# Incorporating mathematical models and biocontrol into IPM programs for invasive alien insects

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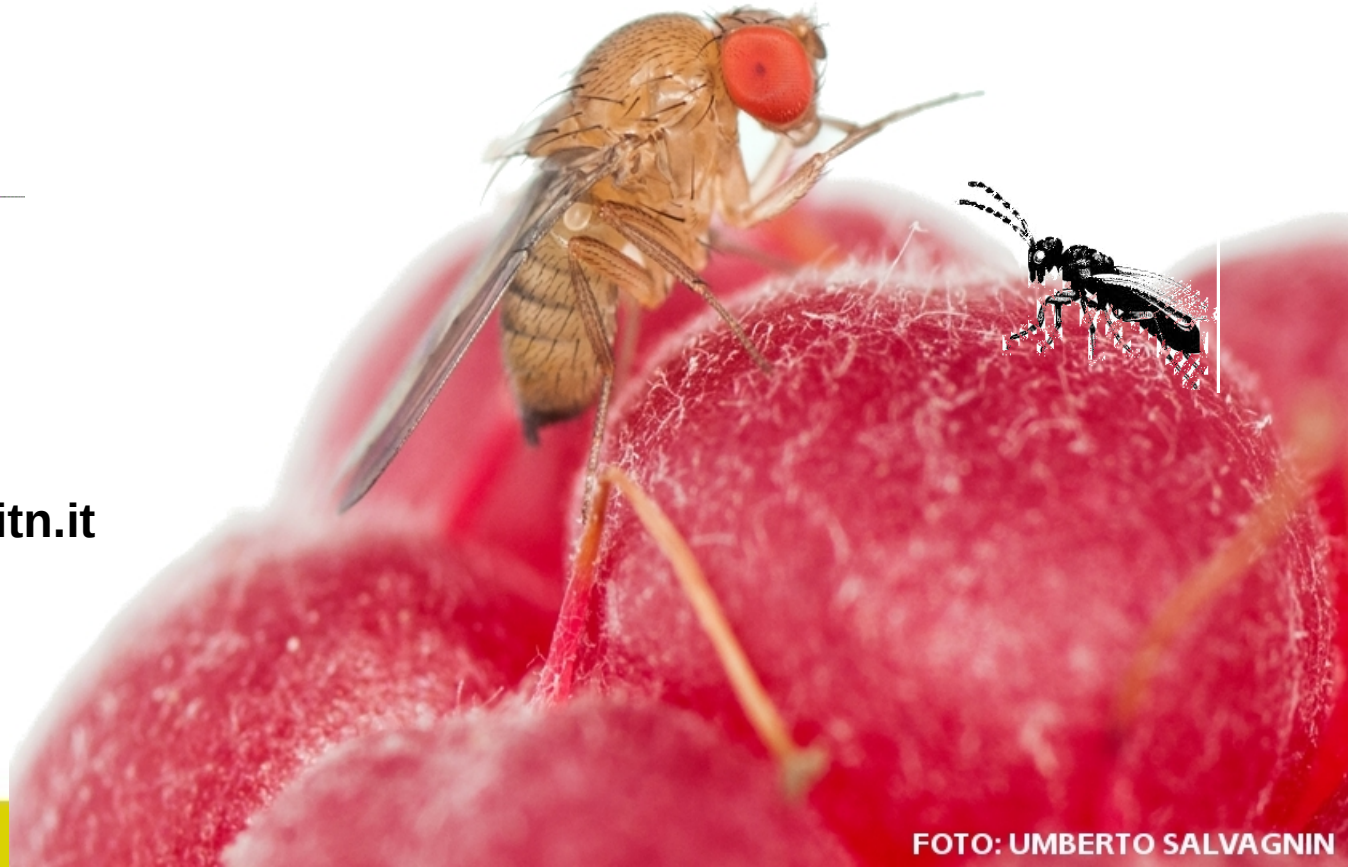
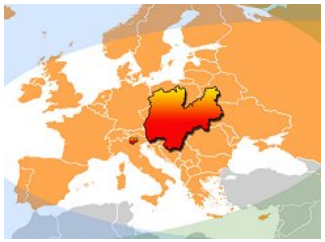


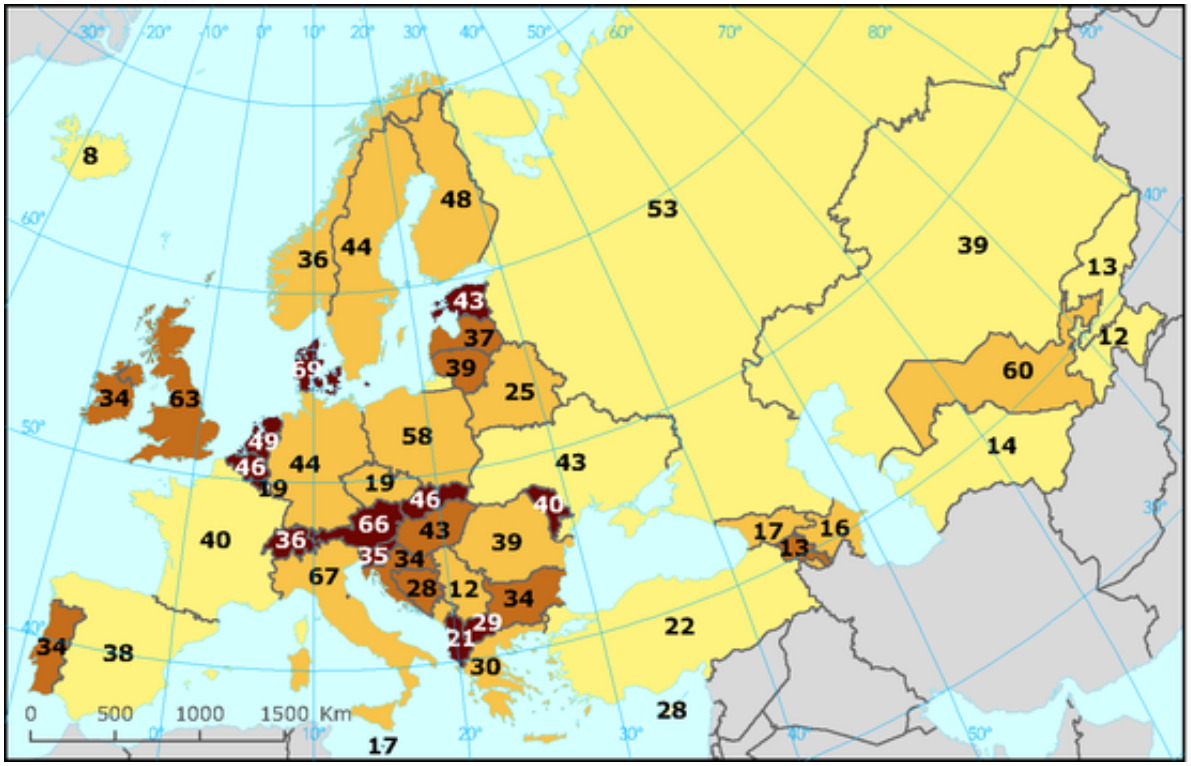


# Invasive alien insects

*Drosophila suzukii*

*Halyomorpha halys*

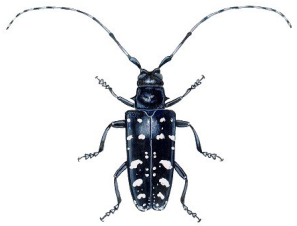
# INVASIVE ALIEN INSECTS




**Number of worst invasive alien species registered per country**

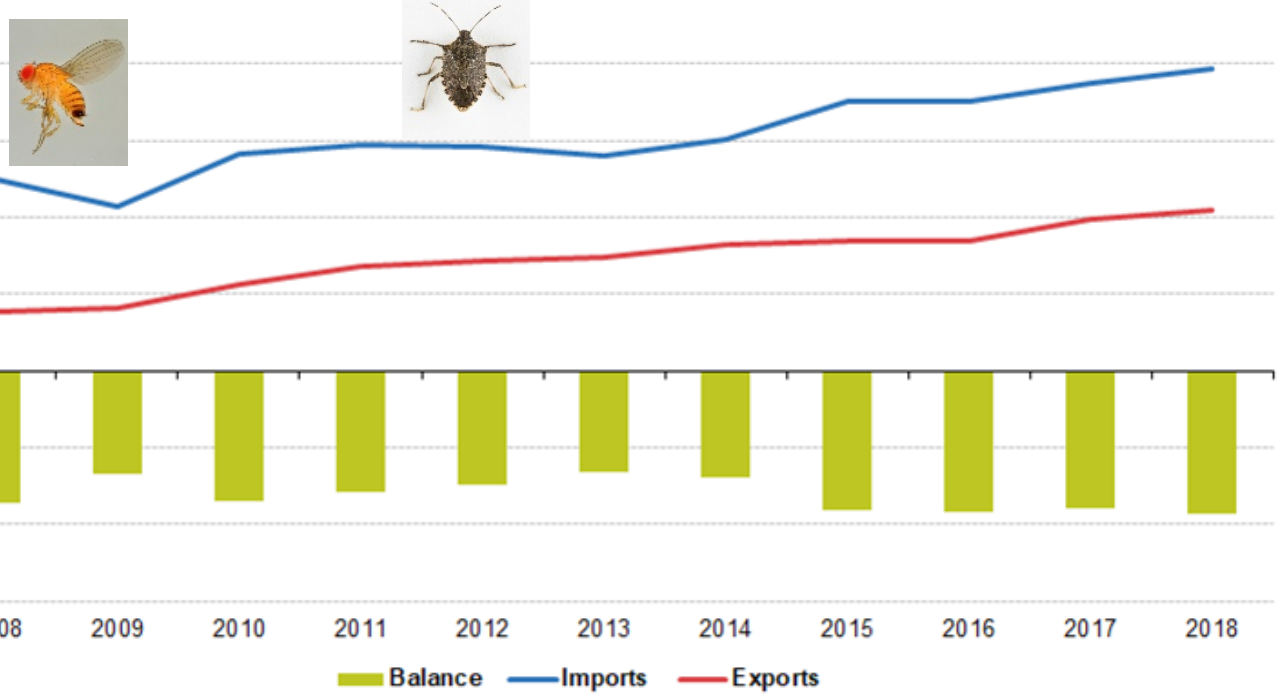
Species per 1 000 km²

- < 0.10
- 0.10–0.25
- 0.25–0.7
- 0.7–3.0
- Outside report coverage



# Global trade routes

**Imports, exports and balance for trade in goods between the EU-28 and China, 2008-20**
(EUR billion)




*Source:* Eurostat (online data code: ext_lt_maineu)

eurostat

# Italy is strongly exposed to the incursions of alien species


63 milioni tourists/year
from 1 to 4 a year

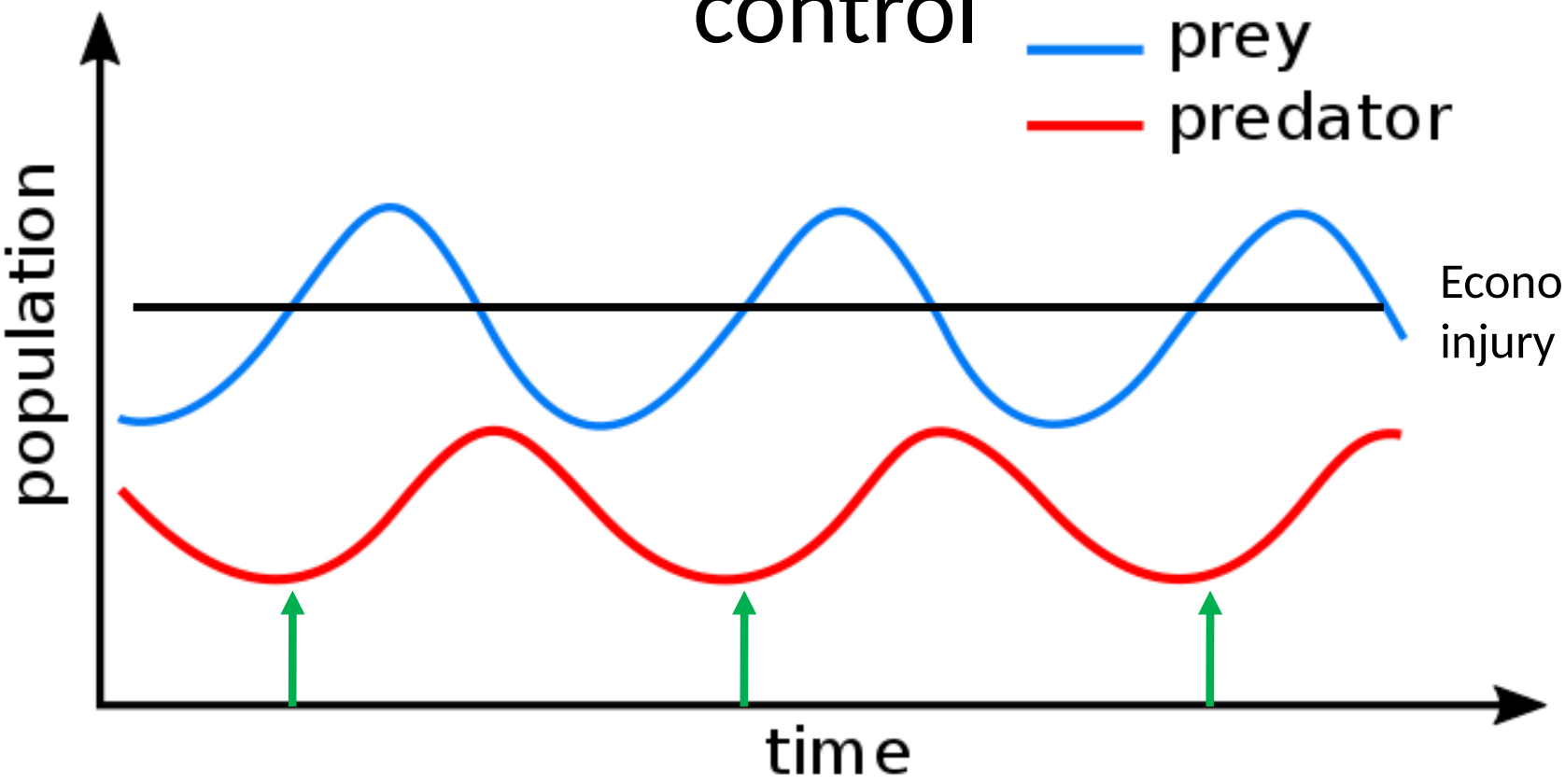
n° of alien species arrived In Italy in the last 20 years

number of alien insects recorded per country

(Roques et al., 2010)

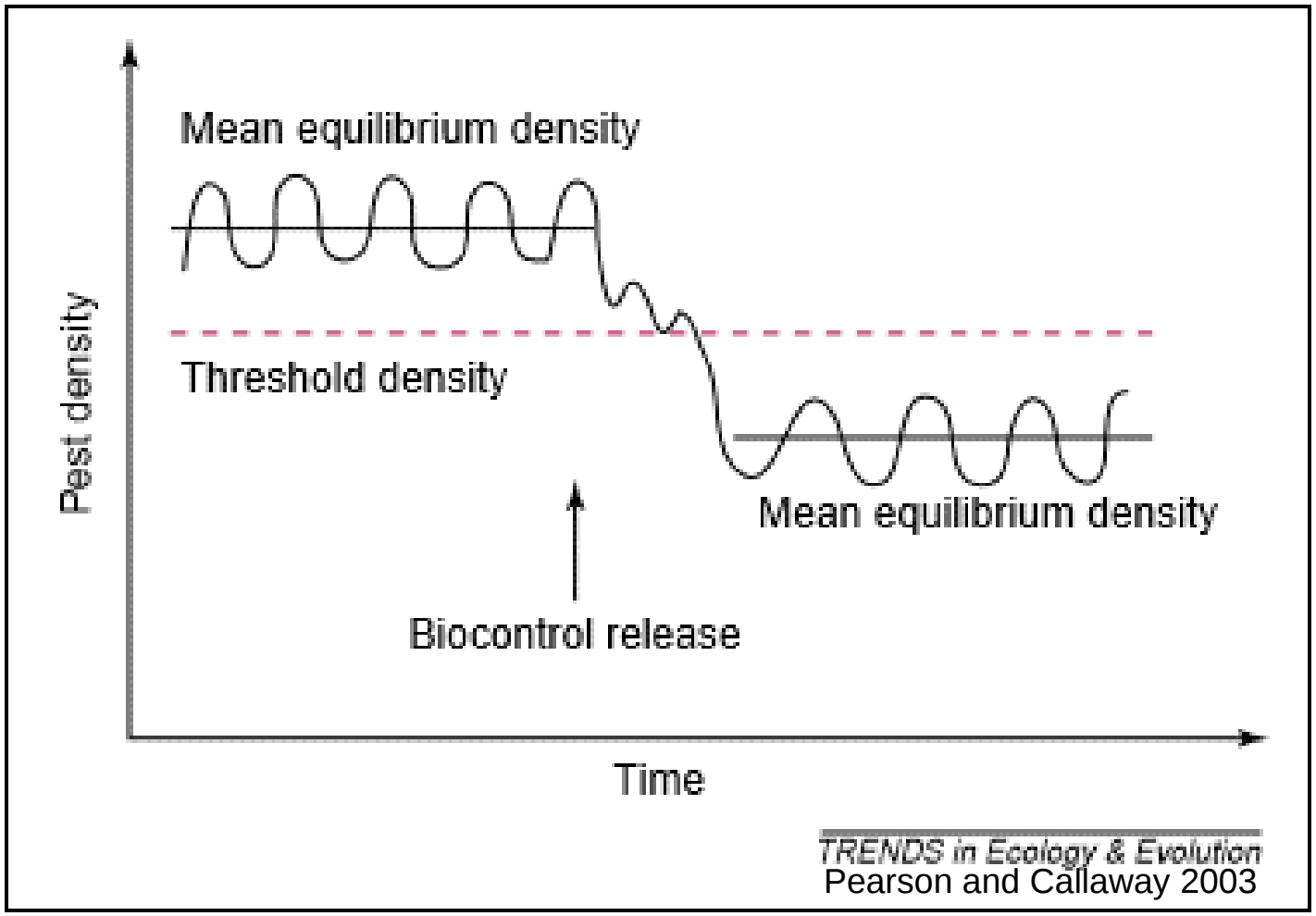
- The cost to Europe in terms of controlling and eradicating invasive alien species, and repairing the damage they cause in agriculture is estimated at more than €10 billion a year
- **Biological control** is likely the most effective, durable and sustainable control method against exotic pests

# Inundative/augmentative biological control



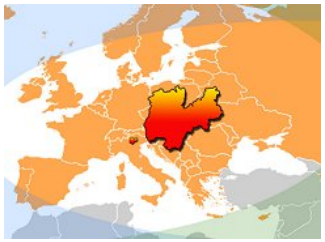

Releases of local generalist biocontrol agents

# Classical biological control



Pearson and Callaway 2003

Release of exotic specialized biocontrol agents



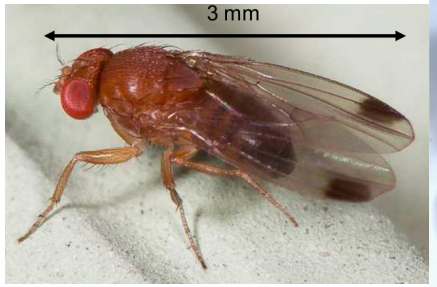
# Invasive alien insects

***Drosophila suzukii***

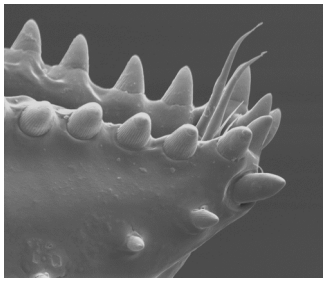
*Halyomorpha halys*

# *Drosophila suzukii*

Species identikit




**Invasive pest in EU and Americas (2009) originated from eastern Asia**


Female

It is the only *Drosophila* species known to oviposit in <u>healthy ripening fruit before harvest</u> by means of the serrated ovipositor

<u>Enormous reproductive capability</u>

- Short generation time: from egg to adult in 8-10 days
- From 10 up to 15 generations per year
- Averaging 400 eggs in a female lifetime

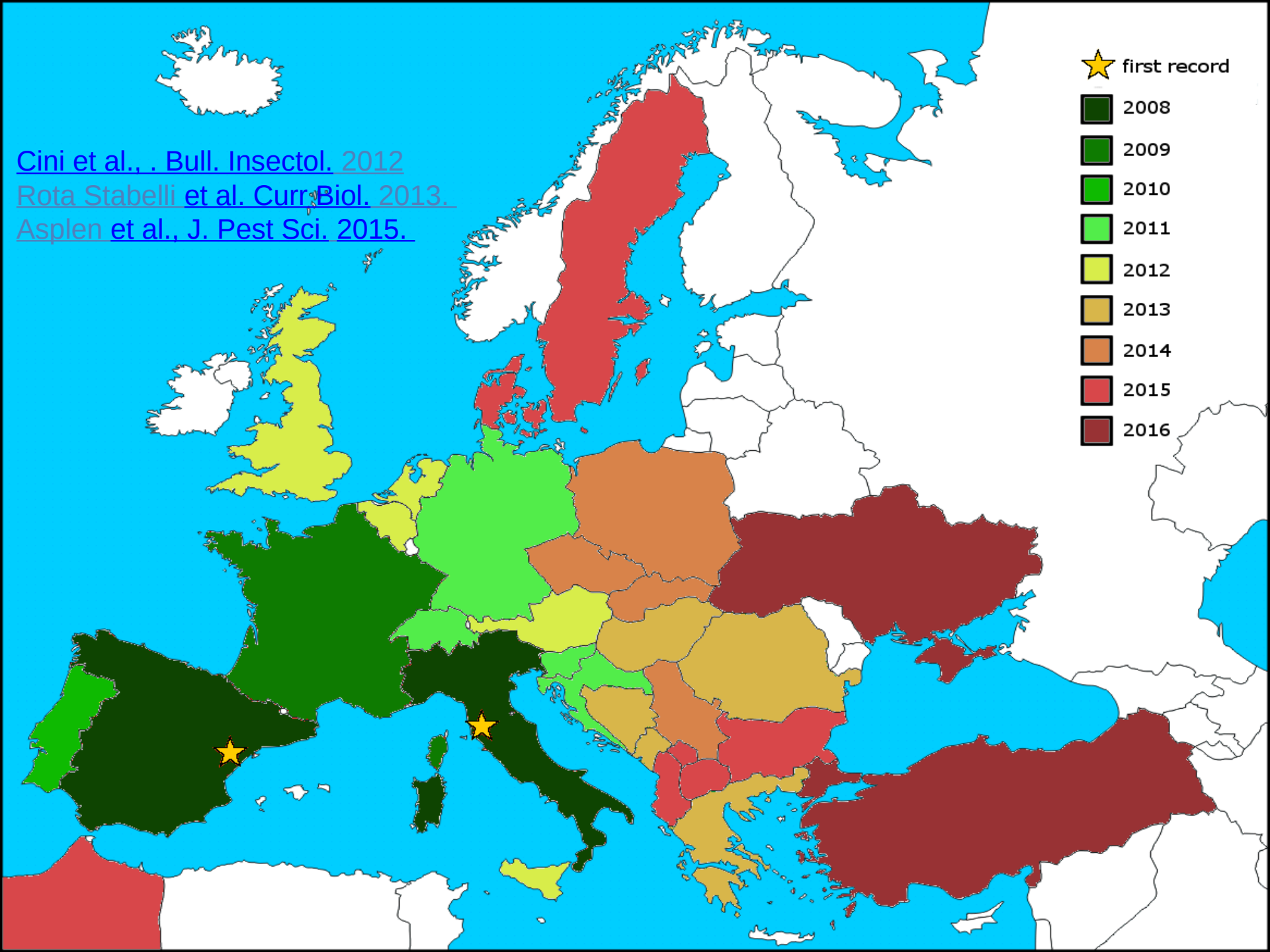
First fruit damage was reported in 2009 in soft fruits in Trentino (Grassi et al., 2009)

*D. melanogaster*

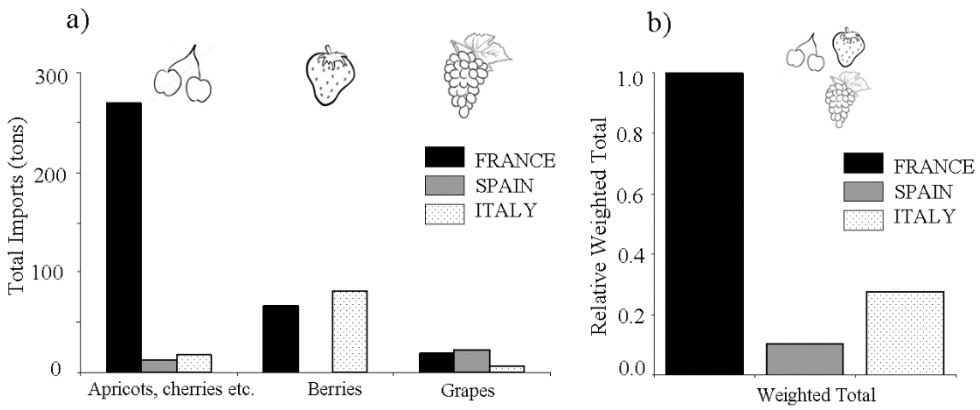
*D. suzukii*

Their close relationship offers fascinating opportunities for addressing some longstanding questions in the field of insect biology with a practical outcome.

Comparative research is sheding light on the evolution of ecological innovations in *D. suzukii* and helping researchers in understanding what makes a species invasive.


Cini et al., . Bull. Insectol. 2012
Rota Stabelli et al. Curr Biol. 2013.
Asplen et al., J. Pest Sci. 2015.
first record
2008
2009
2010
2011
2012
2013
2014
2015
2016

Geographic profiling coupling trap catches with trade flows quantification



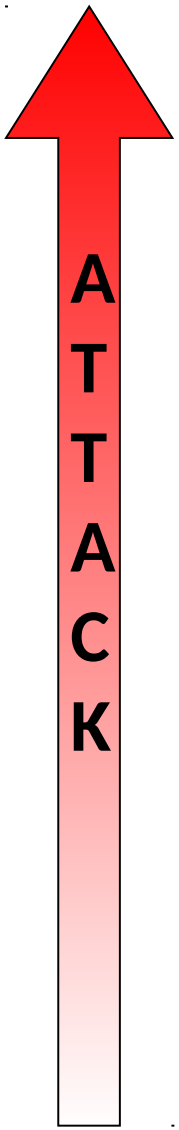

Cini *et al., 2014. Biol. Inv.*

# Damage and host range


**In Trentino**

**2010**: 500.000 € losses

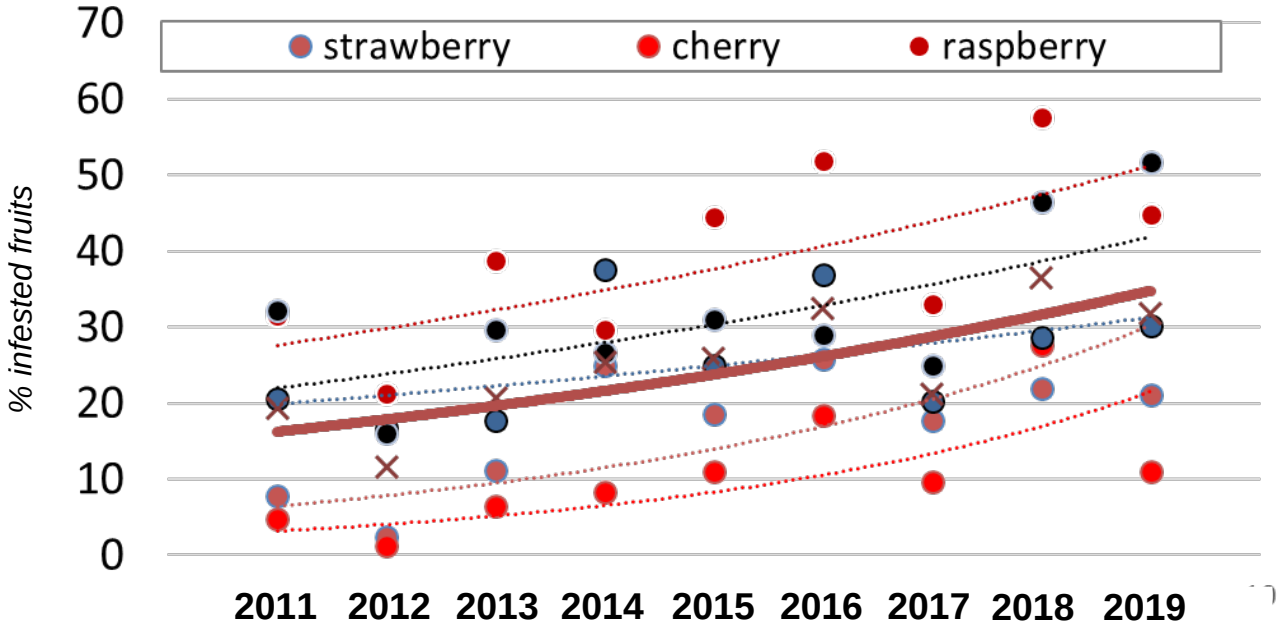
**2011**: 3.000.000 € losses



# Seasonal *D. suzukii* infestation on sweet cherry and soft fruits

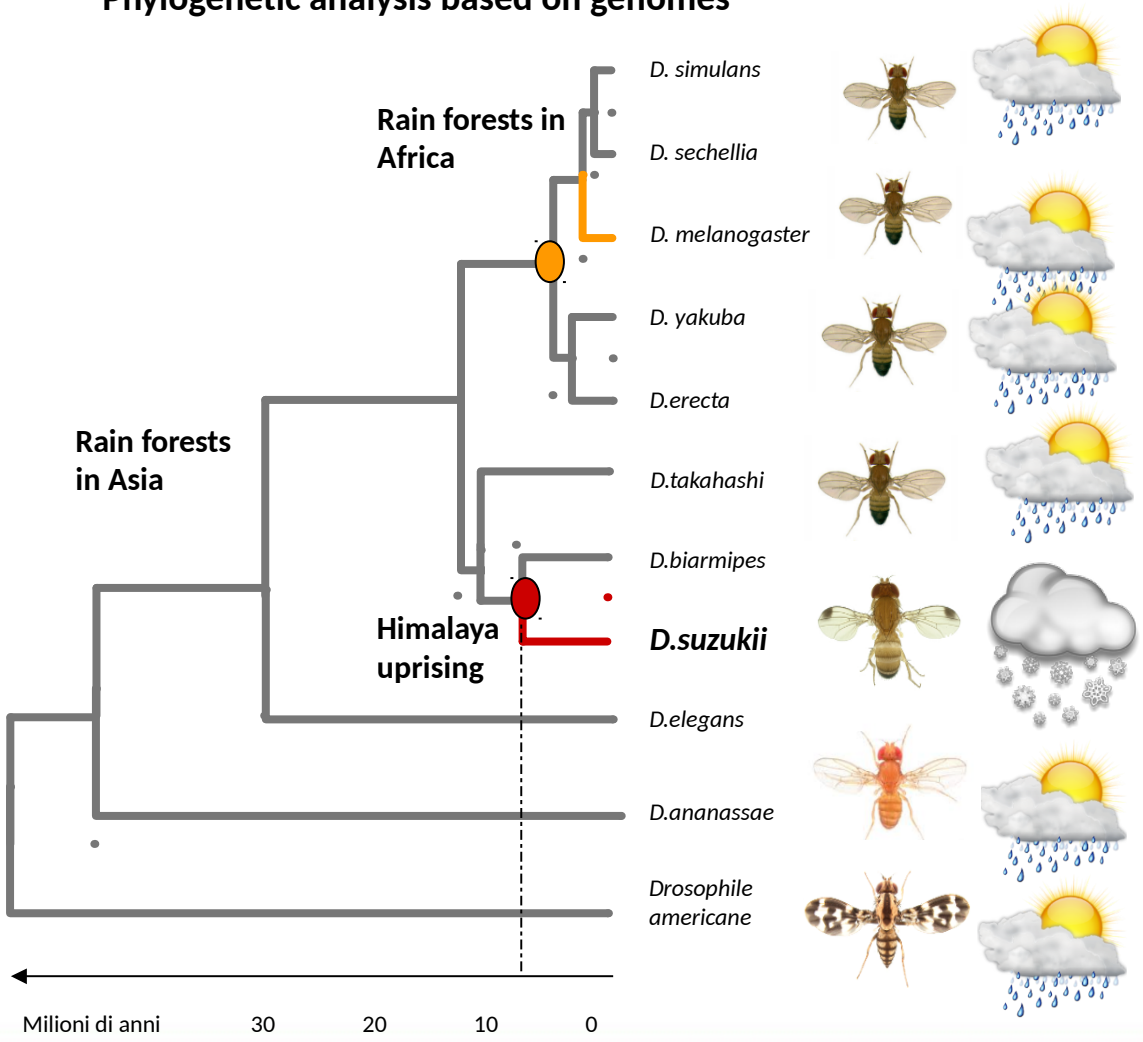




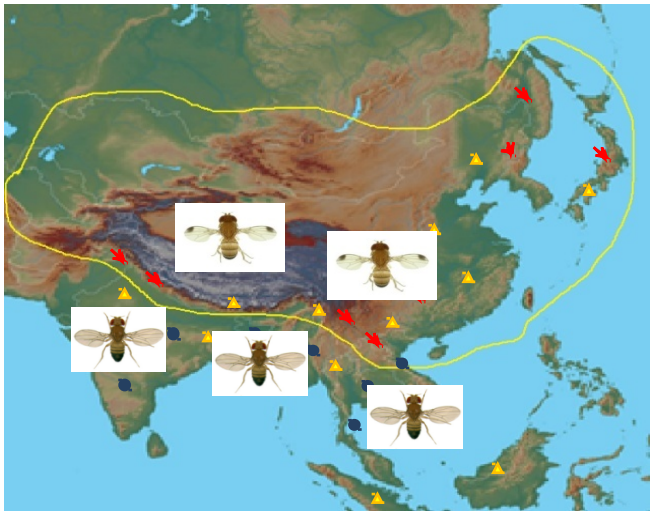


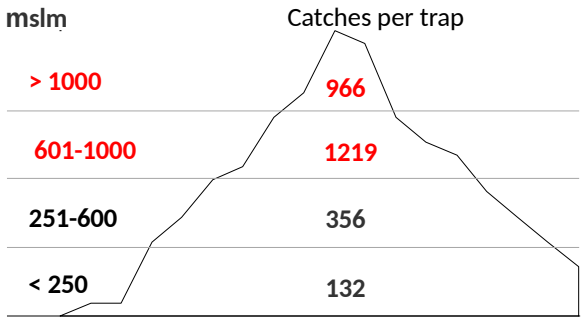
# Paleobiology provide indications for insect management

**Phylogenetic analysis based on genomes**




**Myocene. about 7.000.000 years ago**






**Ometto et al. 2013. Gen. Biol. Evol**

# Winter diapause: key bottleneck period

**male**

2 mm

**female**

2 mm

**summer**

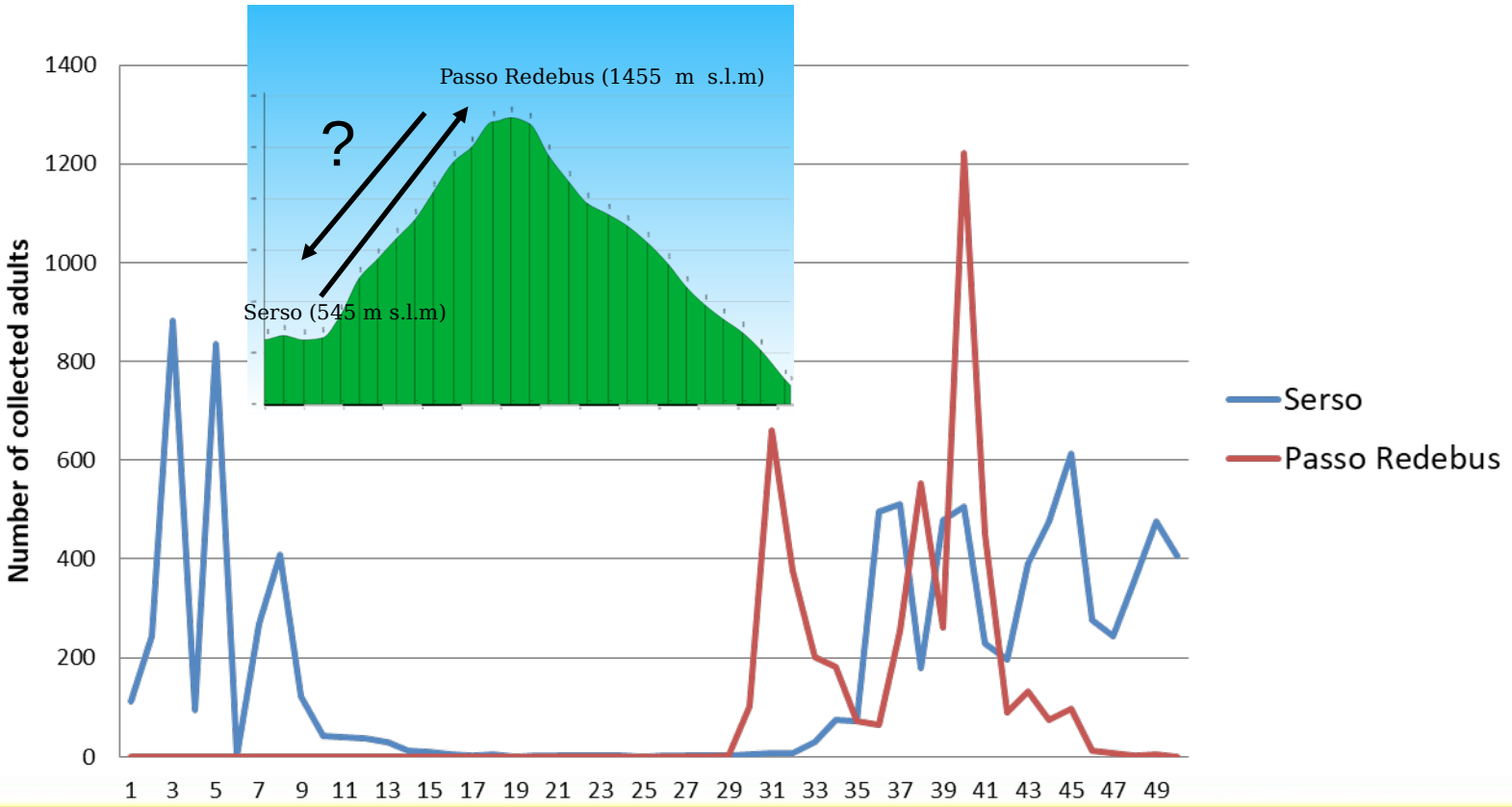
**winter**

# Population dynamics along altitudinal gradients

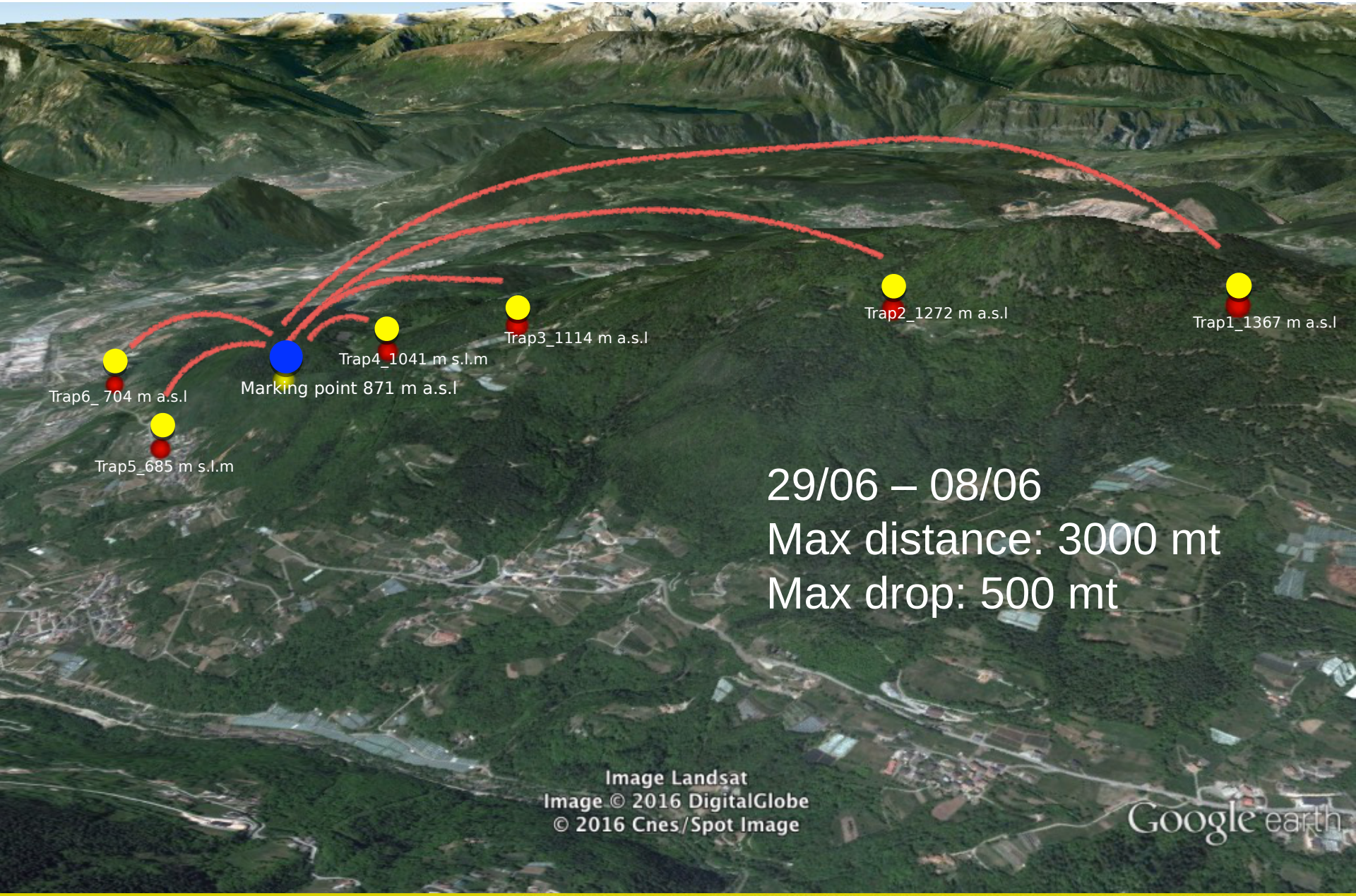
**Seasonal migration?**

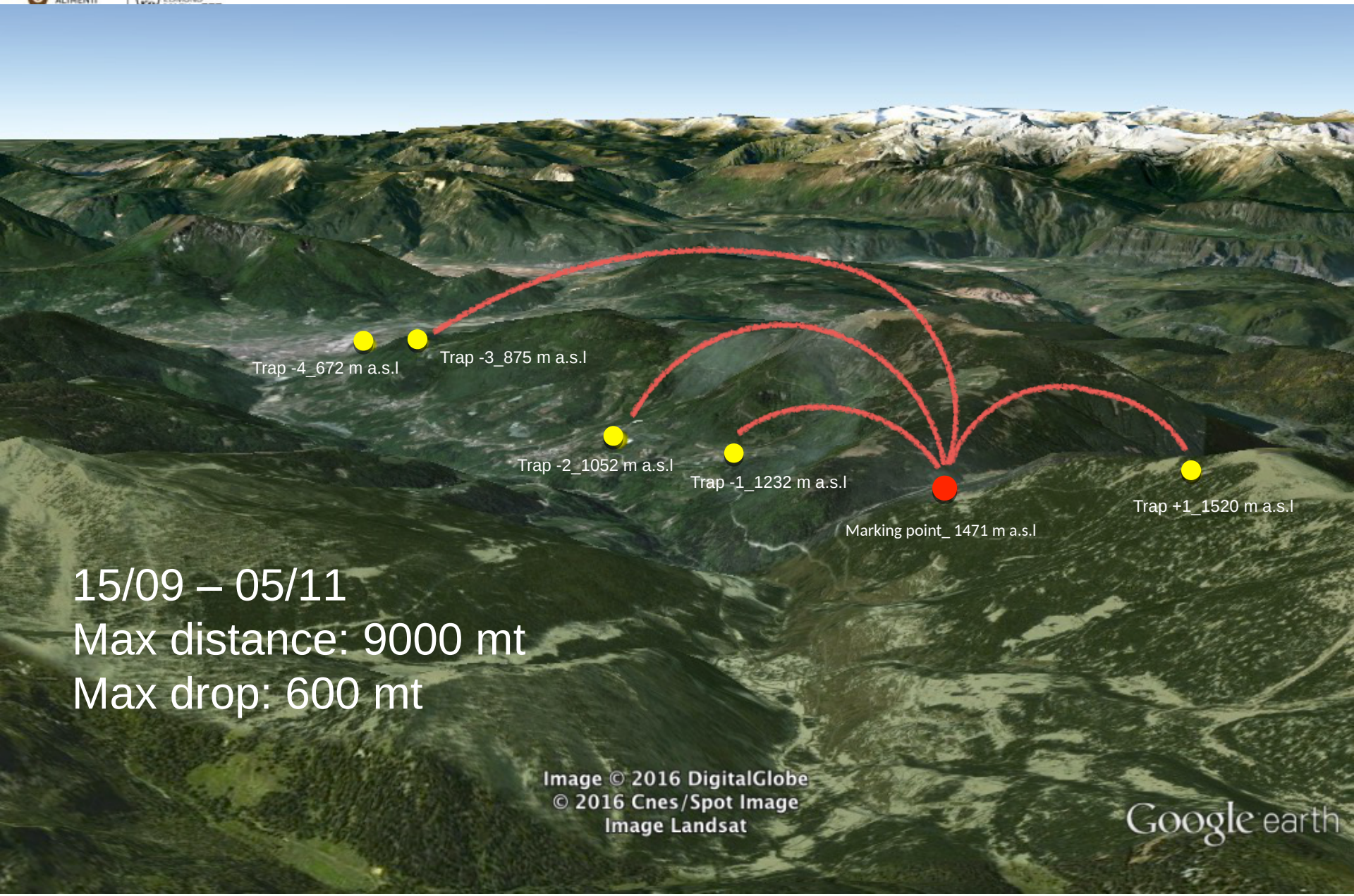
Escape from resource-poor conditions in summer at low altitudes or exploit resources at high altitudes.

Avoid unsuitable temperatures

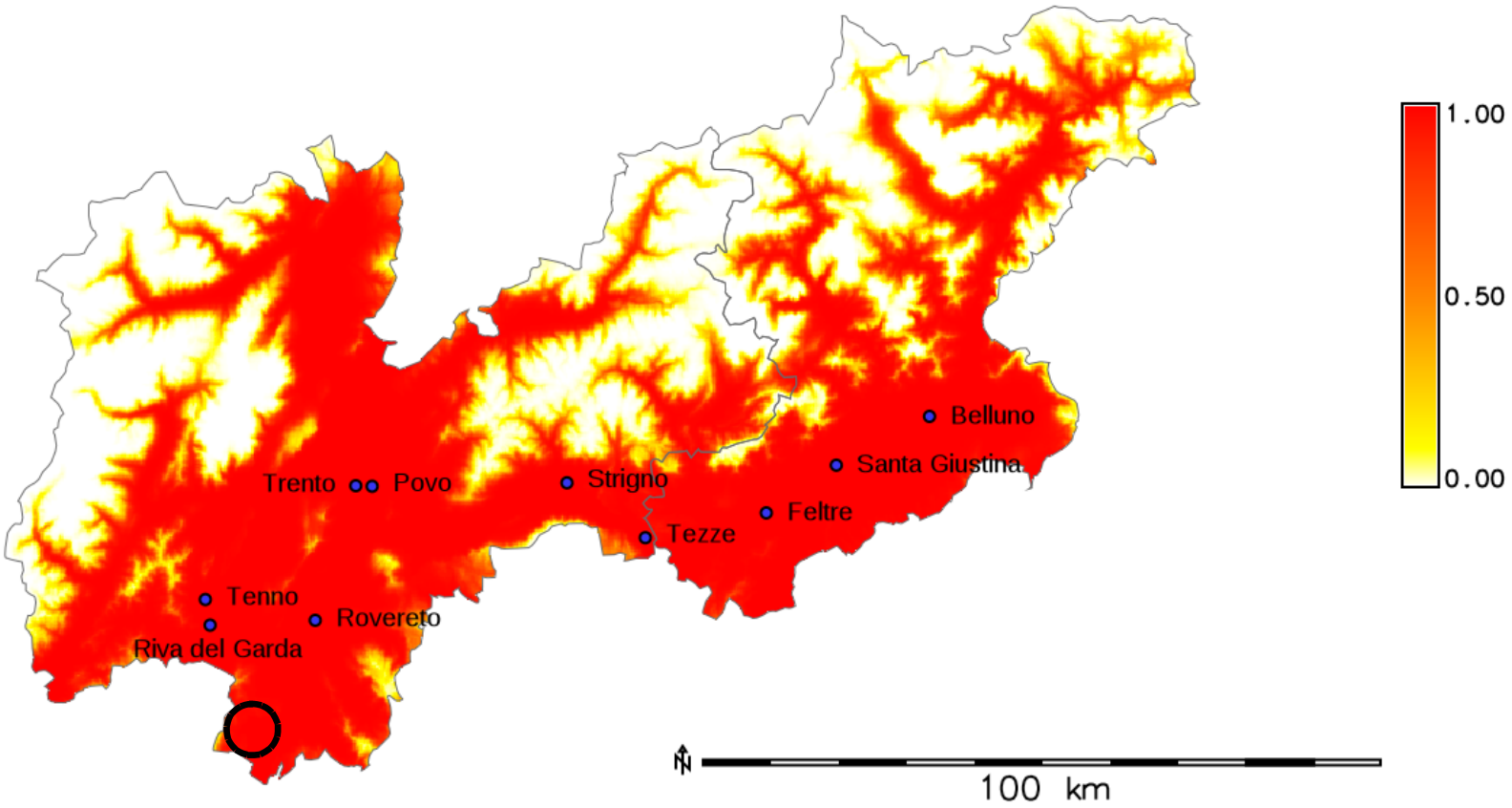


# Mark-recapture experiment




Trap -4_672 m a.s.l
Trap -3_875 m a.s.l
Trap -2_1052 m a.s.l
Trap -1_1232 m a.s.l
Marking point_ 1471 m a.s.l
Trap +1_1520 m a.s.l
15/09 – 05/11
Max distance: 9000 mt
Max drop: 600 mt
Image © 2016 DigitalGlobe
© 2016 Cnes/Spot Image
Image Landsat
Google earth

# Suitability map of Trentino



# Biological control

**2013:** Faunistic survey

**2013-14:** Laboratory efficacy tests

**2015:** Life history and host preference

**2016:** Preliminary semi-field and field tests

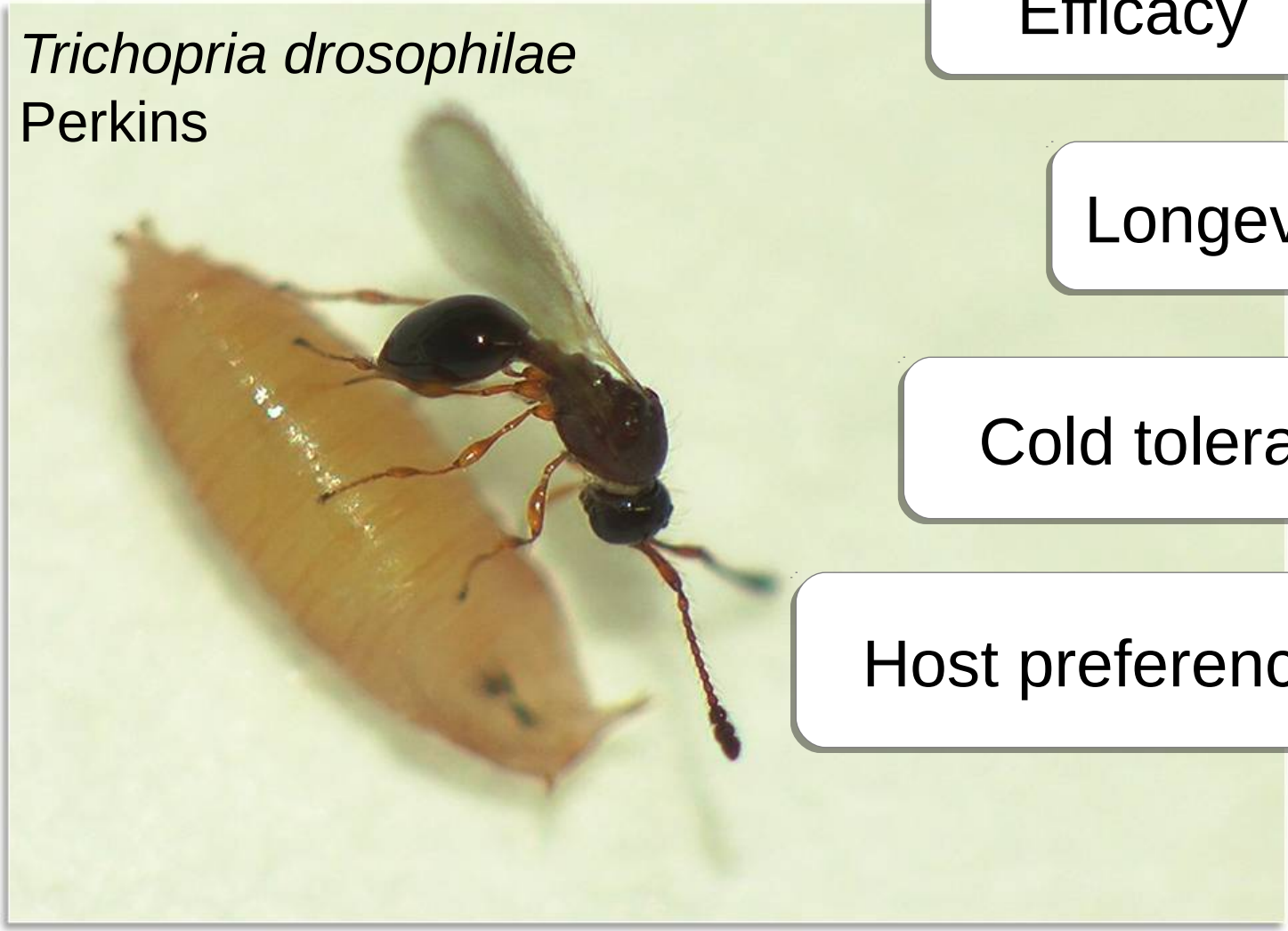
**2017:** Field efficacy trial

*Pachycrepoideus vindemiae* (Rondani)
**Pteromalidae**

*Trichopria drosophilae* (Perkins)
**Diapriidae**

*Leptopilina heterotoma* (Thomson)
**Figitidae**

*Trichopria drosophilae*
Perkins



Efficacy

Longevity

Cold tolerance

Host preference

# Augmentative biontrol based on early-season area-wide releases

**First seasonal fly generation**

(the direct offspring of those individuals surviving the winter cold period and reproducing on wild host plants in the early spring)

**Working hypothesis:**

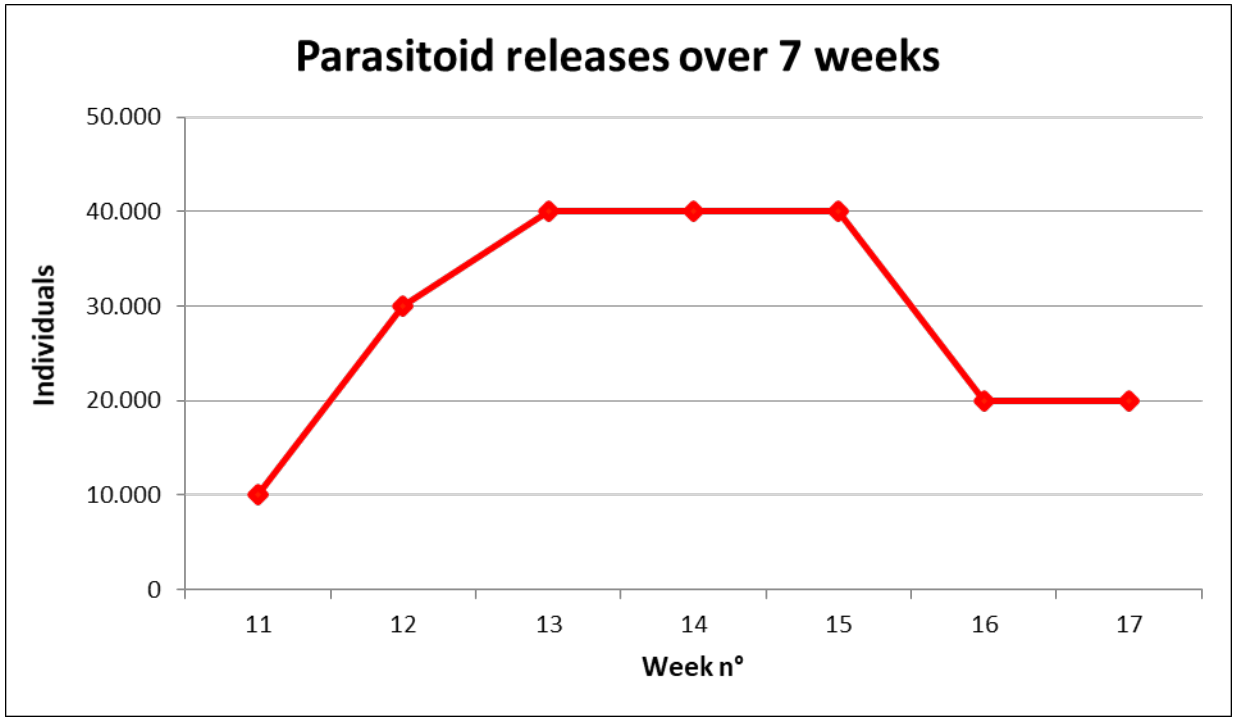
augmented *T. drosophilae* populations within the non-crop areas would **reduce pest populations prior to fruit ripening** in commercial cherry orchards

**1**

To lower severity or delay development of pest outbreaks

**2**

To decrease pest re-infestation events throughout the season.



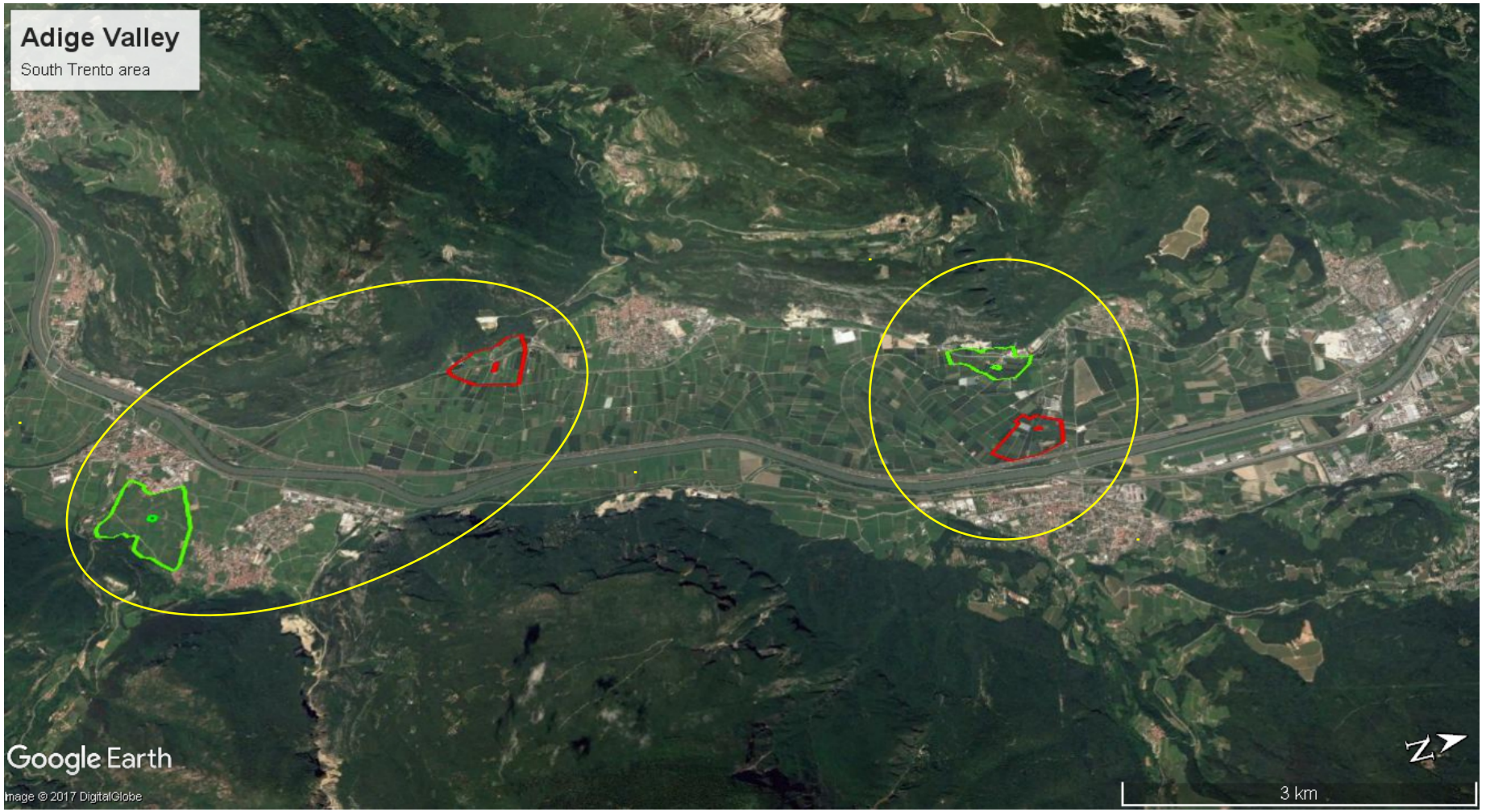

Average daily temperature **11.7**
**-15.4°C**

**never below 4.8°C**

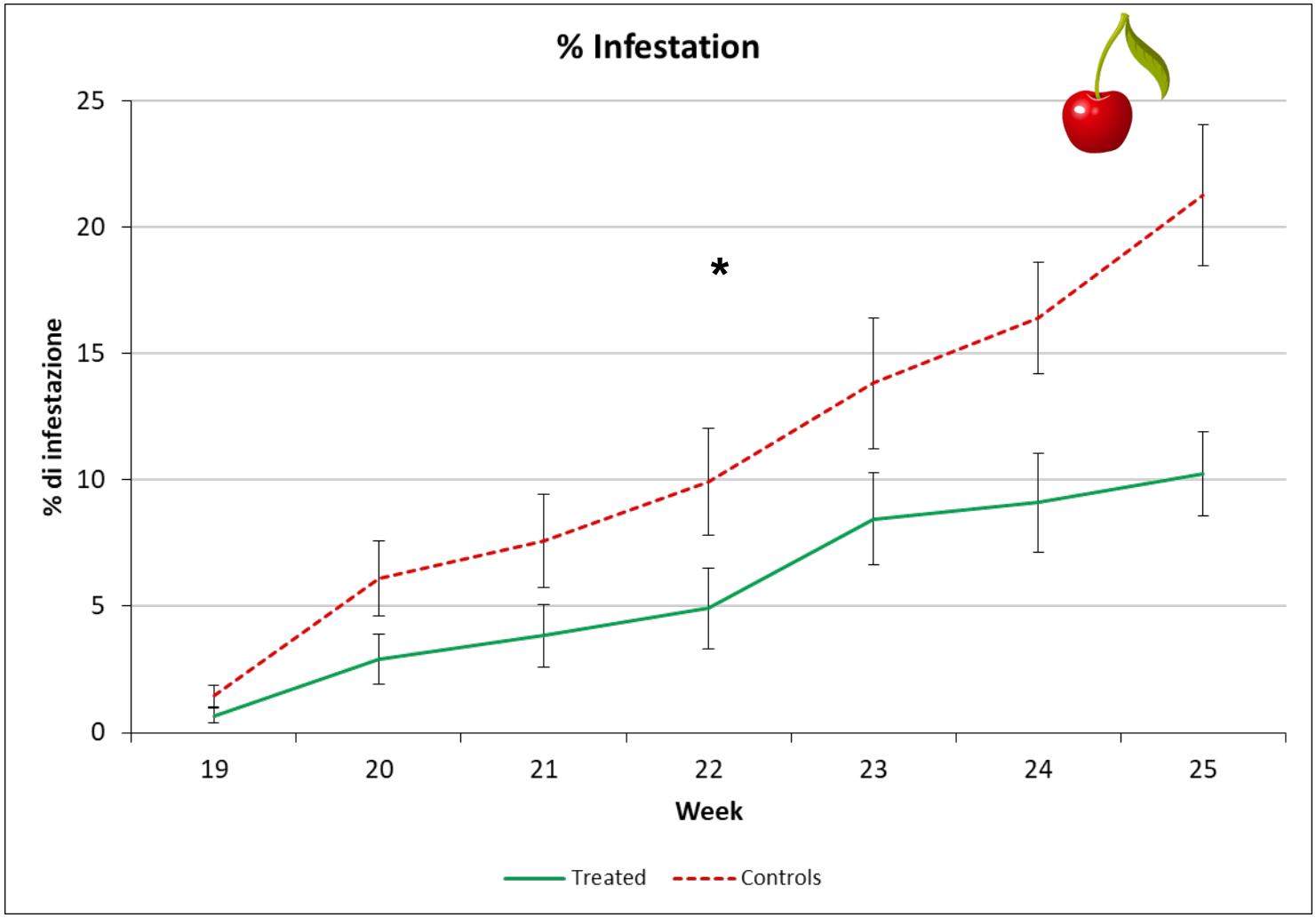
ca. 500 individuals/bottle
Pupae and adults

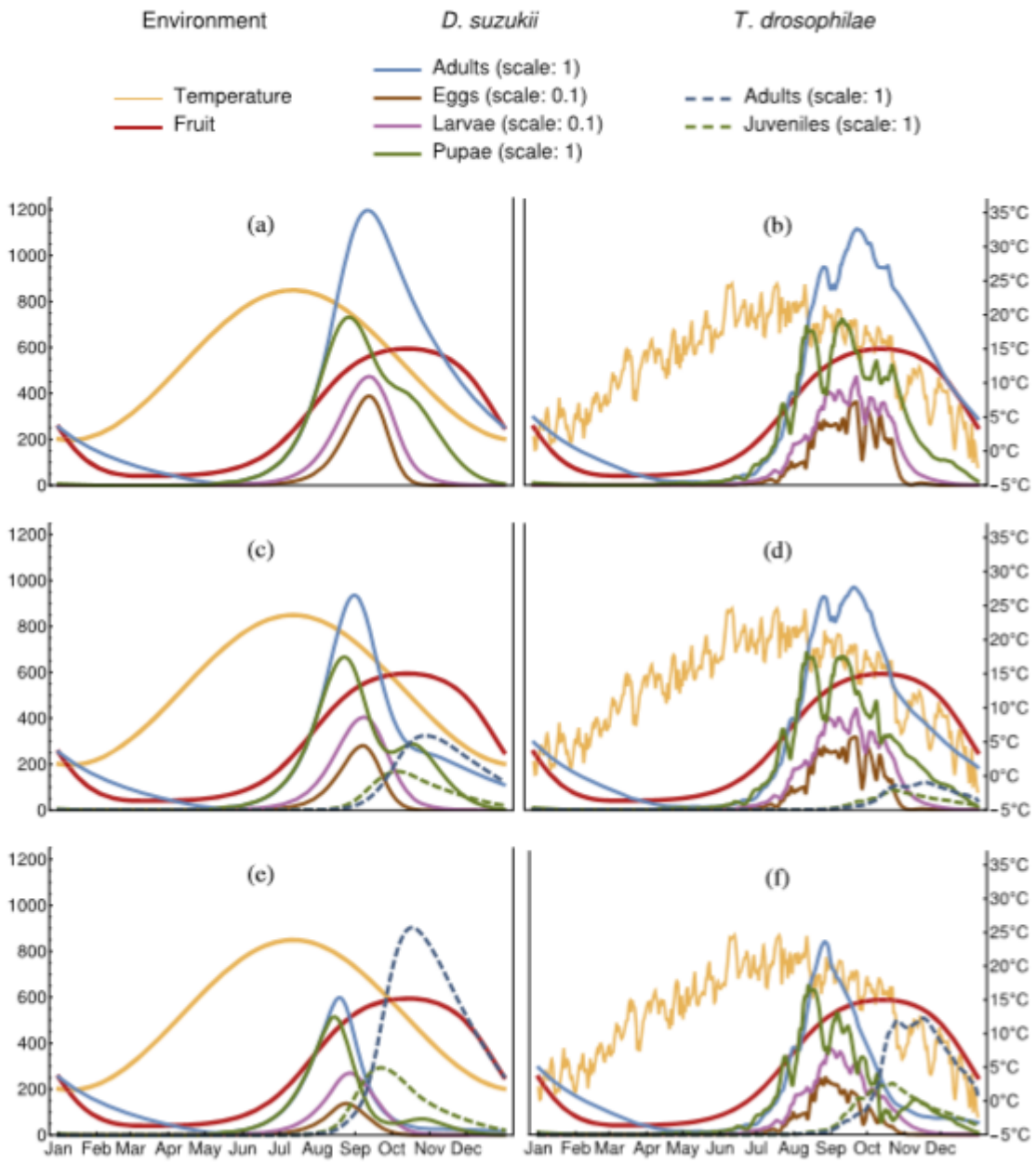
Total treated area **≈60 ha**
**X**
Total released parasitoids
**200.000**
**=**
**0.3 parasitoids/m²**

# Area wide field experiment (2017-2018)



<10%


% Infestation
% di infestazione
25
20
15
10
5
0
*
19
20
21
22
23
24
25
Week
Treated
Controls




Without parasitoids

Releases in april

Releases in june

*1) Augmentative releases of T. drosophilae significantly decrease the population density of D. suzukii in non-crop areas*

*2) Releasing T. drosophilae is most effective in late spring when host population begins to dramatically increase*

*3) A single parasitoid release event can be more efficient than multiple releases over a prolonged period, but multiple releases are more robust to suboptimal timing choices.*

**Reduce the risk of potentially catastrophic losses of parasitoids due to late spring frosts**

# Classical biological control

J Pest Sci
DOI 10.1007/s10340-016-0740-0

CrossMark

ORIGINAL PAPER

## First exploration of parasitoids of *Drosophila suzukii* in South Korea as potential classical biological agents

Kent M. Daane[1] · Xin-Geng Wang[1] · Antonio Biondi[1,2] · Betsey Miller[3] · Jeffrey C. Miller[3] · Helmut Riedl[4] · Peter W. Shearer[4] · Emilio Guerrieri[5] · Massimo Giorgini[5] · Matthew Buffington[6] · Kees van Achterberg[7] · Yoohan Song[8] · Taegun Kang[8] · Hoonbok Yi[9] · Chuleui Jung[10] · Dong Woon Lee[11] · Bu-Keun Chung[12] · Kim A. Hoelmer[13] · Vaughn M. Walton[3]

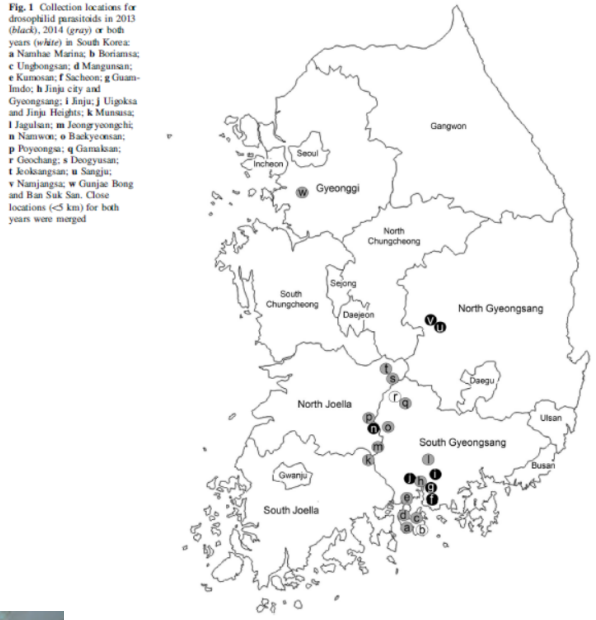



Fig. 1 Collection locations for drosophilid parasitoids in 2013 (*black*), 2014 (*gray*) or both years (*white*) in South Korea: **a** Namhae Marina; **b** Boriamsa; **c** Ungbongsan; **d** Mangunsan; **e** Kumosan; **f** Sachoen; **g** Guam-Imdo; **h** Jinju city and Gyeongsang; **i** Jinju; **j** Uigoksa and Jinju Heights; **k** Munsusa; **l** Jagulsan; **m** Jeongyeongchi; **n** Namwon; **o** Baekyeonsan; **p** Poyeongsa; **q** Gumaksan; **r** Geochang; **s** Deogyusan; **t** Jeoksangsan; **u** Sangju; **v** Namjangsa; **w** Gunjae Bong and Ban Suk San. Close locations (<5 km) for both years were merged

***Ganaspis brasiliensis* (Ihering)**

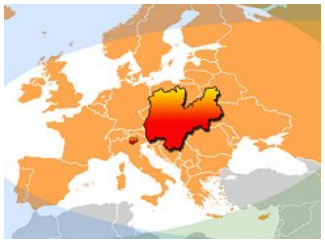
*Asobara japonica* (Belokobylskij)

*Leptopilina japonica* (Novkovic & Kimura)

# Conclusions

- Understanding the invasion history of alien species helps tracking introduction pathways and organizing integrated management strategies

- Information on the life history of the pest and the population dynamics across key bottleneck periods, such as winter diapause, is crucial to better predict serious outbreaks (population models) and increase the effectiveness of IPM methods (i.e. biocontrol strategies)



# Invasive alien insects

*Drosophila suzukii*

***Halyomorpha halys***

# Life history of BMSB → 2 generations/year in Italy

Egg mass and
I Instar nymphs

II Instar

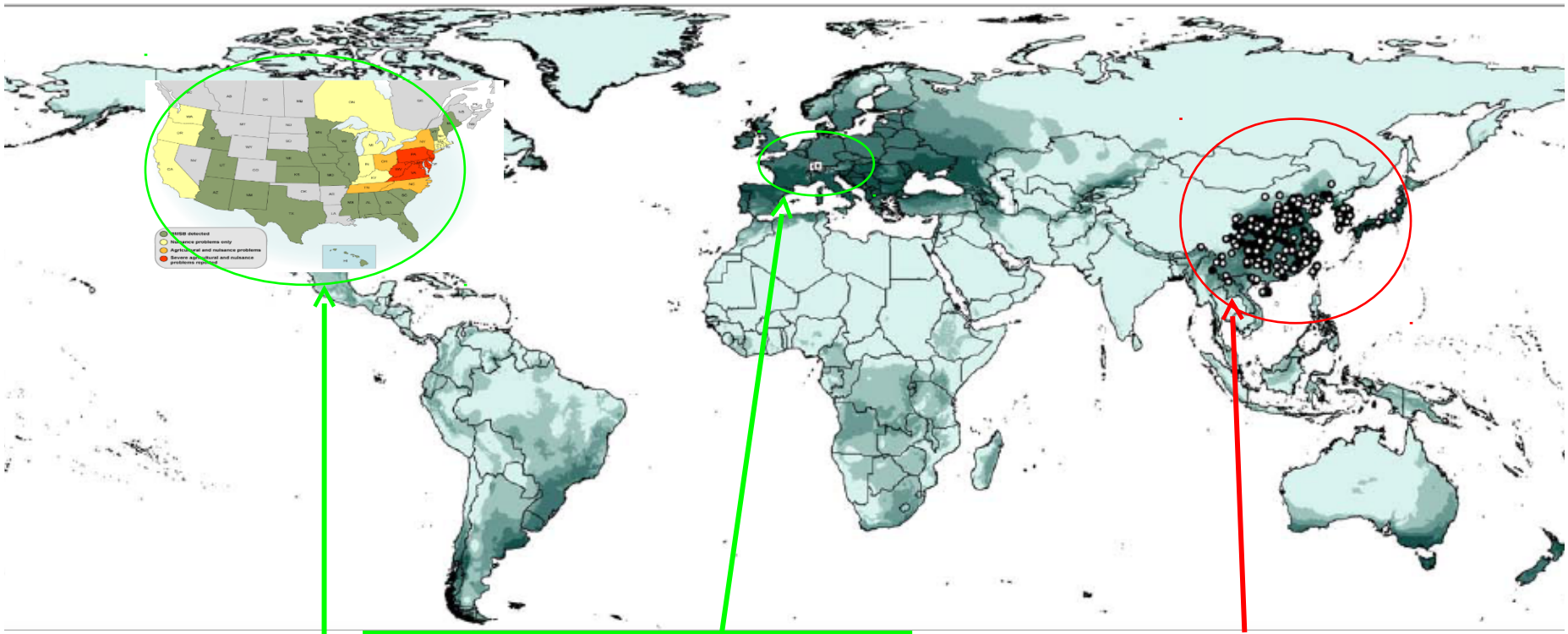
III Instar

IV Instar

V Instar

Female

Male



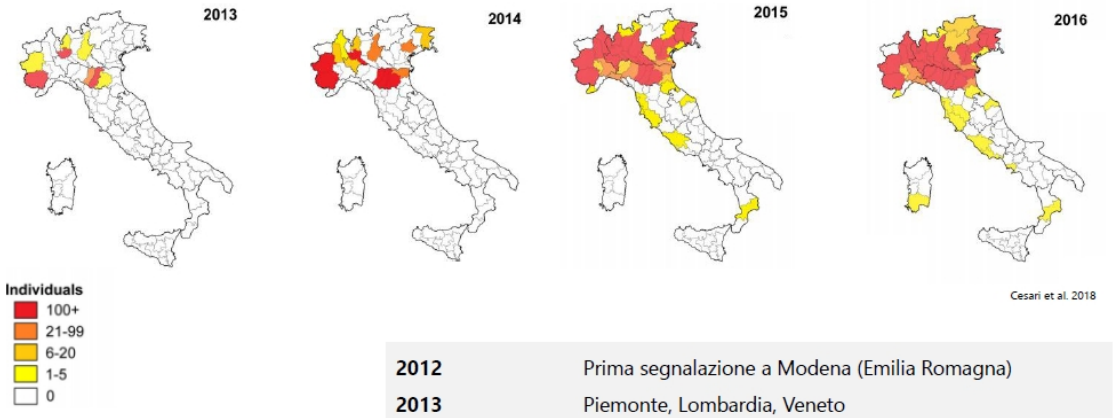
INVADED REGIONS

NATIVE AREAS

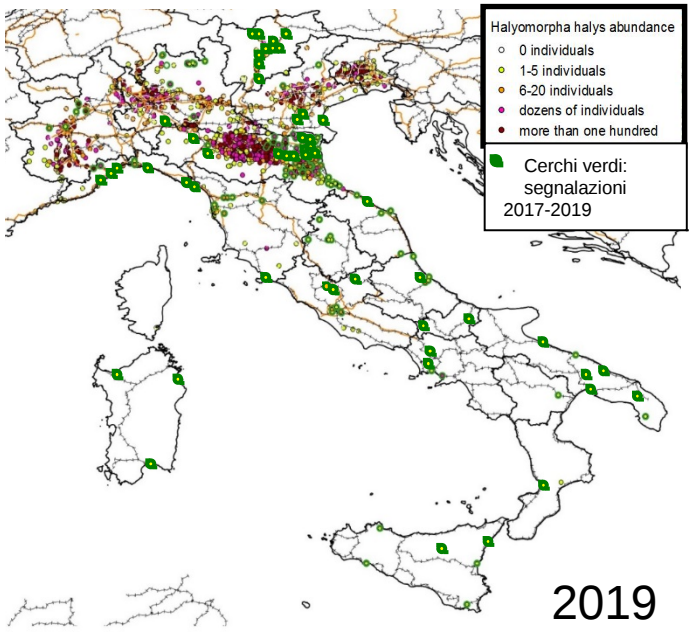
**NORTH AMERICA**: since 1996,
41 states and 2 provinces in Canada
1-2 generations/year

1-4 generations/year

# BMSB rapidly spread in Italy




| | |
|---|---|
| **2012** | Prima segnalazione a Modena (Emilia Romagna) |
| **2013** | Piemonte, Lombardia, Veneto |
| **2014** | **Friuli-Venezia Giulia, .....** |



# Highly poliphagous: the role of wild and ornamental plants

ash

crabgrass

hazelnut

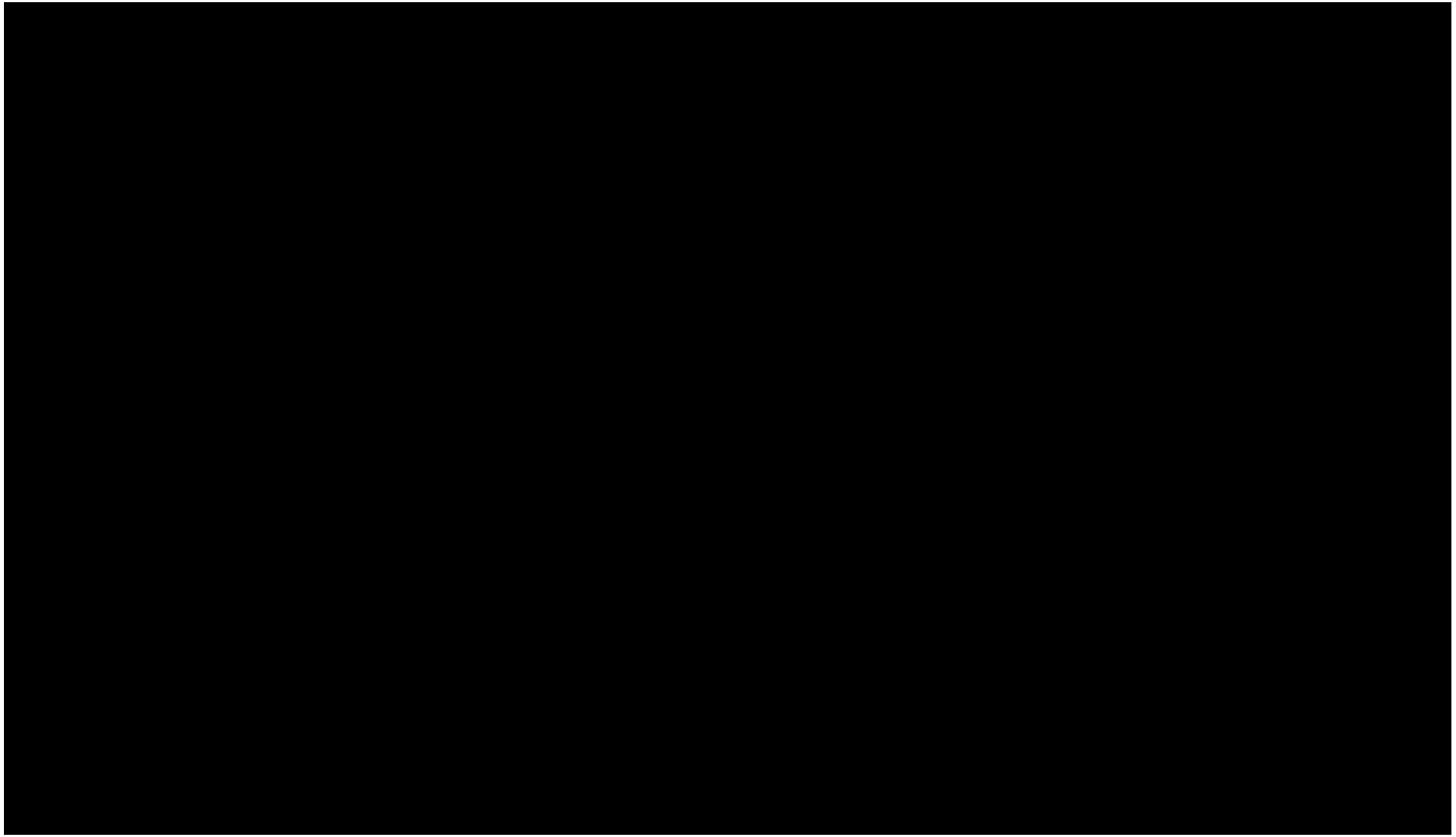
dogwood

Tree of heaven

maple

# Overwintering in urban areas: nuisance pest

Photo: Greg Krawczyk



# *Halyomorpha halys*

## Hitchhiker: ADULTS

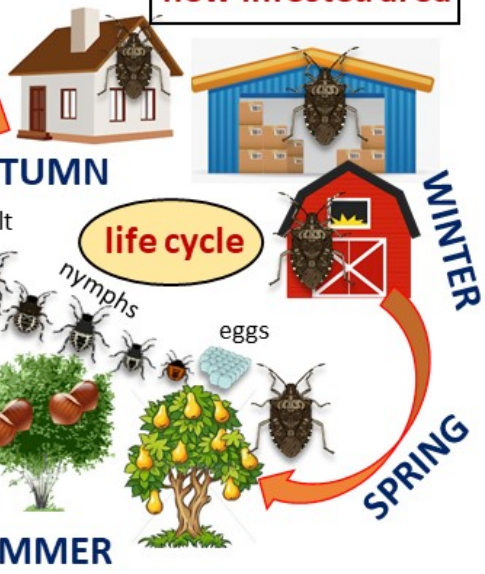
**Start:** endemic area

1

AUTUMN - WINTER

2

new infested area




3

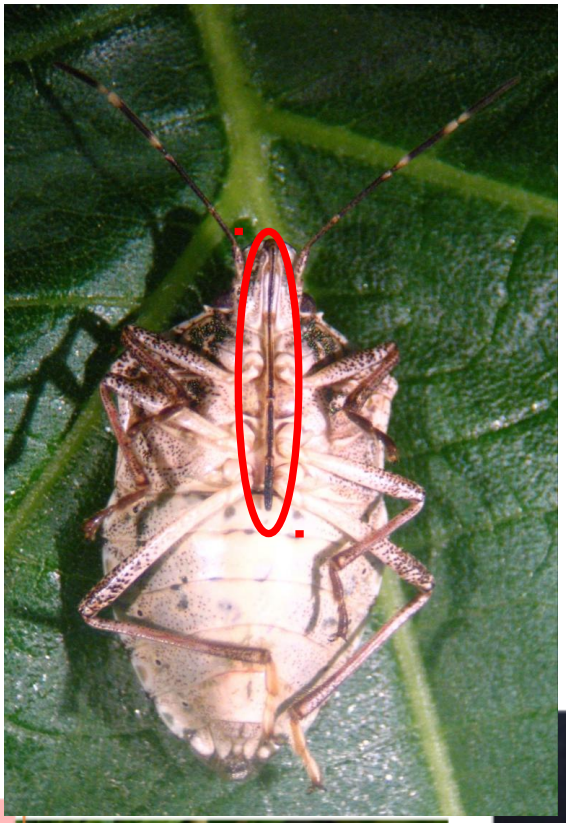
further spread

4

new infested areas

DAMAGE TO FRUIT CROPS

# Fruit damage



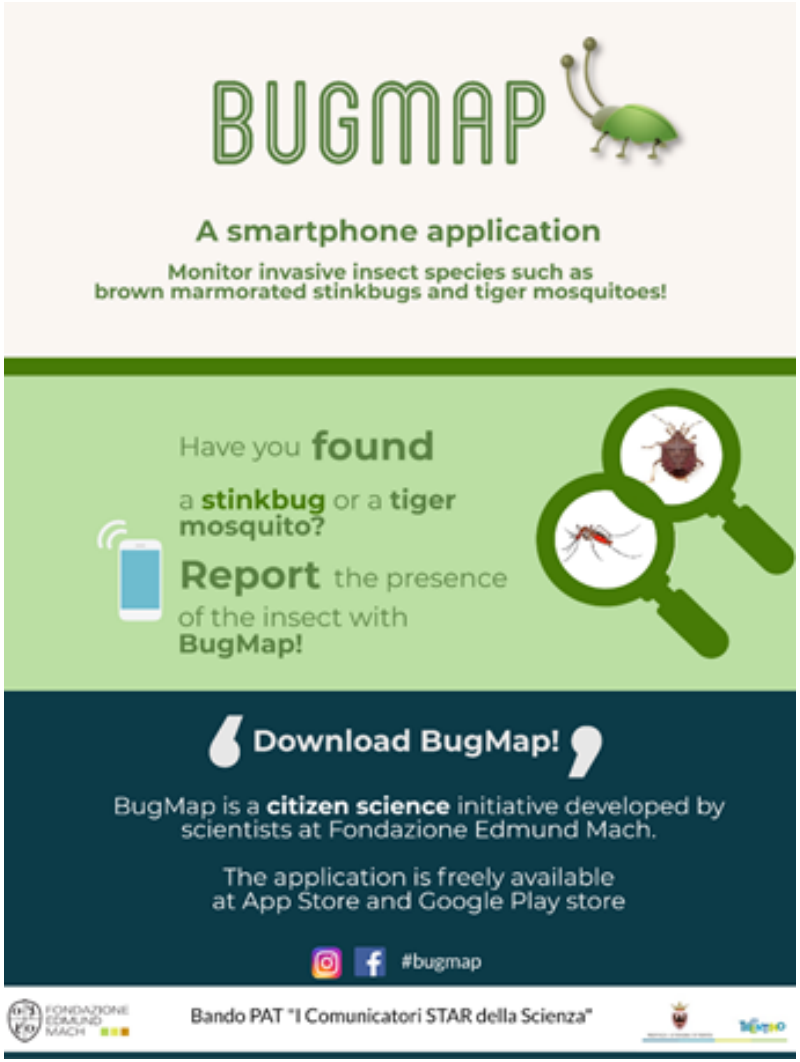
1

2


150 M€/year losses
2016
740 M€/year losses
2019

# Citizen science

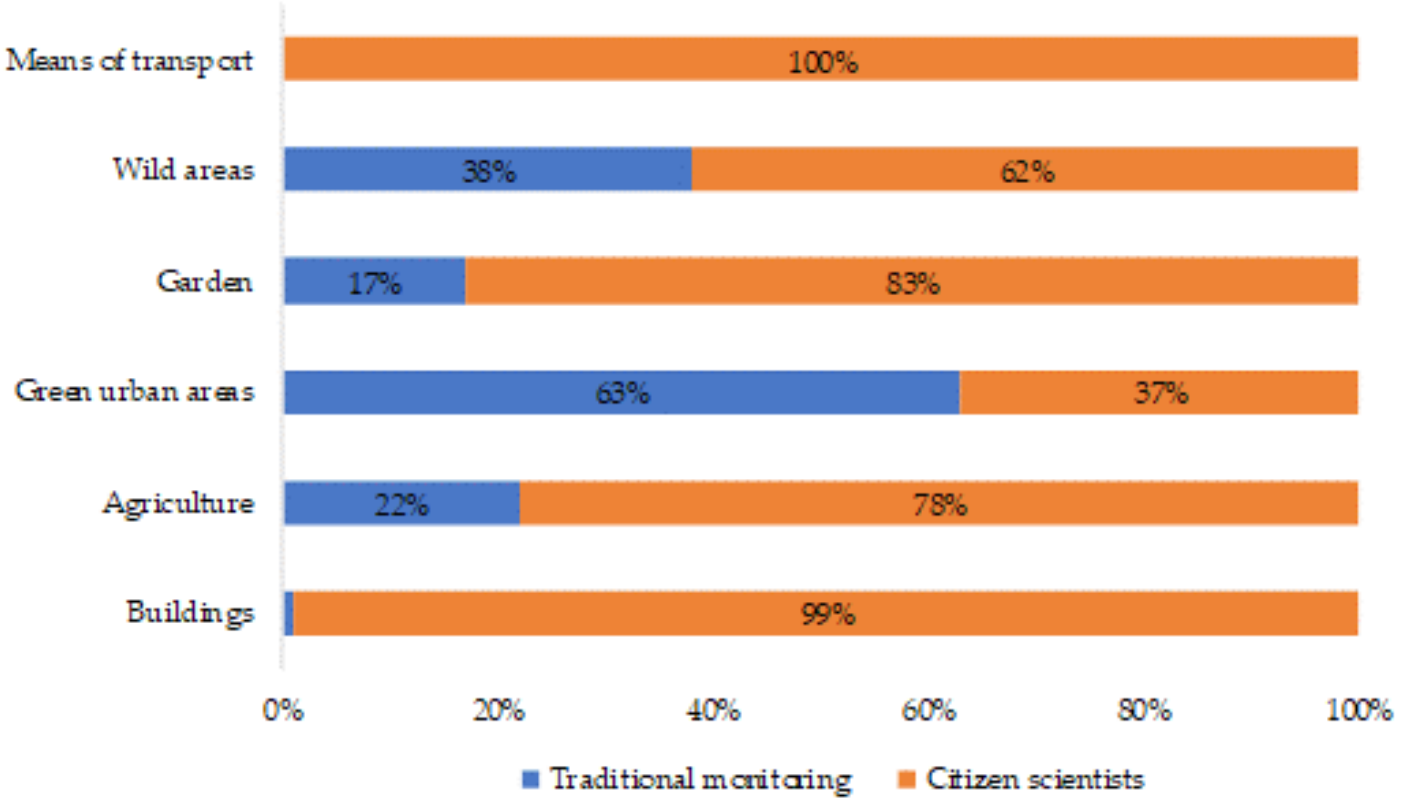
BugMap: a map of *H. halys* made by local citizens



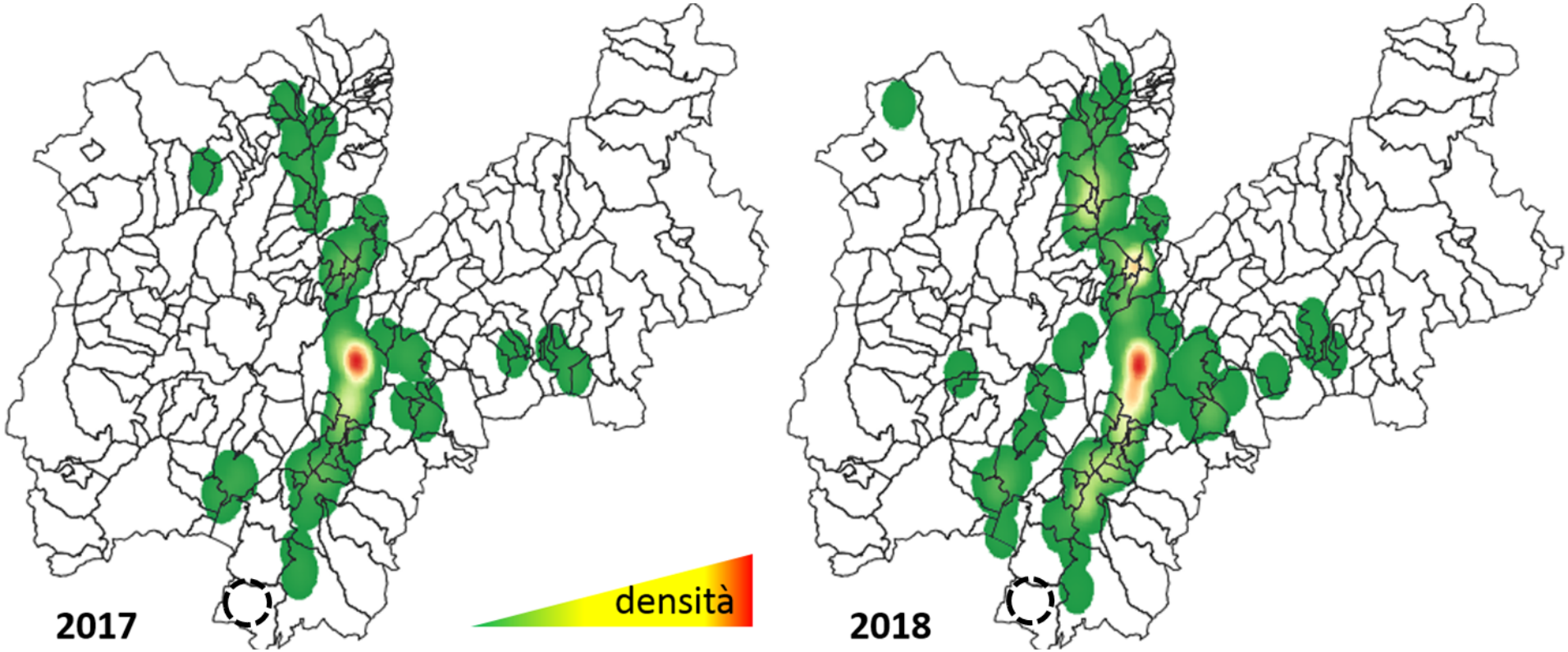
# BugMap permits to:

- Study the lifecycle and seasonal invasion dynamics of BMSB
- Increase our possibilities of data collection
- Engage the public, increasing the interest for science

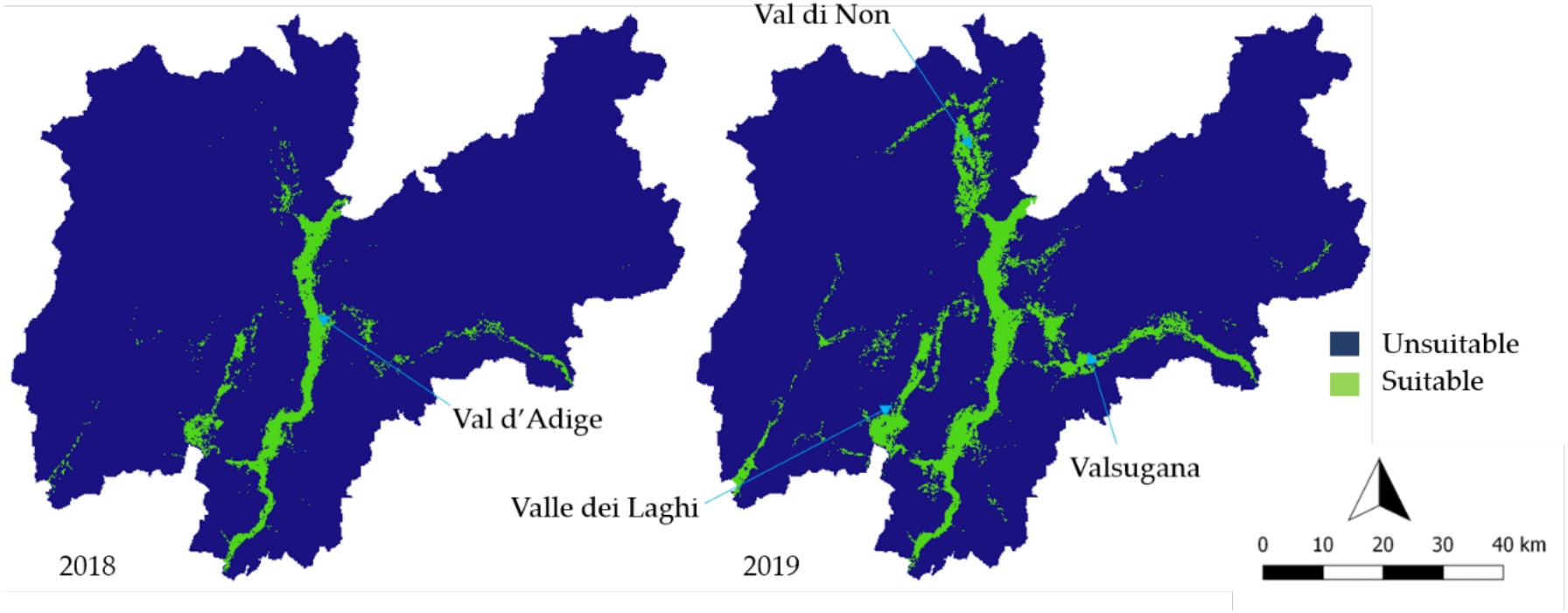
# BugMap reports



# Heatmaps

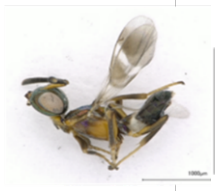


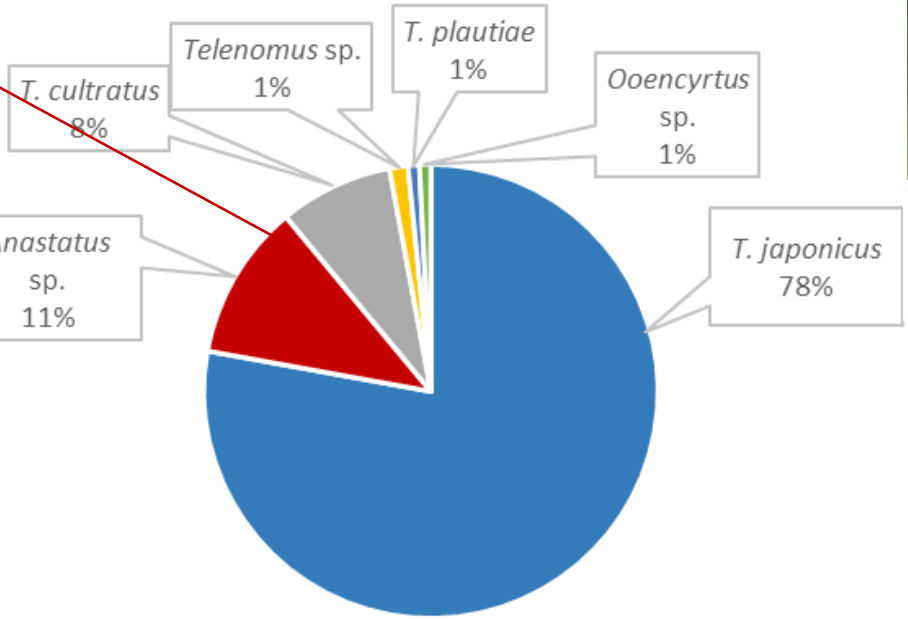
# MaxEnt distribution modeling

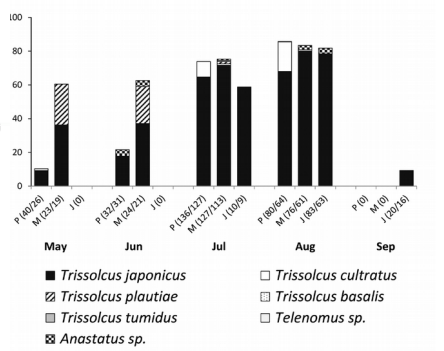


# Biological control

## Egg parasitoids in China




*T. japonicus* is highly active all-along the season

*Zhang et al. 2017*

# Survey 2019 in Trento Province

Exposure of frozen/fresh sentinel eggs
and collection of naturally laid egg masses

# Sentinel eggs

| | Phenology and n° of parasitized egg masses | | | |
|---|---|---|---|---|
| | **June** | **July** | **August** | **September** |
| *Anastatus bifasciatus* | n= 1 | n= 3 | n= 2 | |
| *Trissolcus mitsukurii* | | n= 1 | | n= 3 |
| *Trissolcus japonicus* | | | n= 1 | n= 2 |

Exotic parasitoids

*Anastatus bifasciatus*

*Trissolcus japonicus*
Samurai wasp

*Trissolcus mitsukurii*

# Potential distribution of *T. japonicus*

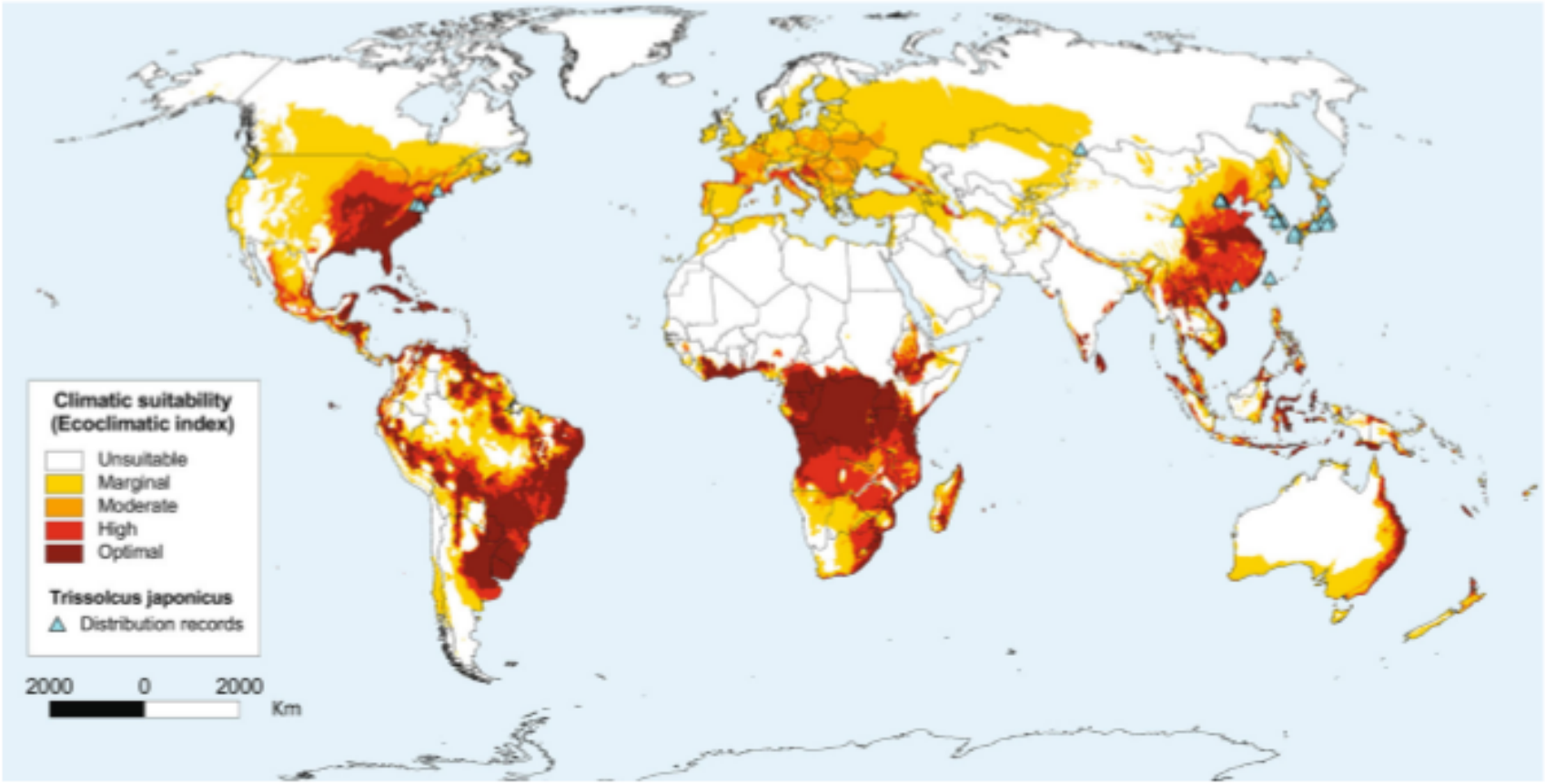



**Fig. 1** Modelled global climate suitability (CLIMEX Ecoclimatic Index) for *T. japonicus* to persist as a permanent population. Known current distribution is shown as point locations (triangles)

Avila and Charles 2018

# Conclusions

- Since September 2019 a new italian law permitting again to release exotic antagonists after risk-assessment (classical biocontrol)
- Quarantine facility in FEM
- Petition for release *T. japonicus* in Italy in preparation. First release during spring 2020
- Need to study and modeling population dynamics of parasitoid-host interactions

# Future invaders

- *Popillia japonica*

Japanese beetle

- *Anoplophora chinensis*

Long-horned beetle

- *Lycorma delicatula*

Spotted lanternfly

# Thank you for your attention!