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Use of thermal data as an establishment screen for non-native biocontrol agents in the UK

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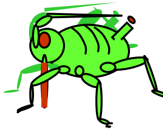
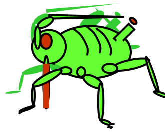


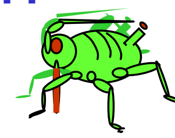
Biological control

- Long history of use in pest management
- Focus of renewed attention
  - Pest resistance
  - Green technology
  - Uncertainty over GM crops



Types of biological control

- **Classical:** Control of alien species using small scale releases leading to *permanent establishment* of co-evolved natural enemies from origin of pest
- **Inundative:** Mass release of laboratory - reared populations (indigenous or non-native) to control outbreaks - *do not persist*
- **Conservation:** Sustainable use of indigenous IBCAs against indigenous or non-native pests



Paradox of establishment

- Open field systems

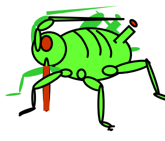
  Permanent establishment is the aim - extensive pre - release research on climate matching between collection and release sites, and on target and alternative prey

- Protected environments (glasshouses)

  Expectation that escaping individuals will die out (in winter) with no disruption of native ecosystems

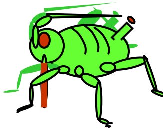
Regulation of non-native IBCAs in Europe

- Some countries have national legislation prohibiting release of non - native species (Wildlife and Countryside Act 1981, UK)
- Import of species for biological control requires licence
- Other countries have no legislation or regulation
- Insects and mites do not respect national or political boundaries



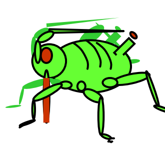
Current issues

- In northern Europe (Norway, Sweden, UK) biological control mainly in glasshouses - licensing system requires risk assessment of establishment outdoors and effects on native species and ecosystems
- In southern Europe, climate allows year round survival and reproduction. Similar need to assess environmental effects of releases
- Current moves to produce Europe - wide ‘harmonised regulation’ for import and release of native and non - native IBCAs



UK context

- Licensing system coordinated by Department for Environment, Food and Rural Affairs (DEFRA)
- Available information often inadequate for reliable risk assessment
- Evidence that recent releases into glasshouses have established outdoors
- DEFRA commissioned research to develop experimental protocols to form basis of an environmental risk assessment



Neoseiulus (*Amblyseius*) *californicus*

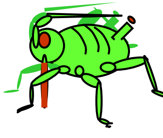
- First released in UK in 1991 as a control for glasshouse spider mite (*Tetranychus urticae*)
- Wild populations found close to release sites in 1998
- Effects on native species and ecosystem unknown

Macrolophus caliginosus

- First released in UK 1995 as control against glasshouse whitefly (*Trialeurodes vaporariorum*)
- Regular occurrence outside of glasshouses in winter
- Effect on native species and ecosystem unknown

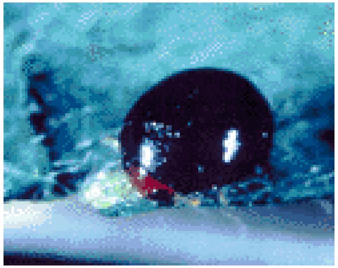
Factors affecting establishment of non-native glasshouse biocontrol agents in the UK

- Most species originate from tropical or Mediterranean climates
- Requires an adequate thermal budget (day-degrees) above the developmental threshold to allow development from egg to adult
- Must be able to produce an overwintering stage capable of survival at low temperature
- Must have alternative wild prey



Establishment of non-native glasshouse biocontrol agents in the UK

Macrolophus caliginosus

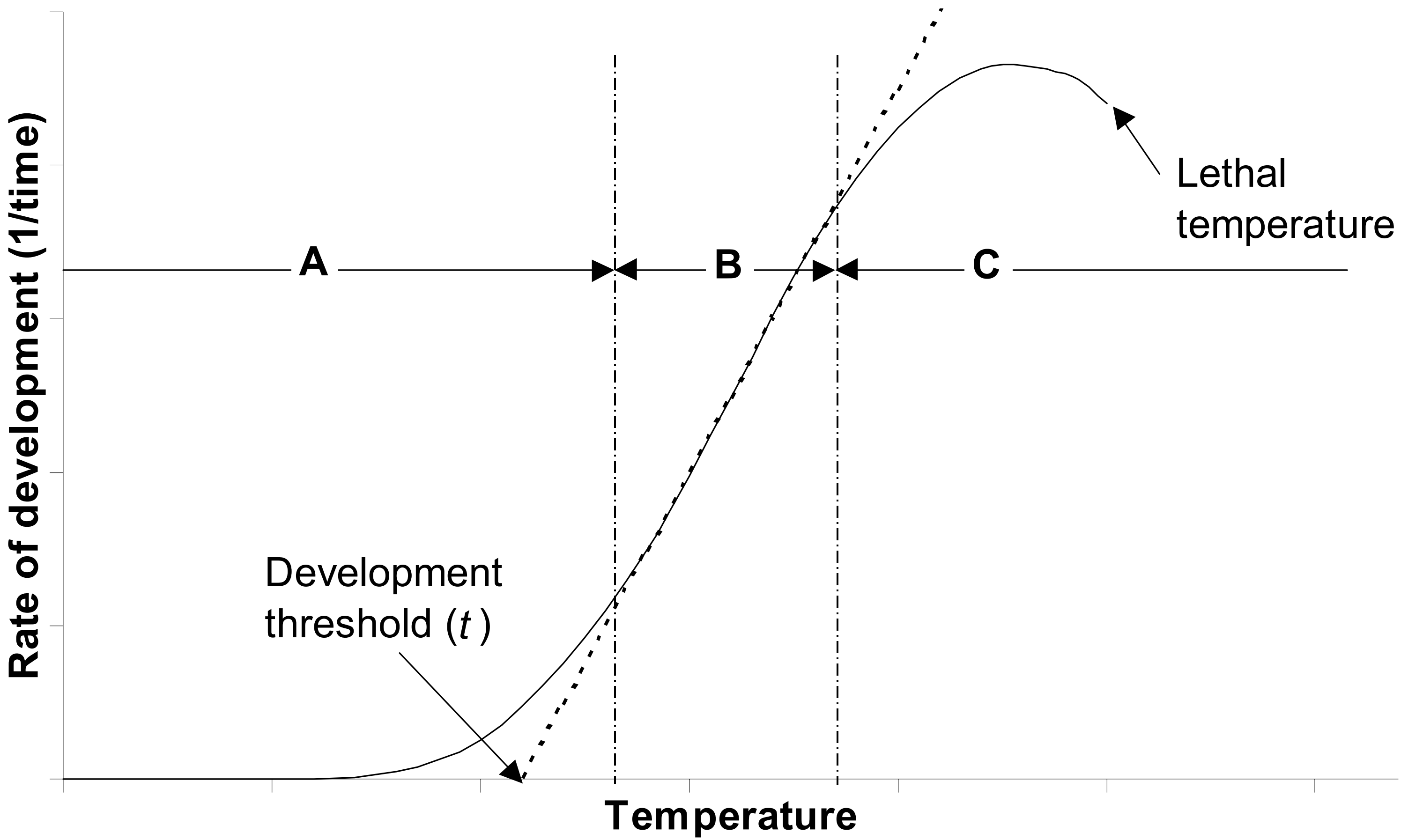


Delphastus catalinae

Neoseiulus californicus

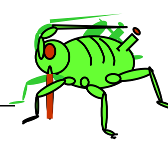
Eretmocerus eremicus

Schematic relationship between temperature and rate of development

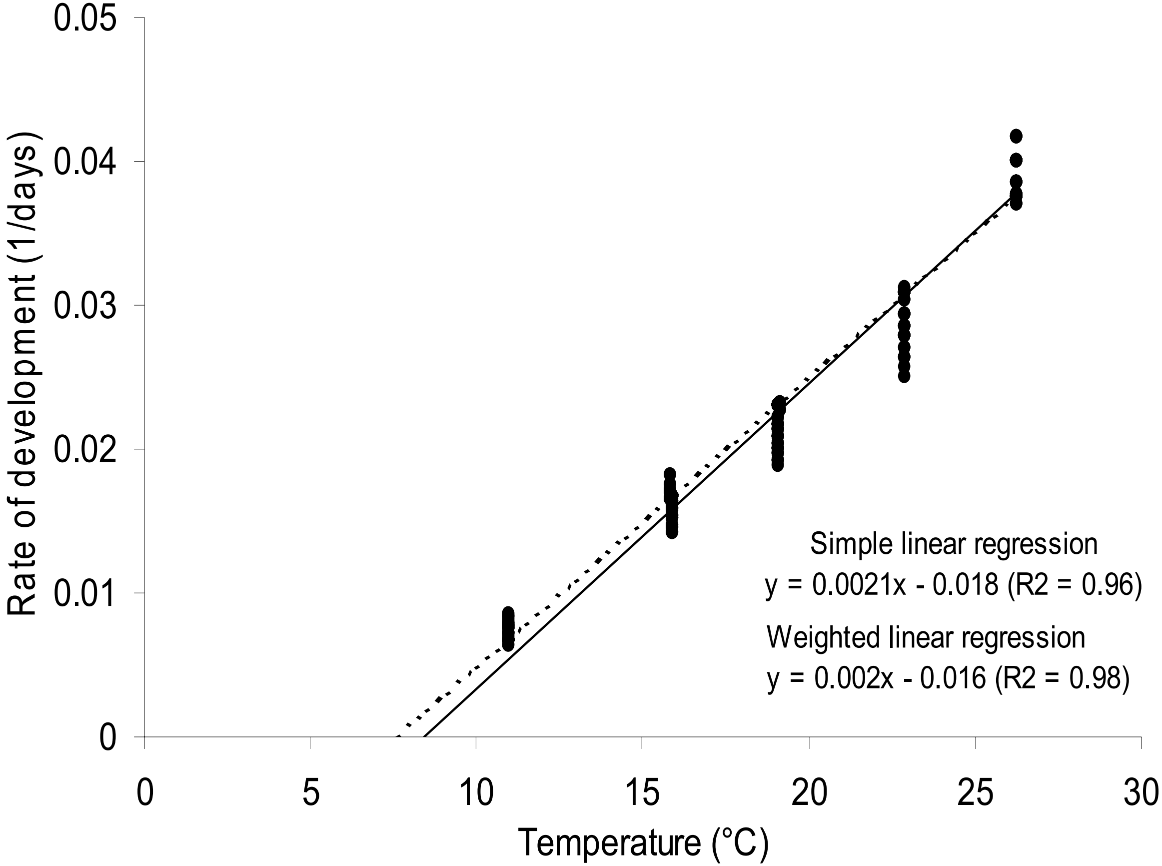


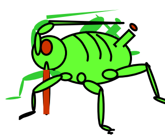
Effect of rearing temperature on development time (days ± standard error) of *Macrolophus caliginosus*

Temp	sex	n	egg	1st instar	2nd instar	3rd instar	4th instar	5th instar	total (egg-adult)
11°C	m	5	54.6±1.1	14.4±1.6	9.4±0.8	12.8±0.6	16.2±1.2	21±0.7	128.4±1.6
	f	7	56.9±1.3	13.4±0.6	11.9±1.9	12.6±1.0	15.7±1.0	19.7±2.2	130.1±2.5
16°C	m	19	26.0±0.1	7.7±0.6	6.4±0.4	5.8±0.5	6.1±0.4	9.9±0.4	61.8±0.8
	f	18	26.3±0.1	7.9±0.5	6.4±0.5	6.7±0.4	6.6±0.4	9.8±0.2	63.8±0.8
19°C	m	22	20.9±0.4	4.7±0.2	4.5±0.3	4.9±0.3	4.6±0.2	7.5±0.1	47.1±0.5
	f	14	21.9±0.6	5.1±0.3	4.9±0.4	4.3±0.3	5.0±0.3	7.5±0.3	48.7±0.6
23°C	m	12	14.3±0.1	5.3±0.3	2.9±0.2	3.6±0.2	4.1±0.2	5.8±0.3	35.9±0.6
	f	9	14.7±0.2	4.2±0.5	2.9±0.1	3.3±0.2	4.0±0.2	5.1±0.1	34.2±0.6
26°C	m	25	10.1±0.1	2.2±0.1	3.6±0.1	2.6±0.1	2.6±0.1	4.0±0.1	25.1±0.2
	f	29	10.0±0.0	2.4±0.1	3.4±0.1	2.7±0.1	2.7±0.1	4.1±0.1	25.2±0.1



Effect of rearing temperature on rate of development of *Macrolophus caliginosus*



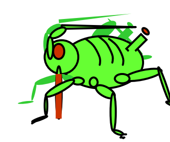


Estimated annual voltinism of *Macrolophus caliginosus* in the UK

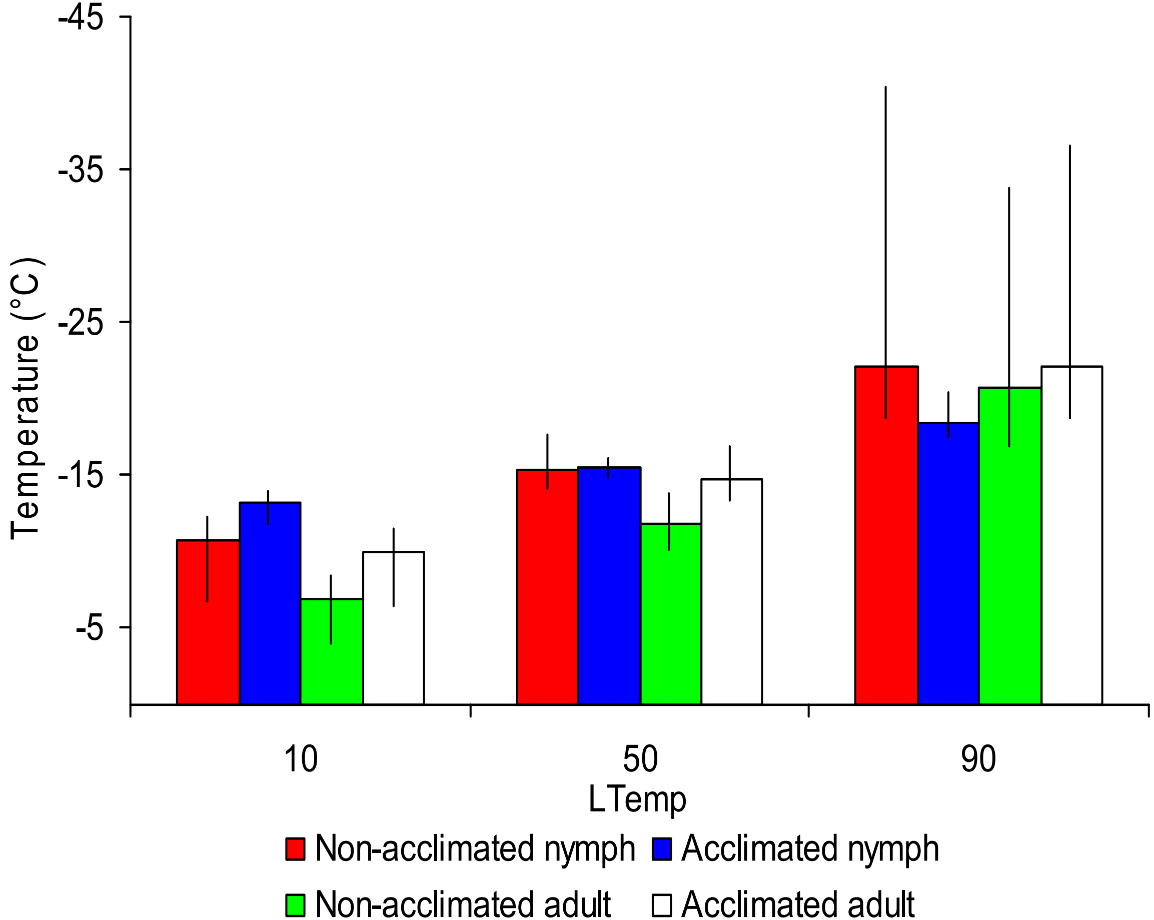
Year	Annual available day-degrees	Theoretical number of generations per year
1991	1216	2.2 (2)
1992	1235	2.2 (2)
1993	1059	1.9 (1)
1994	1208	2.2 (2)
1995	1454	2.6 (2)
1996	1165	2.1 (2)
1997	1347	2.4 (2)
1998	1247	2.3 (2)
1999	1346	2.4 (2)
2000	1257	2.3 (2)
mean	1253	2.3 (2)

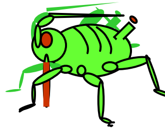
Mean ± SE (°C) and range of supercooling points of different acclimated and non-acclimated life-cycle stages of *Macrolophus caliginosus*

Experimental type	n	Mean ± SE (°C)	Range (°C)
Non-acclimated first/second instar	23	-20.3 ± 0.5	-15.5 to -23.6
Acclimated first/second instar	22	-19.7 ± 0.6	-14.6 to -26.5
Non-acclimated fifth instar/adult	19	-20.2 ± 0.5	-16.2 to -22.7
Acclimated fifth instar/adult	23	-19.0 ± 0.6	-11.8 to -23.3

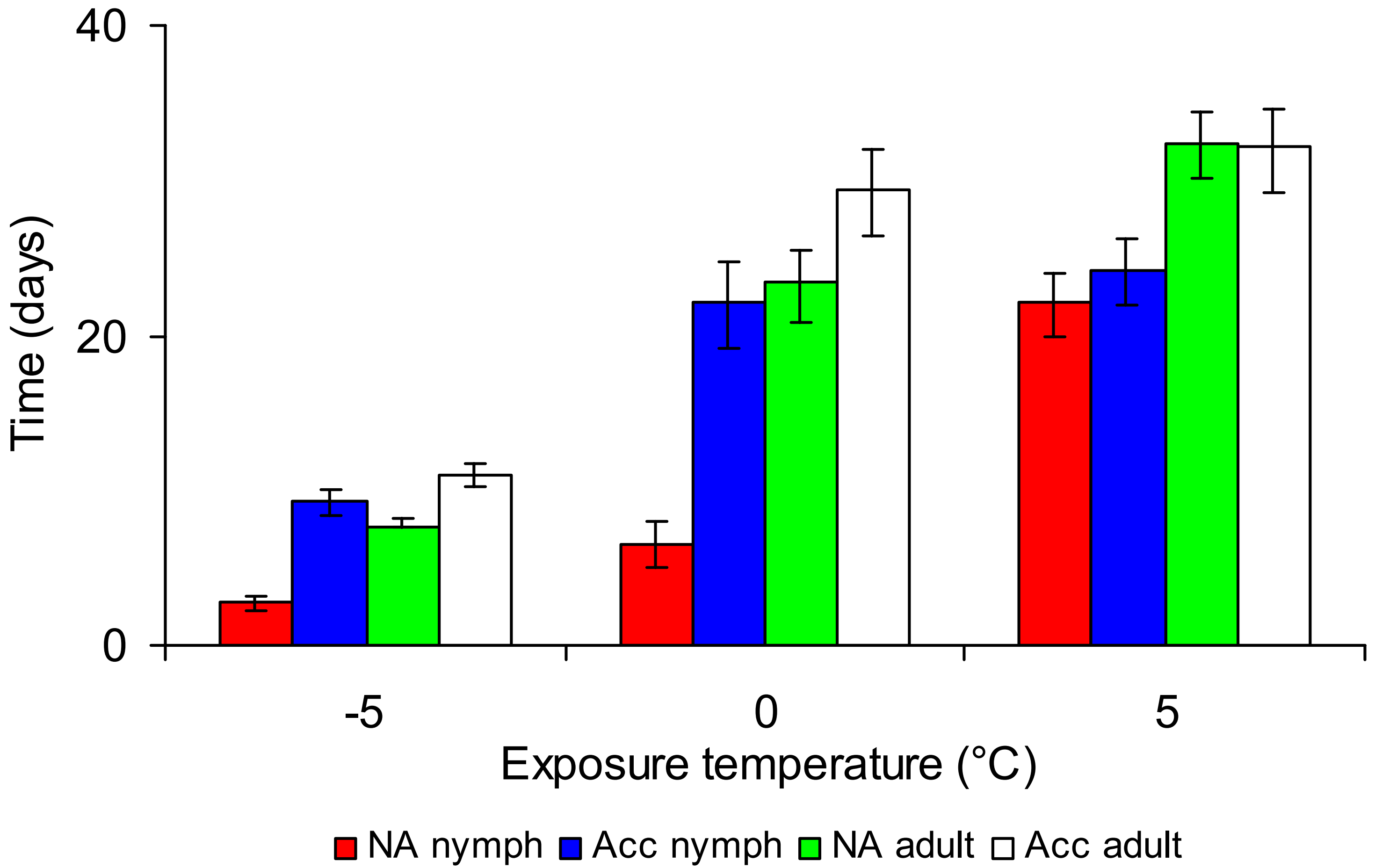


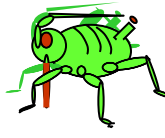
Lethal temperatures (10, 50 and 90%) of different acclimated and non-acclimated life-cycle stages of *Macrolophus caliginosus*



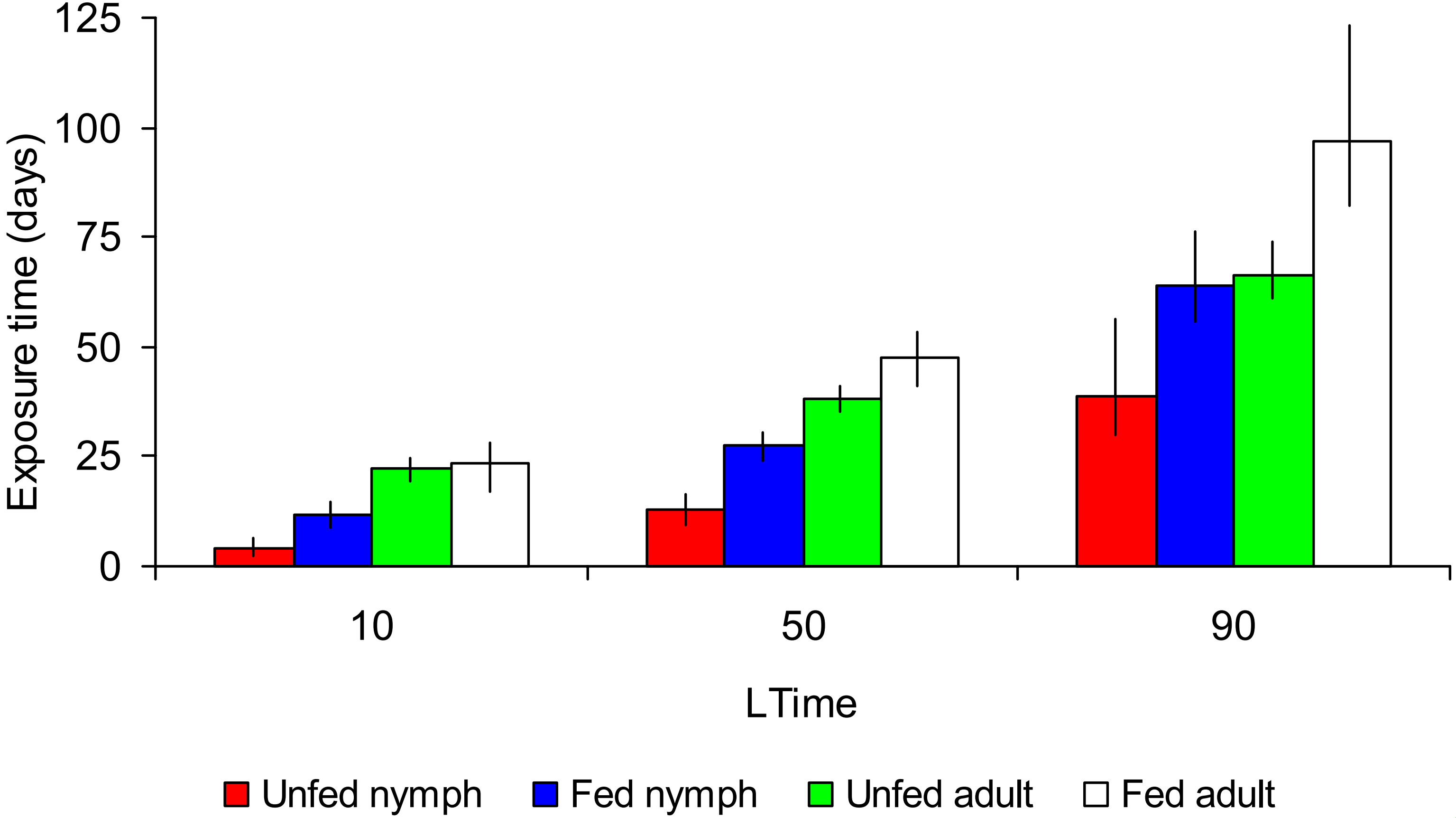


Lethal times (LTime$_{50}$) of different acclimated and non-acclimated life-cycle stages of *Macrolophus caliginosus*

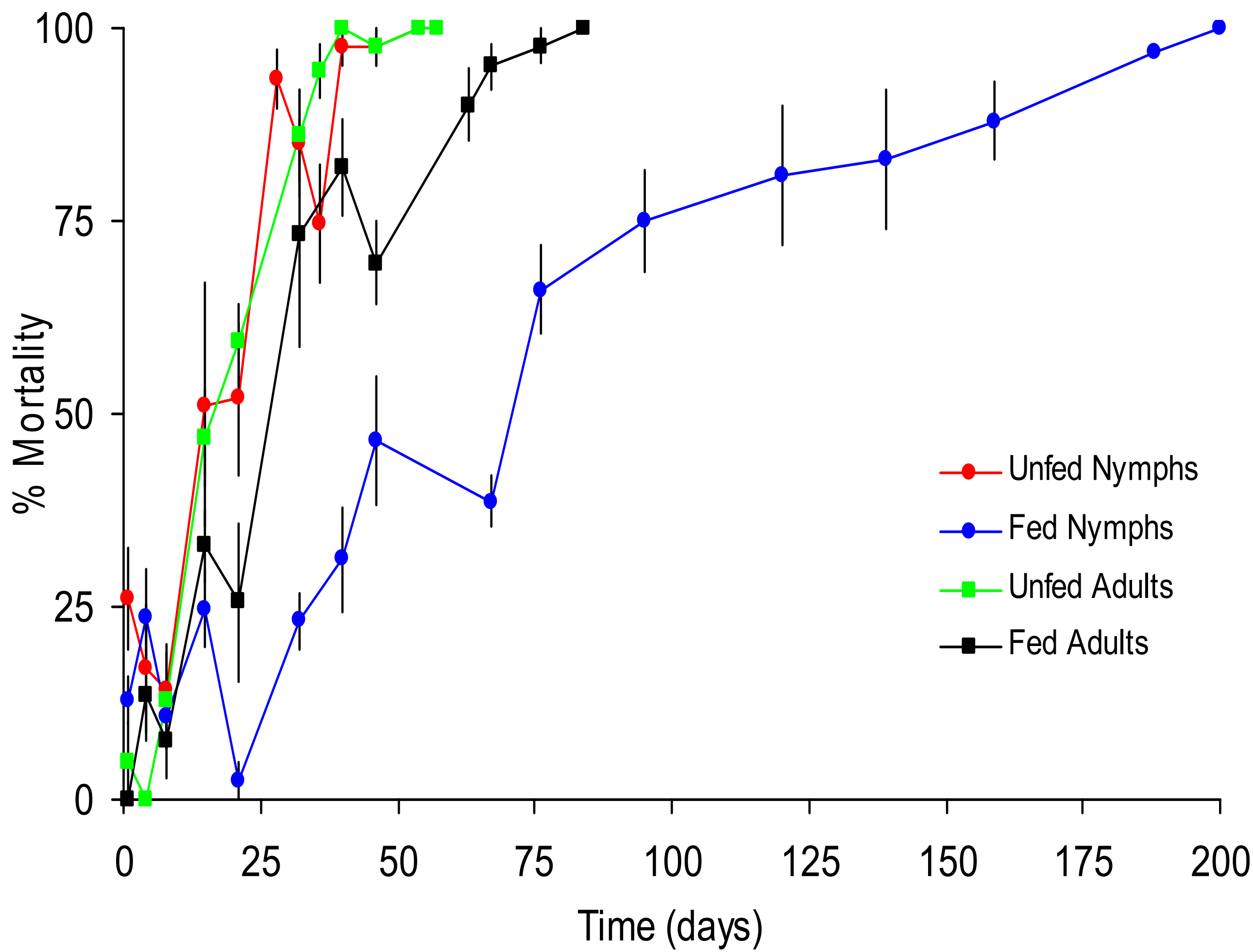




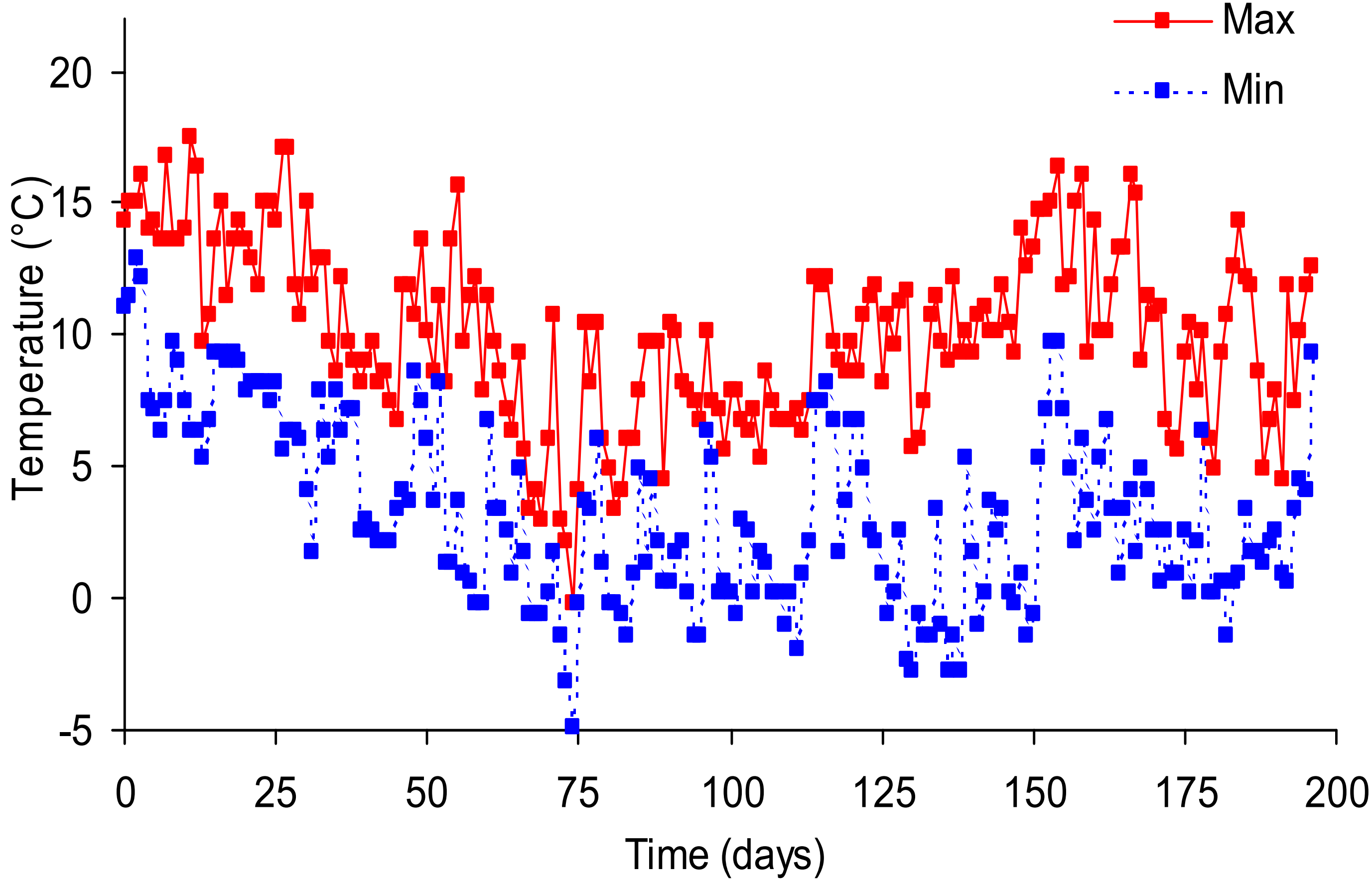
Lethal times (10, 50 and 90%) of different life-cycle stages of *Macrolophus caliginosus* with and without whitefly prey

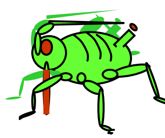


Mortality of non-acclimated nymphal and adult *Macrolophus caliginosus* with and without whitefly prey in winter



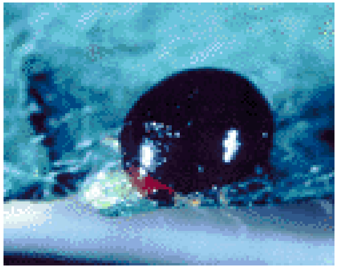
Maximum and minimum microclimate temperatures during *Macrolophus caliginosus* winter field exposure





Establishment of non-native glasshouse biocontrol agents in the UK

Macrolophus caliginosus



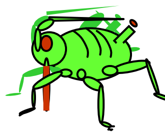
Delphastus catalinae

Amblyseius californicus

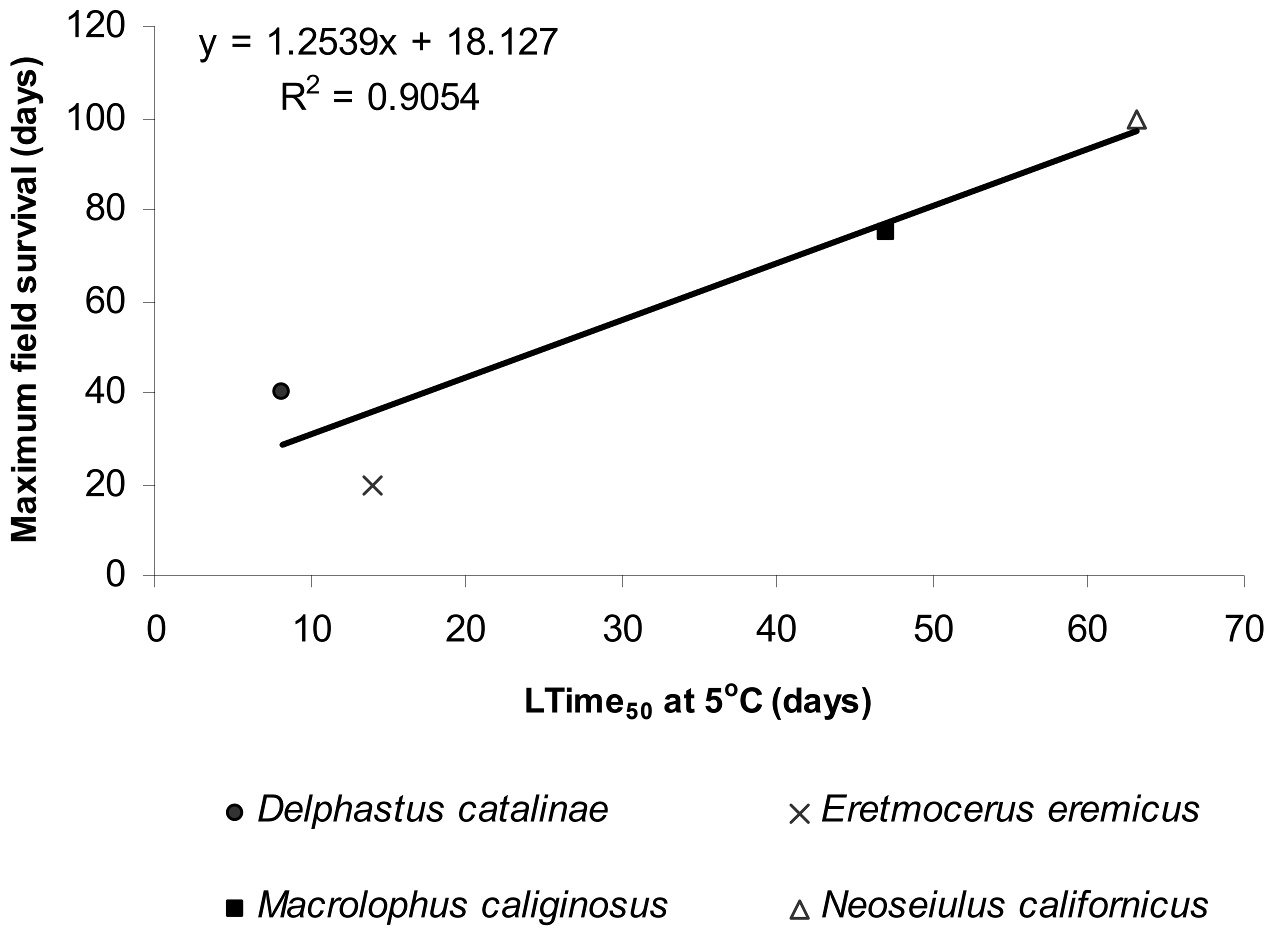
Eretmocerus eremicus

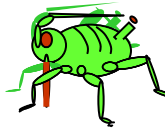
Comparative thermal data of non-native glasshouse biocontrol agents in the UK

Index	*M. caliginosus*	*A. californicus*	*D. catalinae*	*E. eremicus*
SCP	-19.7	-22.2	-19.5	-24.8
LTemp (°C)	-15.6	-17.7	-16.3	-20.5
LTime (days @ 5°C)	47	63	32	14
Winter survival	>6 months	3 months	1 month	1 month

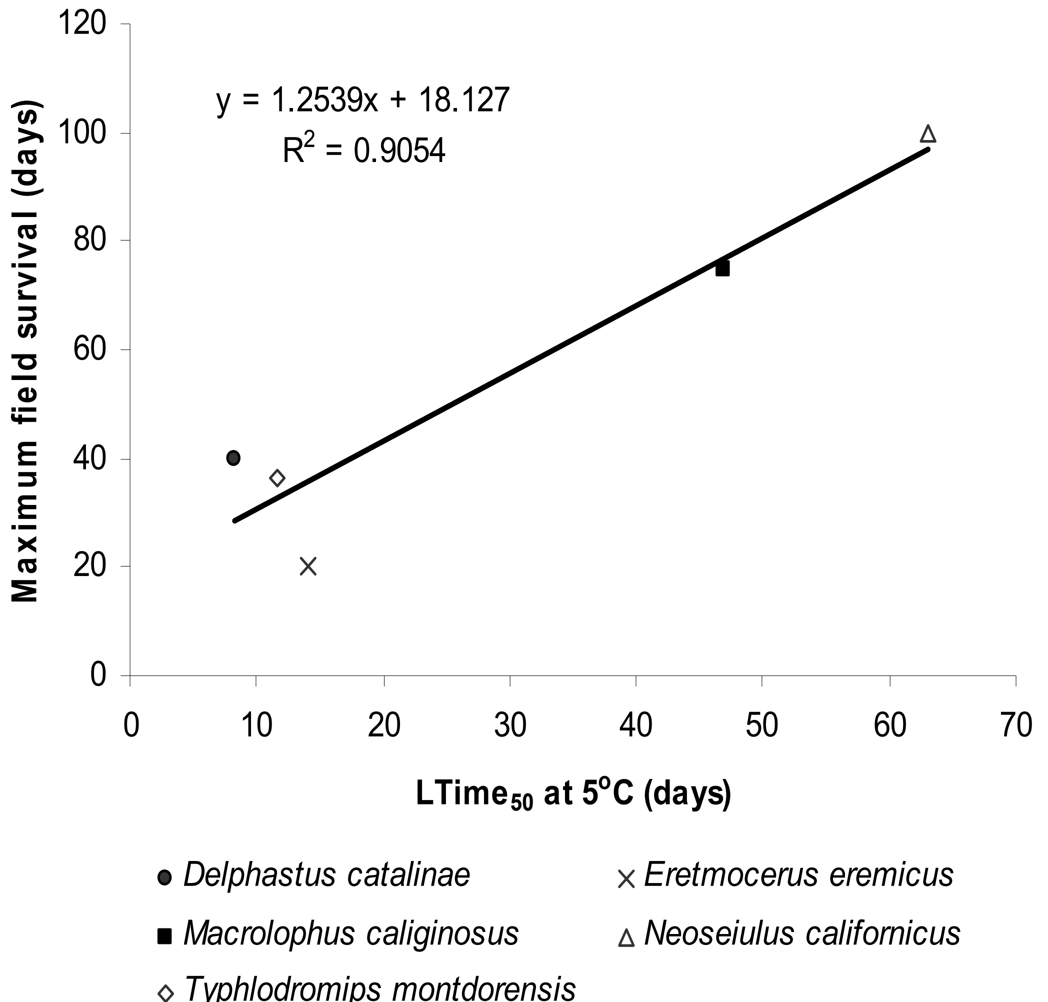


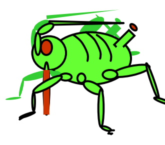
Relationship between $LTime_{50}$ at 5°C (laboratory) and winter field survival of four non-native glasshouse biocontrol agents



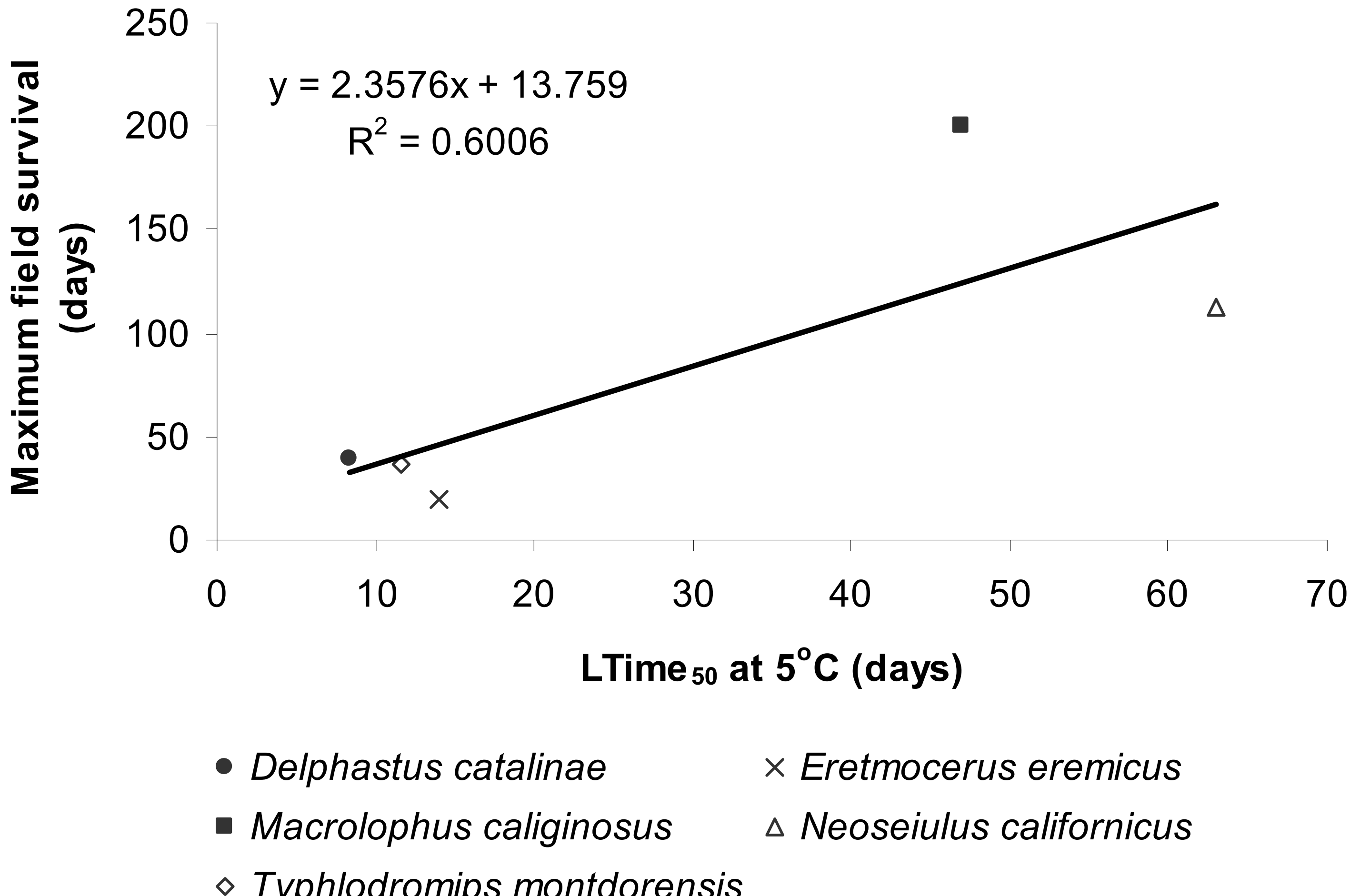


Relationship between $LTime_{50}$ at 5°C (laboratory) and winter field survival of five non-native glasshouse biocontrol agents

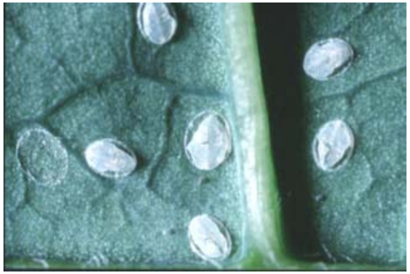




Relationship between maximum $LTime_{50}$ at 5°C (laboratory) and known winter field survival of five non-native glasshouse biocontrol agents

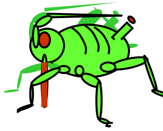


Establishment of resident and non resident crop pest insects in the UK

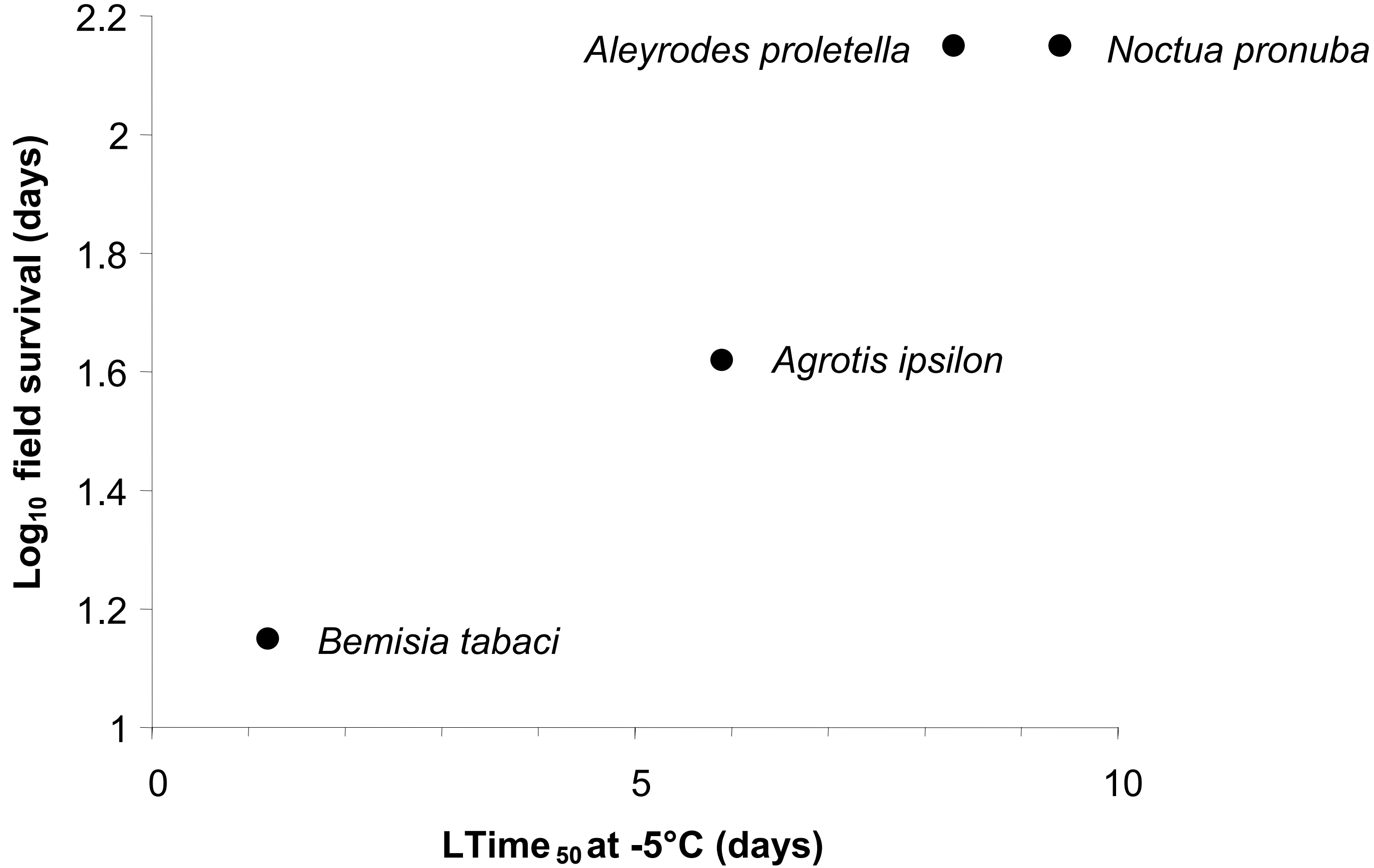
	Resident	Non-resident
Lepidoptera	 *Noctua pronuba*	 *Agrotis ipsilon*
Hemiptera	 *Aleyrodes proletella*	 *Bemisia tabaci*

Comparative thermal data of resident and non-resident pest insects in the UK

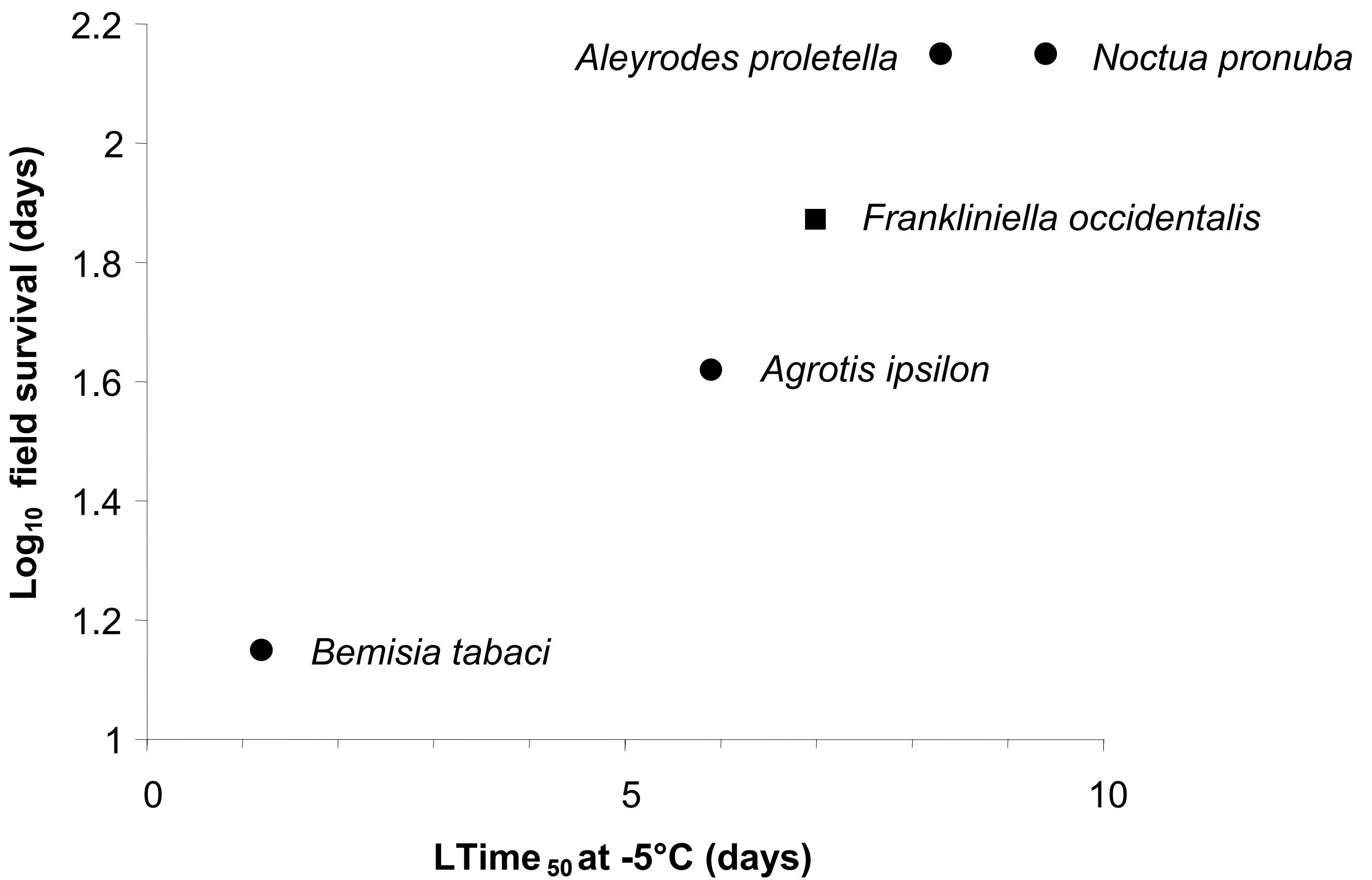
Index	**Lepidoptera**		**Hemiptera**	
	N. pronuba **(R)**	***A. ipsilon (NR)***	***A. proletella*** **(R)**	***B. tabaci*** **(NR)**
SCP	-15.4	-12.6	-23.4	-23.9
LTemp (°C)	-15.8	-8.9	-21.2	-5.8
LTime (days @ -5°C)	9	5.8	8.1	1.2
Winter survival	>6 months	6 weeks	>6 months	3 weeks

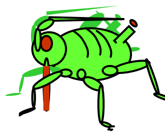


Relationship between LTime$_{50}$ at -5°C (laboratory) and winter field survival of resident and non-resident pests in the UK



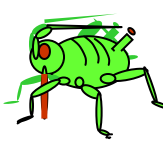
Relationship between LTime$_{50}$ at -5°C (laboratory) and winter field survival of resident and non-resident pests in the UK - validation with additional species





Conclusions

- Strong correlation between laboratory - derived indices of cold tolerance and field survival
- System provides retrospective explanation for establishment of *N. californicus* in UK and occurrence of *M. caliginosus* outside of glasshouses in winter
- Combining assessments of cold tolerance with availability and use of wild prey provides an effective screen for establishment potential of non - native IBCAs in UK



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