



NAPPFAST

NCSU APHIS Plant Pest Forecasting System

Comparison of the observed and predicted number of generations for 21 arthropod pests

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Summary

We conducted an informal study to compare the number of generations observed in the field with those predicted by NAPPFAST for 21 arthropod pests. The NAPPFAST predictions were based on species-specific day degree models and 32k global grid data. Overall, 52% of 21 model results were rated as excellent, 24% as moderate, and 24% as poor. The primary causes of model failure were day degrees being non-limiting, insufficient biological data for model parameterization, insufficient grid resolution, or poor representation of island climates. A limiting factor in this study was that the pest observations were often reported at a low spatial resolution (e.g., reported at the country or region level, rather than at a specific location). Additional validation work using stage specific pest observations collected at a known location is needed.

Introduction

The NCSU APHIS Plant Pest Forecasting System (NAPPFAST) is an internet application for the weather-based mapping of plant pests (Magarey et al., 2007). The purpose of NAPPFAST is to support pest detection, risk analysis, and emergency programs. NAPPFAST users create models by entering biological parameters identified through literature sources into an interactive template. We conducted a validation study in which NAPPFAST maps were compared with field-based observations of exotic pest development collected in off-shore locations. In particular, the validation study compared the observed number of generations per year with those predicted by the species specific NAPPFAST day degree model. Other factors that might influence generation number, such as extreme heat or cold and food supply, were not considered in the study.

Method

The test pests included 21 arthropod pests selected from the CAPS 2010 AHP (Analytical Hierarchy Process) list for which NAPPFAST

models had been created. For each pest, we conducted literature searches to record the observed location, the observation period, and the observed number of generations per year. For many pests, there was more than one literature observation. For each pest, an average history map based on the last ten years of climate data was used to create a map of predicted generations. A single sine curve was used to calculate day degrees (Allen, 1976). The maps were created using a 32k daily global gridded database NCEP/DOE AMIP-II Reanalysis (Reanalysis-2) from the [Reanalysis II](#) National Centers for Environmental Prediction (NCEP). Data from the National Climate Data Center [Integrated Surface Hourly](#) station network was used to supplement the grid data set. Predicted maps were also created for specific years when data was available for the period during which the observation was collected. We compiled the details from the literature review and NAPPFAST predictions (Table 1). It was not possible to create maps for periods before 1979. When the observed period was long (i.e., > 5 years), observations were compared to predicted ten-year average histories. The ten-year average history calculates the number of generations in each year (1999-2008) and then takes the average for all ten years. A limiting factor in this study was that the pest observations are often reported at a low spatial resolution (e.g., reported at the country or region level, rather than at a specific location). Due to these uncertainties, statistics to quantitatively assess accuracy were not calculated.

Results

We classified the results for each study as excellent, moderate, or poor. Excellent performance occurred when the field-based observed generations were identical to the NAPPFAST-predicted generations; moderate performance was when observed and predicted generation numbers were within +/- 1 or 2 generations, and poor performance was for a +/- 3 generations difference (Table 1).

Of the 21 pest models, eleven were categorized as excellent, five moderate, and five poor (Table 1). The models for the following 11 pests had excellent performance: *Autographa gamma*, *Ceroplastes destructor*, *Chilo suppressalis*, *Cydia funebrana*, *Epiphyas postvittana*, *Helicoverpa armigera*, *Nysius huttoni*, *Spodoptera litura*, *Scirtothrips dorsalis*, *Rhynchophorus ferrugineus*, and *Thaumatotibia leucotreta*.

We classified the following five pests as having pest models with moderate performance: *Diabrotica speciosa*, *Leucoptera malifoliella*, *Ostrinia furnacalis*, *Tuta absoluta*, and *Unaspis yanonensis*. The differences between observed and predicted generation numbers are likely attributable to temporal and spatial uncertainties. The temporal uncertainties include the actual observed dates versus predictions made using the average history dates (1999-2008). The spatial uncertainties

include the differences between the location of the observations and the location of the model predictions which use the average elevation of the 32k grid.

Five pest models showed poor performance. For example, the model for *Aleurocanthus spiniferus* underestimated by three to four generations. This poor level of performance might be attributed to the original model parameters being based off of a similar species, *A. woglumi*. An additional source of performance loss was that small islands such as Guam are not well represented in the global gridded database. The *Lobesia botrana* model performed moderately well in Romania, but in Israel it overestimated generation number by one to four generations. Since Israel has a warm Mediterranean climate, the moth's generation potential is likely limited by food availability and not by climate. The *Lymantria mathura* model overestimated all three observations by two generations per year. The *Monochamus saltuarius* model was greatly over-predicted by NAPPFAST because the observations were collected in cooler mountainous terrain that could not be modeled by the 32k grid data. Based on observations in Italy, the *Tomicus destruens* model overestimated by three generations. This outcome may be due to day degrees being non-limiting or because the model was parameterized from a related species, *T. pineperda*.

Discussion

NAPPFAST is used to predict the potential number of generations that an exotic pest may develop in the United States. Climate risk maps created using day degree models are used to guide pest detection programs, for risk analysis, and for emergency programs. Generally, there are usually few or no observations for validation of models for exotic pests, since in the United States the pest is either absent or recently established. Consequently, there is a need to validate the use of day degree models for these purposes using off-shore data. Results from the literature are the most readily available source of pest observations. The results demonstrate the potential for a day degree model to predict the exact number of generations of an exotic pest in 50% of cases and within two generations in 75% of cases. Stage specific validations should always be conducted when data is available, but these results lend credibility to the general process.

The study was limited by the low temporal and spatial resolution of the observed data sets. There is a need to work with international cooperators who are collecting stage specific pest observations collected at georeferenced locations. If available, these types of data would enable the validation of models to predict specific flight or emergence times of pests and so guide the tactical deployment of traps by field staff.

General References

- Allen, J.C. 1976. A modified sine curve for calculating day degrees. *Environmental Entomology*. 5:388-396.
- Kalnay, E., M. Kanamitsu, R. Kistler, W. Collins, D. Deaven, L. Gandin, M. Iredell, S. Saha, G. White, J. Woollen, Y. Zhu, A. Leetmaa, R. Reynolds, M. Chelliah, W. Ebisuzaki, W. Higgins, J. Janowiak, K. C. Mo, C. Ropelewski, J. Wang, R. Jenne, and D. Joseph. 1996. The NCEP/NCAR 40-Year Reanalysis Project. *Bulletin of American Society of Meteorology* 77:437-471.
- Lott, N., R. Baldwin, and P. Jones. 2001. The FCC Integrated Surface Hourly Database, A New Resource of Global Climate Data.
- Magarey, R.D., Borchert, D.M., Fowler, G.L, Sutton, T.G., Colunga-Garcia, M., and Simpson, J.A. (2007). NAPPPFAST, an Internet System for the Weather-based Mapping of Plant Pathogens. *Plant Disease* 91:336-345.

Table 1. Comparison of the number of generations that were observed according to various literature sources and the predicted number using a species specific day degree model for 21 arthropod pest species.

Pest	Reference	Country	Observed Years	Generations	
				Observed	Predicted
<i>Aleurocanthus spiniferus</i>	Gyeltshen J, Hodges A, and Hodges G S. 2005. Orange Spiny Whitefly, <i>Aleurocanthus spiniferus</i> Quaintance (Insecta: Hemiptera: Aleyrodidae) (EENY341). 1-4. University of Florida, Institute of Food and Agricultural Sciences. Retrieved October 31, 2007, from http://edis.ifas.ufl.edu/pdffiles/IN/IN61800.pdf Introduction, distribution, description, life history, economic importance, management, references	Japan	Unknown	4	1-2
		Guam		5-6	1
	Chien CC, Chiu SC, 1986. Biology of the citrus spiny blackfly <i>Aleurocanthus spiniferus</i> .. Journal of Agricultural Research of China, 35(2):222-229; [5 fig.]. Chinese with English summary	Wanfeng, Kuansi, Cholan, Wanchiao, Taiwan	Unknown	6	4
<i>Autographa gamma</i>	Dochkova B. 1972. Some biological and ecological studies on <i>Autographa gamma</i> L. (<i>Lepidoptera: Noctuidae</i>). Rasteniiev-cini-Nauki (Plant Science): 141-149.	Unknown, Bulgaria	Unknown	3	3-4
<i>Ceroplastes destructor</i>	Habitats of New Zealand Soft Scales: Soft wax scale, <i>Ceroplastes destructor</i> . (1996-2007). Landcare Research. Retrieved December 21, 2007, from http://www.landcareresearch.co.nz/research/biosystematics/invertebrates/softscales/fauna/destruc.asp	Northland, New Zealand	Unknown	1	2
		Gisborne, New Zealand		1	1

Pest	Reference	Country	Observed Years	Generations	
				Observed	Predicted
<i>Ceroplastes destructor</i>	Smith D, Ironside DA, 1974. The seasonal history of <i>Gascardia destructor</i> (Newstead) in Queensland. Queensland Journal of Agricultural and Animal Sciences, 31:195-199.	Tanawha, Palmwoods, Landershoot, Nambour, Australia	1964-1967 Average	2	3
<i>Chilo suppressalis</i>	Whittle K and Ferguson DC. 1988. (PNKTO), No. 97: Asiatic Rice Borer. 1-10. USDA-APHIS-PPQ	Unknown, Japan	Unknown	1-3	1-3
<i>Cydia funebrana</i>	Kozlowski J 1993. Forecasting the occurrence and signaling the control date of the plum moth (<i>Laspeyresia funebrana</i> Tr.) in Wielkopolska. Prace Naukowe Instytutu Ochrony Roslin, 35: 47-52.	Wielkopolska, Poland	1981-1992	3	3
<i>Diabrotica speciosa</i>	USDA, 1957. Cooperative Economic Insect Report, 7:5-6	Buenos Aires, Argentina	Unknown	3	4-5
<i>Epiphyas postvittana</i>	Thomas WP, 1975. Light brown apple moth, Life Cycle Chart. Auckland, New Zealand: Department of Scientific and Industrial Research.	Otago, Southland, New Zealand Canterbury, New Zealand	Unknown	2	2
	Thomas WP, 1975. Additional notes on leaf rollers. Orchardist of New Zealand, 48(10):354-355; [3 pl.]. Madge DG and Stirrat SC 1991. Development of a Day Degree Model to Predict Generation Events for Light Brown Apple Moth (<i>Epiphyas postvittana</i>) (Walker) (Lepidoptera: Tortricidae) on Grapevines in Australia. Plant Protection Quarterly Vol. 6: 39-42	Mildura, Australia	1987-1988	4	5
	USDA-APHIS-PPQ CAPS 1993. Fact Sheet	Netherlands,	Unknown	2	2

Pest	Reference	Country	Observed Years	Generations	
				Observed	Predicted
	for Exotic Pest Detection Survey Recommendations: Light Brown Apple Moth. United States Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine, Cooperative Agricultural Pest Survey. Retrieved June 28, 2007,	France		2	3-4
	Meijerman L and Ulenberg SA 2000. Eurasian Tortricidae: Epiphyas postvittana. <i>Arthropods of Economic Importance</i> . University of Amsterdam, Zoological Museum. Retrieved June 28, 2007,	South-Western England	Unknown	2	2
		Southern Australia	Unknown	3	2-4
	Anonymous, 2007. Lightbrown apple moth, Epiphyas postvittana (Walker). Insects and mites of stonefruit. HortNET: BugKEY. Retrieved June 28, 2007, from	Canterbury, Otago, Southland, NZ	Unknown Unknown	2-3 2	2 2
	Retrieved June 28, 2007, from http://www.hortnet.co.nz/key/stone/info/lba- info.htm	Northern, NZ	Unknown	4	3-4
<i>Eutetranychus orientalis</i>	Baker, E. W. (Preparer) (1983, September). (PNKTO), No. 41: Oriental RedMite. 1-6. Beltsville, MD: USDA-APHIS-PPQ.	Unknown, Israel	Unknown	18	17-23
	Smith-Meyer MKP, 1981. Mite pests of crops in southern Africa. Science Bulletin, Department of Agriculture and Fisheries, Republic of South Africa, (No. 397):65-67.	Unknown, South Africa	Unknown	25	9-23
<i>Helicoverpa armigera</i>	CABI 2006. Crop Protection Compendium [CD]. Wallingford, UK: CAB International. Current online version at http://www.cabicompendium.org/cpc	Unknown, Bulgaria	Unknown	2	2

Pest	Reference	Country	Observed Years	Generations	
				Observed	Predicted
<u>Leucoptera malifoliella</u>	References cited in GPDD are as follows but these have not been obtained.	Hungary	Unknown	3-4	2
	Correspondence of references with observations is uncertain.	Bulgaria		3-4	2-3
		Italy		2-4	2-4
		France		2-4	1-3
	Ivanov S, 1976. Leaf-miner moths on fruit-trees in Bulgaria. Dissertation. Fruit-Growing Institute, Plovdiv, Bulgaria.	Holland/Austria/ Belgium		1	1
		Locations Unknown			
	Dulinafka G, 1983. Data on the biology and damage of the fruit-tree leaf miner, <i>Leucoptera scitella</i> Zeller (<i>Lepidoptera: Leucopteridae</i>). <i>Novenyvedelem</i> , 19(4):155-160.				
	Gulii VV and Pamuzak NG, 1992. Guide of Plant Protection for Farmers. Moscow, Russia: Rosagroservis.				
	Maciesiak A, 1999. Pear leaf blister moth (<i>Leucoptera scitella</i> Zell.) appearance and control. <i>Progress in Plant Protection</i> , 39(2):444-447.				
	CFIA, 2005. Plant Protection Import Requirements for Fresh Apples (<i>Malus</i> spp.) from the People's Republic of China. Canadian Food Inspection Agency. Online at http://www.inspection.gc.ca/english/plaveg/protect/dir/d-02-07e.shtml .				
HYPP, 2005. Cémiostome du pommier,					

Pest	Reference	Country	Observed Years	Generations	
				Observed	Predicted
	Mineuse cerclée. On-line at <a href="http://www.inra.fr/Internet/Produits/HYPPZ/R
AVAGEUR/6leumal.htm">http://www.inra.fr/Internet/Produits/HYPPZ/R AVAGEUR/6leumal.htm Mey W, 1988. The life-cycle, bionomics and population ecology of the pear leaf blister moth <i>Leucoptera malifoliella</i> (Costa, 1836) (Insecta, <i>Lepidoptera</i>). Zoologischer Anzeiger, 221:319- 342	Berlin*, Germany/Poland	Unknown	2	1
<i>Lobesia botrana</i>	Filip I, 1986. Breeding zones of the grape moth (<i>Lobesia botrana</i> Den & Schiff) in Romania. Probleme de Protectia Plantelor, 14:25-30.	Murfatlar, Niculitel, Ostrov, Romania Cotnari, Drăgășani, Romania Tîrnaveni, Romania	Unknown	3 2 1	4 3 2
	USDA-APHIS-PPQ. Whittle K. 1985. (PNKTO), No. 60: European Grape Vine Moth. Hyattsville, MD: USDA-APHIS-PPQ	Unknown, Israel	Unknown	3-4	7-8
<i>Lymantria mathura</i>	Dey RK and Tiwari KP, 1997. Detection of an imminent defoliator attack on the borer infested sal forests of Madhya Pradesh. Vaniki Sandesh, 21:21-24.	Unknown, Japan Unknown, Korea Unknown, Hong Kong	Unknown	1 1 3	2-4 3 5
<i>Monochamus saltuarius</i>	Zinno Y, Takizawa Y and Sato H, 1987. Pine wilt disease in cool areas and mountain regions in Japan. Tokyo, Japan: Ringyo Gijyutu Shinkosho Original Source Not Available	Unknown, Japan	Unknown	1-2	>4
<i>Nysius huttoni</i>	Holtz T. 2006. NPAG et Report: <i>Nysius huttoni</i> (White), Wheat bug. 1-5. USDA, APHIS, PPQ, NPAG. Retrieved October 30, 2007, from http://npag.cphst.org	New Zealand Netherlands, Belgium	Unknown	2-4 2	3 2

Pest	Reference	Country	Observed Years	Generations	
				Observed	Predicted
		Locations Unknown			
<i>Ostrinia furnacalis</i>	Liu, S. and Hou Z. 2004. Observation on bionomics of <i>Ostrinia furnacalis</i> in Longdong, Gansu. Entomological Knowledge 41: 461-464	Longdong, Gansu Province, China	Unknown	1-2	2-3
<i>Rhynchophorus ferrugineus</i>	Salama, HS Hamdy MK and Magd El- Din M. 2002. Anz. Schadlingskunde/ Journal of Pest Science 75: 26-29	Ismailia, Egypt	Estimated	20.7	20
<i>Scirtothrips dorsalis</i>	Tatara A. 1994. Effect of temperature and host plant on the development, fertility and longevity of <i>Scirtothrips dorsalis</i> Hood (<i>Thysanoptera: Thripidae</i>). Applied Entomology and Zoology 29: 31-37.	Shizuoka, Japan	1984-1988	7-8	8
<i>Spodoptera litura</i>	CABI 2006. Crop Protection Compendium [CD]. Wallingford, UK: CAB International. Current online version at http://www.cabicompendium.org/cpc	Andhra Pradesh, India	Unknown	11-12	11-12
<i>Thaumatotibia leucotreta</i>	Daiber CC. 1980. A study of the biology of the false codling moth <i>Cryptophlebia leucotreta</i> (Meyr.): the adult and generations during the year. Phytomythologica, 12:187-193; [2 fig.].	Pretoria, South Africa	Estimated	5	5
	Anon. 2003. False Codling Moth. Clemson Entomology. Retrieved June 4, 2003, from http://entweb.clemson.edu/caps/state/survey/exotic/fcm/fcm.htm Biology, distribution, and pheromones used for trapping	Unkown, South Africa	Unknown	6	3-7
<i>Tomicus destruens</i>	Nanni C and Tiberi R 1997 <i>Tomicus destruens</i> (Wollaston): biology and behaviour in Central Italy. Pages 131-134 in J.C. Grégoire, A.M. Liebhold, F.M. Stephen, K.R. Day, and S.M.	Alberese, Italy	Unknown	2	5
		Feniglia, Italy		2	5
		Cervia, Italy		2	5
		Classe, Italy		2	5

Pest	Reference	Country	Observed Years	Generations	
				Observed	Predicted
	Salom, editors. Proceedings: Integrating cultural tactics into the management of bark beetle and reforestation pests. USDA Forest Service General Technical Report NE-236.				
<i>Tuta absoluta</i>	EPPO 2005. Data sheets on quarantine pests: <i>Tuta absoluta</i> . <i>EPPO Bulletin</i> , 35: 434-435. Retrieved November 21, 2007, from http://www.eppo.org/QUARANTINE/insects/Tuta_absoluta/DS_Tuta_absoluta.pdf	Buenos Aires*, Argentina	Unknown	5	7
<i>Unaspis yanonensis</i>	USDA-APHIS-PPQ. Blackburn, V. L., & Miller, D. R. (Preparers) (1984). (PNKTO), No. 45: Arrowhead Scale. 1-14.	Nagasaki, Japan	Average	3	2

* indicates an assumed location

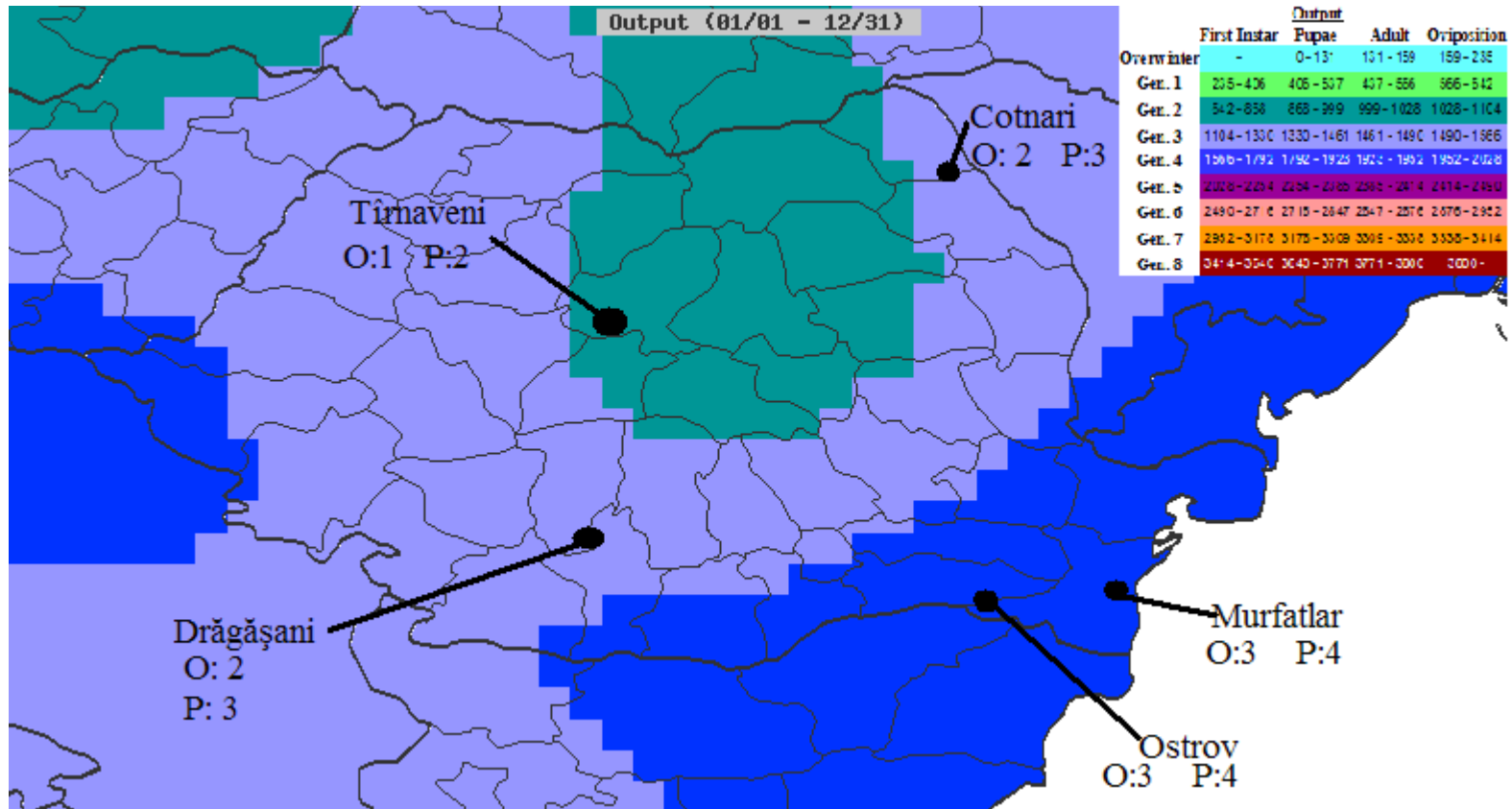


Figure 1. Average history map showing the number of generations occurring per year of *Lobesia botrana* in Romania compared to predictions made by a NAPPFAST degree day model using a 32k global grid data. O=observed generations, P=NAPPFAST predicted generations

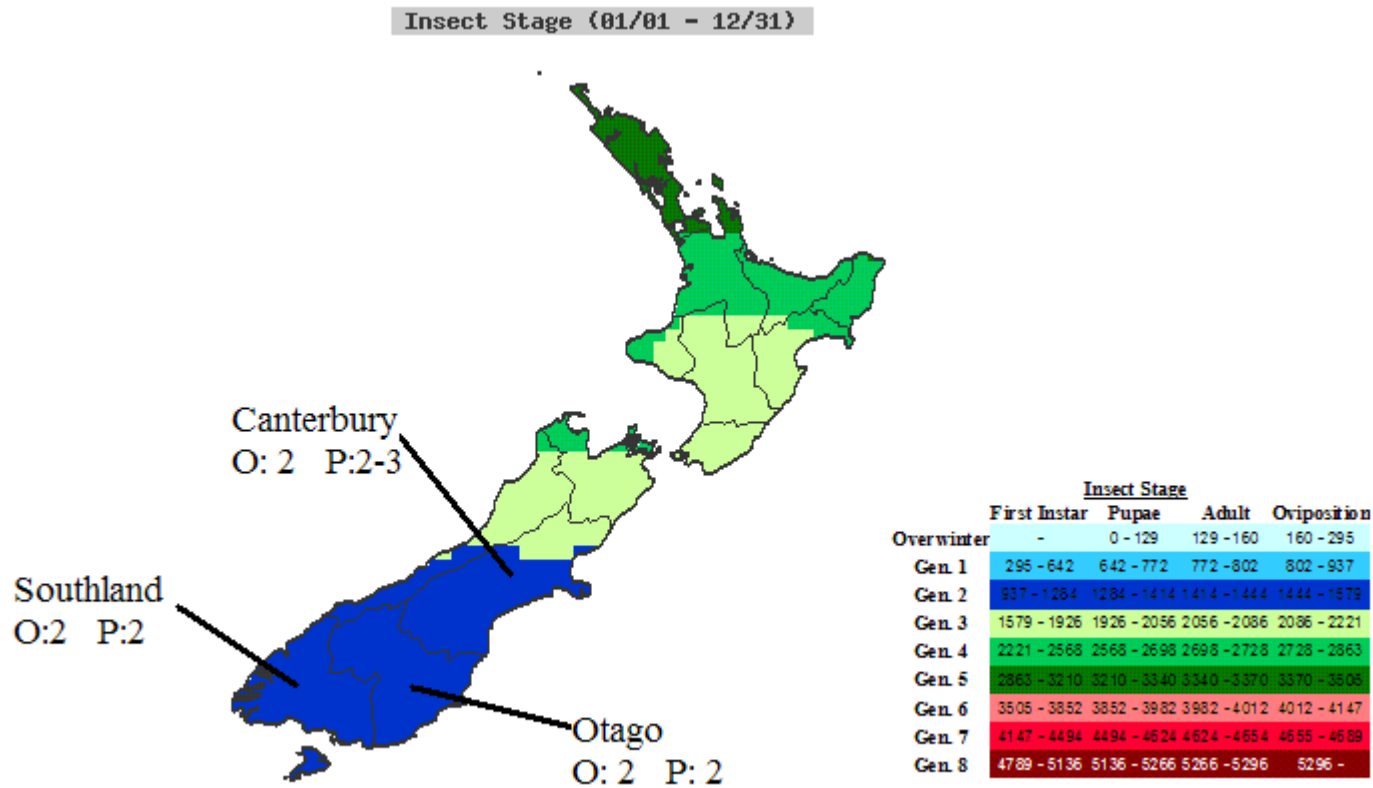


Figure 2. Average history map showing the number of generations occurring per year of *Epiphyas postvittana* in New Zealand compared to predictions made by a NAPPFAST degree day model using a 32k global grid data. O=observed generations, P=NAPPFAST predicted generations

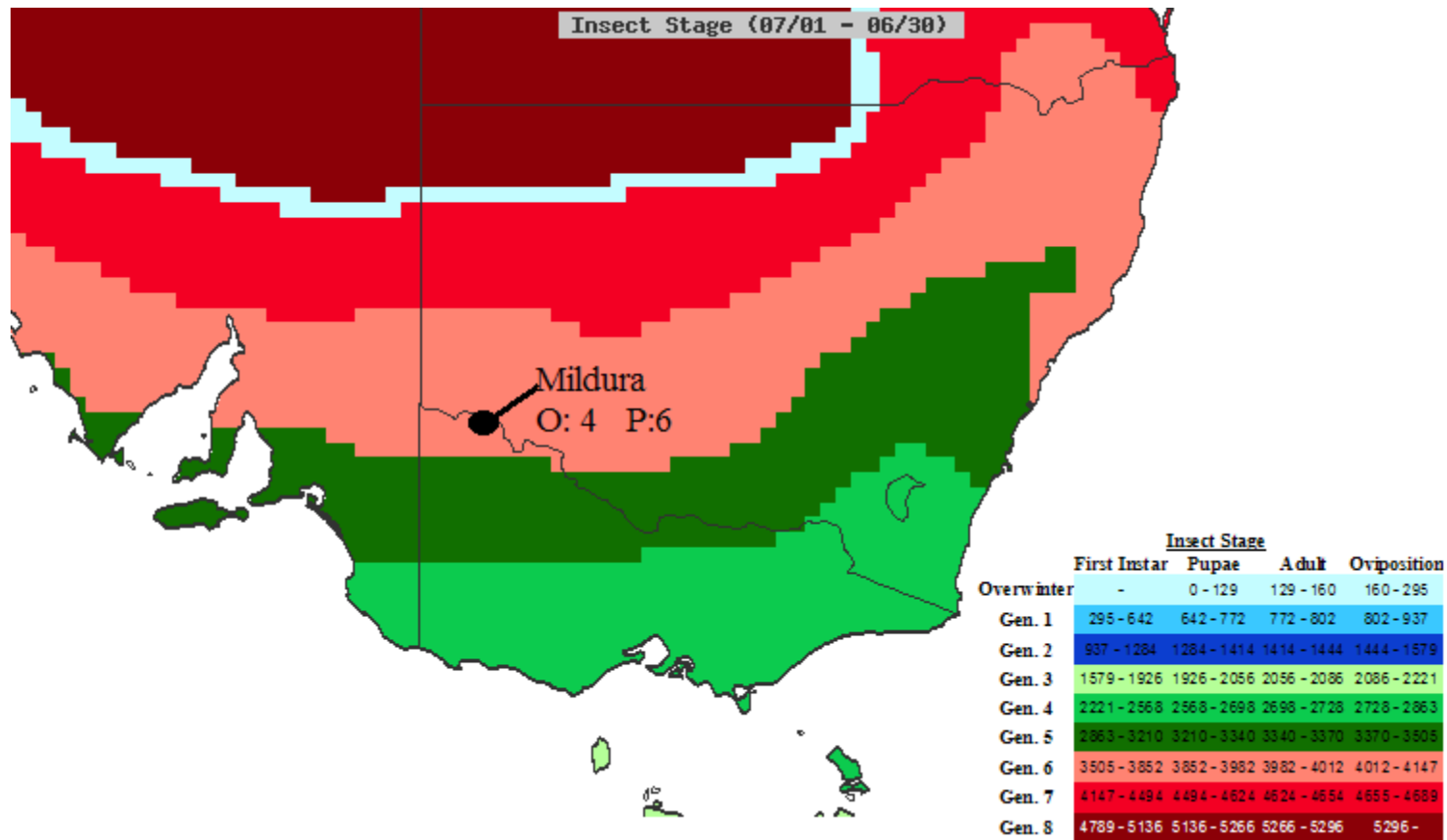


Figure 3. Average history map showing the number of generations occurring per year of *Epiphyas postvittana* in New South Wales and Victoria, Australia compared to predictions made by a NAPPFAST degree day model using a 32k global grid data. O=observed generations, P=NAPPFAST predicted generations