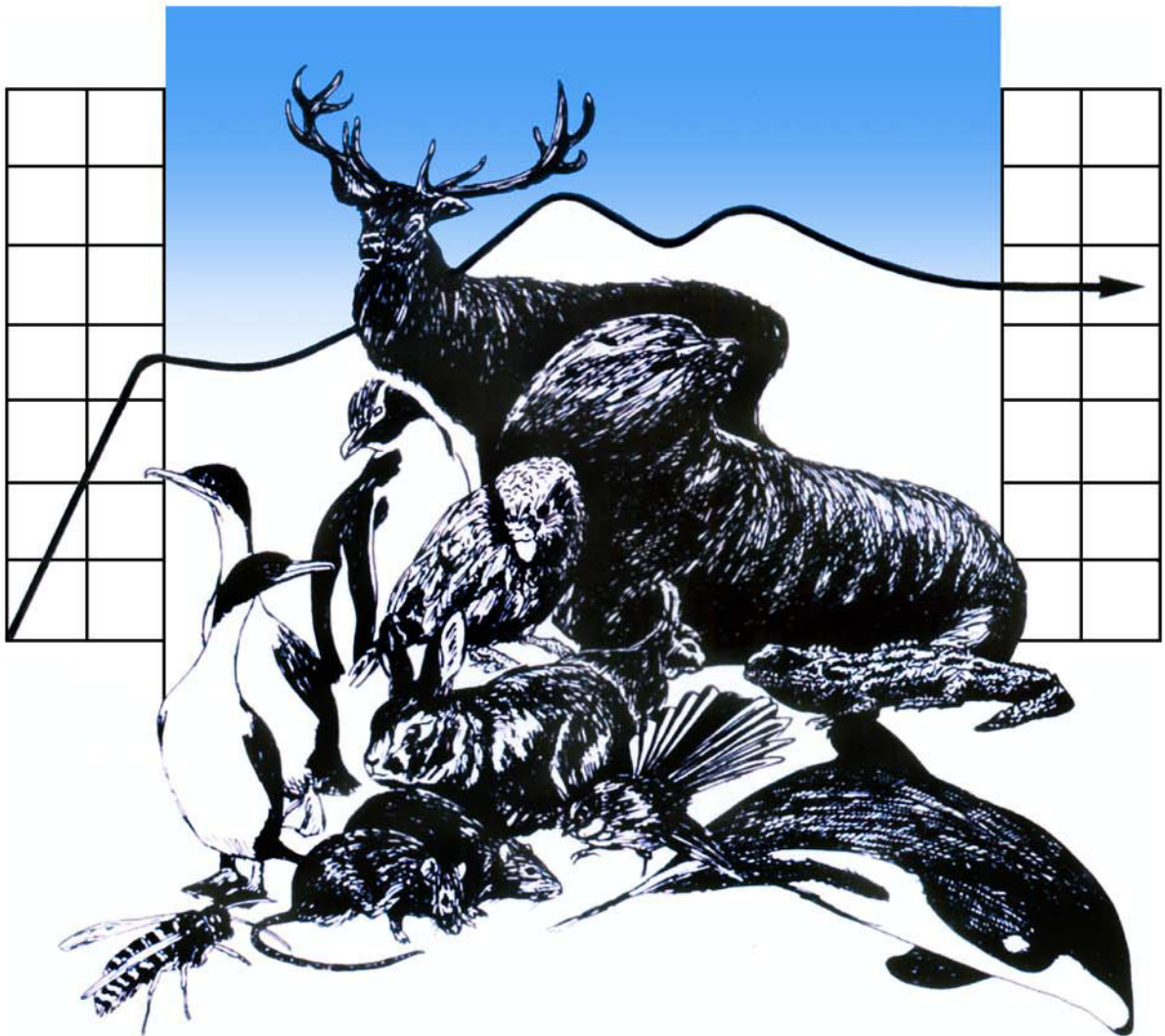




## DEPARTMENT OF ZOOLOGY



## WILDLIFE MANAGEMENT

# **Great White Butterfly Eradication Programme: A Summary of Background, Progress and Future Implications**

**Victoria McKenzie**

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University of Otago  
Department of Zoology  
P.O. Box 56, Dunedin  
New Zealand

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Victoria McKenzie  
Department of Zoology  
University of Otago

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## **Abstract**

Biological invasions of non-native species are one of the greatest threats to biodiversity and ecosystem function. The Great White Butterfly (*Pieris brassicae*) (GWB) is a common pest throughout the world and was first discovered in Nelson, New Zealand in May 2010. Following the discovery of this species the Ministry for Primary Industries (MPI) responded with a monitoring and slow the spread strategy, and since then an all-out eradication programme has been launched in an attempt to entirely eradicate this species from Nelson. The Department of Conservation (DOC) has been successful in preventing the spread north of the Port Hills core area, however there have been recent finds south of the central core in Richmond and Hope outlier areas, indicating that the GWB has spread further from the core area than initially thought. Whether the outcome of this eradication programme will be successful it is still too early to tell, however the continued intensive efforts of DOC staff is vital in order to place amounting pressure on this pest to reduce its spread and eliminate it entirely from the New Zealand mainland. By doing so this will avoid huge economic losses in the form of brassica production, as well as prevent further destruction of some of our endangered native cresses.

## **Introduction**

### Biological invasions

Biological invasions are one of the greatest threats to biodiversity and ecosystem function (Vitousek et al. 1997; Mack et al. 2000; Clavero and Garcia-Berthou 2005; Hoffmann 2011), which require even greater management actions. Biotic invaders are species that establish a new range in which they spread and persist to the detriment of the environment (Mack et al. 2000). Biological invasions of non-native species is one of six major ongoing global changes, all of which are caused by humans (Vitousek et al. 1997).

These invasions have become so widespread that they are now a significant component of human-driven global environmental change, and represent a human-induced breakdown of the regional uniqueness of the Earth's flora and fauna (Vitousek et al. 1997). Based on the number and variety of species introductions, it has become evident that biological invasions are breaking down the biogeographical barriers that have created and maintained the major floral and faunal regions of the world (Vitousek et al. 1997).

Humans are the key drivers of biological invasions as they move species beyond their native ranges, both deliberately and unintentionally, resulting in many of the species becoming established and spreading in their new habitat. The geographic scope, frequency, and number of invasive species have grown substantially as a direct consequence of expanding transport and commerce (Wells et al. 1986; di Castri 1989; Mack et al. 2000).

The list of established introduced species continues to grow, as does the economic and ecological effects damage that these exotic species bring to their

new habitat (Vitousek et al. 1997). The number of species that have invaded new habitats as a result of human facilitation has increased by orders of magnitude over the last 200 years, and the dramatic increase in species immigration worldwide roughly tracks the rise in human transport (di Castri 1989; Mack et al. 2000).

Biotic invasions cause two main types of economic impact – loss in potential economic output (loss in crop production) and the direct cost of combating invasions (Mack et al. 2000). In addition to this, biological invasions also contribute substantially to extinction of native species (Vitousek et al. 1997).

#### Eradication of Exotic Species

Biotic invaders can inflict enormous environmental damage. In agriculture the principle pests of crops are exotic species, and the combined expenses of pest control and crop losses can be huge (Mack et al. 2000). Failure to address the issue of biological invasions could result in severe global consequences, including loss of agricultural, forestry and fishery resources, as well as disruption of ecological processes (Mack et al. 2000).

Eradication of exotic species is the most desirable outcome, however successful eradication attempts are rare as it is the most difficult management option (Wittenberg and Cock 2009; Hoffmann et al. 2010; Hoffmann 2011). Taking effective steps to prevent dispersal and establishment of exotic species constitutes an enormous challenge (Mack et al. 2000).

Eradications of exotic mammals have the highest success rate, but in contrast there are few documented cases of successful invertebrate eradications, and none of which involves completely eradicating an exotic invertebrate from a mainland. Some potentially damaging non-indigenous species have been eradicated – an infestation of the Asian citrus blackfly (*Aleurocanthus woglumi*) on Key West in the Florida Keys was eradicated between 1934 and 1937 (Hoelmer and Grace 1989). This eradication succeeded due to the lack of highway to the mainland at the time, and the only railroad bridge was destroyed by a hurricane in 1935 (Mack et al. 2000).

Insularity was also a key feature in an eradication attempt of the screwworm fly (*Cochliomyia hominivorax*) on Sanibel Island, Florida, by the release of sterile males. The apparent success of this approach led to a similar trial on Curacao, and eradication in that trial led to widespread release of sterile males throughout the southeastern United States (Mack et al. 2000).

There have been only ten documented cases of successful invasive ant eradications despite nearly a century of eradication effort (Hoffman et al. 2010). There are three key factors vital to success of previous eradications – host specificity and poor dispersal ability (not the case for GWB); sufficient resources devoted for a long enough time; and widespread support from the relevant agencies and the public (Mack et al. 2000).

#### GWB vs. Small White

The small white or cabbage butterfly (*Pieris rapae*) is a well known pest in New Zealand and throughout the world, and shares some similar attributes with the GWB. However there are a number of behavioural aspects of the GWB that differ



from the small white butterfly which make the GWB much more of a threat, due to significant implications for New Zealand's native cresses as well as for economic production of brassicas (Toft 2013).

One of the most detrimental attributes of the GWB is that the adult butterflies lay their eggs in clusters (compared to small white butterflies laying a single egg), meaning the voracious larvae feed in clusters, which completely defoliates smaller host plants and can reduce host plants to their skeleton. The caterpillars can then move more than 100m in search of other hosts (Feltwell 1982). This behaviour potentially puts small, clustered populations of rare native brassicas at additional risk (Toft 2013).

Research also shows that mid to late instar GWB caterpillars can have a direct impact on the reproductive capacity of the plants due to their preference for feeding on flower and buds (Smallegange et al. 2007).

In addition to this, GWB are expected to have a higher cold tolerance than small whites, making them more resilient to seasonal factors that may otherwise have reduced their numbers. GWB are also stronger fliers, and when populations reach high densities they are predisposed to mass migrate over long distances to new locations (Toft 2013). GWB have a longer period of activity through the year, meaning that cresses under attack by small white will be even more threatened due to the longer timeframe (Toft 2013).

Although there is likely to be some competition between GWB and small white, the impacts of both species on threatened native cresses is likely to be additive, based on their sympatric feeding behaviour overseas (Toft 2013). In addition to this, establishment of GWB may result in native cresses that are not

currently at risk to become threatened as a result of attack by this species (Toft 2013).

#### Parasitoid Activity

*Cotesia glomerata*, a small parasitic wasp, was introduced in the 1930s as a biological control for small white butterflies. Fortunately, this small wasp favours the GWB as a host over the small white, and is acting as an ally for eradication of this species. A small study was done to determine rates of parasitism, and it was found that about 22% of individual GWB larvae were found to be parasitized (Toft 2013).

In addition to this, some GWB pupae collected from the field have been parasitized by a pupal parasite, *Pteromalus puparum*, which was also introduced as a biological control again for the small white (Toft 2013). As these two parasites target different life stages of the GWB the impact is additive rather than alternative, and both have been a significant contributor to controlling GWB populations.

#### Global Spread of GWB

The GWB is found throughout Europe, the northern coast of Africa, the Middle East, Afghanistan, Pakistan and India (Feltwell 1982; Toft 2013). In the 1970s it is believed to have crossed the Ural Mountains and made its way east through Siberia and arriving in Hokkaido, Japan around 1994 (Sato and Ohsaki 2004). Adventive populations established in Chile around 1970 and in South Africa in the early 1990s (Gardiner 1974; Gardiner 1995; Toft 2013).

### First detection in Nelson

The GWB was first detected in Nelson on 14 May 2010, by a member of the public who reported unusual caterpillars on a nasturtium plant in a residential garden located about 1.5km from Port Nelson (Toft 2013). The caterpillars were formally identified as *Pieris brassicae*, which is an unwanted organism under the Biosecurity Act. The Ministry for Primary Industries (MPI) responded with a monitoring and slow the spread strategy (Phillips et al. 2013).

By the end of 2010 there had been a total of 19 confirmed sites from the Nelson area through a publicity campaign by the Ministry for Primary Industries (MPI). These findings were mainly clustered within 1.5km of Port Nelson, so it was therefore concluded that the port acted as a gateway for GWB into New Zealand (Toft 2013).

By September 22, 2012 there had been 110 detections since first discovered, over 28 months (Phillips et al. 2013). On 19 November 2012, DOC began an eradication attempt. By December 2012 the GWB had spread northeast to Glenduan and southwest to Richmond, a spread of minimum 6km and maximum 12km (Phillips et al. 2013).

Preliminary genetic analysis on the Nelson population indicates that multiple individuals arrived into the Nelson area, which could have happened in a single occurrence (Toft 2013). There is a record of about 100 live GWB pupae attached to the outside of a shipping container travelling from Spain to the USA (Toft 2013). Container ships arrive in Nelson Port regularly from all over the world, so it is possible that a similar scenario to that mentioned above resulted in the GWB entering New Zealand.

## **Threats to New Zealand**

### Biodiversity

The establishment and spread of GWB in New Zealand is likely to have significant consequences for the survival of many of New Zealand's native cresses (Toft 2013). GWB has a similar range of host plants as the small white butterfly (Feltwell 1982), which are mostly confined to members of the cosmopolitan family Brassicaceae (cresses). All of New Zealand's native cress species are potentially susceptible to attack by GWB (Toft 2013).

All but 6 of the 79 species of native cresses are endemic to New Zealand, which equates to 92% endemism (Toft 2013). Of most concern is that 74% (57 species) of our native cress species are currently either at risk or threatened with extinction, which represents more than 6% of New Zealand's threatened plant species (Toft 2013). Eleven *Lepidium* are ranked as Nationally Critical, and two *Lepidium* are already extinct, with the small white butterfly being a key contributing factor to the extinction of one of these (Toft 2013).

The small white is a well known pest to our native cresses and is listed in the Coastal Cress Recovery Plan (Norton and de Lange 1999) as a key factor in the current decline of coastal cresses (Toft 2013). There is also a good correlation between the most threatened cress species and those that are known hosts to the white butterfly (Toft 2013).

### Economic Impacts

Brassica crops are very important in New Zealand. This is due to the production of brassica seeds, vegetable brassicas for human consumption and the

dependence on supplementary feed for livestock from our meat and dairy industries (Toft 2013). All of these components contribute substantially to the country's economy. The production of brassica seeds is worth an estimated \$25.7 million in revenue per annum, whereas vegetable brassicas grown for human consumption is valued at nearly \$91 million per annum, grown over about 4300 hectares (Toft 2013). The largest area of brassica production is as supplementary feed for stock, with an estimated 40% of the ~300,000 hectares grown in 2012 expected to be for New Zealand's dairy industry (Toft 2013).

Although growers already have control regimes in place for the small white butterfly, additional insecticide applications will be required to control the GWB due to different seasonality and longer feeding throughout the year (Toft 2013). It has been (conservatively) estimated that each additional spray cycle will cost the vegetable industry around \$100-\$110 per hectare, resulting in an extra \$646,000-\$710,000 spent per annum on additional treatments (Toft 2013). New Zealand's dairy industry will bear the brunt of this cost, for them to add just one spray treatment to 100,000 ha of forage crops would cost ~\$7 million per annum (Toft 2013).

There is also a threat that forage brassicas will be less palatable to livestock when infested with GWB caterpillars, due to their defense mechanism in the form of their ability to convert glucosinolates in brassicas to a highly distasteful chemical to avoid predators (Toft 2013).

The arrival of GWB is also likely to heavily impact the brassica seed industry, which prefers not to spray at all during flowering periods. As the GWB

can have preferential feeding on flowers and buds (Smallegange et al. 2007), this is likely to be difficult to manage and lead to significant losses for this industry.

## **Methods**

### Surveillance Methods

#### Priority blocks

In order to manage surveillance activities and prioritise areas throughout Nelson, the wider Nelson area was divided into blocks. These blocks were then grouped and defined as being part of the core, satellite or outlier areas (Figure 1). The core area is the hotspot for GWB as it has had the most GWB detections since 2010, and covers the Port Hills; the satellite area extends out from this central core, about 6km to the south and 5km to the north; and the outlier areas cover any possible finds outside the satellite and core areas (Figure 1).

#### Passive

Passive surveillance relies on the public to detect and report any stage of GWB, and is therefore heavily reliant on public awareness and public knowledge of the potential risks of this pest. This form of surveillance is supported by MPI through access to their 0800 exotic diseases and pests hotline. Members of the public can ring this hotline at any time if they think they have sighted a GWB (eggs, caterpillars, adult or pupae) and the gathered information is emailed to a specific site set up to receive GWB reports, accessed by DOC workers who are part of the GWB eradication team.

## Active

Active surveillance is undertaken in response to positive finds of GWB, and involves searching for GWB in the surrounding area of the detection. In the core areas the active search area included properties within a radius of 150m of the positive find, but in the outlier areas this active search area extended from a minimum of 200m from the positive find to a maximum of 1km in areas where finds represented significant extensions (Toft 2013). For example, an adult male GWB was caught in Hope, which is situated in the outlying area. In response to this find the majority of this area was searched in order to eliminate the GWB spreading further from the core area.

## General

General surveillance involves a wide-area method in which properties are searched within a given area at a particular time, rather than in response to a positive find (active surveillance). It has become a key strategy in the eradication project over autumn, however it is highly dependent on sufficient staffing levels (Toft 2013).

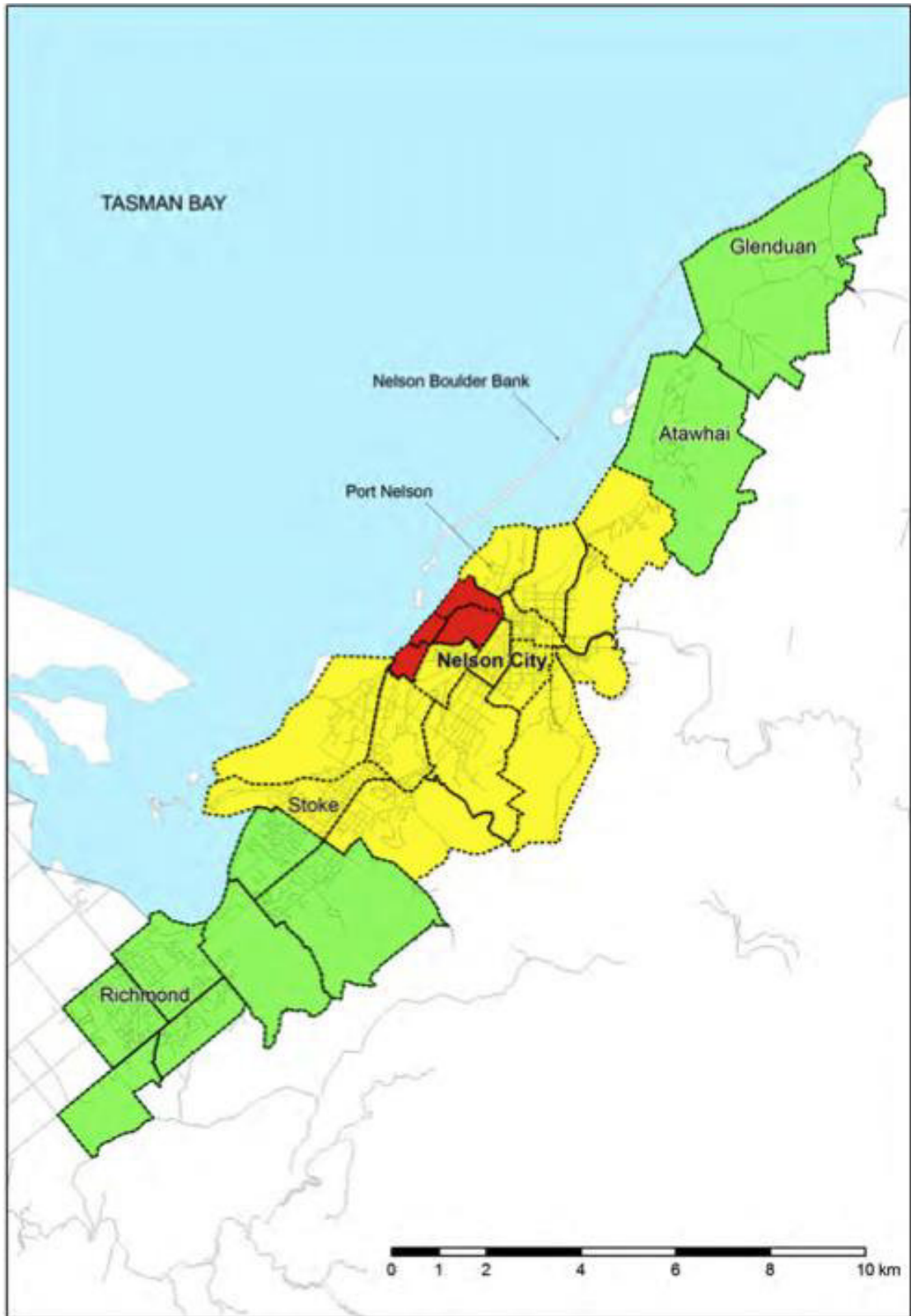


Figure 1: Nelson area divided into priority block for the GWB eradication programme. Red = core, yellow = satellite and green = outlier areas (Toft 2013).



## Follow-up

Whenever a positive find was made at any site, follow-up surveillance involved searching the property again 7-10 days later. If a further detection was made then follow-up visits would continue until two consecutive visits were negative.

## Treatment of GWB detections

Whenever eggs or caterpillars were detected, the host plants were thoroughly searched and all GWB were removed and placed into pottles. These finds were taken back to DOC base and either frozen or put aside for research purposes.

Once the GWB had been manually removed an assessment was made on-site about the requirement for further treatment of using insecticide, or removal of the host plants all together.

## Nasturtium control

The major areas of nasturtium being utilised by GWB are on overgrown, sheltered slopes. The most favoured spots are in the Port Hills area, patches along the hills at Atawhai and Glenduan, and also in the Wood hills to the east (Toft 2013). There are smaller patches of nasturtium in the flat residential areas of Tahunanui, Stoke and Richmond, however there are also plenty of alternative host plants in these areas, so removing all nasturtium in these areas was seen as unproductive (Toft 2013). Therefore the primary issue with nasturtium was the GWB breeding hotspots provided by large overgrown areas of nasturtium on steep hillsides that are difficult to access. The focus of nasturtium management became the detection and management of these sites.

## **Results**

### Current Distribution of GWB

From May 2010 to 30 June 2013, GWB had been detected at 821 sites in the Nelson Tasman region. Of these, 31.7% (260 finds) were found within the core area; 60.9% (500 finds) were in the satellite areas, and 7.4% (61 finds) were in outlying areas (Figure 2).

The highest density of positive finds, which was 16.2% of all positive sites (133 properties) was on the hillside immediately south of the Port, in a small area called Stepneyville. This area is considered to be the epicentre of the infestation (Toft 2013). Within 6km of this epicentre 96% (788) of known GWB sites are located. The finds beyond the 6km radius were at Glenduan (10km to the north) or 12km to the south in Stoke, Best Island and Richmond.

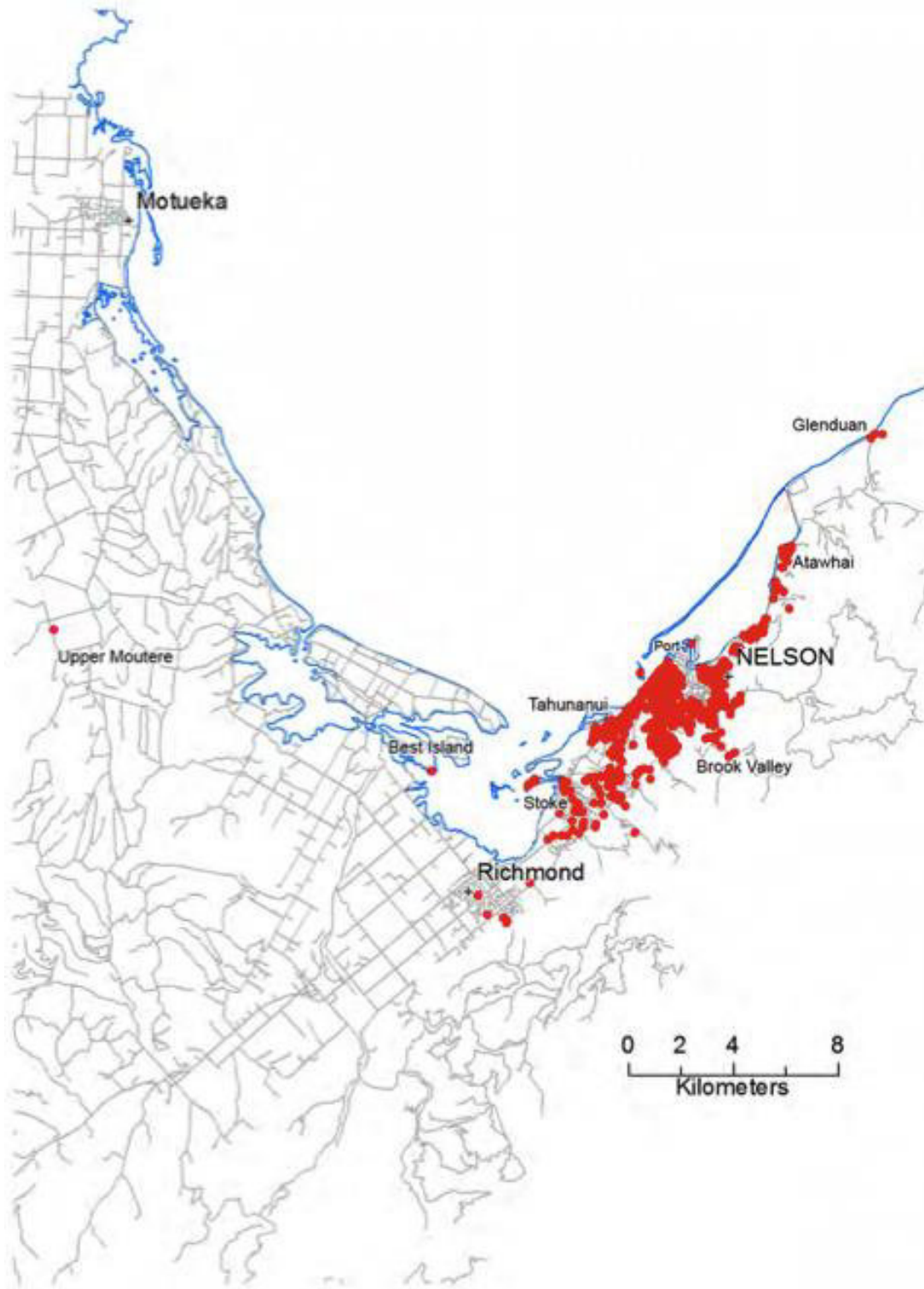


Figure 2: Map of positive finds to 3 July 2013 (Toft 2013).

In addition to this, from May 2010 to 30 November 2013, there were 48,138 site inspections resulting in 2051 GWB detections (Table 1). Of these, eggs, larvae and pupae were found and removed from 31%, 58% and 3% of infested sites respectively (Table 1). The proportions of these findings correspond with detectability of each life-stage based on staff perceptions, with larvae being easiest and pupae most difficult (Phillips et al. 2013). However detection of pupae will also be low as they were only targeted from 2013 onwards, which also applies to detections of adult GWB which were captured at 10% of infested sites.

From January to 30 November 2013, staff captured 292 GWB adults, 233 (80%) of them since late August, and 180 (62%) during the post-winter emergence of GWB adults in late August and September (Phillips et al. 2013). The mean sex ratio of adults collected from late August 2013 was approximately two males per female (the proportion of captured females that have mated is not yet known) (Phillips et al. 2013).

In addition to this, bounty captures (children were paid \$10 for every adult GWB caught and brought into the DOC office during the school holidays) resulted in 133 adult GWB captures, all of which were caught within the core area.

Overall, detections per inspection declined markedly between 2012 and 2013. This is primarily due to an increase in active and general surveillance with the start of the eradication programme, which increased the proportion of uninfested sites inspected (Phillips et al. 2013).

Table 1. Total GWB detections, inspections and detections per inspection by year, plus number of sites where eggs, larvae, pupae or adults were detected.

Year	Sites inspected	Sites with GWB	Sites with GWB/ sites inspected	Sites with eggs	Sites with larvae	Sites with pupae	Sites with adults
2010	20	20	1	0	15	4	4
2011	84	26	0.31	0	24	1	2
2012	918	288	0.31	17	128	7	12
2013	47116	1717	0.04	609	1013	53	193
Total	48138	2051		626	1180	65	211

#### Distribution over time

To date, there remains no evidence of long-distance dispersal of GWB out of the wider Nelson urban area. A very slow spread of GWB has been revealed through an analysis of the distance-from-epicentre of confirmed detections over time, although the slope of the trend line is statistically significant (Figure 3) (Toft 2013). If populations of GWB were able to build up substantially it is expected there would be a rapid increase in the rate of spread (Toft 2013). This is through the increased likelihood of stochastic dispersal events, such as the chance of human-mediated dispersal events or the number of adult GWB exposed to strong winds (Toft 2013). Overall, the spread of GWB (albeit a slow one) throughout the Nelson region needs to be quashed if the eradication is to be a success.

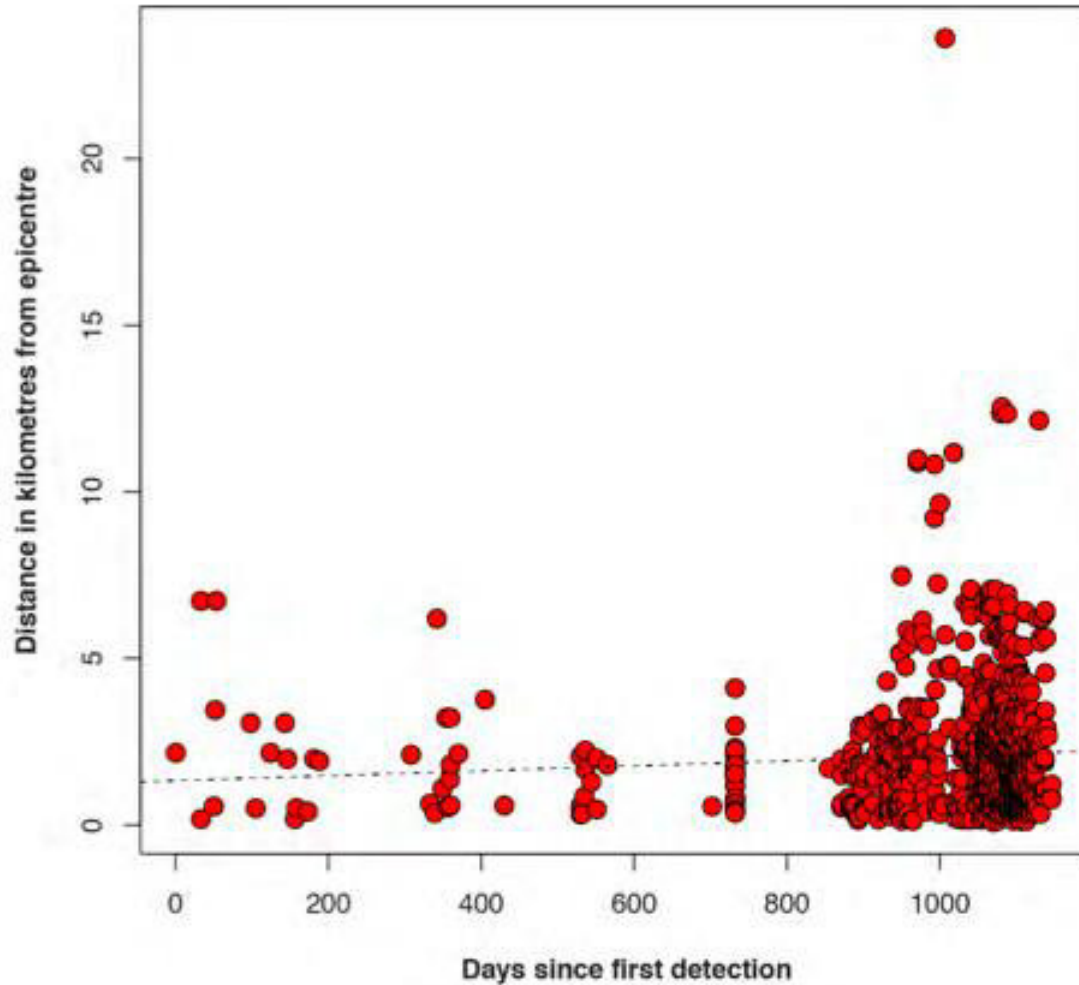


Figure 3: The distance of GWB detections from the epicentre (Port Hills) by time since the first detection in Nelson in May 2010. Although the spread of GWB is slow the trendline is significant ( $P = 0.03$ ). The outlier at the top of the graph is the find of a single caterpillar in Upper Moutere from what was likely a human-mediated dispersal event. There is no indication of an established population there (Toft 2013).

## **Discussion**

### Is the population responding to control efforts?

The best evidence of a response by GWB to control work is that of Glenduan, which is an outlier area 11-12km north of the Port Hills. During March 2013 GWB was detected in this area, with four more detections being discovered from April – June 2013. In response to this, general surveillance and host plant management continued through September and November 2013, with no further GWB detections discovered (Phillips et al. 2013).

A similar situation occurred in Richmond, an outlier area 9-12km south of the Port Hills. Between December 2012 and April 2013 there was a series of 13 GWB detections made in this area, resulting in another intensive response which seemed to curb growth of the GWB population in this area. However, as general surveillance continued throughout Richmond, there were three more positive detections of GWB in Richmond during December 2013. Although the spread of GWB appeared to have reduced during 2013 in the outlier areas, it has recently become evident that once again GWB has spread further from the core area, which will require continued intensive control efforts.

Furthermore, during December 2013 there was two of positive finds in the Hope area, which is south of Richmond. This was an indication that the GWB was spreading much further than had been thought, and will again require intensive control efforts to eliminate GWB in this area and prevent further spread.

It is evident that GWB populations have responded to control efforts through the instance of reducing GWB spreading north, such as in Glenduan. However the spread of GWB south to Richmond and Hope areas is of concern

and will need considerable attention and further intensive control efforts to reduce further spread.

#### Probability of eradication success

Four cost-benefit analyses for eradicating GWB from New Zealand have used various estimates of the probability of eradication success: 50-75% (Dustow 2010); 50-65% (Dustow and van Eyndhoven 2012); 30-60% (Manning 2012); and 56-76% (East 2013).

These differing estimates of the probability of success were based on a number of different factors. The 50-75% estimate by Dustow (2010) was obtained without using any systematic approach. Dustow and van Eyndhoven's (2012) estimate of 50-65% for a ground-based eradication attempt was based on overseas examples and expert opinion. Manning (2012) based his estimate of 30% also on overseas examples and expert opinion, but estimated that the probability of success could increase to 60% if effective lures were developed.

The most recent estimate of 56-76% (East 2013) was derived in September 2013 from six people, chosen for their scientific expertise and detailed knowledge of the programme (Phillips et al. 2013). The 56% estimate was based on the probability of success if current tools were continued, and the 76% was if better tools were developed.

There were a number of factors listed, both for and against success. The factors against success were: GWB's ability to escape Nelson unaided or with humans as the facilitator; lack of an effective attractant; lack of an aerial spraying operation; risk of 'public fatigue' with the programme; difficulty of killing GWB at low



densities; high detections of GWB in the core area during spring despite general surveillance the previous autumn; risk of additional GWB incursions as the pathway is unknown; and the spread of GWB in Chile and South Africa (Phillips et al. 2013).

Factors favouring success were: limited spread of GWB to date and small spatial distribution; ocean and mountain barriers to dispersal; energetic, well-managed eradication programme; presence of natural enemies; early indication the population is responding to control; detectability of eggs and larvae; public support; and a high potential to develop additional tools.

## **Conclusion**

In conclusion, the Great White Butterfly Eradication programme is a dedicated and ambitious programme aimed at reducing the spread and eliminating the GWB entirely from the New Zealand mainland. If the eradication of GWB is successful, it will save New Zealand from huge economic losses in the form of brassica production, as well as conserving our unique biodiversity. While there have been some successes in response to control efforts so far, the recent finds in Richmond and Hope are very worrying. Public support is vital for this programme to succeed, particularly as detections decrease and control becomes more difficult at detecting GWB at low densities. The success of this programme would be a world first, and DOC needs continued support in order to eradicate this pest and conserve New Zealand's unique biodiversity.

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