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CLIMEX models for selected glasshouse biological control agents

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Executive summary

CLIMEX models for selected tomato BCAs

David Logan, May 2012, SPTS No. 6938

This report details work undertaken for PFR contract no.28292, for Tomatoes NZ. The report details work from the period 15/4/2012 to 15/5/2012. The suitability of the New Zealand environment for the survival and persistence of three biological control agents (BCAs) (*Delphastus catalinae* (Horn), *Macrolophus caliginosus* (Wagner) and *Nesidiocoris tenuis* (Reuter)) was determined using the climate modelling tool CLIMEX. Outcomes of the models may be used to support an application to the Environmental Protection Agency by Tomatoes NZ for the introduction of one or more of the BCAs. The basis of support would be that the BCAs are unlikely to establish outside glasshouses.

Initial CLIMEX models for each organism (*D. catalinae*, *M. caliginosus* and *N. tenuis*) were constructed using published research for temperature-dependent development and for survival. Mapped model output Ecoclimatic Index (EI) scores were compared with mapped locality and country records from literature and internet data, and some model parameters adjusted iteratively to improve fit. The best-fit model was then applied to New Zealand and an interpretation was made of the likely persistence of populations outside glasshouses. Mapping of EI scores and taxon collection records was in ArcMap 10.0.

The coccinellid *D. catalinae* is the least tolerant of all three BCAs to cold temperatures. It has a native range that extends from Colombia to southern California. In New Zealand, *D. catalinae* may survive outside glasshouses only in the warmest localities such as Cape Reinga, Kaitaia, Mokohinau Island and Leigh.

The mirid taxon *M. caliginosus* is a junior synonym of *M. melanotoma*. Mirids marketed for biological control in European covered crops as *M. caliginosus* (= *M. melanotoma*) were found to be another species *M. pygmaeus* based on mtDNA analysis. *M. pygmaeus* was illegally introduced to New Zealand during or prior to 2007. It may not have established outside glasshouses in New Zealand as original stocks were destroyed and none has been detected during monitoring at Pukekohe since 2009. The potential distribution of *M. pygmaeus* and *M. melanotoma* in New Zealand can be modelled by the same parameters as there is insufficient biological information to separate them. CLIMEX EI scores suggest that *M. melanotoma* and *M. pygmaeus* may persist outside glasshouses in Auckland, many areas of Northland, and on the east coast of the North Island as far South as Castlepoint.

The third species is the widely-distributed mirid *N. tenuis.* CLIMEX EI scores suggest that *N. tenuis* may persist outside glasshouses in many areas of Northland and on the east coast of the North Island, particularly between Gisborne and Napier.

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1 Introduction

Tomatoes NZ plans to submit an application to the Environmental Protection Authority (EPA) to approve the use of three biological control agents (BCAs) (*Delphastus catalinae* (Horn), *Macrolophus caliginosus* (Wagner) and *Nesidiocoris tenuis* (Reuter)) for control of pests on glasshouse crops. CLIMEX modelling to assess whether any of the three BCAs could establish outside glasshouses in New Zealand is reported here and may form one component of the application to the EPA.

2 Method

CLIMEX (http://www.hearne.com.au/attachments/ClimexUserGuide3.pdf) is model-building software to simulate a species' geographical distribution based on climatic variables (Sutherst & Maywald 1991). A CLIMEX model consists of growth-related and stress related indices. Conditions that favour growth are grouped into dormancy/chilling, temperature, moisture and light indices. Limits to growth imposed by adverse climatic conditions are grouped into cold, hot, dry and wet stresses and combinations of two states (cold-wet, cold-dry, hot-wet and hot-dry). Initial CLIMEX models for each organism (*D. catalinae*, *M. caliginosus* and *N. tenuis*) were constructed using published research for temperature-dependent development and for survival. Locality and country records from literature and internet data such as the Global Biodiversity Information Facility (http://www.gbif.org/) were mapped as a basis to verify or modify the model parameters. Localities where the BCAs occurred only in covered crops/greenhouses were excluded from verification maps. The final model was based on a subjective assessment of best-fit to the known field distribution. The model was then applied to New Zealand and an interpretation was made of the likely persistence of populations outside glasshouses.

CLIMEX model outputs were Ecoclimatic Index (EI) scores (Table 1) and were mapped together with locality records in ArcMap 10.0. EI scores are the combination of growth indices based on temperature and moisture requirements and on stresses (temperature only in this case) and are scaled between 0 and 100. EI scores can be interpreted by assuming that there is a favourable and unfavourable season for insect growth (Sutherst 2003). For example, winter in temperate regions is a period when insect populations have limited growth and may enter diapause when no growth occurs. In equatorial regions, species may aestivate to survive unfavourable hot and dry periods. A consequence of this assumption is that most growth occurs in half the year. An EI score of 30 indicates that maximum growth has been achieved in at least 60% of the favourable season. Low EI scores can reflect suboptimal growth conditions and/or high stress conditions. Here I have grouped EI scores into four classes to indicate suitability for long-term population growth. Localities with EI scores of ≤2, 2.01-16.00, 16.01-30.00 and >30.01 have positive growth indices for ca. <8, 8-16, 16-24 and >24 weeks of the year respectively. The division was based on a CLIMEX model for the relatively well-known passionvine hopper (*Scolypoa australis*) in New Zealand and Australia (D. Logan, unpubl.). Other divisions are possible. In particular the division between marginal and suitable may be equally valid at an EI value of 10. Part of model development is to iteratively modify parameters so that EI scores reflect collection records and any knowledge of annual population variation. For most organisms data on distribution and population size is limited. Hence maps of EI scores are indicative only and should be interpreted accordingly.

Table 1. Ecoclimatic index scores and interpretation applied to mapping suitable sites for *Delphastus catalinae*, *Nesidiocoris tenuis* and *Macrolophus pygmaeus*.

Eco-climatic index range	Interpretation
0.00–2.00	Unsuitable
2.01–16.00	Marginal
16.01–30.00	Suitable
>30.00	Optimal

3 *Delphastus catalinae* (Horn) (Coleoptera: Coccinellidae)

3.1 Identity and distribution

Gordon (1994) (referred to in Hoelmer and Pickett 2003) revised the genus *Delphastus* and in the process clarified the status and geographic distribution of *D. catalinae*. The native range of *D. catalinae* extends from Colombia to southern California. The taxon *D. pusillus*, previously considered synonymous with *D. catalinae*, is a separate species that is distributed in the eastern half of USA. Geographical locations in North, Central and South America to validate the CLIMEX model were from GBIF, Gordon (1970), Heinz et al. (1999), and Hoelmer and Pickett (2003). Field populations of *D. catalinae* also occur in Egypt (Abd-Rabou & Simmons 2008), Hawaii, Fiji and the Canary Islands (Hoelmer & Pickett 2003), but were not mapped.

3.2 CLIMEX model and mapped EI values

CLIMEX model parameters are given in Table 2. Hemachandra (1994) and Legaspi et al. (2008) give values for thermal constants (333.3DD, 293–323DD respectively) and lower development threshold temperature (10.0°C, 9.0–9.9°C respectively). Parameters for limitations imposed by moisture and temperature were based on Liu (2005), Simmons and Legaspi (2004) and Simmons et al. (2007, 2008). Maps were constructed for Central America (Figure 1) and New Zealand (Figure 2).

Table 2. CLIMEX parameters for *Delphastus catalinae.*

Parameter group	Parameter	Value
Temperature Index	Lower Temperature Threshold (DV0)	11.5
	Lower Optimum Temperature (DV1)	20
	Upper Optimum Temperature (DV2)	27.5
	Upper Temperature Threshold (DV3)	37.5
	Minimum degree-days above DV0 to complete a generation or thermal constant (PDD)	320
Moisture Index	Lower Soil Moisture Threshold (SM0)	0.05
	Lower Optimal Soil Moisture (SM1)	0.1
	Upper Optimal Soil Moisture (SM2)	1
	Upper Soil Moisture Threshold (SM3)	1.5
Cold Stress	Cold Stress Degree-Day Threshold (DTCS)	16
	Cold Stress Degree-Day Rate (DHCS)	-0.025
	Cold Stress Temperature Threshold (Average) (TTCSA)	10
	Cold Stress Temperature Rate (Average) (THCSA)	-0.025
	Cold Stress Degree-day Temperature Threshold (DVCS)	10

3.3 Interpretation of New Zealand map

D. catalinae could persist outside glasshouses in only the warmest areas of the North Island (e.g. Cape Reinga, Kaitaia, Mokohinau Island, Leigh).

4 *Macrolophus caliginosus* (Wagner) (Hemiptera: Miridae)

4.1 Identity and distribution

Macrolophus caliginosus (Wagner) is a junior synonym of *M. melanotoma* (Costa). Martinez-Cascales et al. (2006b) separated *M. melanotoma* from *M. pygmaeus* (Rambur) by differences in morphology and mtDNA sequence. Martinez-Cascales et al. (2006b) also found some evidence for differences in plant preference with only *M. pygmaeus* found on tomato and only *M. melanotoma* found on the ruderal weedy species yellow fleabane, *Dittrichia viscosa*. Mirids marketed for biological control in European covered crops as *M. caliginosus* (e.g. Mirical-N) were found to be *M. pygmaeus* based on mtDNA analysis (Perdikis et al. 2003; Martinez-Cascales et al. 2006a; Machtelinckx et al. 2009; Urbaneja et al. 2009). Given these observations, *M. pygmaeus* is likely to be a better candidate than *M. caliginosus* for potential introduction to New Zealand glasshouse production systems. *M. pygmaeus* was illegally introduced to New Zealand during or prior to 2007. It may not have established outside glasshouses in New Zealand as original stocks were destroyed and none has been detected during monitoring at Pukekohe since 2009 (G. Walker, pers. comm.).

Locality records were from published papers (Alomar et al. 2002; Lykouressis et al. 2001; Perdikis & Lykouressis 2002; Perdikis et al. 2003; Martinez-Cascales et al. 2006b; Fantinou et al. 2009) and from internet sources (Schuh 2008).

4.2 CLIMEX model and mapped EI values

CLIMEX model parameters are given in Table 3. Values for thermal constant (495DD) and lower development threshold temperature (7.7^{o}C) were from Hart et al. (2002). The insects used by Hart et al. (2002) are likely to have been *M. pygmaeus* and not *M. caliginosus* as reported, as they were commercially produced by Syngenta Bioline. In any case the response to climatic variables may only differ slightly between *M. pygmaeus* and *M. melanotoma* as they are largely sympatric. In the absence of further information differentiating their response to climate, the CLIMEX model constructed is equally suitable for predicting distributions for *M. pygmaeus* and *M. melanotoma*. Parameters for limitations imposed by moisture and temperature were based on Lykouressis et al. (2001), Perdikis and Lykouressis (2002), and Hart et al. (2002). Maps were constructed for Europe (Figure 3) and New Zealand (Figure 4).

Table 3. CLIMEX parameters for *Macrolophus melanotoma/M. pygmaeus.*

Parameter group	Parameter	Value
Temperature Index	Lower Temperature Threshold (DV0) Lower Optimum Temperature (DV1) Upper Optimum Temperature (DV2) Upper Temperature Threshold (DV3) Minimum degree-days above DV0 to complete a generation or thermal constant (PDD)	7.5 20 30 35 495
Moisture Index	Lower Soil Moisture Threshold (SM0) Lower Optimal Soil Moisture (SM1) Upper Optimal Soil Moisture (SM2) Upper Soil Moisture Threshold (SM3)	0.1 0.4 0.7 1.5
Cold Stress	Cold Stress Degree-Day Threshold (DTCS) Cold Stress Degree-Day Rate (DHCS) Cold Stress Temperature Threshold (Average) (TTCSA) Cold Stress Temperature Rate (Average) (THCSA) Cold Stress Degree-day Temperature Threshold (DVCS)	20 -0.0005 2.5 -0.001 8

4.3 Interpretation of New Zealand map

M. melanotoma and *M. pygmaeus* could persist outside glasshouses in Auckland, many areas of Northland, and on the east coast of the North Island, particularly between Gisborne and Castlepoint.

5 *Nesidiocoris tenuis* (Reuter) (Hemiptera: Miridae)

5.1 Identity and distribution

Nesidiocoris tenuis (Reuter) is a widely distributed species and currently a stable taxonomic entity. Synonyms include *Cyrtopeltis tenuis*, *C. javanus*, *Dicyphus tamaricis*, *D. nocivus*, and *Engytatus tenuis*. Country and locality records were from internet records and published papers including CABI (2012), Cuesta Segura et al. (2010), Linnavuori (1961), and Schuh (2008).

5.2 CLIMEX model and mapped EI values

CLIMEX model parameters are given in Table 4. Values for thermal constants (278DD, 344.8DD) and lower development threshold temperature (12.9^{o}C, 10.3^{o}C) are provided by Hughes et al. (2009), and can be calculated from Sanchez et al. (2009) respectively. Arno et al. (2010) give a value of 330.9DD as the thermal constant for *N. tenuis*, but this value is incorrectly calculated from data in Sanchez et al. (2009). Parameters for limitations imposed by moisture and temperature were based on Hughes et al. (2009, 2010) and Sanchez et al. (2009). Maps were constructed for the world (Figure 5) and New Zealand (Figure 6). A number of records (North and South Korea, Japan, New Mexico) are outside the predicted geographic range and may have come from covered crops.

Table 4. CLIMEX parameters for *Nesidiocoris tenuis.*

Parameter group	Parameter	Value
Temperature Index	Lower Temperature Threshold (DV0)	15
	Lower Optimum Temperature (DV1)	20
	Upper Optimum Temperature (DV2)	32.5
	Upper Temperature Threshold (DV3)	40
	Minimum degree-days above DV0 to complete a generation or thermal constant (PDD)	311
Moisture Index	Lower Soil Moisture Threshold (SM0)	0.1
	Lower Optimal Soil Moisture (SM1)	0.4
	Upper Optimal Soil Moisture (SM2)	0.7
	Upper Soil Moisture Threshold (SM3)	1.5
Cold Stress	Cold Stress Degree-Day Threshold (DTCS)	20
	Cold Stress Degree-Day Rate (DHCS)	-0.001
	Cold Stress Temperature Threshold (Average) (TTCSA)	8
	Cold Stress Temperature Rate (Average) (THCSA)	-0.0005
	Cold Stress Degree-day Temperature Threshold (DVCS)	8

5.3 Interpretation of New Zealand map

N. tenuis could persist outside glasshouses in many areas of Northland and on the east coast of the North Island, particularly between Gisborne and Napier.

6 Summary

CLIMEX EI scores suggest that there are localities in the North Island that are suitable for the mirids *M. melanotoma*, *M. pygmaeus* and *N. tenuis* to persist outside of glasshouses. The coccinellid *D. catalinae* is less tolerant of cool temperatures than the mirids and there are relatively few localities in New Zealand where it could persist outside glasshouses.

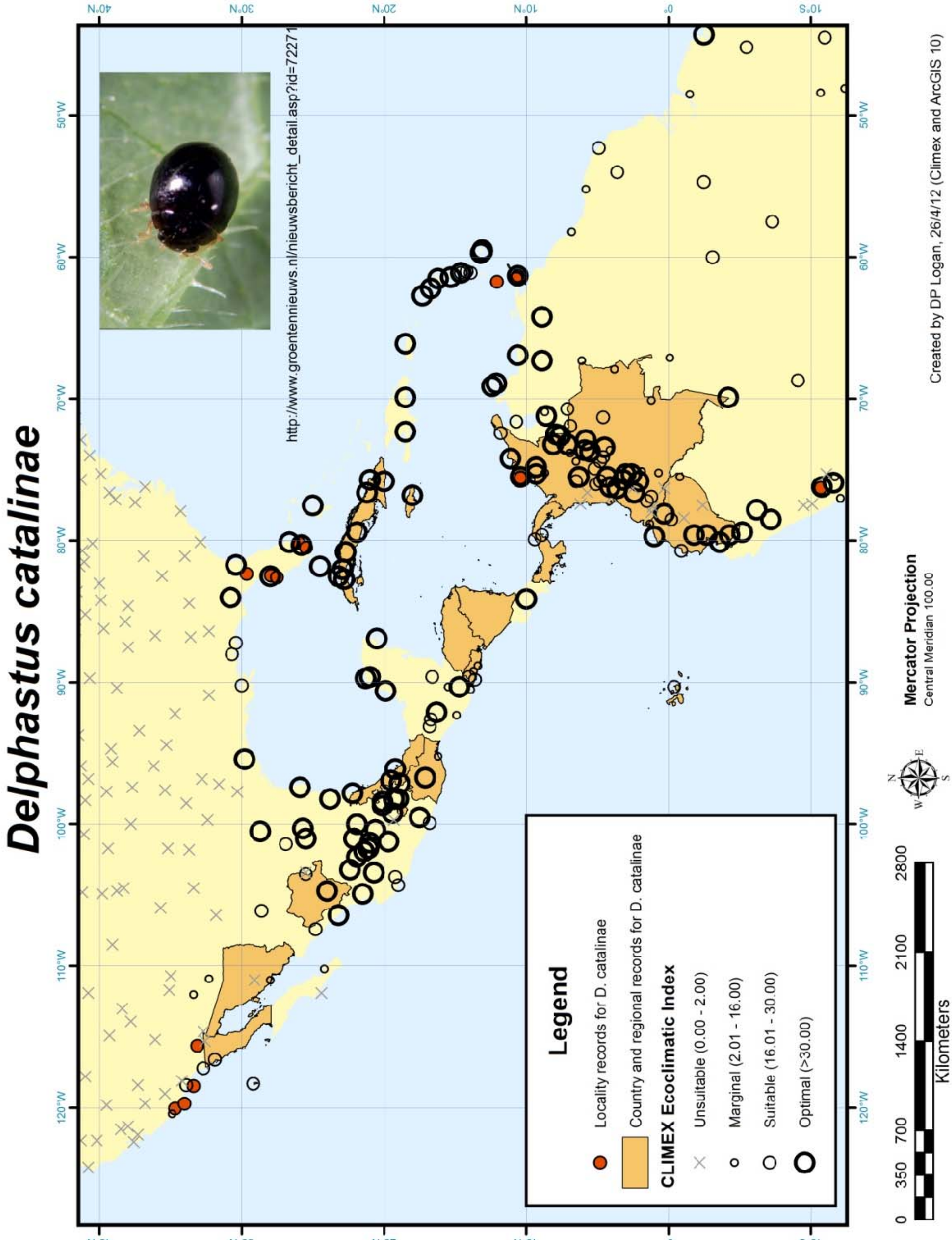

Figure 1. Known distribution of the coccinellid *Delphastus catalinae* (filled circles, orange regions) and CLIMEX Ecoclimatic scores indicating unsuitable (0–2) to optimal localities (>30) for population persistence in its native range of Central America.

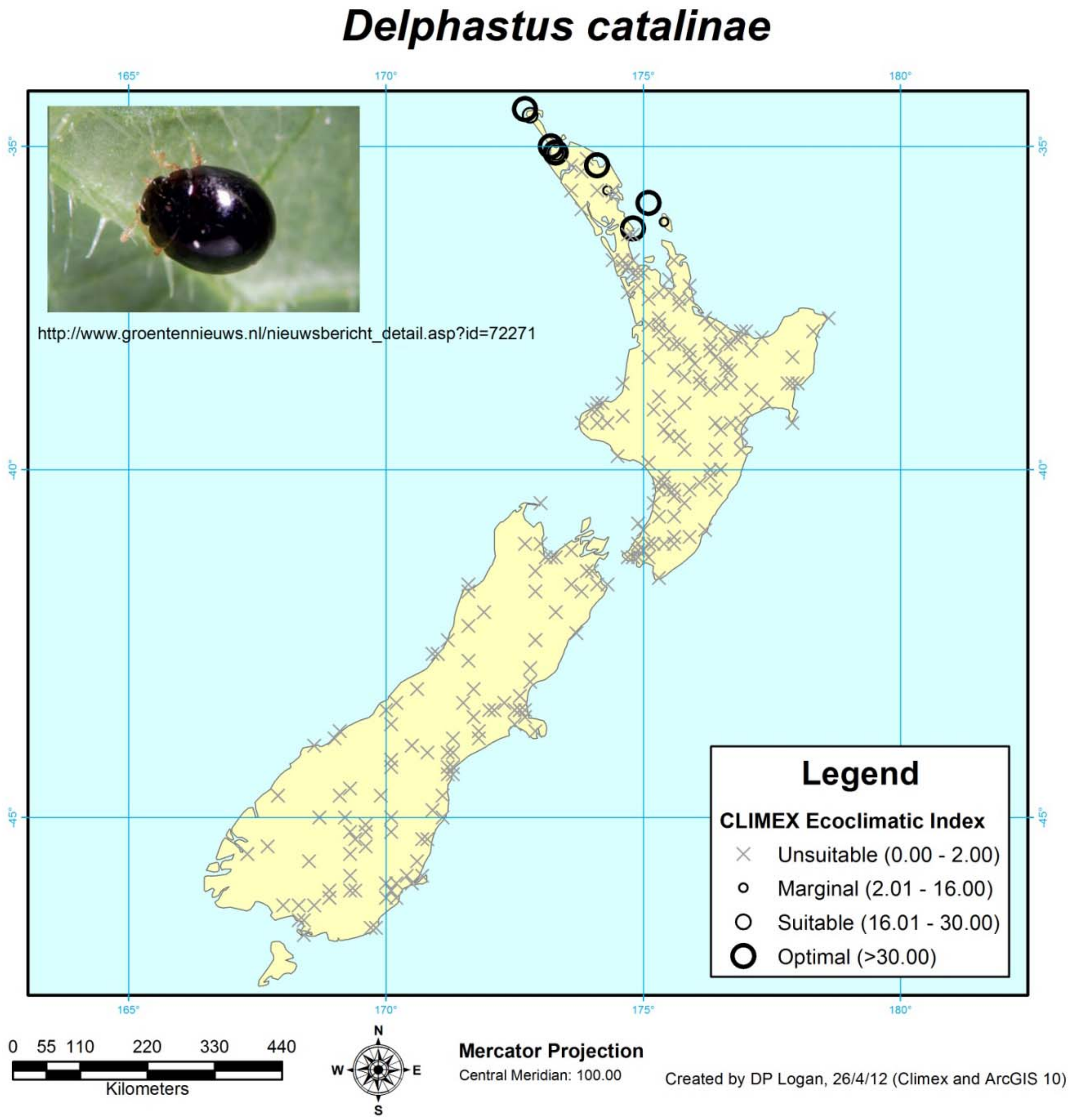

Figure 2. CLIMEX Ecoclimatic scores indicating range of unsuitable (0–2) to optimal localities (>30) for population persistence of the coccinellid *Delphastus catalinae* in New Zealand.

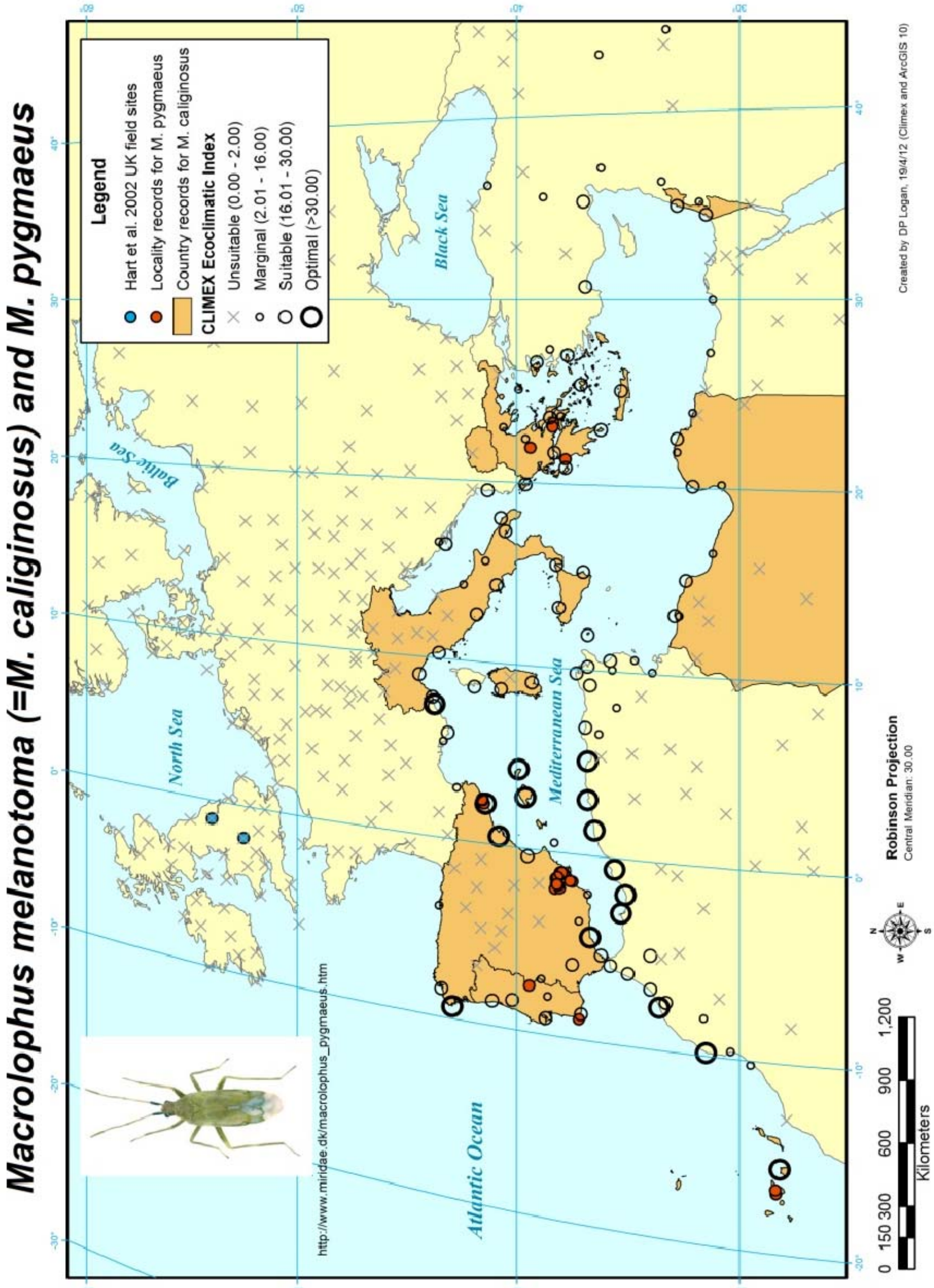

Figure 3. Known distribution of the mirids *Macrolophus melanotoma* (= *M. caliginosus*) and *M. pygmaeus* (red filled circles, orange regions) and CLIMEX Ecoclimatic scores indicating unsuitable (0–2) to optimal localities (>30) for population persistence in Europe.

Macrolophus melanotoma (=M.caliginosus) and M. pygmaeus

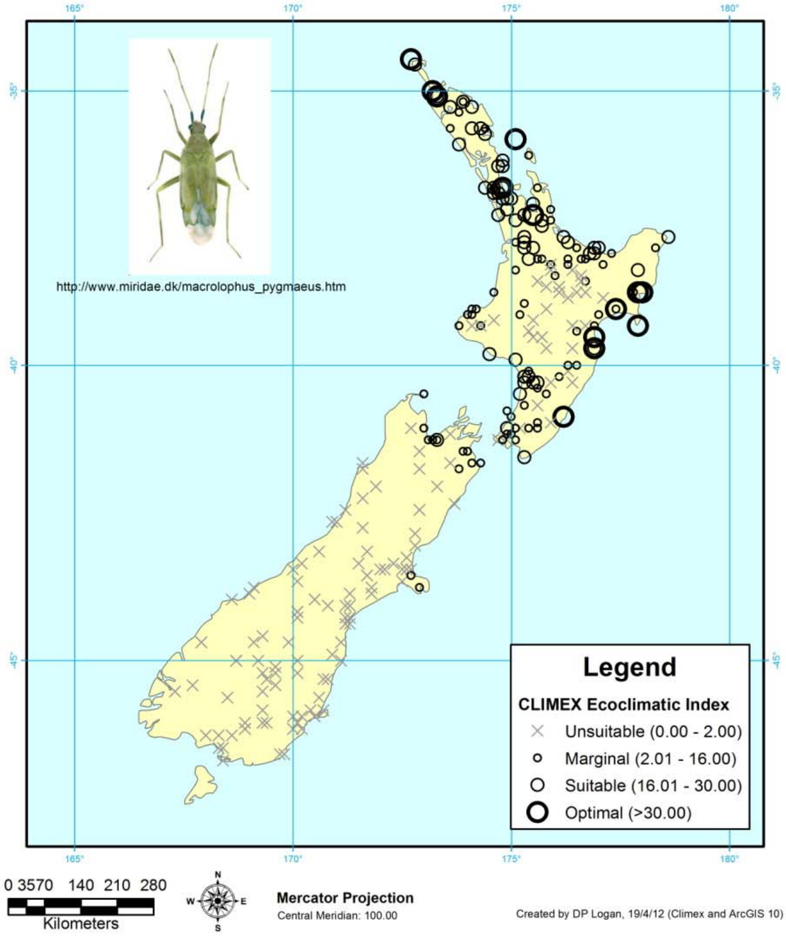

Figure 4. CLIMEX Ecoclimatic scores indicating range of unsuitable (0–2) to optimal localities (>30) for population persistence of the mirids *Macrolophus melanotoma* (= *M. caliginosus*) and *M. pygmaeus* in New Zealand.

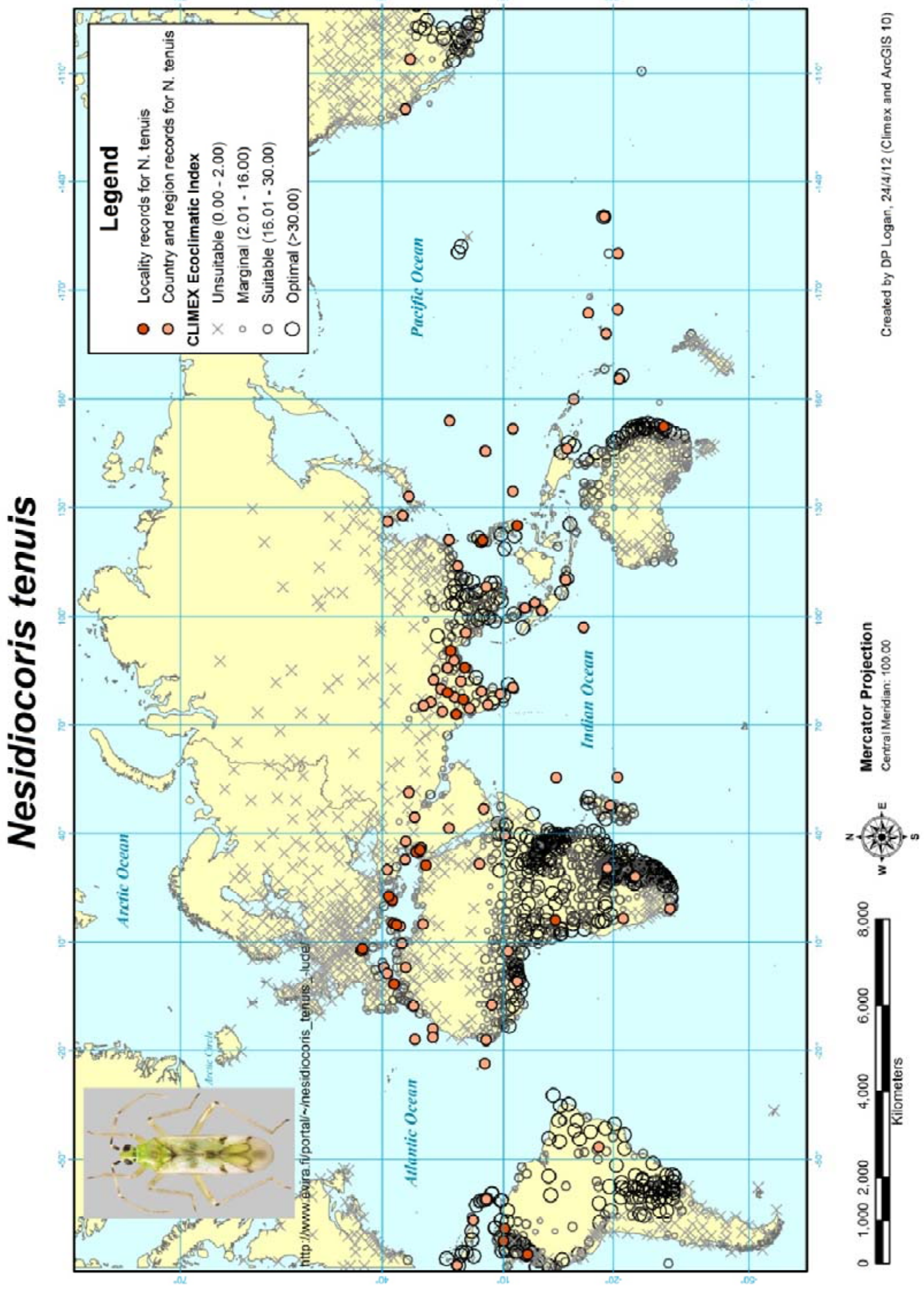

Figure 5. Known distribution of the mirid *Nesidiocoris tenuis* (red and orange filled circles) and CLIMEX Ecoclimatic scores indicating unsuitable (0–2) to optimal localities (>30) for population persistence.

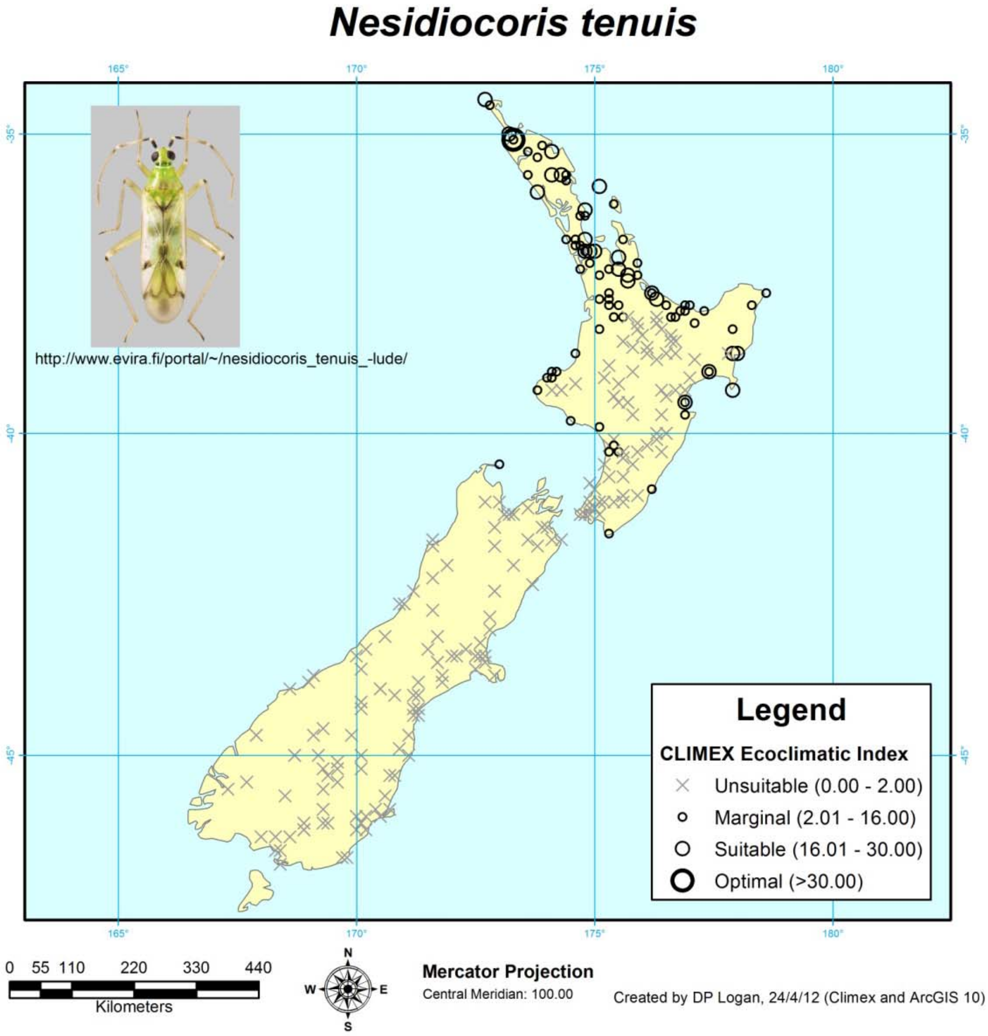

Figure 6. CLIMEX Ecoclimatic scores indicating range of unsuitable (0–2) to optimal localities (>30) for population persistence of the mirid *Nesidiocoris tenuis* in New Zealand.

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