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Abstract

New Zealand has stringent biosecurity measures to prevent and manage the invasion of new organisms, many of which have harmful effects on human health, wealth and culture, or the natural environment. However, public resistance to control methods, or a lack of awareness of the impacts of invasive species, can act to prevent effective management of the risks. Art has a role in promoting conversation and debate about controversial issues. The premise of Alien Nation is to use scientific data and modelling to predict possible future invasion scenarios for selected plant and animal species, and to then use art to depict and explore these scenarios in a way that challenges perception. The first species to be modelled is the Queensland fruit fly (*Bractocera tryoni*), and its potential interaction with taraire (*Beilschmiedia tarairi*), a New Zealand native tree species. Modelling shows that there is a high likelihood of the Queensland fruit fly spreading widely in New Zealand and coming into contact with taraire forests. Based on what is already known of the impacts of the Queensland fruit fly on the fruits of a range of species, and of the ecology of taraire, it is likely that the consequences for taraire and its broader ecosystem would be severe. The watercolour painting Fly in the Ointment explores this scenario, a scene that does not and may never exist. The painting requires the viewer to see the impacts of a possible invasion on native biodiversity, an examination through the lens of cultural rather than fiscal currency.

Introduction

The colonisation of New Zealand by humans brought thousands of new exotic plant and animal species, many of which are now invasive (Lee et al., 2006). Deliberate introductions of animals for hunting and/or food, and plants as horticultural or pasture crops or just as reminders of home were made by acclimatisation societies in the 1860s. The effects of these invasive species on our landscapes are now managed nationally by government, industry and iwi. Efforts are made to prevent incursions by new invasive species at the border and to eradicate or control those pest species already in the country. These efforts are not without controversy: there is resistance to the use of toxins to control pest species; some species may have cultural significance or may be considered to be a resource; some sections of society may believe that it is wrong to kill pest animals; and much of the population remains unaware of the value of the native biota and the threat invasive species pose.

New Zealand has stringent biosecurity measures in place to prevent and manage the invasion of new plants, animals and other organisms, many of which can have a harmful effect on human health, culture, agriculture or the natural environment. However, many introduced organisms are already present within the country, arriving as deliberate introductions or accidentally, and incursions of new species occur regularly. A large amount of funding is allocated for the detection of these exotic invaders, research into their impacts and control, and public advocacy and social marketing.

Many potentially invasive species have not yet reached New Zealand. Some species are present in the country but in low numbers, or with a limited distribution (Royal Society of New Zealand, 2014). Future climate change may affect the ability of organisms to invade, and any subsequent impacts they may have.

Art has a potential role in exploring and addressing these issues, whether it is examining and depicting the past, raising awareness of invasive species, promoting conversations and debate around controversial issues, or warning of possible future consequences of our actions. The ultimate success in biosecurity is the prevention of an invasion, or the eradication of an invasive species. Art can depict a scene that no longer exists or one that does not yet, and may never, exist.

The idea of the *Alien Nation* project is to use scientific data and modelling to predict possible future invasion scenarios for selected plant and animal species, and to use art to depict and explore those scenarios in a way that could challenge public perceptions.

Art serving science

There is a long history of association between art and science with naturalistic depictions of flora and fauna an essential element of sciences such as botany, zoology and geology. As early as AD 512 botanical illustrations were generated to accompany a copy of the text *De Matera Mediaca* by the Greek physician Pedanius Dioscorides (AD c.40-c.90) (Stokstad, 1995). In *The History of Animals*, a five-volume study, published by the Swiss naturalist Konrad Gesner (1516-1565), there are nearly twelve hundred woodcut illustrations. This tradition accelerated during the Age of Enlightenment with yet more publications by scientists and natural historians. Relatively recently and closer to home the ornithologist Sir Walter Buller (1838-1906) published *A History of the Birds of New Zealand* (Buller, 1888), which features illustrations by the Dutch artist, J. G. Keulemans (1842-1912).

> It is interesting that … [this tradition] … continues … despite the advent of photography. Most field-guides to birds – including the current New Zealand field-guide – use paintings of birds. The individual bird image, contrived in the postures, can be arranged on the page to make comparisons of distinguishing features obvious and easy (Gill, 2006).

The field of paleontology also gives us some good examples of the use of art to depict scientific concepts. Direct observation or photography of prehistoric animals, plants and landscapes is not possible. However, artists' impressions of reconstructed landscapes can be created from a range of geological data sources including fossils (Northcut, 2011). There are numerous early examples from geologists such as Henry Thomas De la Beche (1830), Louis Figuier (1867), Charles Knight (1925), Arthur Seward (1933), and Carroll and Mildred Fenton (1937) (Davidson, 2008), and such images are commonplace in modern textbooks. In addition, the artist can emphasise key features of a species that are of importance taxonomically or ecologically, showing what they "think should be known" (Northcut, 2011, p. 311). One can read and reach a certain level of understanding about them and what they could do; seeing, however is believing (McGowna-Hartman, 2013).

> …experts and non-experts must rely exclusively on representations – images … to shape our understanding of paleontology. … The importance of images in constructing paleontology knowledge … cannot be overemphasised. (Northcut, 2011, p.311)

Exploration of the past: Colonisation and ramifications

The negative perception of exotic or invasive species is a relatively new phenomenon in New Zealand. Many exotic plant and animal species were deliberately introduced. Early importations of species to New Zealand were uncoordinated, and the work of individuals. Captain James Cook (1728-1779) for example, during his voyages to the Pacific, liberated the 'Captain Cooker' pig:

> … in Queen Charlotte Sound…he made the Māori to whom he gave the pigs promise not to kill them. "If he keeps his word and proper care is taken," the navigator wrote in his diary, "there are enough to stock the island in due time." (Hutton & Drummond, 1905, p. 22

These activities were consolidated and accelerated a century later by acclimatisation societies. An image of the time (Figure 1), which fuelled the business of colonisation, reveals the success of their endeavours: a transformed landscape. A tame New Zealand is depicted complete with stock-covered rolling pasture and the quintessential British game bird, the pheasant, plentiful. With beef and game in abundance the issue of sustenance (the lack thereof), identified and addressed so pragmatically by Cook, is depicted to be well and truly resolved.

There were, however, early warning signs that all was not well with the introduction and naturalisation of exotic species. The famous Māori prophet and pacifist Te Whiti of Parihaka (c.1830-1907), speaking to the colonial official J. P. Ward of the sparrow and pheasant, bemoans their arrival along with the ensuing ramifications:

> … it was not good work bringing those birds out here; they eat all the potatoes and the oats; they are not good birds to bring out. … [W]ere there not plenty of good birds in New Zealand that eat no man's food? (McDowall, 1994, prelims)

Figure 1. Frederick Rice Stack, *View of the Wairoa Creek (pheasant shooting on the estate of Alexander Kennedy, Esquire) on the road leading to the Wairoa Valley / drawn from nature*. Day & Son, lithographers to the Queen, London [1862]. Courtesy of Alexander Turnbull Library, Wellington, New Zealand.

Figure 2. Hamish Foote, *Allegorical Triumph of Sir George Grey*, egg tempera on gessoed kauri panel, 2002.

The impacts of some species have been overlooked quite deliberately. Rainbow and brown trout and salmon have enjoyed adulation and reverence by both locals and tourists. Furthermore, law has protected this cossetted and precious resource from overfishing. Now naturalised, however, trout have been implicated in the extinction of at least one native freshwater fish, the grayling (Hansford, 2012). It is a proven threat for other indigenous species such as the Canterbury and alpine galaxias. "Researchers are calling for trout to be removed from some streams to protect threatened species of [these] small native fish" (Daly, 2013, para. 1)

This reality stands in stark contrast to the popular and picturesque depictions of New Zealand trout fishing. It would seem that many of the species introduced to New Zealand over the years are at one time promoted (trout fishing imagery springs to mind) and perceived as valuable, and yet in the fullness of time, once naturalised, prove problematic. Possums, rabbits, mustelids, pigs, carp, trout and wallabies (Department of Conservation, n.d.), all introduced with either noble or mercantile intentions, attest to this.

One period of sustained deliberate introduction of exotic species to New Zealand by Colonial British Governor Sir George Grey (1812-1898) was the focus of a 2002 series of paintings entitled *Biota*, by Hamish Foote. The works concentrated on the Governor's Kawau Island residence and referenced, amongst other sources, the Auckland Acclimatisation Society and Department of Conservation historical records of both introduced and existing species of flora and fauna.

The painting *Allegorical Triumph of Sir George* (Figure 2) makes parallels between aspects of the fifteenth and nineteenth centuries, in particular the omnipotent, God-like human activities of, for example, Federico da Montefeltro (1422-1482) and Sir George Grey. To reinforce this, the image appropriates the compositional framework of Renaissance artist Piero della Francesca's (c.1415-1492) *Allegorical Triumph of the Federico da Montefeltro*, ca. 1465. (Uffizi Gallery, Florence). Grey, an avid natural history enthusiast, appears in the zebra-drawn carriage he was known to possess before a panorama of his South Pacific domain. Cleared land, smoke and an assortment of exotic species are evidence of colonial activity.

Exploration of the present: *Inflorescence*

Exotic and native species in particular mutualistic and parasitic relationships between species provided the subject matter in 2012 and 2013 for an interdisciplinary research collaboration between botanist Dan Blanchon and artist Hamish Foote entitled *Inflorescence*. The investigation culminated with an exhibition and journal article exploring a series of biological scenarios (Foote & Blanchon, 2013).

The image *Ramification* (Figure 3) concerns the relationship between the feral pig and New Zealand kauri tree, in particular the implication that the former plays a vectoring role in the spread of the pathogen, *Phytophthora agathidicida*, which causes kauri dieback (Bassett et al., 2017; Krull et al., 2013; Waipara et al., 2013; Weir et al., 2015).

The New Zealand kauri (*Agathis australis*) shown in *Ramification* is infected by the invasive plant pathogen, kauri dieback, which will eventually lead to its death. Kauri, an ancient conifer in the Araucariaceae family,

Figure 3. Hamish Foote, *Ramification*, egg tempera on gessoed panel, 2013.

was a dominant tree of lowland forests in northern New Zealand. Following excessive exploitation for timber during the nineteenth and early twentieth centuries, it is today restricted to relatively small fragments (Steward & Beveridge, 2010). Kauri is an iconic species that is significant to all New Zealanders and a culturally significant taonga (treasure) species to indigenous Māori. Ecologically, kauri is also a keystone species supporting a unique indigenous ecosystem and biodiversity (Steward & Beveridge, 2010; Waipara et al., 2013).

The Berkshire and Large Black breeds of pig (*Sus scrofa*) depicted in the image *Ramification* are English domestic breeds, corresponding to a common view that the first pigs released in New Zealand came from there. Feral pigs in the South Island in particular are derived from 14 breeds from Polynesia, Europe and Asia, nine of which were English breeds, and it is likely that the pigs released by Captain Cook were of Polynesian and Eurasian origin (Clarke & Dzieciolowski, 1991).

Exploration of the future (prediction): *Alien Nation*

The relationship between science and art, a recurring theme in the aforementioned paintings, culminates in the current project, *Alien Nation*, where science serves art and art in turn serves science. The concept and ongoing investigation grew from initial discussions between Foote, Blanchon, Glenn Aguilar, an expert on computer modelling using geographic information systems (GIS), and Nick Waipara, a biosecurity expert at Auckland Council. The *Alien Nation* project aims to predict the potential spread of selected invasive organisms in New Zealand using GIS under both current and predicted future climate conditions and to depict possible future landscapes and/or biological relationships. The four researchers are interested in the fertile synergy between art and science.

Foote, Blanchon, Waipara and Aguilar reviewed the most significant invasive species threats to New Zealand – looking at likelihood of invasion and potential impact (economic, cultural, environmental or human health). Some of these species were potential threats, some very real – either they had invaded New Zealand once, or were already in the country and spreading. Of these species, five were ‘shortlisted’, based on environmental risk attributes, and also on how compelling they would be in art. The shortlist included the Chinese fan palm (*Trachycarpus fortunei*), red eared slider (*Trachemys scripta elegans*), European alpine newt (*Ichthyosaura alpestris*), red vented bulbul (*Pycnonotus cafer*) and the Queensland fruit fly (*Bractocera tryoni*). The potential geographic spread of two of these species, the Queensland fruit fly (Aguilar et al., 2015) and the Chinese fan palm (Aguilar et al., 2017) has now been modelled under current and future climate scenarios. For the Queensland fruit fly, an investigation of its possible impacts on native flora and fauna was carried out, the results of which were used to inform the creation of an image.

The Queensland fruit fly and its possible impacts on native species

To determine the subjects in the painting, it was necessary to investigate which host plants the Queensland fruit fly would potentially favour. The Queensland fruit fly is a significant horticultural pest in Australia and parts of the Pacific (Clarke et al., 2011; Drew, 1989; White &

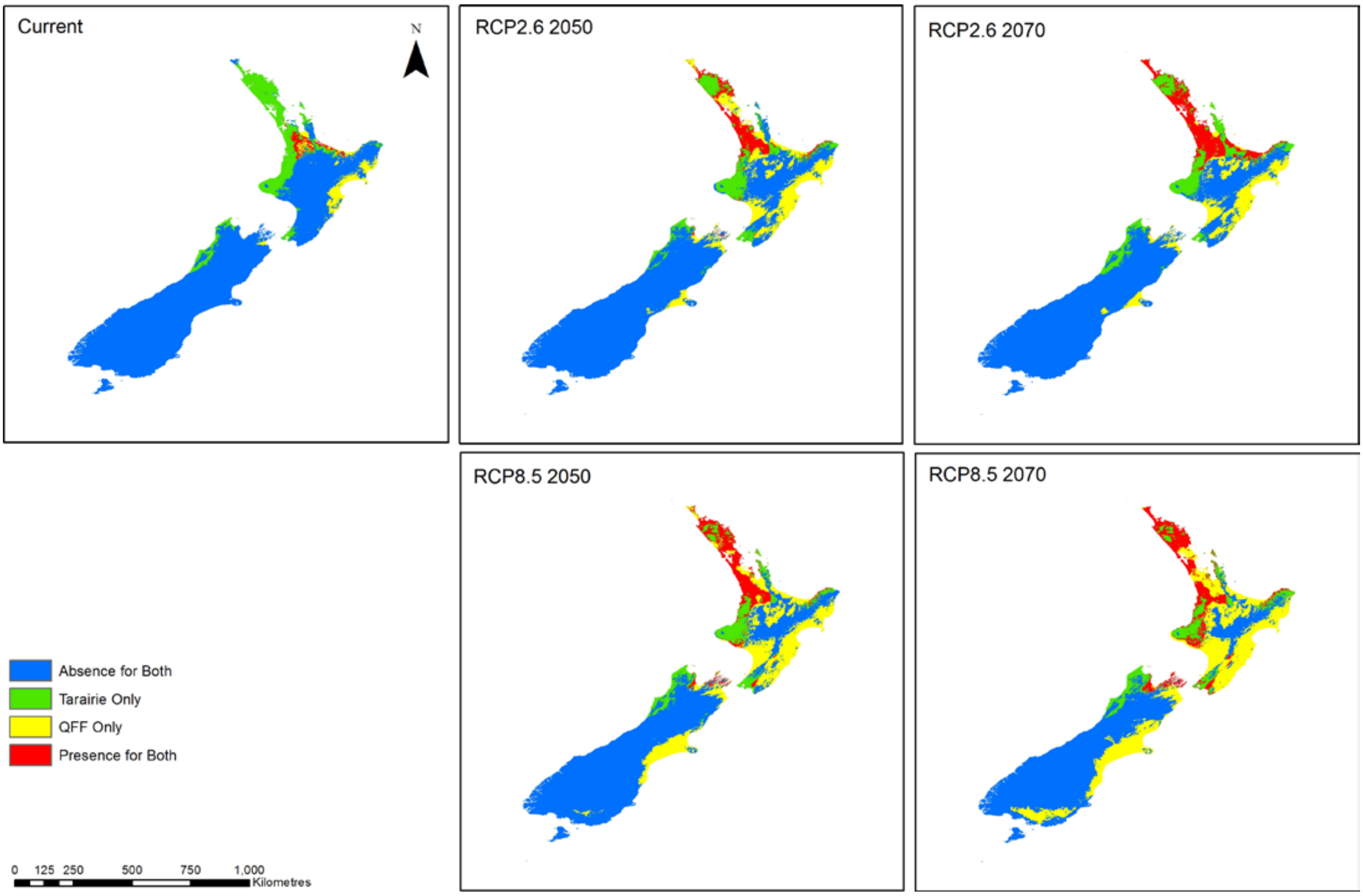

Figure 4. Predicted presence and absence of the Queensland fruit fly and taraire in New Zealand under current and future climatic conditions for 2050 and 2070 using lower emission (RCP2.6) and higher emission (RCP8.5) scenarios.

Elson-Harris, 1992). While not currently present in New Zealand, several incursions have occurred, the most recent one in 2015 (Aguilar et al., 2015). The economic risk to the New Zealand horticultural sector, worth $3.6 billion a year, is significant, with a wide range of crops potentially affected (Drew, 1989; White & Elson-Harris, 1992). Modelling of the potential spread of this species in New Zealand indicated a low to medium predicted suitability of most of the country to the species under current climatic conditions (Aguilar et al., 2015). While the focus of most of the literature and news media is on crop host plant species, the Queensland fruit fly has a wide range of non-crop host species in its natural range in Australia (Aguilar et al., 2015) and several native New Zealand fruit-bearing plant species have been listed as possible hosts (Ministry of Primary Industries, 2015), including the forest trees taraire (*Beilschmiedia tarairi*) and tawa (*B. tawa*). While we have been unable to find any studies testing if *B. tarairi* and *B. tawa* are actually hosts in practice, based on their similarity to the known Australian host tree species *B. obtusifolia* (a rainforest tree of New South Wales and Queensland with black ovoid fruit similar to those of tawa and taraire) (Drew, 1989) it would seem to be a reasonable assumption that they could be utilised by the Queensland fruit fly. We chose to focus on one New Zealand endemic tree species, taraire, due to it being a key forest species of northern New Zealand forests, the availability of good distributional data, some known relationships with other species and artistic merit. Taraire is commonly found with kauri (*Agathis australis*), podocarps and other broadleaf tree species. Individual trees grow to 22m in height and may be canopy or understory components of northern forests (Wright, 1984). The species produces large (2.5-3.5cm-long) single-seeded, dark purple fleshy drupes that are dispersed by the kereru (*Hemiphaga novaeseelandiae*), a native wood pigeon and taonga (treasure) species to indigenous Māori.

While taraire may be an excellent host for the Queensland fruit fly, it is necessary to determine if the predicted range of the insect matches the current distribution for the tree. Incursions of the Queensland fruit fly are most likely near to points of entry of people and goods, such as airports and sea ports. Depending on the initial site(s) of incursion, the speed of spread of the Queensland fruit fly would be difficult to model, but it is known to spread rapidly (up to 20km within three weeks in Australia) (Drew & Hooper, 1983). Transportation networks and human population density would also have an effect on the spread of this insect (Aguilar et al., 2015). Modelling indicates that under current climate conditions, most of the country has a low to medium suitability for the spread of the Queensland fruit fly (Aguilar et al., 2015). However, using predictions of a warmer future climate based on emission trajectories referred to as Representative Concentration Pathway (RCP), two RCP models (a lower emission model RCP2.6 and a higher emission model RCP8.5) suggest a significantly greater suitability for most of the country for the years 2050 and 2070. Based on the known current distribution of taraire (natural and planted occurrences) and the modeling of the predicted distribution of the Queensland fruit fly under current and future climate scenarios (Figure 4), it can be seen that there is considerable likelihood of the Queensland fruit fly coming into contact with taraire.

Assuming the Queensland fruit fly does successfully invade New Zealand and reaches taraire forest, it is not clear what the impact on the tree species would be and how this should appear in a painting that is constrained by a scientific scenario. However, the effects of Queensland fruit fly infestation on crop plants is well known (Dominiak & Ekman, 2013). Female flies lay their eggs in the fruit, typically four to six per fruit (Fletcher, 1989). The larvae feed on the fruit, causing direct damage, potentially introducing decay organisms and causing premature fruit drop (Clarke et al., 2011; Putulan et al., 2004). The loss of fruit before the seed is mature would directly reduce the number of potential taraire seedlings. Damage to more mature fruit could also reduce the dispersal of viable seeds. In addition, kereru are the main dispersal agent for taraire seeds, removing the fruit's flesh in their gut (Myers & Court, 2013). Members of another bird species, the kōkako (*Callaeas wilsoni*), have been known to disperse taraire fruits (Myers, 1984), but due to the large size of taraire fruit (and the rarity of kōkako), kereru are the only dispersal agent available for most of the country (Kelly et al., 2010). If taraire fruit are rejected by kereru because of damage, or if they prematurely drop, this may have an impact on seed germination and survival. Undispersed seed has been found to be significantly less likely to successfully produce viable seedlings (Wotton & Kelly, 2011). This could be due to higher levels of predation of whole fruits or high levels of pathogens in the whole fruit increasing mortality (Wotton & Kelly, 2011).

The potential impacts of recruitment and regeneration failure are significant, not only to the persistence of this tree species in its local area, but also potential negative impacts on gene flow between smaller, isolated populations (Wotton & Kelly, 2011). The possible future loss or reduction in population size of taraire from northern forests has further impacts on species associated with taraire. One lichen species, the silver paint lichen (*Strigula novae-zelandiae*) grows almost exclusively on the leaves of taraire (Sérusiaux, 1998), and is not present at all of the sites where taraire is found (D. Blanchon, personal observation). One saprophytic orchid has previously been reported associated with a puffball fungus (*Lycoperdon perlatum*) on the roots of taraire and nikau (*Rhopalostylis sapida*), although it is thought the host range could be wider (de Lange & Molloy, 1998).

Creation of the image: composition and technique

It is the artist's ability to 'contrive' that is of relevance to this investigation. It is extremely unlikely that anyone has seen a Queensland fruit fly in the company of a taraire tree and yet, as discussed. the ramifications of this occurring are potentially catastrophic. We have the high risk of invasion, we have the predicted spread to include the range of taraire, we have the further risk of harm to the kereru and other species associated with taraire such as the silver paint lichen. These are all depicted in the image *Fly in the Ointment* (Figure 5).

In order to underline the relationship between disciplines and continue this fruitful liaison, the image *Fly in the Ointment* makes numerous references. For example, both the tradition of botanical art and that most quintessential location of scientific enquiry, the laboratory, are cited. An acutely observed, watercolour-rendered, centrally-placed specimen on a neutral ground is typical of botanical illustration (Rice, 1999). So too is the inclusion of potential companion species, which may enjoy either a parasitic, symbiotic or mutualistic relationship with the subject. The isolation of a specimen outside its natural habitat, along with the clamp, recalls scientific endeavor, in particular the empirical aspect with which art practice has been so inextricably entwined.

There are also art historical and compositional

Figure 5. Hamish Foote, *Fly in the Ointment*, watercolour, 2015.

references of a more generic variety. The fruit fly specimens, for example, which reside on the fallen drupes are scaled appropriately, the specimen on the wing on the other hand is oversized. This is in keeping with the tradition of scaling subject matter relative to their importance, such as the depiction, during the Renaissance, of significant religious figures and patrons so that they towered over mere mortals (Hartt, 1994).

On the subject of content, collaboration and dialogue between scientist and artist permits a unique and invaluable responsiveness and flexibility. For example, the inclusion of the silver paint lichen arose as the image was forming. This discussion was followed by research into species associated with taraire trees, and as a result the lichen was incorporated.

Finally, it is perhaps worth noting with regard to species threats to New Zealand, that the focus is often on the potential economic impact. The Ministry for Primary Industries, for example, emphasises that the Queensland fruit fly jeopardises a horticulture industry worth $3.6 billion a year. The aforementioned species, however, have no such association and as such offer us the chance to focus on greyer and more sophisticated territory; that of social and environmental currency, and our 'sense of place', as opposed to more mercantile imperatives. We have the opportunity to revisit our values. This is not unknown in recent history with kauri dieback, for example, prompting consideration of a similar nature. As the conservationist Stephen King observed on the subject:

> Kauri are one of the largest rainforest trees on earth and they are to New Zealand what the pyramids are to Egypt and Stonehenge and cathedrals are to England. They're worth more than tourism; it's about our identity. (Keep Kauri Standing, (5th September 2013)

Taraire, which are often found with kauri, have their own unique qualities – blue fruit, for example, which ensure that their fortune is inextricably entwined with that of the kereru.

Conclusion

The aim of *Alien Nation* is to use scientific data and modelling to predict possible future invasion scenarios for different animal and plant species. For the Queensland fruit fly, modelling shows that this species could indeed invade and spread over parts of New Zealand under both current and predicted future climate conditions. The impacts on horticultural crops would be significant, what is less clear is the impact on native ecosystems. Modelling using one native tree species (*Beilschmiedia tarairi*) shows that there is considerable likelihood of the Queensland fruit fly coming into contact with taraire forest. Based on the reports of the effects of this insect on the fruits of horticultural crops and wild plant species in Australia, it is likely that the fruits of taraire would be damaged by any infestation. This could cause early fruit drop, negatively affecting seedling recruitment, and reducing food reserves available for bird species. *Fly in the Ointment* explores this scenario, a scene that does not, and may never exist. The painting requires the viewer to see the impacts of a possible invasion on native biodiversity, an examination through the lens of cultural rather than fiscal currency.

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