# Mapping the potential range of the brown marmorated stink bug (BMSB) *Halyomorpha halys* in New Zealand

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## Characteristics of the BMSB

- Destructive orchard pest
  - > US$37 million in crop damage 2010
- Stinky household invader
- Native to China, Japan, Korea and Taiwan

https://commons.wikimedia.org/wiki/File:Halyomorpha_halys_nymph_lab.jpg

## Characteristics of the BMSB

- Introduced to the US in 1996 and widespread by 2011 in US Orchards
  - Pennsylvania 1996, Oregon, California 2005
  - Entire Atlantic Coast 2011/ Canada 2012
- Europe
  - Switzerland 2004
  - France Germany Greece Liechtenstein 2009, 2012
  - Italy Hungary 2013
- Intercepted in Australia and NZ
  - NZ: Between 1-36 individuals in commodities (Duthrie, 2015)
  - Vehicles and shipping containers
  - Arrive during Northern Hemisphere Autumn and Winter (overwinter)

https://commons.wikimedia.org/wiki/File:Halyomorpha_halys_nymph_lab.jpg

## Damage to fruits

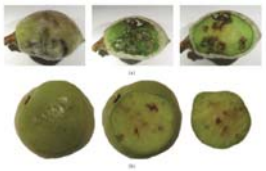


**Figure 3.** Internal injury to 'Pink Lady' apple as a result of BMSB feeding.

(Leskey et al., 2012)

## Damage to agriculture crops

**Figure 6.** BMSB adult and nymphal feeding damage to sweet corn kernels.

**Figure 7.** BMSB feeding injury to the periphery of a soybean field illustrating the "stay green" effect and contrasting with the unaffected, normally senescing plants at the center of the plot.

(Leskey et al., 2012)

## Home invasions

(A)

Inkley et al., 2012

(B)

**Figure 9.** BMSB adults aggregating (A) beneath a mattress and (B) in the attic of a home in rural MD in 2010-2011. Over 26,000 overwintering adults were removed from the interior of this home in 2011 (Inkley 2012).

## Characteristics of the BMSB

- Maximum flight distance of 66.54k for males and 75.12k for females (Wikman et al, 2016)
- Overwinters in natural landscapes (dead wooden logs, trees with thick bark and crevices), buildings and homes (Basnet et al., 2015)
- Minimum temperature threshold for development is 11-14.17C
- 120-300 different host plants

## Characteristics of the BMSB

- Intercepted in Australia and New Zealand
- Pathways include movement on inanimate objects
  - Cargo
  - Packing crates
  - Aircraft
  - Machinery and Vehicles
  - Personal luggage
- Earlier models (Zhu et al., 2012) show widespread suitability in the Middle East, West Africa, West Coast of the US and Eastern America, Southern Central America, a large swath of Europe, New Zealand and South Africa

## MPI Fact Sheet

https://www.mpi.govt.nz/protection-and-response/responding/alerts/brown-marmorated-stink-bug/


## Aim and Objectives

Predict the suitability of New Zealand to the BMSB

Ensemble the predictions of best performing Species Distribution Modelling algorithms using worldwide occurrence of BMSB and environmental data

Project the model into New Zealand using current and future climate scenarios

## Methods

- Occurrence data preparation
  - Check for redundancy
  - Rarefy to address autocorrelation
- Environmental layers preparation
  - Check for cross correlation
  - Prepare layers representing current conditions and future scenarios RCP2.6 (representing lower emissions) and RCP8.5 (representing higher emissions)
- Run Species Distribution Modelling (SDM) algorithms in R (dismo package) for the World Model
  - Random Forest
  - Support Vector Machine (SVM)
  - Maxent

## Methods

- Evaluate the performance of each algorithm (Train with 80% occurrence, Test with 20% - get the mean of k-fold models)
  - AUC – Area Under Curve - shows accuracy of model in correctly predicting presence and absence; values > 0.7 shows good performance
  - Kappa – prediction performance measure; values near 1.0 are better
  - True Skill Statistic – another measure commonly used; values near 1.0 better
- Project World Model into New Zealand current and future conditions
- **Ensemble** the prediction maps of each weighted by values of AUC, Kappa and TSS
- Generate presence/absence predictions from the ensembled predictions

## Spatially rarefied occurrence points


## Environmental variables at the occurrence points

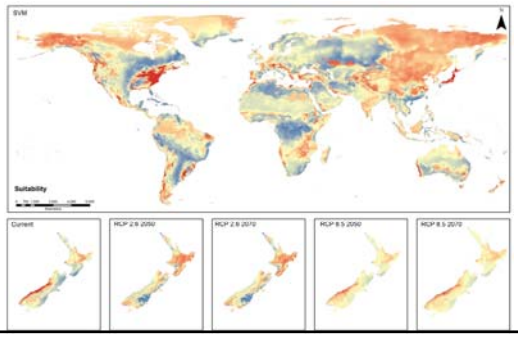
| Layer | Climatic Variable | Mean | Max | Min | Range |
|---|---|---|---|---|---|
| *BIO1 | Annual Mean Temperature | 11.58 | 19.60 | 1.20 | 18.40 |
| *BIO2 | Mean Diurnal Range (Mean of monthly (max temp - min temp)) | 10.98 | 14.10 | 7.70 | 6.40 |
| BIO3 | Isothermality (BIO2/BIO7) (* 100) | 3.32 | 5.50 | 2.30 | 3.20 |
| BIO4 | Temperature Seasonality (standard deviation *100) | 791.09 | 1000.20 | 303.20 | 697.00 |
| BIO5 | Max Temperature of Warmest Month | 28.65 | 35.20 | 16.90 | 18.30 |
| BIO6 | Min Temperature of Coldest Month | -4.54 | 8.60 | -15.50 | 24.10 |
| BIO7 | Temperature Annual Range (BIO5-BIO6) | 33.19 | 41.20 | 19.10 | 22.10 |
| *BIO8 | Mean Temperature of Wettest Quarter | 18.11 | 24.70 | -1.50 | 26.20 |
| *BIO9 | Mean Temperature of Driest Quarter | 4.83 | 22.70 | -7.10 | 29.80 |
| BIO10 | Mean Temperature of Warmest Quarter | 21.64 | 28.00 | 11.00 | 17.00 |
| BIO11 | Mean Temperature of Coldest Quarter | 1.30 | 14.30 | -8.70 | 23.00 |
| *BIO12 | Annual Precipitation | 1125.71 | 1928.00 | 315.00 | 1613.00 |
| BIO13 | Precipitation of Wettest Month | 132.11 | 257.00 | 68.00 | 189.00 |
| BIO14 | Precipitation of Driest Month | 63.00 | 106.00 | 0.00 | 106.00 |
| *BIO15 | Precipitation Seasonality (Coefficient of Variation) | 27.40 | 101.00 | 7.00 | 94.00 |
| BIO16 | Precipitation of Wettest Quarter | 367.72 | 739.00 | 184.00 | 555.00 |
| BIO17 | Precipitation of Driest Quarter | 207.45 | 344.00 | 4.00 | 340.00 |
| BIO18 | Precipitation of Warmest Quarter | 315.41 | 589.00 | 9.00 | 580.00 |
| *BIO19 | Precipitation of Coldest Quarter | 259.65 | 685.00 | 105.00 | 580.00 |
| | *non-correlated variables used in the model | | | | |

## Results: Model Evaluation

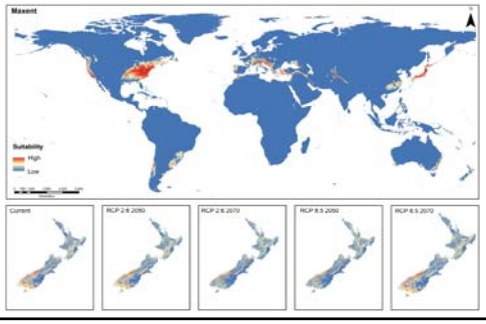
| Algorithm | AUC | Kappa | Max TPR TNR |
|---|---|---|---|
| RF | 0.98828 | 0.28835 | 0.03698 |
| SVM | 0.95062 | 0.06115 | 0.00936 |
| Maxent | 0.98661 | 0.06814 | 0.08357 |

## Results: Random Forest

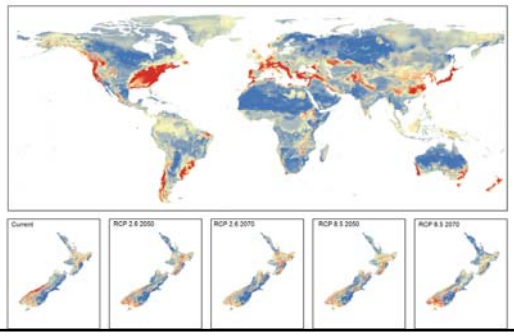
## Results: SVM



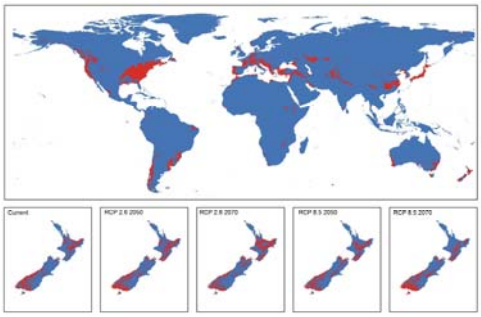
## Results: Maxent



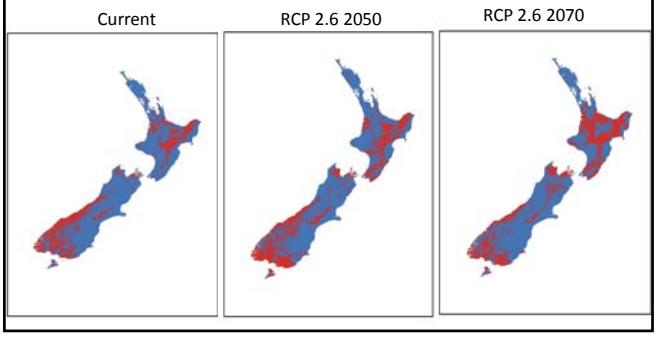
## Results: Ensemble models at current conditions



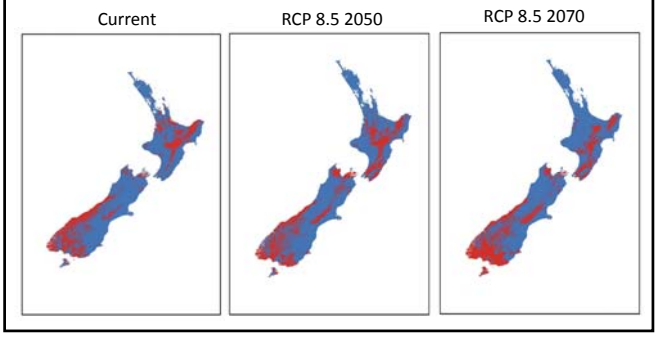
## Results: thresholded for presence/absence



## Presence/Absence

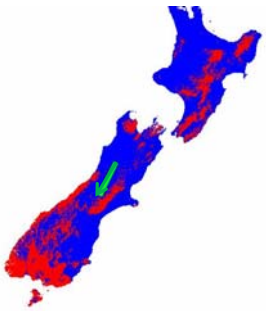



## Presence/Absence




## Movement of Presence Centroid South

Centroid calculated to show predicted presence between Current and RCP8.5 2070

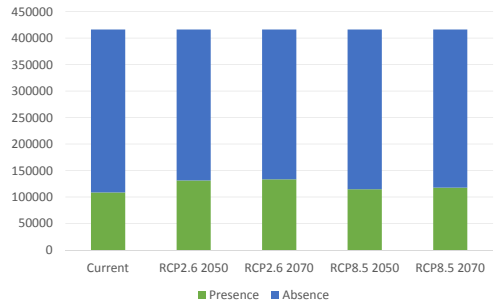


## NZ Territories BMSB presence prediction with climate change

## Number of Pixels representing Presence and Absence

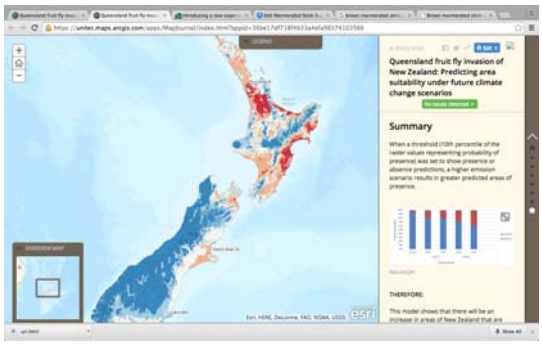
| Scenario | Presence | Absence |
|---|---|---|
| Current | 108754 | 307494 |
| RCP2.6 2050 | 131499 | 284749 |
| RCP2.6 2070 | 133668 | 282580 |
| RCP8.5 2050 | 114802 | 301446 |
| RCP8.5 2070 | 117885 | 298363 |

## Areas of predicted presence/absence




## Summary

- Slight increase in suitability from current to future scenarios in terms of presence/absence prediction
- RCP 2.6 shows greater increase and increasing trend than RCP 8.5
- Shift to the South is evident
- BMSB dies before it reaches freezing temperatures (Cira et al., 2016) so increased warming in currently colder regions will increase the suitability of those areas for the organism
- Queensland Fruitfly Climate Change model http://arcg.is/1SVpny3

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