhikers' some of these visitors may be inadvertently bringing into the country as well. Clothing and luggage of air passengers is a recognised pathway for new pests and fungi. In December 1981, 45 tents belonging to air passengers were thoroughly examined.[32] Live insects were found in six tents (13%) along with plant and animal debris. It was concluded that this posed "a major risk", especially given the likelihood that travelling owners of tents will camp in national parks or other indigenous forest areas. Another study showed there was a high probability of visitors bringing pathogenic fungi into New Zealand on their clothing that threatened forests and agricultural crops.[33]

Promoting our 'clean green' values and outdoor pursuits carries with it the threat that 'eco-tourism' visitors, a fast-growing international market, will be arriving from a wide range of destinations and may head into locations that are perceived as remote, but are easily accessed by air or sea. Off-shore islands are also important places to protect from inadvertent 'hitchhikers' and various codes of practice are in place to reduce such threats. The likelihood of un-authorised landings and accidental releases remains a threat for some of these islands. (Islands already face problems with invasives – see Section 5.1.4)

With the establishment of the Hazardous Substances and New Organisms Act (HSNO) the legal pathways for importing new organisms has been changed significantly. One area of 'exotic arrivals' that New Zealand should now have under better control than many other countries is the importation of pets. This should make it much more difficult to import animals such as chinchillas. This rodent is native to arid areas of the Andes, farmed for its fur, and currently sold in New Zealand as expensive pets. The successful application to import chinchillas to New Zealand, in pre-HSNO days, was vigorously opposed by various groups, including the New

Zealand Ecological Society, because of the potential for them to become established in the dry high country of the South Island.

While there is currently no evidence chinchillas have become established in the wild, the possibility remains. Releases of pets by owners, like the release or escape of farmed goats, deer, ferrets and other animals have often created populations of invasive species. This continues to be a significant problem in New Zealand (see Section 6). Many species of aquarium fish have ended up in the wild in the USA.[34] The threat remains that people attempt to smuggle in exotic species for pets (including fish species) or for breeding purposes and by-pass the expensive legal process of making an application under the HSNO Act requirements.

2.4 Convenient Containers

While global volumes of trade have been growing at significant rates, the growth in the use of shipping containers has been growing even faster. Containers have revolutionised the freight industry in the past 20 years and introduced qualitatively new pathways for alien and invasive species. Containers are now known to be significant pathways for insects, snails, slugs and seeds of weeds. Since containers keep moving around the world they create new and complex pathways between ports and freight operators linking developing and developed countries. With shorter travel times between counties the chances of pests surviving the voyage are increased.

Containers are rarely cleaned between shipments, can be stored for weeks at places where pests can enter and, most significantly, can be unloaded from a ship and railed to a distant destination before they are opened for unpacking or inspection. This simple and significant freighting advantage means that containers have integrated sea and land transport. "They have broken the old link between shipborne exotic and portside invasion."[35]

By their nature they are difficult to inspect inside when full, and it is time consuming to thoroughly inspect the outsides. Consequently, only a small percentage of the approximately 360,000 containers that arrive annually in New Zealand are inspected.

2.5 Aliens are Coming

The 'global village' of mass media now has its counterpart in the global village of commodity and species exchanges. Trade and global tourism have enormously lowered the barriers to movements that existed for millenia but have eroded substantially in the past 50 years. As a consequence, the speed and extent of the spread of invasive species is still not widely appreciated. For example, the well-known Rabbit Haemorrhagic Disease (RHD) was first reported from China in 1984. In six years, aided by the trade in domestic rabbits, it had spread throughout all of Europe and within another four years it had spread to 41 countries on four continents, all without deliberate human assistance.

The sum of these unprecedented movements of plants, animals and pathogens is that, as well as many arriving in New Zealand, many more have also moved to countries from which they are now more likely to be transported to New Zealand. Global movements of invasives need not be simple one-step movements from host country to a new destination. An invasive may become established in a new country from which it spreads to several others, depending on trade patterns. So the threats to New Zealand's biodiversity rise whenever alien species establish in places that increase the likelihood they may be transported here in due course. A number of potential marine invaders, now established in Australia, are clearly in this category (see Section 4).

2.6 Dirty Water and Fouled Ships

For hundreds of years, wooden-hulled sailing ships supported diverse fouling communities of seaweeds, barnacles, fish, shrimps, crabs, boring molluscs and shipworms. These were transported to harbours around the world and marked the beginning of a pathway for invasives that has grown much larger and more costly in recent decades. Hull-fouling communities are now much less, thanks to metal hulls, anti-fouling paints and faster ship speeds. But as hull fouling reduced there was a switch from the use of solid ballast to water ballast tanks. Ballast, solid or liquid, is used to keep a ship upright. Large ships, such as modern tankers, can have a ballast capacity greater than 200,000 cubic metres. Ballasting is generally done around harbours, in shallow waters, and the powerful pumps can suck in large amounts of marine sediment along with marine plants and animals.

The sheer volume of ballast water in transit and that is being pumped in and out of ships is hard to comprehend. *Every minute*, 40,000 gallons of foreign ballast water is dumped into US harbours.[36] This comes from a fraction of the world's merchant fleets of over 28,700 vessels that move about 80% of the world's traded commodities. This trade doubled between 1970 and 1996, and continues to grow.[37] This fleet has, through its ballast water cargoes, set up unnatural meta-currents that are continually moving perhaps 3,000 species between harbours and coastal waters.[38]

Ballast water has spread some of the world's worst aquatic invaders. The Leidy's comb jelly, a jellyfish smaller than your thumb, is native to the eastern coasts of the Americas. It was pumped out as ballast water into the Black Sea about 1982. Within only six years it had eaten out the zooplankton of the Black Sea and the rest of the food chain that ultimately depended on the zooplankton has collapsed completely. The equally small zebra mussel, *Dreissena polymorpha*, originally from the Caspian Sea region, arrived in the American Great Lakes system around 1986 in ballast water. It has been disastrous for biodiversity (eating algae, disrupting the food chain, and out-competing dozens of native mussel species) and hugely costly for industry with its ability to block intake pipes and other equipment. Cumulative costs probably exceed $3 billion so far and the zebra mussel continues to spread in the US and southern Canada, mostly by hitchhiking on boating equipment.

2.7 Global Change and Invasives

The overwhelming consensus of international science is that significant global changes are occurring as a result of human activities. Major drivers that have been identified are land use, climate change, invasive species, higher levels of carbon dioxide and increases in nitrogen deposition. These changes are inter-related and influence and are influenced by each other, often in unpredictable ways.

High public interest and considerable research effort has gone into climate change. Given that many invasive species are opportunistic 'pioneer' species it is likely that they will have more opportunities to thrive under changing climatic conditions. Changes in moisture, temperature, and seasonality can create new habitats and thereby 'move the goalposts' for the relationships between species. These could have dramatic, but unpredictable consequences. For example, mild winters could lead to early blooming before pollinators are present in their usual numbers. Disruptions to local species could increase the opportunities for generalist invasive species.
Warmer climate improves conditions for infectious diseases and disease vectors. In these conditions cholera, malaria, and yellow fever are likely to spread.[39] Diseases of wildlife, including bird species may also increase, although the implications for New Zealand biodiversity have not been investigated.

Weeds are likely to benefit from higher levels of carbon dioxide and from extra nitrogen. Some weeds absorb carbon at higher rates than do slower growing natives. Also, longer growing seasons in temperate regions would enable many introduced plants that are currently limited to asexual spread to flower and set seed as well.[40] Sexual reproduction allows plants to adapt more rapidly and achieve greater dispersal power by producing seeds. Extra nitrogen, from industrial pollution, automobile emissions and agricultural fertilizers, returns to earth and is taken up by plants. Where this occurs in naturally nutrient-poor soils, extra nitrogen accelerates the spread of fast growing grasses and other species. Elevated levels of nitrogen deposition are implicated in the bio-invasions of grassland ecosystems in Central Europe and California.[41]

Finally, climate change is also predicted to increase the frequency of severe climatic events, including storms, hurricanes, floods and droughts. Severe droughts stress natural communities as well as agricultural systems. When the outcome is land degradation, conditions favour opportunistic species, which are often alien species.

2.8 Pathogens and Diseases

The threat of diseases has been mentioned in relation to growing concerns about the fate of certain groups of animals (Section 1.2) and how climate change also favours the spread of infectious diseases. A risk that emerged centuries ago is the spread of diseases through trade and human migration. The current volume of trade and tourism has expanded the possibilities considerably. A well known current example, certainly with relevance to New Zealand, is the rapid global spread of the Asian tiger mosquito. This did not occur until the mid-1980s, when it rode the world in container loads of used tyres, a little water sustaining the insect on the voyages. In less than two decades the Asian tiger mosquito, which carries at least 18 viral diseases, including the painful

and fatal dengue fever, was established in the south-eastern USA, Brazil, southern Europe, Nigeria, South Africa, Australia and New Zealand.

Plant virus diseases appear to be proliferating at ever increasing rates.[42] While the current concerns are with the impacts on agricultural crops, the flexibility of emerging viruses gives good grounds for concern about the potential impacts on indigenous biodiversity. There are three parts to these diseases- the plant host, an arthropod vector, and the plant virus itself. Humans have knowingly and unknowingly been manipulating all three via: misuse of antibiotics leading to development of bacteria with multiple resistance; overuse of pesticides leading to increases of resistant vectors; germplasm collecting expeditions; international movements of plant material.

2.9 Natural Arrivals

Plants and animals have been arriving in New Zealand, without human assistance, for millions of years. Indeed, many of these arrivals have become what we now regard as valuable species in our indigenous flora and fauna. Therefore, it can questionable if these arrivals should be discussed in the context of invasive species. Indeed, using the international definitions of alien and invasive species (see Glossary) it would seem that natural arrivals should not be included in this discussion.

There is a case, however, for including the category as it applies to the natural arrival in New Zealand of species that are clearly invasives in neighbouring countries. The main source of 'naturally arriving invasives' in New Zealand will be Australia. In many cases it may be very difficult to tell if an invasive arthropod blew here across the Tasman Sea or crawled out of a shipment of old railway sleepers. The main point is that as more and more alien and invasive species establish in this region, the higher the chances that some of the more mobile ones will arrive naturally and establish in New Zealand. Such arrivals are more likely to go undetected for longer as they unlikely to be landing at the usual arrival points for hitchhiker species.

3. LEAKY BORDERS

This section of the report will look briefly at some issues that influence the ability of the biosecurity system to detect and intercept threats to our biodiversity at New Zealand's borders. While the definition of 'border' literally means the 'boundary' or 'frontier of a country' this was a more accurate definition in the days of sailing ships than it is today. The 'border' can now mean an inland airport receiving international flights or the place where a 'risk' container is opened, which may be many kilometers from its port of arrival.

Part of the problem with leaky borders is therefore the public perception that the detection, interception and destruction of unwanted arrivals are only focused on our major ports and coastal international airports. Indeed, these are the major focus of the efforts of the MAF Quarantine Service (MQS), which is appropriate. The inadequate budget available for MQS for inform the public of biosecurity risks means, however, that the border zone is very 'thin'. Far too little is spent on a key border issue: "Awareness on the part of every New Zealander of the need to report suspicious pests, disease or species is critical." (MQS overhead).

3.1 Entry Points

The entry points with the largest volumes of goods and people are the Port of Auckland facilities and Auckland International Airport. While there is considerable effort put into quarantine and detection efforts at these places there are inevitable breeches. The white-spotted tussock moth (*Orgyia thyellina*), the painted apple moth (*Teia anartoides*) and Varroa bee mite (*Varroa jacobsoni*) all appeared in Auckland suburbs within the past 5 years. Unusual insects, arriving as hitchhikers, are more likely to be noticed and reported by observant Auckland residents than are unusual plants or pathogens. Marine invasives are far less likely to be spotted quickly, although the consequences of delays in their detection almost guarantee they will be able to spread unchecked if they can establish a breeding population (see Section 4).

The concern is whether the MQS operations are as skilled as picking up hitchhikers, contaminants and biosecurity risk goods that are potential threats to indigenous biodiversity as they with identifying the more traditional biosecurity threats to primary industries. Given that the 'zero risk' option is officially regarded as impractical in most situations and has been replaced by a risk analysis process, there is a major onus on getting the risk analysis right for indigenous as well as productive ecosystems.

Despite the history and inevitability of incursions of invasive species at major arrival points (such as Auckland and Tauranga) there seems to be no extra effort to raise the awareness of the populations living within a certain radius of these places about invasive threats. There would seem to be important roles they might play in assisting the more formal surveillance systems that are in place.

3.2 Genetic Variants

Of the 20,000-plus alien plants now growing in New Zealand, the majority of these are beneficial or neutral in their impacts on indigenous ecosystems. One subtle problem regarding border control for plants concerns the arrival (whether deliberate or accidental) of genetic variants of alien species already established here.

A study commissioned by the Department of Conservation[43] to assess the risk to indigenous biota from new plant species and genetic material concluded that the importation of novel genetic material of a species that is already in New Zealand will increase the chances of that species becoming invasive. "In some cases, this potential is well known, e.g. willow (*Salix*) species, while in others the actual problem is unknown." This problem arises because many alien plant species came from only a few founder individuals from only part of the species' home range. A few studies have shown that adding to that limited genetic variability increases the ability of some plants to cope better with the new environment and become invasive, or even more invasive than previously.[44]

The border problems are obviously very difficult with respect to this issue. In addition, trade protocols would require that any efforts to prohibit imports of species already in New Zealand, but not subject to an official control programme, were closely examined and scientifically justified.

3.3 Containing Hitchhikers

The current border inspection process by MQS is superior to that of most other countries and leads to the seizure of many thousands of risk goods per year. MQS staff also detect pests and contaminants on items of cargo, such as used vehicles, timber shipments, and on the outside and inside of shipping containers. It is containers that are a growing concern, given the ideal conditions they offer for a wide range of invasive hitchhikers from slugs to insects and snakes. The increasing numbers of containers being processed through New Zealand ports (approximately 360,000 per year are landed) means that current resources and inspection techniques only allow for the inspection of a small percentage of the total number arriving here, even though the total number inspected is impressive.

What percentage of this total has plant or animal material that is a 'risk' and should have quarantine treatment? More research is needed, but one recent study looked at this question with respect to risks to New Zealand forestry of contaminants on the external surfaces of shipping containers.[45] Of the 3681 containers examined 23% carried quarantinable contaminants, but the rate varied widely between regions. The lowest rates were for containers from Korea, Taiwan and Japan (13.7%), rising to 28.3% for Australia, 33.2% for south-east Asia, 47.5% for the Pacific Islands and 50% for South Africa. Soil stuck to the bottom of containers was the major source of contaminants, such as fungi and nematodes. The study concluded "the nature and frequency of occurrence of contaminants on the external surfaces of shipping containers represents a risk to forestry in New Zealand." To this must be added the hitchhiker species which travel *inside* containers.

Some containers are classified as "high risk" based on ports of origin or contents and a higher percentage of these are inspected either at the port or at the point of final opening and unloading. A question with respect to biodiversity threats is how many high risk containers are slipping through the inspection regime that may, nonetheless, be carrying invasive hitchhikers – either inside or outside? It is obviously difficult to estimate the number accurately, since this requires information of the percentage of 'missed', but contaminated containers. Studies by Forest Research Institute (FRI) scientists have looked at internal inspections of high risk containers. These suggest the number of containers with *internal* items of forest quarantine significance that slip through the system could be in the order of 2,000 to 6,000 per year.

How many contaminated containers does it take to result in the successful establishment of a new pest or disease? FRI scientists have discovered about 0.6 new pests that could have entered New Zealand in containerised sea cargo per year over the last 20 years. Using 4,000 as a rough average for the number of contaminated containers that slip through annually means it takes about 4,000/0.6, or 6,700 internally contaminated containers to result in one successful pest establishment. Obviously this is a rough estimate. To this figure must be added additional pests arriving and possibly establishing from external surfaces of containers, air cargo containers and imported used cars. These calculations also only apply for the forestry sector.

3.4 Bio-terrorism or Biological Bullets?

The person or persons who illegally brought Rabbit Haemorrhagic Disease (RHD) into New Zealand would not have seen themselves as bio-terrorists. Presumably, they saw their action as helping solve the rabbit problem by introducing a 'biological silver bullet' to do the job when conventional means had failed. The Biosecurity Council subsequently carried out a review of the lessons to be learned from the RHD experience for the introduction of new organisms.[46] One of the lessons was the real difficulty of planning for covert behaviour and non-cooperation from the public. What are the implications for biosecurity and border control? As one senior Government official dryly remarked during the RHD inquiry, "Border control of microbes is exceedingly difficult".

While the scenario may seem far-fetched, and the possibilities very low, there is a need to consider bio-terrorism as a potential threat to indigenous biodiversity. As with RHD, however, any bio-terrorism might more likely target primary production systems rather than indigenous ecosystems. Federal agencies in the United States are now considering the vulnerability of agricultural crops and animals to various terrorist and bio-warfare attacks. The vulnerability of crops to plant diseases in this context was the focus of a 1999 Symposium of the American and Canadian Phytopathological Societies.[47] One relevant point made was that an attack with plant or animal diseases of limited success in biological terms could have major trade impacts from bans that might be imposed subsequently. Fungi have been identified and tested as biological control agents against Asian opium poppies and the South American coca shrub (from which cocaine is produced) by some countries for use in other countries. Plant

pathologists and others have warned of major ecological risks associated with these two proposals which have also been described as 'biological warfare'.

Closer to home, and of less international concern, was the report[48] of the mysterious arrival of the parasitoid *Psyllaephagus gemitus* which is highly specific to an invasive defoliator of two Eucalyptus species, *Eucalyptus saligna* and *E. botryoides*. The defoliator is the brown lace lerp (*Cardiaspina fiscella*), first discovered near Auckland Airport in May 1996. It spread rapidly, and now occurs from Whangarei in the north, to Rotorua in the south, and east to Gisborne. *P. gemitus* was investigated as a possible biological control agent for the lerp and Australian research, funded from New Zealand, concluded it would probably be specific and effective.

An application was made to ERMA for permission to import the parasitoid into containment for safety testing. Approval with strict controls was granted by ERMA in May 1999. There was strong feeling in the farm forestry sector about the perceived slowness, lack of funding, and costs of the host testing process. Then in November 1999, the parasitoid was found attacking brown lace lerp in Auckland and Northland. The approval to import for testing was never followed up. Scientists are puzzled as to how the highly specific parasitoid got here. It may have arrived in a second timely incursion of the lace lerp, but there is also the possibility of a deliberate introduction by frustrated farm foresters who perceived major costs and long delays while trees continued to be defoliated. The parasitoid is reducing populations of the brown lace lerp and tree recovery is noticeable, however, any impacts on native psyllids remain to be assessed.

3.5 People Behaving Badly

The perception that the costs associated with obtaining approval from ERMA to import new organisms are too high is not limited to the above example of *P. gemitus*. Since the passage of the HSNO Act and the establishment of ERMA there has been about three applications to bring in new plant species in two years. This was a dramatic change from the large annual inflow of new species that was previously taking place.

It seems most unlikely that New Zealanders have suddenly lost interest in importing novel plants coincidental with the passage of the HSNO Act. Evidence from MQS is that smuggling of plant seeds or viable plant fragments is certainly taking place. This in turn has increased the costs and efforts devoted to screening all international mail and packages to cut down the importation of new plant species. While hundreds of interceptions are made, the problems of detecting small seeds which are smuggled or declared as a 'safe' species mean that an unknown percentage are getting through.

The ERMA New Zealand is currently looking at ways to reduce the costs to the applicant for new plant introductions, at least for those where the risks are deemed to be acceptable. However, unless these costs are extremely low, which seems unlikely, then the outcome will probably be a continuation of smuggling and unknown risks for biodiversity. This raises basic questions about the rationale for the funding regimes for biosecurity activities. The present emphasis on 'user pays' in the ERMA context

will continue to provide an incentive for smuggling of plants, regardless of the illegality of such actions.

The attitudes of visitors to New Zealand regarding the threats we face from invasives are another potential source of undesirable arrivals. Many visitors come from countries where the concept of “invasive’ plants and animals are largely unknown and it is common practice to travel with food or even animals. Such practices are not acceptable in New Zealand. The MAF “Primary Source” newsletter of July 2000 mentions a passenger arriving at Auckland Airport who was attempting to smuggle in a live Giant African Snail, allegedly for a gourmet meal. Or the 14-year old passenger from China with two live freshwater fish in his hand luggage. Given the huge volume of trade in exotic pets into Asian counties, it is not surprising that such interceptions occur. This raises a number of issues about how to best influence such behaviours and where these responsibilities should fall.

4 MARINE INVASIVES

4.1 Current Biosecurity Threats and Pathways

The lives of marine animals and the diversity of marine ecosystems below sea-level are largely invisible to us. Consequently their values and the risks they face from human impacts and invasive species are harder to measure and appreciate. Unfortunately, this ignorance and indifference has translated into a much lower level of biosecurity for our marine environment than has been the case for terrestrial species. In reality, the same unique features that apply to terrestrial ecosystems on islands also apply to marine systems. They tend to have more unique or endemic species than continental coastal areas and are often vulnerable to invasives.

A good, if unfortunate example of this is the invasive Asian kelp, *Undaria pinnatifida*. This aggressive kelp arrived in the 1980s and may be seriously affecting New Zealand's coastal ecosystems.[49] It is a highly opportunistic annual, unlike all the large New Zealand kelps which are perennials and far less competitive at pre-empting available space.[50]

Many marine coastal species are sedentary and their spores and larvae do not survive long voyages on ocean currents. Consequently, there are major differences between New Zealand's coastal marine systems and the closest shoreline with identical temperature regimes, which is Tasmania. At a larger scale, the warm tropical waters of the Pacific are an effective barrier between the Northern and Southern Hemisphere marine communities. And at the small-scale, comparisons of marine life within New Zealand reveal considerable differences between regions. Small islands can have low species diversity and a number of unique marine species, just like their terrestrial ecosystems.

4.1.1 Hull fouling – the first pathway

As mentioned in Section 2.6, hull fouling was the first major pathway for marine invasive species. When, in 1769, Captain James Cook cleaned the hull of the Endeavour in Ship Cove, Queen Charlotte Sound, he may have introduced the first fouling organisms to New Zealand. Many have certainly arrived since. Of the 130 species that are thought to have been introduced and now established in our waters 69% arrived as fouling organisms on the hulls of vessels and floating structures (e.g. oil rigs).[51] Most of these were introduced by shipping in the early decades of the 1900s. Modern fast cargo ships have very little external fouling.

Only about 3% of these species probably arrived in ballast water, but another 21% may have arrived via either route – as fouling organisms or from ballast water. In general, the most important pathway, particularly for future threats, is probably from ballast water (see 4.1.2). but hull fouling is still an important biosecurity threat, including the fouling of floating structures. Barges, oil and gas drilling platforms are potential threats. Oil rig platforms and clip-on side structures floated here from Asia during the 1970s for extensions to Auckland's harbour bridge are responsible for introducing some of New Zealand's conspicuous fouling organisms.[52]

Also since the 1970s, a significant proportion of New Zealand fishing companies have chartered foreign fishing vessels. During the long periods they are tied up in foreign ports before coming here they accumulate a considerable community of fouling organisms. Before use, they are often cleaned in New Zealand harbours. In 1994, a heavily fouled Russian super trawler was cleaned in Calliope Dock in Auckland and 90 tonnes of fouling material was removed that originated mostly from the Black Sea.[53] The scare raised by Cawthron Institute scientists with this particular incident led to the NZ Fishing Industry Association recognising that some overseas fishing vessels operating in New Zealand waters are a significant biosecurity threat. The industry subsequently adopted a voluntary Code of Practice.[54] Given the large number of marine invaders now established in the Black Sea these concerns would seem to be well justified.

While the focus has moved to ballast water problems, hull-fouling remains an important issue and significant biosecurity threat to coastal marine ecosystems. One concern is the arrival of heavily fouled vessels arriving for cleaning, the second concern is brief visits by vessels with heavily fouled hulls. These will not be notified and animals and plants attached to the hull can release larvae or spores that colonise structures such as wharf pilings. A third concern identified recently by NIWA scientists is the particular risks from ocean-going pleasure craft. These vessels are usually slower than large cargo vessels, may spend longer in a wide variety of ports, and have a more variable history of antifouling treatment. Also, the hulls of these vessels are often cleaned at anchor, adding to the risks of leaving exotic organisms behind. Current risks from hull fouling have not been quantified, but it should be a priority to do so.

4.1.2 Ballast water – the widening pathway

Ballast water introductions in New Zealand are increasing and correlate closely with changing trade patterns and modernisation of cargo ships. Trade with the United Kingdom dropped off in the 1960s. Trade diversification followed, especially with Japan, other parts of Asia, the USA and Canada. These new trade routes marked a notable increase in foreign marine species that established in our waters from Japan, other parts of the northern Pacific and Asia. Before 1960, less than 2% of New Zealand's foreign marine species were thought to have arrived from Japan and other northern Pacific countries; after 1960, about 38% of new introductions came from this region.[55]

An unknown percentage of alien marine species have become invasive in harbours and around our coastlines. This percentage is probably not high, but the most significant invasives potentially threaten unique New Zealand marine ecosystems. To a significant extent we are ignorant of the full complement of accidental marine introductions and their impacts in New Zealand waters.

There are also threats to the steadily developing marine farming industry, which is worth about $NZ 150 million annually. Ships from 'dirty' harbours such as Hong Kong are potential carriers of new pests and diseases such as blooms of toxic dinoflagellates and other damaging marine micro-organisms. Toxic algal blooms were

first noticed in New Zealand in 1993. Some argued that these tiny algae had been here, but undetected, for years. Others said ballast water discharges were responsible.

A 1997 Royal Society publication[56] described the toxic phytoplankton *Gymnodinium catenatum* that causes paralytic shellfish poisoning. It arrived in eastern Tasmanian ports from Japanese and Korean woodchip ships when they discharged their ballast water before taking on wood chips. The publication concluded by saying "…microalgae do survive in the [ballast water] tanks and the risk of new introductions, e.g. *G. catenatum*, is always a possibility." By August 2000, this phytoplankton, *G. catenatum*, had clearly arrived, somehow, in the Manukau Harbour, and was responsible for a ban on harvesting shellfish along the whole west coast of the North Island. The turbulent waters of Cook Strait failed to act as a barrier and the phytoplankton was detected in South Island waters by mid-September 2000, thereby putting the mussel farms of the Marlborough Sounds (which represent 80% of NZ production) at risk.

The ports most at risk from ballast water discharges are those where vessels arrive heavily ballasted, then discharge in the harbour while taking on large volume products like logs or wood chips. Bulk carrier ports such as Tauranga and Taharoa receive a disproportionate amount of the 5-6 million tons of ballast water discharged here each year. By comparison, the 1994 discharges in Australian ports were estimated at 121 million tons, six times the New Zealand volumes. A more recent estimate put the volume at 150 million tons, a greater volume than the Sydney Harbour. About 70% of these ballast waters with their floating communities originated in Asian ports.[57]

Volumes are not directly related to biosecurity threats however. The diversity of places of origin of ballast water may well be more important than the volume. Tasmania receives only 1% of the Australia's total ballast water, but has suffered enormously from invasive kelp, starfish and toxic dinoflagellates, presumably because it has sea temperatures that match those of Japan[58] and, coincidentally, those of New Zealand. Given the enormous reproductive potential of many species the amount of water needed to introduce a critical number of larvae, spores or individuals, may be quite small. More important factors may be suitable substrate, absence of predators, favourable temperatures, nutrient and light regimes, and the health and vigour of the species concerned.[59]

4.1.3 Degrading Marine Systems

Many of these 'important factors', such as availability of substrate, absence of predators, favourable nutrient and light regimes are more in evidence as marine ecosystems are degraded. Unfortunately there has been significant degradation of our coastal marine ecosystems in just those places where the bulk of alien species are most likely to arrive – in our major ports and harbours. The 1997 report on the New Zealand environment[60] catalogued elevated nutrients, sediment run-off, contamination and debris from urban stormwater, the latter a particular problem in Auckland's estuaries. About half of Auckland's 3,500 hectares of coastal sediment have excessive concentrations of lead, zinc and copper with high levels of contamination in shellfish and crustaceans. These heavy metal contaminants come mostly from motor vehicles. Oil spills, bottom dredging, non-biodegradable litter, the ocean dumping of fish

wastes (50,000 tons of hoki offal are dumped annually off the West Coast) add further stresses to our marine ecosystems.

Bottom dredging and trawling could well be the most serious of this last group of factors that degrade marine ecosystems. A lot of dredging and trawling occurs in soft-sediment habitats in coastal waters. NIWA studies are showing that these activities, as well as directly killing marine life, reduce the complexity of, and simplify the seafloor. Much of this seafloor complexity in these habitats is provided by the immobile organisms that grow up into the water (such as sponges, black corals, bryozoans) or burrow into the sediment (worms, shrimps, clams).

4.2 Potential Threats

The most significant threats are the serious marine invasives now in Australia that have yet to arrive, or be discovered, in New Zealand waters. These include the northern Pacific seastar (*Asterias amurensis*) from Japan a large, predatory starfish of bivalves such as mussels, first noticed in the estuary of Hobart, Tasmania, in 1985. Back in 1954 it caused a loss of approximately $NZ6 million to the shellfish industry of Tokyo Bay.[61] If it arrived in New Zealand it could only be eradicated if individuals were detected and destroyed before the start of the breeding season when a single large ripe female *Asterias* can produce up to 15 million eggs. The European green (or shore) crab (*Carcinus maenas*) another voracious predator of native species and now in Australia, is regarded as a likely arrival at some time.

These are just two of the more than 50 invasive plants and animals in Australian harbours and coastal waters, courtesy of ballast water. Port Phillip Bay in Melbourne has 145 recorded alien species. A 1997 Cawthron Institute study listed listed 32 species that are invasive elsewhere, would have significant impacts here, but have not been reported from New Zealand waters.[62] One of the 32 species Cawthron listed was *G. catenatum,* which is now clearly established in the North Island, and threatens the South Island.

There are more distant threats. New Zealand has, so far, been spared the damage caused by the zebra mussel, a fresh water species (see Section 2.6). While our harbours are regarded as too salty for the mussel to survive, its recent arrival in Ireland has interested scientists and probably alarmed biosecurity authorities. The mussels were thought to have arrived there on the hulls of private boats and barges imported on trailers. Live zebra mussels have also been reported arriving in Germany, at densities of up to 53,00 mussels per square metre, on the hulls of ships coming from the US Great Lakes – an 8-10 day journey.[63] The zebra mussel is now in the headwaters of river systems on the Pacific side of the Rocky Mountains. As it continues to spread west, the chances of it establishing close in western ports, and being carried to New Zealand or Asian ports, increases. On the US Pacific coast the waters of San Francisco Bay are dominated by over 200 alien species. Since 1970, new species have been accumulating there at the rate of one every 24 weeks.[64]

The increasing volume of trade generally, as well as trade expansions with South American countries, will open up new opportunities for temperate water species to be transferred to New Zealand ports. Linked to this is the threat of diseases, which may

arrive via ballast water or in foreign fish and fish products. The Australian Quarantine and Inspection Service has listed 148 pathogens that could arrive in ballast, including cholera and some devastating fish diseases.[65] In 1991, ships from South Asia are thought to have discharged cholera bacteria in Peruvian ports. The resulting epidemic, the first in the hemisphere for over a century, killed thousands of people.[66] Subsequently, ships outbound from South America have had cholera detected in their ballast water in Australian and USA ports. Despite the chilling nature of these examples, and the obvious threats to human health, very little effort has gone into estimating the diversity of microbes present in ballast water. What then happens to micro-organisms that are discharged from ballast tanks is unknown.

The growing number of pleasure ocean-going vessels visiting New Zealand waters constitute a biosecurity threat that may well be underestimated at present (see 4.1.1). While vessels normally cruising tropical waters are less likely to be a problem, the larger and faster vessels arriving from temperate waters may be a concern, both with respect to hull fouling organisms and the discharge of ballast water. A similar threat is the potential for more ship owners to undertake hull cleaning in New Zealand to take advantage of our lower costs. Some ports permit scuba divers to clean ship hulls while the ships are in harbour, creating a potentially important quarantine issue.

Creating new points for international trade need to factor in a risk analysis of the biosecurity threats involved. The new port at Shakespeare Bay in the Queen Charlotte Sounds could significantly increase the risk of arrival and establishment of alien species, especially the toxic dinoflagellates that threaten shellfish industries. It will be handling bulk carrier vessels with large ballast tanks. As well as threats to shellfish industries there are also high conservation values in Queen Charlotte Sounds.

To limit the spread of animal diseases on land, such as bovine tuberculosis, it is common practice to put bans on the movement of stock from diseased areas. The problem is more complex in the marine environment, but at present internal quarantine requirements are inadequate regarding the movement of vessels trading between New Zealand's 16 domestic shipping ports. There is no current standard for hull fouling or discharge of ballast in New Zealand waters that was loaded in another New Zealand port. Nor are there even voluntary requirements on vessel operators regarding ballast water exchanges around New Zealand coasts. Given that some high-risk species can disperse hundreds of kilometers in coastal currents the priority is clearly prevention. For more sedentary alien species, however, it is sensible to limit their further spread via vessels as much as practicable.

The final potential threat that needs greater exposure and discussion is the growing international aquarium trade in marine species. It is relatively easy for international purchase of a wide range of fish, molluscs, crustaceans, and seaweeds via catalogues. Some of these species are known invasives.[67] The green algae *Caulerpa taxifolia* is a known invasive in the Mediterranean Sea, yet Germany imports 5 tons a year for the aquarium trade while Australia has banned any *Caulerpa* imports. A USA marine biological laboratory will send live shipments of the invasive European green crabs anywhere in the world, $US 250 for 100 crabs. This is a potential means of spreading new and recognised pests between Europe and America and therefore increases the risks of accidental introductions to their trading partners, including New Zealand.

4.3 Surveillance and Response Issues

The surveillance of New Zealand's coastal marine environment and harbours for alien species has been non-existent to poor. The low levels of scientific effort, Government expenditure, and public understanding of the threats from marine invasives are in marked contrast to the national efforts and expenditure to address terrestrial invasives. There is such a lack of baseline data and taxonomic expertise that it has been difficult to determine if many marine species here are native or alien. Funded baseline surveys of New Zealand ports have been extremely limited, in contrast to the importance and effort devoted to them in Australia. Efforts to overcome this deficiency have not been assisted by the response of funding agencies that baseline surveys are not really 'research' topics.

Both the International Maritime Organisation (IMO) and the International Council for the Exploration of the Seas (ICES) regard port surveys as work of international importance. Presumably port surveys should therefore be a call on Government funds. Without port surveys there is limited ability to detect new invaders or to measure the ecological changes that they cause. Since marine invasives have such reproductive potential if they establish, this makes early detection even more critical than for terrestrial incursions. Some ports authorities, such as Tauranga and Taharoa, have commissioned baseline surveys.

The first national workshop on marine biosecurity was held as recently as October 1999.[68] Participants emphasised the need for adequate funding for any biosecurity system, as well as the need for much better baseline data and surveillance systems. They stressed the importance of taxonomic expertise to invasives research. This is a basic discipline in which New Zealand has been losing ground for some time, and not only in marine sciences. There has been a decline in the courses universities offer in systematics since the 1970s.

Response capacity has been similarly handicapped by lack of early knowledge, lack of clarity over responsibilities, and complicated jurisdictional arrangements in the marine environment.[69] The efforts to implement an emergency eradication of Asian kelp (*Undaria pinnatifida)* from Big Glory Bay, Stewart Island by the Department of Conservation in 1997 "…highlighted the lack of biosecurity contingency planning for marine incursions in central Government at that time."[70] This eradication effort is exerting significant control over *Undaria*, but eradication has not yet been achieved. Australia is a world leader into marine biosecurity issues, including research, ballast water treatment and control methods. Extending and strengthening the linkages that currently exist between Australian and New Zealand agencies dealing with marine invasives issues would be beneficial.

4.4 Current Management Programmes

It is useful to separate what is being done to manage marine invasives that are already here, which is very little, from initiatives to block or significantly close down major pathways. There is in place a voluntary control on the discharge of overseas ballast water within New Zealand. There are some mandatory controls within this document. An Import Health Standard is in effect for ballast water although measuring compliance is an area where further work is needed. A Government strategy on ballast water and hull de-fouling was released in January 1998.[71] This strategy has ballast water being managed under the Biosecurity Act. Marine biosecurity is a new issue for regional councils and most lack experience and expertise in the marine environment. As they develop Coastal Plans under the Resource Management Act (RMA) the option for a more proactive approach can be developed.

An international effort, to which New Zealand has been an important contributor, has been research into ways to reduce the multiple threats posed by ballast water. The initial emphasis was on requiring coastal ballast water to be exchanged for oceanic water during the journey. The rationale is that this largely eliminates coastal or freshwater species taken on at the start of a journey. Research has shown that the exchanges are never totally effective and are not the panacea that regulatory agencies might have been hoping for. In 1997, an IMO resolution recognised ballast water exchange as an appropriate short-term measure until research identifies a viable and effective treatment option. While there has been a lot of research into the effectiveness and verification of ballast water exchange,[72] the most promising developments now appear to be with efforts to use heat treatment methods to kill the organisms in ballast water while the vessel is sailing. Recent research in New Zealand has been very promising, both with respect to effectiveness and cost.[73] Conducting field trials is the next step and the continuation of adequate funding and international co-operation will be vital.

4.5 System Needs Against Future Threats

'Prevention' is always given as the best and cheapest option for dealing with terrestrial invasives. This is even more important for marine invasives where detection is currently poorly developed and under-funded and where the ability to control species is so much more difficult than on land. Early detection capacity must be improved as well.

Since ballast water is now the major pathway for invasives, considerably more research and international cooperation on effective and affordable methods to kill all ballast organisms while in transit must remain the primary and most important goal. This is not something for one country to undertake in isolation and the current international efforts need greater funding support and information exchange. One of the challenges in this area will be to engage the nations that are the major ship builders once effective treatments are developed. If methods such as re-cycling the hot water from engine cooling systems through ballast tanks could be incorporated into ship designs then effectiveness and affordability can be maximized.

Unfortunately, with the important exception of the USA, most of the major ship building nations are not overly concerned about invasive species problems.

Reducing the translocation of alien species within New Zealand was a major issue identified at the 1999 workshop on marine biosecurity[74] where the focus needs to be on ballast water exchanges and the need for more surveillance of small craft (yachts and launches) which travel along most of our coastlines. The arrival and spread of the toxic phytoplankton *Gymnodinium catenatum* in New Zealand is a good example of the urgent need to control ballast water exchanges around our coasts. It was only *after* sampling revealed that the phytoplankton had crossed Cook Strait that ferry companies belatedly proposed they would implement a voluntary ban on exchanging ballast water between the North and South Islands. Whether other coastal shipping lines followed suit is not known. However, when an industry worth over $100 million annually is at risk, voluntary approaches seem rather piecemeal.

Hull defouling operations were also identified at the 1999 workshop as needing more monitoring, control and research. Marine biosecurity could also look at the models of how terrestrial invasives are managed, such as the approach to bovine Tb control, given the relative youth of the discipline in the marine context.

Underpinning efforts at the regional and national level is the need to markedly improve the understanding of key sectors, stakeholders and the public about the threats from marine invasives, both in economic and conservation terms. Linked to this is the need for more research on pathways within New Zealand, the ecology and impact of invasive species on New Zealand marine systems as well as a risk assessment model and management options appropriate for New Zealand. A start has been made on the latter[75] and more work is proposed.

5. PLANT INVASIVES

5.1 Current Biosecurity Threats

Thanks to the enthusiasm of European colonists in the 19th century, Acclimatisation Societies, and relaxed laws for most of last century, New Zealand now has one of the highest proportions (50%) of alien to native plants living in the wild in the world.[76] As a consequence, most kinds of weed impacts present throughout the world have already happened here although the impacts vary between ecosystems.

5.1.1 Number of invasive plants

New Zealand has about 2,400 native vascular plants growing on land or in freshwater habitats. A further 2,100 species are alien plant species that are now established in the wild. Of this total the Department of Conservation lists over 240 species as actual or potential invasive weeds,[77] which is about 12% of the total of alien plant species. About 52 aquatic plant species are now naturalised in New Zealand and most (75%) of these were first introduced as ornamentals. Of this total, 26 (50%) are considered as invasive plants. This is a very high percentage and probably reflects the limited number of native plants and the competitive power of many aquatic invasives.

The number of invasive weeds ("weeds" in this report) has grown since the 1860s, at almost two new weeds per year. Since the 1960s, however, this rate has increased to about eight species becoming invasive per year.[78] It is a far higher rate than the establishment rate of new animal pests. Furthermore, this rate shows no sign of diminishing. In the Auckland region over 615 alien plant species are now naturalised, possibly the highest figure for any city in the world, and four new species establish (usually out of gardens) in the region every year. *It is important to record that the dominant (90%) source of weeds is from species that were deliberately introduced to New Zealand.* Of these 75% were brought in as garden plants and 14% for agriculture, horticulture or forestry and only about 10% were accidental introductions.

5.1.2 Impacts on threatened native species

Weeds are a threat to 33% of all nationally threatened plants in New Zealand. They could cause plant extinctions and usually interact with other risk factors to put threatened plants in jeopardy.[79] These risk factors include changes in land use, changes in grazing, erosion, degradation of habitat and other negative human impacts. Grasses are the group of weeds that most often have an impact on threatened plants, while the threatened plants most vulnerable to weeds are short; 54% are less than half a metre tall. These threats to native plants are a major concern for management agencies, especially given that 80% of our vascular plants are endemic.

5.1.3 Impacts on ecosystems

As well as their direct impacts on threatened native species, weeds have invaded nearly all types of indigenous plant communities, from the coasts to the snow-line,

throughout New Zealand. The impacts have been severe on protected subalpine tussock grasslands, frostflats, herbfields and montane shrublands. From the small creeping hawkweeds (*Hieracium* spp - a major problem on grazed hill country) to tall 'wilding' conifers (contorta pine, Douglas fir, Austrian pine, radiata pine, mountain pine and larch) weed species are a growing presence in both North and South Islands. In many places infestations of wilding pines are comparatively localised, so far.

"More than 111 high priority protected natural areas with native forest or shrublands are threatened by invasive weeds."[80] Shade-tolerant vines invade intact forests and smother tall trees, dense carpets of weeds stop native seedlings from growing, weedy shrubs out-compete and replace native species and destroy the natural character of the forest. Scrub areas and damaged forests with large canopy gaps are especially susceptible to invasion by a wide range of weeds, of which old man's beard, ivy and Japanese honeysuckle are probably the best known. Native animals are also affected by weed impacts, though loss of habitat (e.g. native freshwater mussels, grassland moths) and loss of food sources (for some birds), although these interactions have not been studied very much and may be underestimated.

Coastal plant communities are especially threatened by weed invasions, especially following degradation by human activities and coastal development. Some 30 priority coastal places (35,000 hectares) are threatened over the next 10-15 years. Highly valued coastal plants, such as pingao, are threatened by weeds including marram grass, boxthorn, Kikuyu grass and pampas grass. Marram grass is a good example of a grass that was deliberately introduced to stabilise dunes, but it also out-competes and smothers native species, especially the native sand binders like pingao and spinifex.

Aggressive aquatic invaders unfortunately are now found in most of New Zealand's rivers and lakes. Taller, and faster growing than many natives, they either eliminate them or displace them to less favourable habitats. Significantly, the most widespread submerged invasives belong to plant groups that are not found in New Zealand. These plants (*Hydrilla*, *Elodea*, *Lagarosiphon*, hornwort, and others) can form dense monocultures, reducing oxygen levels, smothering and replacing native species to which many native invertebrates are adapted.[81] *Hydrilla verticillata* is presently confined to four lakes in Hawkes Bay, but would be unstoppable if it escaped into the Waikaremoana of Rotorua lakes systems. The potential for it to be accidentally spread on pleasure craft or boat trailers is high. *Hydrilla* probably entered New Zealand attached to a legally imported consignment.[82]

Other highly damaging aquatic weeds, such as *Salvinia*, a native of Brazil, and the infamous water hyacinth are also present in the warmer regions of New Zealand. MAF is currently coordinating national eradication campaigns against both these species. The most invasive and economically damaging plant in Asia and Africa, water hyacinth will require determination and a long-term commitment if it is to be eradicated. Its seeds can remain viable for up to 20 years and new plants have appeared at New Zealand sites that were clear for seven years.[83]

5.1.4 Threats to islands

New Zealand has 295 offshore (within 50 km) and 50 outlying (more than 50 km from the mainland) islands that are larger than 5 hectares. Some of these, such as Kapiti and Hauturu (Little Barrier), are central to efforts to conserve endangered species, such as the kiwi, kakapo and saddleback. Most are uninhabited with high conservation values and unique communities of indigenous plants and animals.

A study of 176 offshore and 14 outlying islands (60% of the total number of islands) identified invasive weeds on at least 38% of the offshore islands and 14% of the outlying islands.[84] The incidences were highest on northern islands, least on southern and outlying islands. Weed risks were strongly related to human settlement or frequency of visits. The great majority of our offshore islands lie east of the mainland and in the path of the prevailing westerly winds. They are therefore more vulnerable to wind and bird-dispersed weeds than the few islands to the west of the mainland.

The study concluded that weeds are having an increasing impact on the soil-plant-animal systems on both the northern and Cook Strait groups of islands. "Until a greater degree of weed control is reached on the mainland, it can be expected that the weed problem on islands will worsen." There are insufficient data from the southern islands to recognise any trends at this time.

The plight of Little Barrier Island in the Hauraki Gulf is significant. A 1956 botanical survey of Little Barrier Island, which has the highest biodiversity values of all our offshore islands, recorded 92 alien species but none as potential invasives, nor were any of these 92 species found in the closed forest. Sadly, at least nine invasive weeds are now present, including Mexican devil weed (*Ageratina adenophora*) and climbing asparagus (*Asparagus scandens*). Climbing asparagus is a shade-tolerant climber, reaching over 3 metres and kills plants by strangulation. It now covers over 100 hectares and "has the potential to change most if not all of the lower forests of the island."[85] An internal DOC report has recommended a grid-search and destroy operation for this species on the island.[86]

5.1.5 Lack of public awareness

Behind the record number of invasive plants in New Zealand and its islands is a story that starts with European colonists who were ignorant of the far-reaching impacts of their introductions and continues with a public that still puts a premium on new exotic plants to brighten their gardens. Whether it is the temptation of foreign plants seen on a web-site catalogue, or a gaudy flower spotted on an overseas trip, New Zealanders continue to put indigenous species and ecosystems at risk by bringing in new species, often illegally.

There is now a greater chance of detecting unwanted plants at the border, providing they pass through the full quarantine procedures. However, 34% of the plant items seized at the border because they do not comply with import regulations are undeclared.[87] The problem of illegal, undetected arrivals remains a significant concern. This is heightened by the assessment that arrivals are coming increasingly from south-east Asia and Central and South America, both sources of important weed

species. There needs to be a significant improvement in the recognition by New Zealanders of the threats and costs imposed by weeds, and potential new weed arrivals, if the weed problem is to be contained to those species already here. At present, the Department of Conservation strategic weed plan summarises the situation as: "In contrast [to animal pests], invasive weeds have been greatly underestimated as a threat to our natural environment."[88]

5.2 Potential Threats

The potential threats to indigenous biodiversity from weeds have some similarities to marine threats – new and expanding trade routes, human degradation of habitats, Australian developments – but also some which are qualitatively different and warrant specific management responses.

5.2.1 The potential weed pool

The 2,100 alien species that have already established in the wild represent only 8% of the 25,000 introduced vascular plant species that are now in New Zealand. Many of these are of considerable economic benefit, others bring beauty to gardens, and the majority of these plants lack the capacity to become invasive weeds. There are a number of species in this pool that will, however, become established in the wild and eventually become invasive. Even if the percentage that do so is low, say only 0.5% for example, this would add another 115 invasive weeds to the current total of about 250. The threats to our biodiversity from this pool of potential weeds are a major concern for management agencies. It is a process that is well underway, regardless of future improvements in border control, and will test the management skills and capacity of central and regional government for decades into the future.

New Zealand already has species present from the 40 angiosperm genera that have contributed the worst woody weeds in the world. Some of these have not been here long enough to demonstrate their potential as weeds. There is often a considerable delay between a new species establishing in cultivation, escaping into the wild, and then becoming noticed as a weed. The delay is often decades long. Estimates by Landcare Research[89] suggests it takes some 200 fleshy fruited woody plants in New Zealand about 50 years to be first recorded in the wild, once they are available in nursery catalogues. It then takes a further unknown period for them to become recognised as weeds. Unfortunately many trees and shrubs have been introduced into New Zealand within the past 50 years. And, adding to future problems, scrub and shrublands are the most vulnerable ecosystems judging by the high number of weed species (101) that have already established there.

5.2.2 More aliens from Australia

As with potential marine invasives, it is necessary to keep a close watch on developments in Australia, both as a major trading partner and closest major land mass. Australia has major weed problems; one estimate of the annual cost of weeds placed it around $3.3 billion, excluding biodiversity impacts.[90] Every year, ten new alien species, most of them escaped from garden cultivation, establish in the

Australian landscape.[91] Probably about 10% of these become invasives, as a rough guide. Over 250 plant species are declared under Australian law as noxious weeds and the list continues to grow. While not all the weeds in Australia are likely threats to New Zealand, there is a significant number that are. There are also Australian plant species which, while not a threat there, could be in New Zealand.

Wind-blown seed and migratory birds are the two most common pathways for plants to arrive here naturally from Australia. Seeds of aquatic plants arrive on the feet of birds or blow across which helps explain why over half of our aquatic flora is also found in Australia. So 'natural' dispersal to New Zealand of invasive weeds in Australia is a distinct and growing possibility.

5.2.3 Trade expansion

While any importations of new species are legally required to go through the rigours of the HSNO Act process, opportunities remain for accidental arrivals and illegal entries. Both of these pathways have been discussed in general terms earlier, including reference to the levels of contamination on the bottom of shipping containers. Seeds and fruit were a small percentage of the items detected on containers in the study reported earlier.[92]

When the statistics on seizures, passenger numbers, and potential weediness of species are examined, interesting points emerge.[93] The strongest relationship between the origin of seizures, recent traffic volumes, and weeds that have become established in the last few decades is for east Asia or south-east Asia, depending on definitions of regions. Both the numbers of seizures and visitors were high with a clear trend for this region to contribute a growing proportion of conservation land weeds. A majority of these species were woody plants. In contrast, figures from Central and South America are lowest in terms of the number of seizures, compared with its high importance as a source of weeds. This will need to be carefully monitored if trade with this region increases.

In the past, weeds have tended to arrive via the busiest routes of international commerce. The easier access to information and seed catalogues, often via the Internet, is eroding these trends. A greater proportion of new plant species is arriving directly from their countries of natural origin, particularly from the warmer parts of the world.

Three aquatic weeds probably arrived in soil ballast in northern New Zealand, but this is not a likely route for future arrivals. A higher risk route is the exchange of specimens for research and teaching purposes, now recognised a potential pathway for unwanted organisms. But probably the greatest risk for new aquatic species entering New Zealand is through the 'pocket trade' in aquatic plants.[94] It is not possible to estimate the scale or threat posed by this illegal route, but informal evidence suggests it may be common. There is also the evidence that there are more aquatic species available within the trade than were previously thought to exist.

5.2.4 Interactions between invasives – 'bioinvasion ecology'

As the number of invasive plants and animals now flourishing in New Zealand continues to grow, the potential for these species to interact in unexpected ways will also increase. The outcome can be significant changes in the success of individual species, often at the expense of indigenous species. For example, there are major starling roosts on at least 24 offshore islands.[95] Important weed species such as boxthorn (*Lycium ferocissimum*), elderberry (*Sambucus nigra*), and *Solanum* species are often abundant under these roosts. The introduced starling is playing an important part in spreading weeds into vulnerable places, and may be contributing significantly to this weed pathway.

Other exotic birds that eat fruits are also helping to produce new exotic shrub communities. These birds prefer the fruits of exotics species, thereby providing a mechanism for spreading seeds of weeds to areas, such as forest edges, where the native plant communities can be replaced.[96]

Before Rabbit Haemorrhagic Disease arrived in the South Island, the Department of Conservation prepared extensive contingency plans to protect endangered bird species. The concern was that a rapid drop in rabbit numbers would force the introduced predators, especially stoats, to switch to alternative prey, which were likely to include vulnerable and threatened native birds. Also, the arrival of RHD has probably reduced the browsing by rabbits on seedlings of wilding pines in dry South Island hill country. In the Twizel area these pines (mainly *Pinus contorta*) are spreading rapidly and invading scrub and tussock communities. Recent computer modelling by the Department of Conservation suggests that, without control, much of the Twizel area will have a closed canopy of pines in 40-50 years.[97]

One source of new and undesirable interactions between invasives may arise through deliberate efforts to improve pollination of agricultural crops. Writing from an Australian perspective, Low argues[98] that the arrival of a new and superior pollinating species could turn benign alien plants into invasive weeds. He notes the deliberate introduction to South Australia of the American leafcutting bee (*Megachile rotundata*) to pollinate lucerne (*Medicago sativa*). These bees visit many other flowers as well, especially legumes and daisies, which are two major plant families with lots of weeds. Prior to the HSNO Act, there were proposals to introduce several bee species to pollinate vegetable and horticultural crops[99] without considering the pollination of weeds. With the establishment of the *Varroa* bee mite in New Zealand these calls may be renewed, although they would need to go through the ERMA process this time.

While wildlife managers have to factor these developments into their management approaches, the potential for new interactions between alien species to increase the weediness of existing species, or allow new ones to emerge, is a concern and potential threat to indigenous biodiversity. Climate change is also likely to favour the spread of weed species (see Section 2.7).

There are numerous research questions here that are important to explore, but more needs to be done to address them systematically from the perspective of biosecurity risks. Perhaps we are seeing an emerging research field that could be called

"bioinvasion ecology". Unfortunately, New Zealand is well placed to be an ideal country for such studies.

5.3 Surveillance and Response Issues

5.3.1 Assessing the weed risk of plant introductions

Although enormous damage has already been done by unwise introductions in the past, it is essential to have a robust weed risk assessment model that can be used to evaluate proposals to import new plant taxa. Such a model needs to be far more responsive to the potential threats to indigenous biodiversity than were previous methods of assessing the suitability of plant imports. Like much of the policy work on weeds in New Zealand this is a new development and is still undergoing refinement.

New Zealand is using a weed risk assessment model based on the model used to screen plant imports in Australia.[100] It is being modified for New Zealand circumstances to include the potential impacts on indigenous biodiversity. It has already been modified to provide a basis for screening potential aquatic weeds.[101] The intention is to use the model in connection with the ERMA process to handle applications. It is subject, therefore, to the risk of ineffectiveness if plants are brought in illegally, and not through the proper assessment and screening process.

The weed risk assessment model being used in Australia has been criticised as still letting in too many potential weed species. After noting that in its first full year of operation 131 of 260 species were accepted (72 rejected; 57 sent for 'further evaluation') Low wrote: "The plants are coming in for no good reason except that a nursery somewhere wants something new to sell. Nurseries need not show that Australia will benefit in any way from the 131 new plant species."[102]

5.3.2 Border surveillance

With the decline to near zero of formal applications and the ongoing demand for new plants, MQS had to increase their surveillance of incoming mail, packages and visitors to improve the interception rates of illegal plant imports. This has been covered earlier. While the number of interceptions has risen significantly, border services agree that it is likely that illegal imports are getting through the net, most frequently as seeds. Unlike accidental arrivals of hitchhiker species, smuggled plants do necessarily turn up close to ports or airports. Nor is their status as a 'weed' going to be clear-cut in many situations.

This underscores the importance of public awareness and the need to improve the public understanding of risks associated with bringing new plants into New Zealand, regardless of how innocuous they may seem. Deliberate, if illegal, introductions are probably the major source of new plant arrivals. Whereas ballast water is the priority issue to address if marine invasives are to be minimised, changing public awareness of plant risks is a priority task to increase our success in preventing new weeds and potential weeds from arriving in New Zealand.

5.3.3 Post-border surveillance

The Department of Conservation has developed a surveillance plan for early detection of new invasive weeds.[103] It has not been in operation long enough to comment on its effectiveness or what changes might be warranted. It is intended that it be administered at each Area office of the Department. The plan includes planned and 'fortuitous' surveillance and it focuses on both places and species. It aims for responsive and timely control. There is a small 'weed awareness' element in the plan.

The focus of the Department is obviously on weeds that threaten conservation values on public conservation lands. It notes, however, that there is a need to search vulnerable sites (those where invasion is most likely) as well as valuable sites (high biodiversity values). Vulnerable sites tend to be disturbed sites, often not within public conservation lands, but under the control of private landowners or councils. Vulnerable sites include along roadsides and railway tracks, which are often the first sites to be colonised, and from where many species spread. For a weed surveillance plan to be effective it would seem to be necessary to fully engage the organisations with responsibilities for these places, Transit New Zealand and Tranz Rail.

Under the Biosecurity Act regional councils can specify road-controlling authorities to be responsible for pest management on roadside verges. At present Transit only partially complies in some regions. Formal linkages to regional councils are not discussed in the DOC Surveillance Plan. The plan notes that some of the 'fortuitous' surveillance reports may come from regional council biosecurity officers.

5.3.4 Post-border responses

There are serious shortcomings under the Biosecurity Act with respect to the ability of regional councils to respond immediately to organisms not previously identified as a problem in the region. Their powers are confined to those that are undertaken through a pest management strategy or a small-scale management programme (section 100). In contrast, the Crown allows departments to access the Part VI powers in the Act for exigency actions (as specified in Part VII). While these limitations might be more applicable to the need to respond rapidly to new animal pests, it also affects a council's ability to respond to new weed problems.

Nor is the level of coordination between management agencies very high on rapid weed responses. Regional councils are more focused on managing known weed problems than responding to new incursions.

5.4 Current Management Programmes

5.4.1 Conservation's weed management strategy

After the Department of Conservation was formed in 1987 weed issues suffered through a decade of poor funding, low staff awareness and lack of policy. This has changed significantly in the past three years. There is now a genuine cohesion in the Department's approach to managing weeds, based on a clearly articulated

management strategy[104] and supported by a 10-year weed research plan.[105] This work has helped to redress the balance from the previous emphasis on animal pests by showing that plant pests are also a major threat to many native species and ecosystems.

The strategy recognises the importance of prevention and good border control, which it leaves to MAF, noting that DOC's role in border control is defined by the Biosecurity Act and HSNO Act. This role is mostly confined to providing advice, identifying plants as 'unwanted organisms', recommending import health standards, making submissions to ERMA on any applications, or proposing a national pest management strategy for a plant that affects DOC's area of responsibility. In evaluating risk, the Department will use weed risk assessment models.

The management strategy then describes the rationale for establishing a framework with two distinctive objectives and their respective approaches to managing weeds. These are '*weed-led*' control programmes and '*site-led*' control programmes. Since the distinction between the concepts is not widely known, a brief description follows with comment on the significance of this approach.

The objective of weed-led control (minimising future problems) is "To minimise the numbers, or contain the distribution, of significant *new* invasive weeds where this is feasible." (italics added) It addresses the fundamental problem identified in Section 5.2.1, namely the large pool of potential invasive weeds now in New Zealand and the fact that several species are naturalising every year. It also takes the novel step of enabling species to be targeted *before* they are well-established and causing significant damage.

The operational objectives are eradication or containment (within a defined distribution). Weed-led programmes focus on species with a limited distribution and/or low numbers within the defined area, but these are species that have the potential to greatly increase their numbers, distribution and level of impact. *The weed-led approach is a proactive strategy to minimise future risks.* Its focus is on new invaders in a conservancy, not on the conservation values associated with the places where the weed occurs. For the first time DOC managers have a mechanism for identifying potential threats and controlling spread at an early stage. To be successful, a weed-led strategy has to be implemented in all the defined areas, regardless of the ownership of the land. Clearly, therefore, a weed-led approach will often require the cooperation of private landowners and agencies such as local authorities. Success is measured by the eradication or containment of the target species, which may or may not influence the local plant community.

In contrast, the objective of site-led control (protecting specific high value sites) is "To protect land, freshwater and marine sites that are important to New Zealand's natural heritage from the impacts of invasive weeds." The term 'site-led' indicates that any such programme is defined by what is needed to protect the conservation values of a specific high priority place. It is more likely to be reacting to established weeds and the co-operation of local authorities and adjacent landowners, while desirable, need not be a pre-requisite for a control programme. Success is measured by how the natural community recovers after the control. There are more site-led projects undertaken than weed-led programmes.

Both weed-led and site-led control require monitoring, surveillance, storing and disseminating information as well as public awareness programmes focused on ecological weeds: what impacts they have, how the public spreads weeds, how to protect native species and plant communities, and what individuals, communities and interest groups can do to help. The ecology and management of invasive weeds is given in detail in a report prepared for DOC.[106] Williams points out in this report that while the greatest return for dollars and effort spent comes from controlling weeds at the early phases of invasion, this is often the time when it is most difficult to obtain funds for control – a point of concern for management agencies.

5.4.2 Implementing effective weed management

We face problems of human perception with respect to weeds. It is hard (for many) to believe that pretty flowering plants, once confined to suburban gardens, are serious threats to indigenous biodiversity and should be ruthlessly pursued to the point of eradication. Those sentiments are usually reserved for invasive killers and defoliators like stoats and possums. Yet the reproductive power of flowering plants means that delays can increase the funds needed by orders of magnitude and the chances of success become correspondingly lower. Even old man's beard (*Clematis vitalba*), which was deliberately introduced, looks innocuous, despite the destruction it continues to cause in native forests after years of major expenditure on control.

It is too early to tell if DOC's weed strategy will be sufficient to slow the spread and contain the damage being caused by invasive weeds throughout public conservation lands, including national parks. Much will depend on the funding levels it receives against other pest priorities and the capacity to deliver. The department's strategy recognises that prioritising is necessary and that partnerships with other agencies will be needed if weed management is to be successful, especially for weed-led projects.

It is worth noting the results of a 1999 DOC pilot study of the cost effectiveness of weed control. Out of 25 possible conservation projects, which included animal control, weed control, fencing and species recovery projects, the seven most cost-effective were all weed control projects.[107] Four of the weed control projects were potentially up to two orders of magnitude more cost effective than the most cost-effective animal pest control projects. Much of these benefits are gained by early effective action. For example, the pilot study concluded that, for the Twizel area "…in the absence of any management, wilding pines could establish an 80% closed canopy over ungrazed tussock grasslands within 40 years and the *cost of control would escalate 10-fold every six years*." (italics added)

The scale of the weed problem for conservation lands alone is immense. DOC estimates suggest that weeds will threaten 575,000 hectares of New Zealand's unique natural places in 10-15 years if nothing is done. This area represents the total land area of eight national parks (Tongariro, Egmont, Arthur's Pass, Abel Tasman, Paparoa, Nelson Lakes, Mt Cook and Westland). Almost half of the threatened area is in the sub-alpine zones.

As well as the responsibilities of the DOC, regional councils and unitary authorities also have major responsibilities for the eradication and management of weeds under the Biosecurity Act. The main mechanism for this is by way of pest management strategies. There have been numerous criticisms of the (in)adequacies of the Biosecurity Act for pest management purposes. In relation to the site-led and weed-led approaches developed by DOC, the Biosecurity Act is not helpful, since it is focused on individual species, not the DOC holistic ecosystem approach.

Other problems with the Act were well covered by speakers at the 1999 Pest Summit.[108] Criticisms include the question of funding pest management, and the need to put the questions of 'who pays?' and 'who benefits?' in an ecological context rather than the context of immediate private benefits and costs. Major changes to this Act are required, including the provision of a purpose and principles, before we have an effective and efficient mechanism for eradicating and controlling pests in New Zealand.

5.4.3 Coordinating weed control programmes

The focus for weed control by regional councils used to be agricultural weeds. The Biosecurity Act required a move towards a broader consideration of environmental values. Meanwhile the DOC was appropriately continuing to develop its focus on weeds threatening conservation values. The first round of pest management strategies was marked by prolonged difficulties for regional councils that needed agreements with agencies responsible for Crown land.[109] There were problems for councils such as: identifying the exacerbator costs on Crown land; the status of Transit NZ; conflicting funding priorities of Crown agencies for pest management.

As a result, agencies were not well coordinated nationally for weed control for several years after the Biosecurity Act was passed in 1993. Lessons have been learned from those experiences and coordination is occurring, for example, between DOC and regional or city councils for several weed-led programmes, including efforts between DOC and Southland Regional Council for control of Asian Kelp (*Undaria pinnatifida*) and spartina (*S. anglica*)

There are other matters where cooperation between DOC, local government, MAF, Ministry of Fisheries, and landowners is crucial if surveillance and many weed-led programmes are going to succeed. These include: coordinating surveillance programmes; using other legal mechanisms under the Resource Management Act and Conservation Act to prevent the deliberate introductions of aquatic plants; public awareness initiatives; establishing weed hygiene controls; sharing of research and weed databases; declaring species to be "unwanted organisms".

The declaration of a species as an "unwanted organism" under the Biosecurity Act has a number of advantages for agencies with respect to border control, surveillance, management and responding to incursions, as well as stopping the sale, propagation or release of unwanted organisms. There is an initiative currently underway, led by MAF Biosecurity, between regional councils, unitary authorities, and relevant government departments to decide which plants should have 'unwanted' status. This initiative may resolve inconsistencies that exist between councils with respect to 'pest' status

for plants and the incomplete coverage of plant pest management strategies. Without a nationally consistent approach some problem weeds continue to be propagated, sold, and deliberately spread around the country.

5.5 System Needs Against Future Weed Threats

For marine invasives, improved prevention of accidental arrivals, through ballast water, is the top priority. In the case of weeds and potential weeds, 'prevention' means reducing the deliberate importation of new species or genetic variants that are likely to become invasive. The major system need is not to focus just on control at the border, but to develop a better understanding of the complexity of weed pathways and establishment, and how these risks can be reduced.

It is likely that New Zealand is currently experiencing its highest levels of illegal entry of alien plants in its history. Formal applications for importing new plant species have effectively dried up through the expensive ERMA process under the HSNO Act requirements. The funding model of 'user pays' imposed on ERMA and applicants, coupled with low public awareness of the links between garden plants, naturalised aliens and (eventual) weeds, are fuelling the potential increase in weed species through the flow of imports.

Low public awareness is the consequence of little effort by government departments to publicise the impacts of weeds on indigenous biodiversity, compared with the past concentration on agricultural weeds. With only a few exceptions, conservation weeds have received little publicity, nor has there been much coordination between departments and councils to generate campaigns to change that situation. There have been useful regional initiatives, but many more are needed. For example, the Auckland Regional Council publishes 'Friendly Alternatives' which provides environmentally friendly alternatives to pest plants.[110] While many retail plant nurseries are aware of the problems, there is more to be done to limit the spread through propagation, sale and distribution of problem species. The same concerns apply to the aquarium trade, since this has traditionally been the source of many invasive aquatic weeds, both in New Zealand and other countries.

Assessment of weed risks needs more work with respect to research, policy and delivery mechanisms. The current weed risk assessment model is being further refined (Section 5.3.1). Meanwhile there is no mechanism, short of a full application to ERMA, for importers to get any indication of the potential risk or safety of a species they wish to bring in. An assessment system used to operate in the mid 1990s when two Landcare staff worked under contract to MAF. They provided a rapid evaluation service for people wanting to know if a plant species was an acceptable or unacceptable import. While the service was free they responded to hundreds of requests per year. When charges were introduced after about two years the number of inquiries dropped off to very low numbers.

By way of contrast, Western Australia deliberately operates a free formal weed assessment service. This includes assessments for inter-state trade. There were at least three reasons for making this a free service. Firstly, it was considered the programme would derive major public benefit. Secondly, charging the first person

intending to bring a new species, while all subsequent importers would also benefit for free was seen as 'a little unfair'.[111] Thirdly, and most importantly, it was seen as a way of stopping what is referred to as "name shopping", whereby people pick the name of a plant species that has already been assessed and approved and use that instead of paying for an assessment. The two-person team has assessed 'well in excess' of 10,000 species in the 1996-2000. All requests must supply the published Latin names of species.

Surveillance and rapid response are other important areas where improvements are needed. It is crucial to improve the legislative mandate, improve the capacity to respond, and establish coordination mechanisms between the suite of agencies and organisations that need to be linked at national or regional levels. The surveillance needs are different from those needed to detect and respond to accidental animal incursions. Weeds are less likely to emerge near major entry points such as ports and airports, so surveillance will be needed in a wider variety of places. Urgency, while important, is not quite so crucial as it is for pests such as Tiger mosquitoes or lepidopteran species. But as the recent work by DOC suggests, long delays can result in massive increases in control costs (see Section 5.4.2).

For new weed species it would seem appropriate to develop surveillance and response procedures that are sensitive to the common invasion pathways of many weeds. This would require changes to the Biosecurity Act and more cooperative involvement of the organisations and landowners that are responsible for those disturbed sites which often provide plants with their first niche in the wild. Road verges, railway lines and embankments, tracks, service roads and degraded lands are prime places for weeds to establish. From such places, wind-blown seeds travel many kilometres to establish new populations. Establishing the necessary coordination along this 'pathway' route should reduce the time taken to detect new weeds outbreaks and allow for quicker, cheaper and more effective control.

Finally, the success of future weed management will depend on adequate funding levels for control programmes, agreed weed lists between relevant management agencies, more 'weed awareness' initiatives, and greater coordination between management agencies. It would also be helped by more sharing of research information and better access to weed databases. At present, Landcare, DOC and regional councils run separate databases.

6. ANIMAL INVASIVES

6.1 Current Biosecurity Threats

Of the three categories of threats (marine, plant, animal) covered in this paper, the impacts of animal invasives on New Zealand's biodiversity are the best known, most researched, and have had the greatest expenditure in terms of eradication and control operations. In particular, a veritable tidal wave of mammals in the nineteenth century, released into a landscape that was effectively without mammals until Polynesians arrived, continues to have massive impacts on native species and ecosystems.

6.1.1 Current impacts of animal pests

The sorry state of New Zealand's indigenous biodiversity is well summarised in the 1997 state of the environment report.[112] It notes the dominance in the environment of 34 introduced mammals and that their gains have been at the expense of indigenous plants and animals. The grazers (rabbits, sheep), browsers (goats, deer, thar, chamois), predators (stoats, ferrets, weasels, cats, trout) and omnivores (rodents, possums, pigs) continue to degrade ecosystems and threaten many native species with further declines or extinction. The challenge of halting the decline in indigenous biodiversity is detailed in the New Zealand Biodiversity Strategy.[113]

6.1.2 Accidental arrivals

As with our invasive plants, most of the animals that are now pests were also introduced deliberately. Any future deliberate imports of new species will need to go through the ERMA process for risk assessment before approval is given. Unlike plant seeds, it is much more difficult to smuggle vertebrate animals into the country, although bird smuggling has gone on for some years, with varying degrees of success.

It is the accidental arrivals of small pests and pathogens, rather than new vertebrates, that are a current threat to biosecurity. More work needs to be done on the nature of these risks to indigenous species, which is not an area that has received attention from DOC or funding agencies in the past. Internationally, there is more concern now about the threat of plant and animal diseases than there has been previously (See Section 2.8).

What needs more attention is analysis of the biosecurity risks of different pathways and where the relative effort of MQS staff should best be directed. A case in point is the high profile of used cars imported from Japan as a potential route for the arrival of gypsy moth. Egg masses of the gypsy moth are intercepted on used cars, at a rate of about one per annum off the approximately 140,000 used car imports. All of these cars are inspected on arrival or prior to shipment from Japan. By comparison, about 360,000 containers are unloaded in New Zealand ports every year. A survey of the six sides of 3,500 containers (less than 1% of the annual total) detected one gypsy moth

egg mass.[114] This one-off survey suggests the exteriors of containers may well be a more serious risk than used cars, but they continue to get much less attention than they probably deserve. Containers also carry risk goods from many countries. Only a small proportion of these are inspected when they are first opened.

6.1.3 Illegal releases and local escapes

A 1996 survey by Landcare scientists revealed disturbing information about new populations of large mammals in New Zealand.[115] They recorded 264 new populations of 16 species. *Natural dispersal had contributed to only 5% of these new populations*. Over 70% of the new populations were for just three species (red deer, feral goats and fallow deer). Sixty-six percent of the new deer populations were in Northland and Auckland, which had previously been deer-free, apart from two local fallow deer herds.

Most of the new populations had resulted from farm escapes (38%) or illegal liberations (27%), "…indicating that some recreational hunters and farmers have little awareness of or concern for the ecological and economic costs associated with these new populations." These new populations added to the threats to conservation values in those areas. Thanks to human error or deliberate assistance, many large mammal species turned out to be more widespread than previously thought.

As a consequence of the illegal deers releases in Northland a 10-year plan to eradicate wild deer in Northland was launched in June 1977 by DOC, Northland farmers, Northland Regional Council and Agriquality New Zealand. After three years, 132 of an estimated 140 wild deer had been shot,[116] a positive result indicating the benefits of early detection, a well focused plan, public support and a dedicated operational team. The cost of responding to these careless liberations was $160,000 for 1999-2000.

Small mammals are also spread with human assistance. Many pet owners find it easier to release unwanted pets than have them killed. Wild cats have been responsible for bird extinctions in the past in New Zealand and contribute to lower bird numbers in many locations.

The Taranaki Regional Council tried to ban the farming, breeding and sale of mustelids since they are voracious predators of birds as well as vectors for bovine tuberculosis. (A number of pet mustelids were known to have escaped.) The Council attempted to do so through a rule in its Animal Pest Management Strategy, prepared under the Biosecurity Act. It wrote to the Department of Conservation asking that it not issue any licenses permitting the farming, breeding or sale of mustelids in Taranaki under the Wildlife Act Regulations. However, the Department replied that it was obliged to issue licenses as long as the regulations were met. The focus of the regulations is to ensure that animals are properly secured and declining an application is effectively limited to farming situations.

In the view of the Taranaki Regional Council there is a need for a "…comprehensive review of all the legislation administered by the Department to achieve better integrated pest management. This would involve not just reviewing the Wildlife (Farming of Unprotected Wildlife) Regulations but also the Wildlife Act itself, and

other relevant legislation such as the Wild Animal Control Act and its links with the Biosecurity Act."[117]

Not all illegal releases are of mammals. Deliberate releases of the Australian rainbow lorikeet (*Trichoglossus haemadotus*) in Auckland have led to the establishment of wild flocks, numbering up to 50 birds. A prolific breeder, lorikeets will compete with honeyeaters for food and also use the same nesting sites as kakariki, kaka and stitchbirds. They could easily reach the very sensitive offshore islands (Little Barrier, for example) that are important sanctuaries for threatened species.

6.2 Potential Threats

6.2.1 Potential new arrivals

Despite the best efforts to improve border security there is the inevitability of new arrivals threatening native animals and ecosystems. The eradication campaigns against the white-spotted tussock moth and Asian tiger mosquito are two well-known recent examples. There is the related need to improve risk analyses by including a fuller analysis of the threats to indigenous species. In the past, threats to indigenous species have been considered with less rigour than for established agricultural industries. The relative risks of containers versus used vehicles as a pathway for insect hitchhikers is a case in point (see Section 6.1.2). One area of risk analysis that was examined recently for the Department of Conservation concerns the risk to indigenous fauna from the introduction of exotic diseases and pests.[118] That particular analysis looked at a case study on native parrots.

It would be timely to look in detail at the risks posed by imports of freshwater and aquaria fish and their potential to inadvertently bring in fish diseases. These risks are seen as potentially very serious in Australia. While escaped fish have disrupted local ecosystems it is the threats of diseases, including to the growing Australian aquaculture business, which is now a major concern. A major report[119] noted that "live ornamental finfish are a special case because they are known or potential vectors of diseases of high quarantine importance, are traded widely internationally, and are imported in large numbers into Australia each year." The report also noted that while most of the world's worst diseases have not reached Australia, little is spent and done to control the spread of diseases within Australia by ornamental finfish. There is another warning here for New Zealand. As we have seen with other invasives and diseases that reach New Zealand, many travel via the Australian connection.

The potential for deliberate illegal introductions (see Section 3.4) also needs ongoing consideration and to be factored into contingency planning. While such events are likely to be rare in the case of bioterrorism, they have potentially large impacts. More common are smuggling attempts involving birds (with unknown disease risks), fish and plants.

6.2.2 Invertebrates at risk

With the successes that have accompanied the use of offshore islands as sanctuaries for threatened species, a more subtle consequence of these successes may have been

overlooked. Gibbs presents evidence[120] that numbers of threatened endemic insects have undergone severe population drops, or local extinctions, because of the predator pressure from a combination of invasive and native predators on some islands. On Takapourewa (Stephens Island) in Cook Strait the tuatara population, in the absence of cats, is now an estimated 50,000 animals. Several important and threatened insects and a giant carnivorous land snail have now declined to very low numbers or disappeared under the pressure of tuatara predation (1,500 – 2,000 tuatara per hectare) and loss of deep moist litter in the forest. Hauturu (Little Barrier Island) is home to the only population of the giant weta, or wetapunga (*Deinacrida heteracantha*). It was widespread on the island in 1958-61 when the island was infested with both kiore and cats. In 1994-95 few weta were found. By then, the cats had been eradicated, kiore numbers were up, and saddleback numbers were increasing. Both kiore and saddleback are expert weta predators and their combined pressure could account for the decline in wetapunga numbers. Gibbs surmises "[In 1958-61] the cats kept the rats in check and saddleback had not been re-introduced. Today it appears that wetapunga cannot sustain the two-pronged attack."

The major focus for species recovery work has been on our charismatic feathered fauna and relict reptiles, and with good reason. The lesson is, however, that some threatened endemic invertebrates may have been the unintentional victims of some island conservation 'success' stories. It is another example of 'bioinvasion ecology' and the resources that still need to be invested in sound management-oriented research.

6.2.3 Human Impacts

There is still much potential for people to subvert the biosecurity efforts currently in place. It is important to include movements of invasives within the country when assessing biosecurity issues. The example of the illegal releases of large mammals throughout the country (see Section 6.1.3) is more visible than those of 'liberated' pets and fresh-water fish which also occur, but which are difficult to document. The impacts of invasives are often exacerbated by the assistance they receive from people. This underscores the importance of maintaining and improving public awareness efforts directed at key sectors and groups, such as the pet trade, pet owners, farmers and recreational hunters. Veterinarians could also play a useful role in assisting with the control of unwanted pets.

6.3 Surveillance and Response Issues

6.3.1 Border surveillance

Border surveillance authorities recognise the risks of both deliberate and accidental arrivals and have organised their systems accordingly. Unwanted organisms can arrive on undeclared food, plant and animal products or be smuggled in as has occurred with plants, exotic birds and, probably, with aquarium fish. While there is a need to find effective ways to change human behaviour, there is an urgent need to make the penalties for illegal actions more of a deterrent than they are at present. There have been calls for changes to the Biosecurity Act to accommodate these needs.

With the ERMA assessment system that is in place, New Zealand is much less likely to see imports of animals that are a threat to indigenous biodiversity. Small, but nasty surprises, however, will continue to arrive accidentally. This requires more work on risk analyses associated with changing trade patterns, risk goods, and quality research on what potential invasives are arriving here, and where they are coming from. The down-grading of the capacity of the Plant Reference Laboratory was an alarming outcome of the restructuring of MAF. There is less known about the invertebrates that now arrive in New Zealand than was gathered previously as routine information. This makes it more difficult to modify risk analyses, track trends in patterns of unwanted organisms, and improve the surveillance systems. It also downgrades that national capacity with respect to an early-warning system in the rare, but highly significant case of a major pest arriving in New Zealand. A previous Minister of Biosecurity, the Hon. Simon Upton, has raised this as a concern.[121]

6.3.2 People behaving well

In welcome contrast to those people who seek to smuggle in a Giant African Snail, mangoes or exotic plants, are the majority of New Zealanders who are concerned about biosecurity risks (even if they do not use that term) and keen to play their part in keeping out unwanted organisms. The country owes much to those citizens who have taken the initiative and reported an unusual insect to the authorities, as was the case with the first notification of the white-spotted tussock moth incursion. Given that a high proportion of incursions of these sort are likely around a few main ports and airports (especially Auckland), it could well be cost effective to invest specifically in awareness-raising for these populations. At present the budget for MQS to consider any such initiatives is totally inadequate. Not does there seem to be much interaction between central government and local government organisations to develop such programmes.

Yet given the reasonable position that no border control can be 100% effective, a logical consequence is to improve the capacity for post-border detections, in a cost-effective manner of course. Utilizing the populations around high-risk arrival points would seem a useful element to add to such initiatives.

6.3.3 Responding to incursions

The shortcomings of the Biosecurity Act with respect to inhibiting the ability of regional councils to respond immediately to unwanted organisms has been covered in Section 5.3.4 with respect to plant invasives. The same concern applies, but probably with more force, to unwanted animal species.

An issue of contention for rapid response decisions is the question of "who pays?" The long-standing view of The Treasury is that departments should pay for the extra costs for emergency responses to incursions by re-prioritising programmes within existing budget allocations. While this may be fiscally prudent, it has led to delays in taking decisions when time is of the essence and also undermined other important work within departments. As Upton put it: "Repeated attempts to fund emergency

response initiatives by re-prioritising other activities within MAF's (or other agencies') baselines has often compromised long-run capability in a way that has not been properly understood by Ministers."[122]

This problem about who funds emergency responses to incursions might apply to the current concerns expressed by the Royal Forest & Bird Protection Society about the spread and damage being caused by the Argentine ant (*Linepithema humile*).[123] Described as the second most serious ant pest in the world, it can affect native species, both vertebrate and invertebrate, as well as horticulture, and is a major household pest in California. It was discovered in Auckland in 1990, has appeared on Tiritiri Matangi Island and has satellite populations in Northland, the Bay of Plenty, Christchurch and now in a Wellington suburb. Since it is a problem for agriculture (MAF) as well as native species (DOC) there is a potential for debate over where control or eradication costs should come from, given the absence of a separate response fund for incursions. This debate will inevitably be coloured by departmental perceptions of what other activities would suffer should eradication or control be required.

What role should the Biosecurity Council play, or be mandated to play, with respect to decisions on such issues?

6.4 Current Management Programmes

The major vertebrate pests, such as rabbit, deer, possums and stoats have been the subject of various eradication and control programmes for many decades and are the 'icon invaders' in the eyes of the public. DOC and its predecessor agencies have spent many millions on research and control efforts, both to reduce the impacts of pests and to protect threatened species. As a result, the Australian brushtail possum is the world's most researched marsupial[124] with about $50 million spent annually to reduce its negative impacts on agriculture and indigenous biodiversity as well as on possum research. Yet even with the possum we continue to make new discoveries, such as the relatively recent finding that possums prey directly on native birds and their chicks.

There have been continued improvements in control techniques for other species as well as for possums such that the eradication of rodents from offshore islands up to 250 hectares is now considered 'routine'. The success of using offshore islands for species recovery programmes has led to the innovative, if expensive, transfer of the approach to mainland restoration projects by DOC. While the results have been promising, a 2000 review concluded that mainland restoration projects require "the more rigorous application of science as part of management programmes."[125]

Science also has a major role to play in biosecurity in general, from the development of import health standards to pest management. The 1999 Pest Summit participants also emphasised that there "…has to be more integrated, win/win relationships between science providers and other players. This involves questions of ethics, overcoming some of the downsides of competition between CRIs, funding priorities and systems which incorporate the needs of biosecurity."[126]

Despite the notable improvements in management methods of animal pests in recent decades a comparison with the current DOC weed strategy suggests that, at a conceptual strategic level, animal pest strategies have not moved as fast. The 'weed-led', 'site-led' approach gives explicit recognition to both the 'emerging threat' problem and the ecosystem approach. It clearly requires management decisions to be made in the context of rigorously measuring the outcome of any control, either weed eradication or site (ecosystem) recovery. By contrast, animal control is still dominated by a species, not an ecosystem, focus. Thus DOC has long had plans for possums, thar, goats, stoats, and deer, but not for ecosystem recovery per se. The mainland restoration projects have required a shift in focus from species to ecosystem processes, but this has arisen secondarily out of the primary focus on assisting threatened species.

While DOC is responsible for pest control on public conservation lands, regional councils have that role for the rest of New Zealand. Some of the difficulties faced by councils in the integration of their first round of pest management strategies with Crown agencies under the Biosecurity Act were covered in Section 5.4.3.

The question, which is difficult to answer, is - has all of this management effort significantly benefited indigenous biodiversity and national economic security? Are possum or deer depredations less now than before or are we merely slowing the decline towards a point where the ecology of invasive species dominates the interactions between indigenous plants and animals? The New Zealand Biodiversity Strategy seeks to 'turn the tide' and Government has allocated an extra $57 million for control of animal pests and weeds over the 2000-2005 period. This suggests that required expenditure to 'turn the tide' will be more than has usually been spent in the past. It is still well below the rough estimate of $840 million annual cost of pests in New Zealand[127] and begs the next question – what is the appropriate level of expenditure on biosecurity when measured against the economic and ecological risks the country is prepared to accept?

6.5 System Needs Against Future Animal Threats

6.5.1 Technical innovations

With only about 5% of incoming shipping containers being inspected for invasive hitchhikers, and projected increases in container numbers, there is little likelihood that current practices adequately cover this pathway. There is also evidence that new Southern Hemisphere trade routes are likely to be more 'risky' for new arrivals via containers. Just as the priority for reducing marine invasives seems to lie with improving the technology for treating ballast water in transit, so there would seem to be significant opportunities and incentives for smart new techniques to be developed to process containers as they are unloaded.

For the insides of containers there are the possibilities of bio-sensing techniques. For the outside of containers there seems to be two options – inspection, or removing the problem. Inspection is labour intensive, takes time and money, and is not considered practicable for large numbers by port authorities given the need to clear containers quickly to the freight forwarding companies. 'Removing the problem' could involve,

for example, passing containers over a rolling conveyor belt with jets of sea-water blasting contaminants off the bottom and sides of the containers. Since this would remove most of the contaminated material it would significantly reduce the risks of accidental imports and should be much cheaper than inspection costs, once the technology is developed. Nor would the technology seem to require a great level of sophistication or research investment.

6.5.2 Bio-control developments

Animal pest managers acknowledge that current technologies are not going to provide major breakthroughs despite important advances in bait formulations. If there is going to be any significant advance in cost-effective technologies that will 'restore the dawn chorus' it will come via advances in biological control technologies, most likely through genetic engineering techniques. Much research effort has therefore been directed at bio-control options for possums and more recently for predators such as stoats.

Bio-control options for possums face two challenges. The first is the research challenge of developing a possum-specific agent, with a cost-effective delivery system, that will achieve the desired outcomes. The second challenge is to achieve public and political acceptance for its use. It may be that the scientific objective is easier to achieve than public approval for its use, despite the millions of research dollars spent and the enormous damage that possums have caused and continue to cause, both economically and ecologically. Efforts have already been made to explore the public acceptability of using bio-control for possums and this will continue to require investment into the future.[128] Since a successful campaign using bio-control against possums could be followed by similar efforts against other vertebrate pests these current efforts will set the scene for pest control for the rest of the 21st century.

6.5.3 Capacity concerns

New Zealand rightly enjoys a high international standing for its innovative approaches to pest management, species recovery successes, pest eradication programmes, mainland restoration techniques and innovative adaptive management. But it has achieved this standing on the basis of a relatively small scientific establishment and with dedicated operational field staff. There are concerns within several scientific disciplines that this skill base is eroding, particularly in the discipline of systematics. As the number of university courses in 'whole organism' biology continues to diminish, so does the expertise needed for future research and operational practices needed for biosecurity issues. This ranges from the marine sciences, where so much still needs to be done to understand how our marine ecosystems operate, to the capacity to rapidly identify new organisms that arrive on a shipment of timber from a distant port.

6.5.4 Coordinating animal pest control

Pest control across the whole country has some way to go before it could be regarded as integrated and coordinated. At present, there are only two national pest management strategies under the Biosecurity Act, one for bovine Tb and the other, initiated by the National Beekeepers' Association, for American Foulbrood disease. Neither strategy was easy or cheap to develop and the long and contentious process has left a sour taste for some participants.[129] Both national strategies address industry issues. Does this mean there are no 'national interest' pest management issues related to indigenous biodiversity? That would seem unlikely. Does it reflect instead difficulties with the Biosecurity Act including its 'who pays' elements, or with organisational frameworks and relationships between relevant agencies? This situation would be helped by changes to the Biosecurity Act, better linkages between relevant acts dealing with species conservation and control, and the establishment of strategic directions for biosecurity, including policy and research priorities.

7. CONCLUSIONS

1. When viewed in a global context is it likely that external biosecurity threats to New Zealand's indigenous biodiversity are increasing. Emerging threats are: the growing number of alien and invasive species in neighbouring countries, notably Australia; increases in global trade and visitor numbers; new trading routes, especially with South American countries; global changes that favour the establishment and spread of invasive species; rising incidence of pathogens and diseases.

2. Fortunately, the international awareness of the economic and environmental threats posed by invasive species is also growing. There are major scientific initiatives underway to better understand and respond to these problems. In addition, a number of international and regional agreements offer New Zealand a number of opportunities to work with other countries on several invasive fronts.

3. While the control of New Zealand's borders is sophisticated, so are some of the current and future border issues. There is a risk that importing genetic variants of alien plants already here may enable plants to cope better within New Zealand and become invasive. A larger problem is the likelihood that many new plants with weedy potential are currently being smuggled into New Zealand to avoid the costly process involved in obtaining an approval through ERMA. There are large numbers of shipping containers arriving in New Zealand every year and current quarantine resources only allow for the inspection of a small percentage. The risks to indigenous species of unwanted organisms in or on containers need more research, but must be regarded as potentially serious.

4. Once incursions of unwanted organisms occur, the potential to eradicate or contain them varies markedly between marine, freshwater and terrestrial habitats. Invasives are most difficult to eradicate in marine habitats, easiest in terrestrial. In all cases, success is critically linked to early detection, good decision-making systems, inter-agency coordination, and operational capacity. Prompt detection and early action is also the most cost-effective option.

5. There is a low appreciation in New Zealand of the presence and impact of marine invasives. Inadequate knowledge of how many invasives are currently in the New Zealand coastal zone, coupled with a poor detection capacity, means that we are unlikely to be able to respond effectively to the incursion of important marine invasives, regardless of their potential economic or ecological impacts.

6. Ballast water is the major pathway whereby new marine invasives will reach New Zealand, although hull fouling is still a significant threat. New Zealand is contributing to international research on ways to treat ballast water in transit and this should remain an important funding priority. More research is needed on risk assessment models and management options for New Zealand. Reducing the movement of alien marine species around New Zealand should be a major priority with a focus on ballast water exchanges and hull defouling operations.

7. The impacts of invasive plants in New Zealand are not widely appreciated, despite the damage they cause in a wide range of ecosystems, including on offshore islands. The next major weeds will probably come from the pool of 20,000+ vascular plant species currently in cultivation, but not established in the wild, or from the 2000 alien species that have already made the transition to a wild state. This is not a border control issue, but does indicate the importance of good surveillance systems and a response capacity that can effectively target those places where weeds often establish. It also underscores the need for inter-agency cooperation and agreement on what constitutes a national weed list.

8. Work is currently underway to identify what weeds should be declared as 'unwanted organisms' under the Biosecurity Act. This is a positive development that will bring more consistency to how councils and agencies respond to weed issues as well as stopping the propagation, sale and distribution of some weeds. The development of a 'weed-led' and 'site-led' strategy by the Department of Conservation for weed management is a promising development that merits wider discussion and may be appropriate for wider adoption. It breaks new ground by targeting some species before they have become major problems.

9. Weed-led management programmes need to eradicate weeds on any land where the weed has established and therefore need the cooperation of all affected landowners for success. This puts an emphasis on developing and maintaining good landowner – management agency relationships.

10. A current border problem with plant introductions is the lack of formal applications to ERMA to import new species, most likely because of the costly procedures involved. Consequently, large numbers of alien plants are probably being brought into the country illegally, usually as seeds. Increased surveillance and mail screening are intercepting many items, but an unknown number are getting through.

11. Animal invasives have long been the major focus for pest control, have the highest public profile, and are recognised as major threats to indigenous biodiversity. Control of both weeds and pests is primarily a function of regional councils and the Department of Conservation. Councils prepare regional pest management strategies for weeds and animal pests. These have a single species focus, as required by the Biosecurity Act, which does not take into account the ecosystem relationships that are the appropriate context for management of many pests.

12. Despite the high public awareness of pest issues, there are large numbers of illegal translocations of mammal pests around the country. The same undermining of control efforts also applies to the movement of some invasive plants and freshwater species from one region to another. Biosecurity threats are therefore internally generated as well as external, raising questions about the effectiveness of biosecurity priorities and the level of public understanding of the issues.

13. To have a major impact on the animal pest problems the most promising options for the future are biological control techniques. While significant research issues remain to be resolved, there is a parallel need to understand the public concerns to

bio-control, especially to genetic engineering, and how these concerns might be addressed.

14. While some key issues vary with respect to marine, plant and animal invasive threats, there are also some common issues. There is a need to better inform people and key sectors of the risks and consequences of invasives and to change behaviours that are presently working against national biosecurity interests. There is also a need for better coordination across all relevant management agencies, especially for surveillance and rapid response initiatives. Changes to the Biosecurity Act and related legislation are needed.

15. Calculations of what is an ‘appropriate’ level of funding for biosecurity will continue to be in dispute until there is a better understanding of the current costs to the country of invasives species. This calculation must include costs to indigenous biodiversity and ‘ecosystem services’ and what we are prepared to pay to reduce, maintain or allow the depredations of our biodiversity to increase.

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