How to better predict long-term benefits and risks in weed biocontrol: from an ecological to an evolutionary perspective

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IRS Ragweed Symposium
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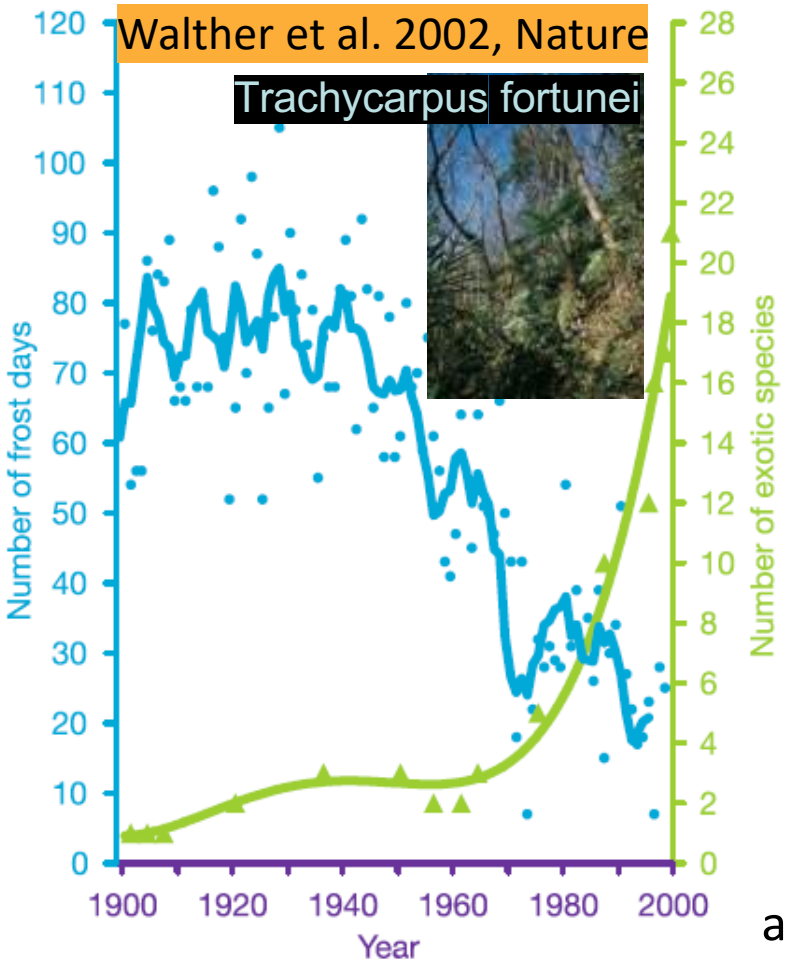
International Ragweed Society

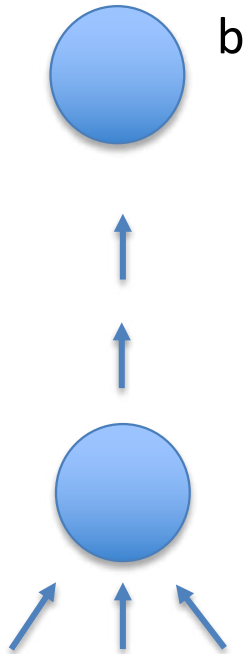
Biological invasion will continue, and global climate is changing rapidly

Ecological response to climate change
might increase plant invasions



Evolutionary responses to climatic change
might even be stronger in introduced than native populations

under climate change



but still experience new abiotic and biotic conditions that could exert strong directional selection

or migrate to follow favourable climatic conditions

locally adapt to novel climatic conditions without migrating

Multiple introductions and admixtures boost genetic variation

- and this could well further increase the spread and impact

Common Ragweed, *Ambrosia artemisiifolia*

origin: North America, now worldwide distribution

Pollen ➜ human health

Seed (plant) ➜ agriculture

Ruderal sites and linear infra-structure: the main surface

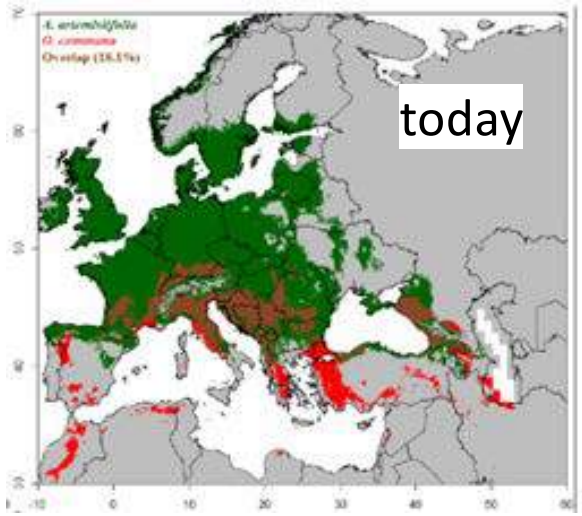
not a typical IAP = being a risk for biodiversity

Up to 2013 in Europe

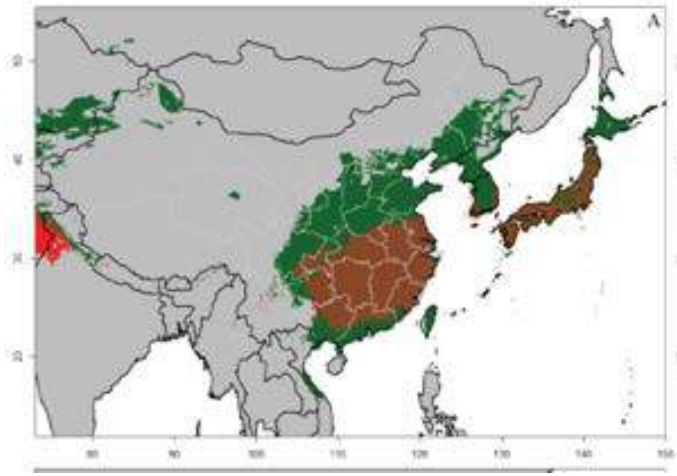
- Local & short-term treatments sufficient to prevent yield losses (except in sunflower)
- but not to prevent spread and impact on human health
- long-term and sustainable control methods are needed

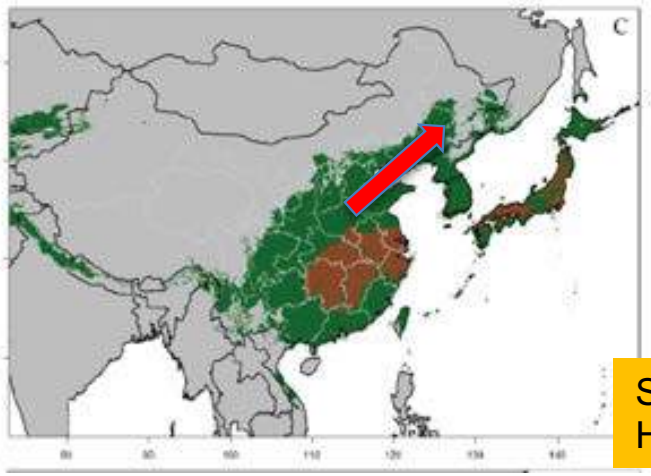
As a researcher: many reasons not to deal with it

In Europe AND in East Asia: Great potential to further expand north and east, with airborne ragweed **pollen concentrations** to **increase in Europe c. 4x** by 2050



Europe





East Asia

Sun et al. 2017, Ecosphere; 2018
Hamaoui-Laguel et al. 2015 Nature

SMARTER

Sustainable management of *Ambrosia artemisiifolia* in Europe 2013-2017

Food and Agriculture - **COST** Action FA1203

2013: Accidental introduction to Europe of the oligophagous *Ophraella communa*

1
Reduce ragweed

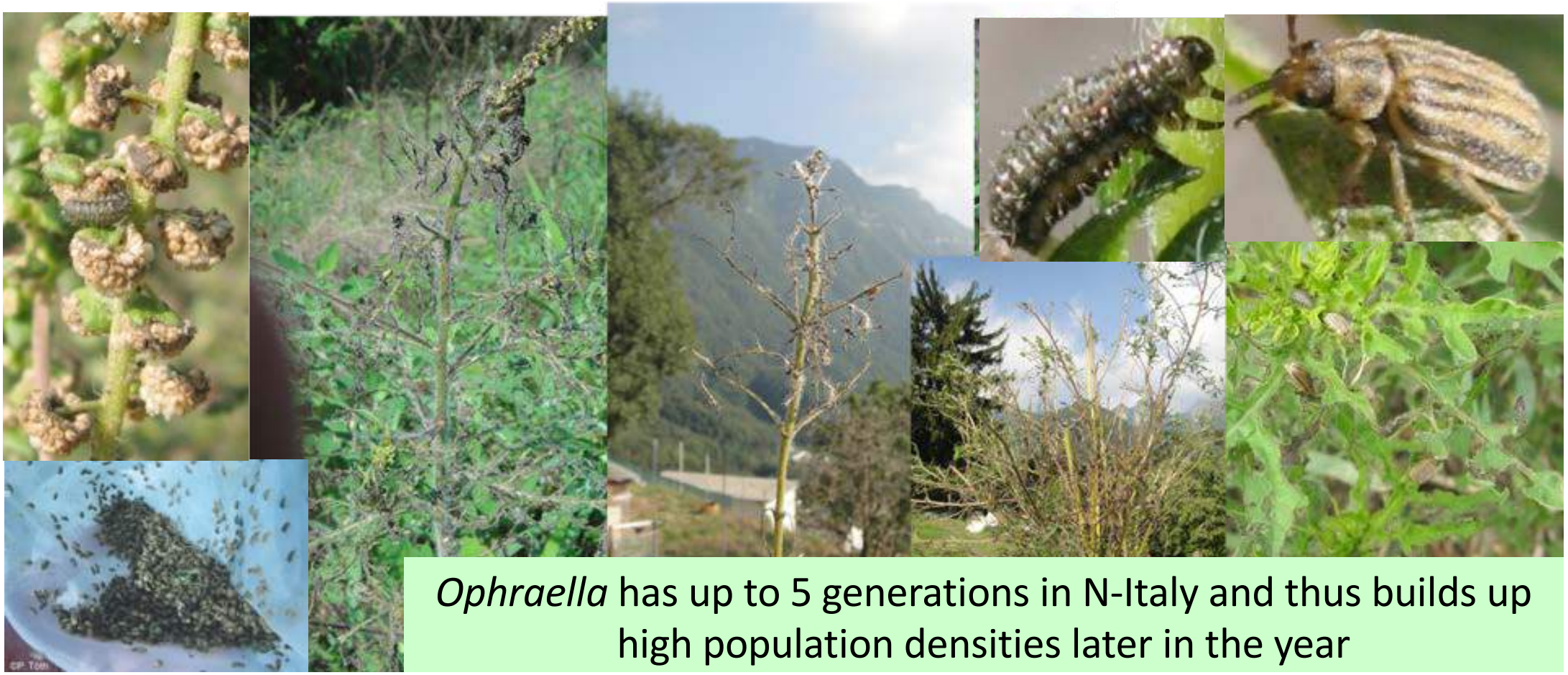
2
Serve as a template for sustainable control of invasive alien plants **IAPs in Europe**

Müller-Schärer et al. 2018, BAAE

ECOLOGICAL STUDIES

Potential benefits:

(1) damage by *Ophraella communa* on ragweed can be high



Ophraella has up to 5 generations in N-Italy and thus builds up high population densities later in the year

(2) Fast spread from 2013 to 2019

Sun and Müller-Schärer, 2020 NEOBIOTA P49
Karrer et al. 2020, IRS talk

WEED RESEARCH An International Journal of Weed Biology, Ecology and Vegetation Management

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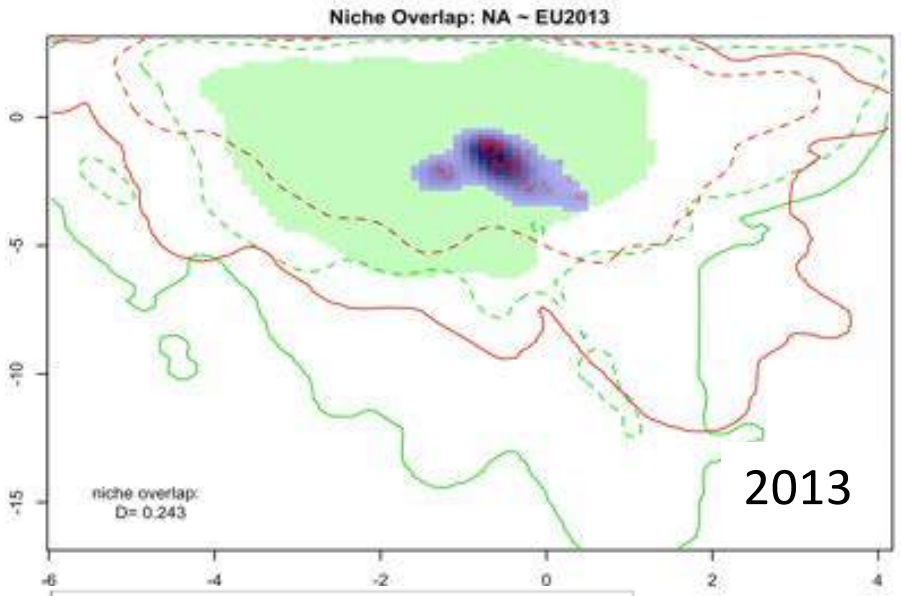
PRIORITY PAPER

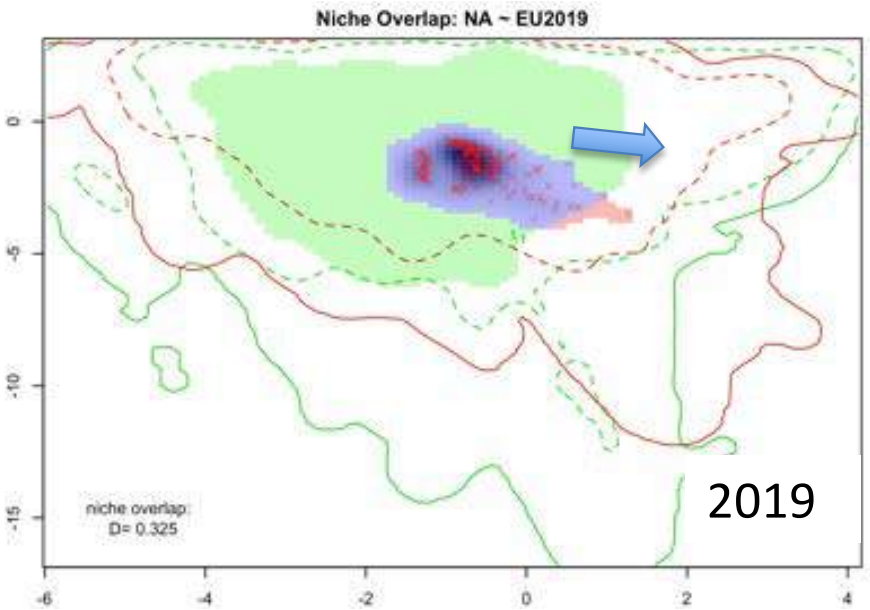
Ophraella communa, the ragweed leaf beetle, has successfully landed in Europe: fortunate coincidence or threat?

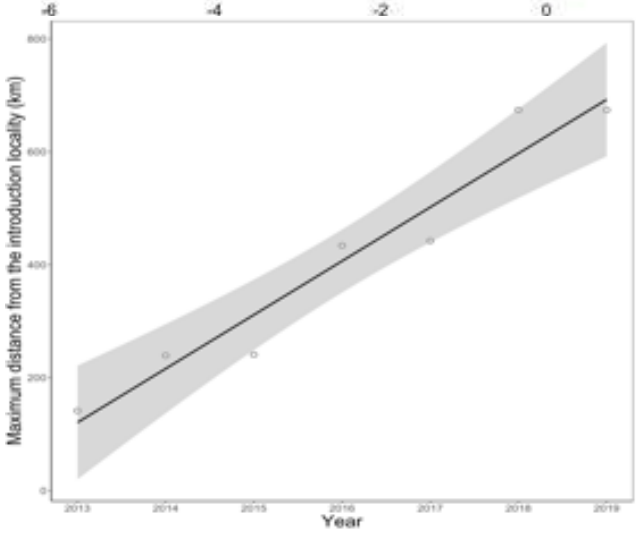
H MÜLLER-SCHÄRER*, S T E LOMMEN*, M ROSSINELLI†, M BONINI‡, M BORIANI§, G BOSIO¶ & U SCHAFFNER**

In 2019, *Ophraella* was repoted for the first time from Bosnia Herzegowina and Romania, but it has not yet been recorded from France and Austria

Niche expansion of *Ophraella* since 2013







- Yet large unfilling, but niche expansion since 2013 towards areas with higher relative humidity and cooler summer.
- This occurred towads the west and higher elevation, but with no permanent populations
- Constant spread velocity of *Ophraella* with c. 100km/year.

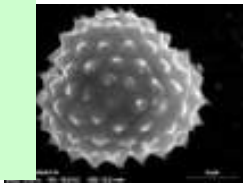
Sun and Müller-Schärer, 2020 NEOBIOTA P49; in prep.

(3) highly cost-effective

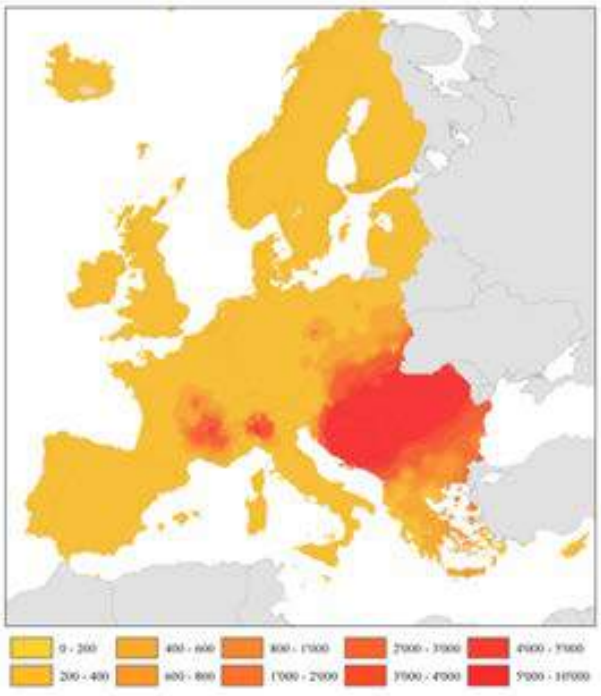
Schaffner *et al.* 2020 Nature Comms

Prior to the accidental introduction and establishment of *O. communa* in 2013

- 13.5 million persons suffered from *Ambrosia*-induced allergies in Europe,
- causing economic costs of approximately Euro 7.4 billion annually.

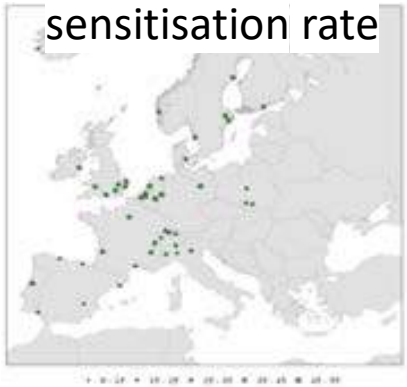


Number of grains per cubic meter of air (2004-2012).

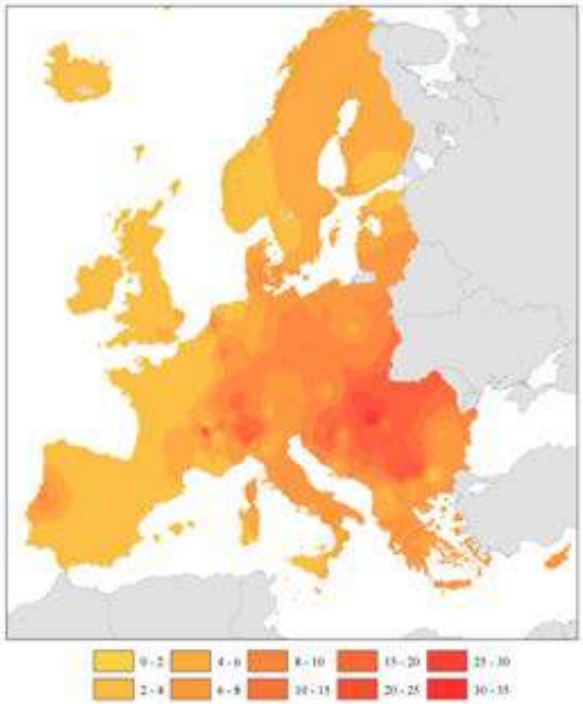


296 monitoring stations

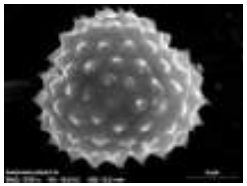
studies assessing ragweed sensitisation rate



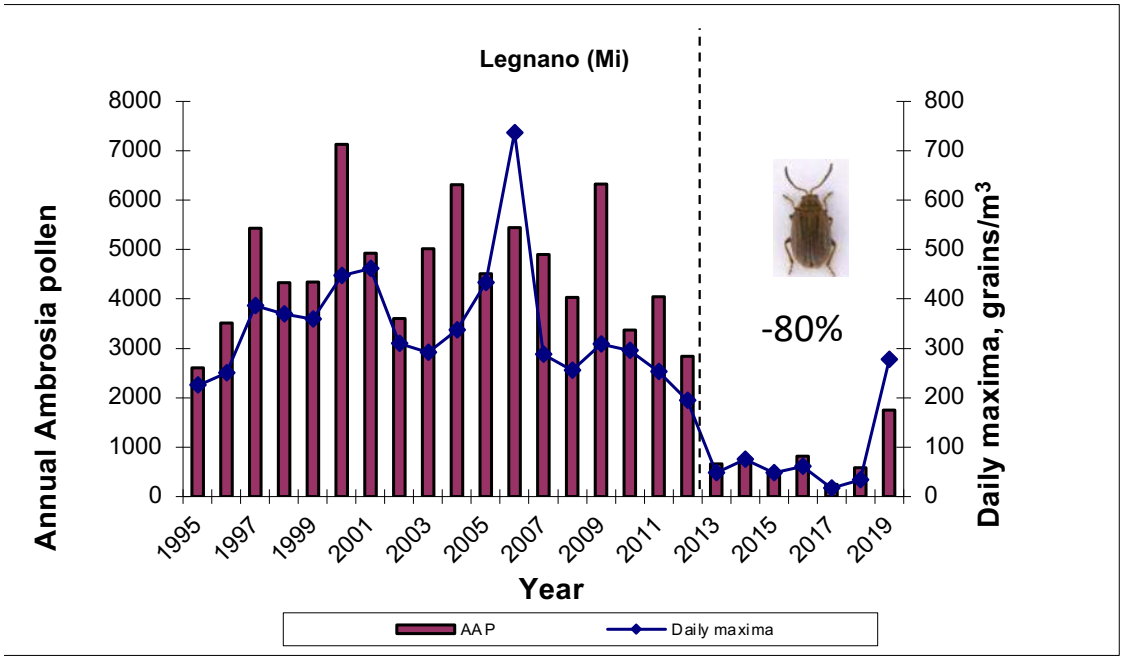
Interpolated % of ragweed sensitised persons in the European population



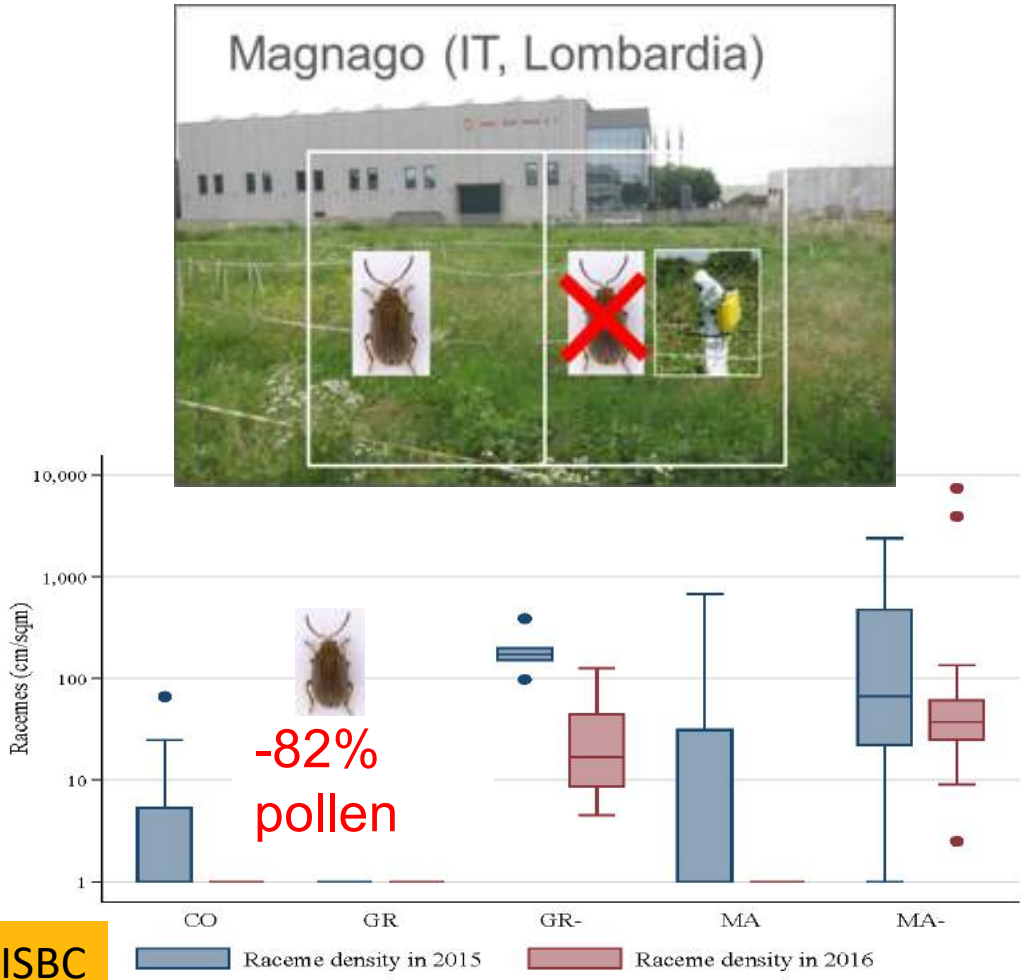
Reduction of aerial ragweed pollen by *Ophraella* of > 80% since 2013



Aerial pollen in Northern Italy

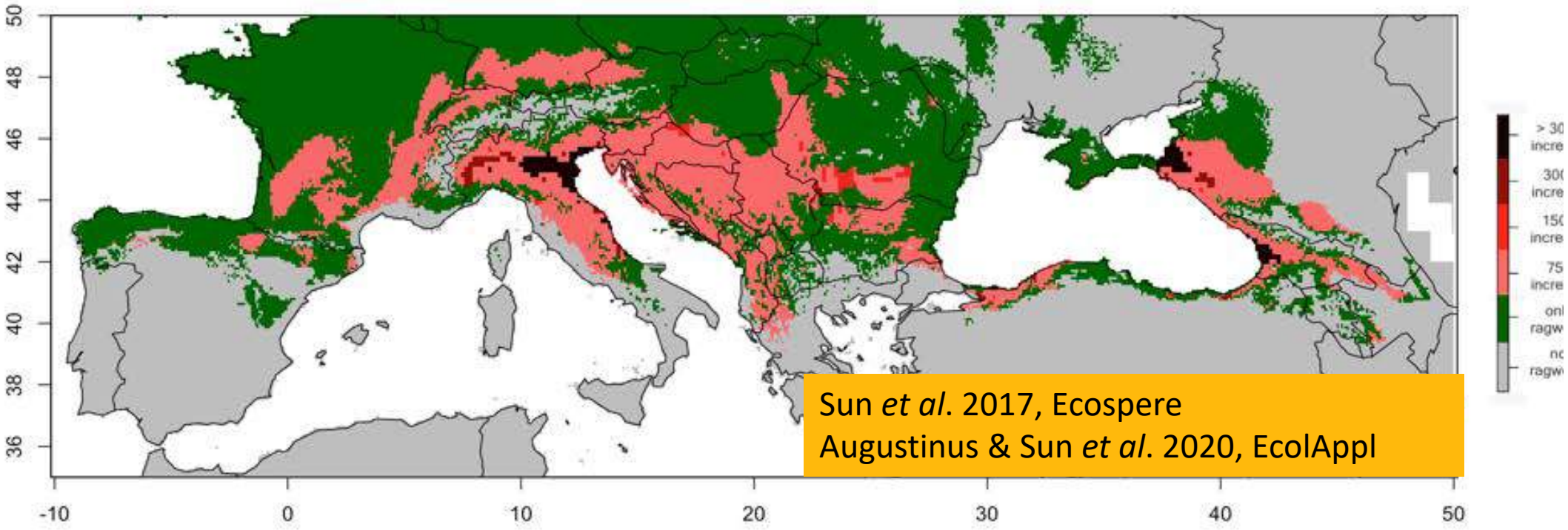


Bonini *et al*. 2014, 2015, unpubl.



Lommen *et al.* 2019 Proc ISBC

Population density of *Ophraella communa* based on monthly rel. humidity and temperature;
combining SDM with habitat-specific vital rates of *Ophraella* to better predict impact



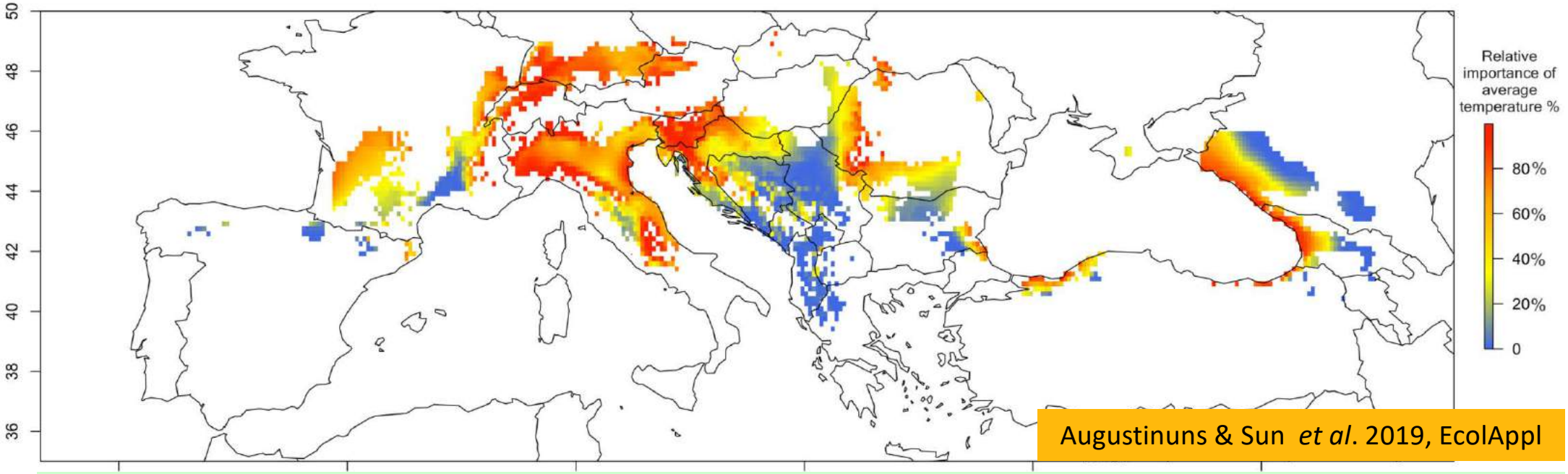
Sun *et al*. 2017, Ecospere
Augustinus & Sun *et al*. 2020, EcolAppl

Impact of Ophraella

Reduction in # patients suffering from allergies	***2.3 Mio (17%)***
Expected **reductions** *in health cost*	***1.1 billion € /Year***

Schaffner *et al.* 2020
Nature Comms

Predicting impact of *Ophraella* in Europe:
Integrating distribution modelling with climate-dependent vital rates



Augustinuns & Sun *et al*. 2019, EcolAppl

The relative importance of average temperature vs. average relative humidity **differs** across the suitable European area (of both *Ambrosia artemisiifolia* and *Ophraella communa)*

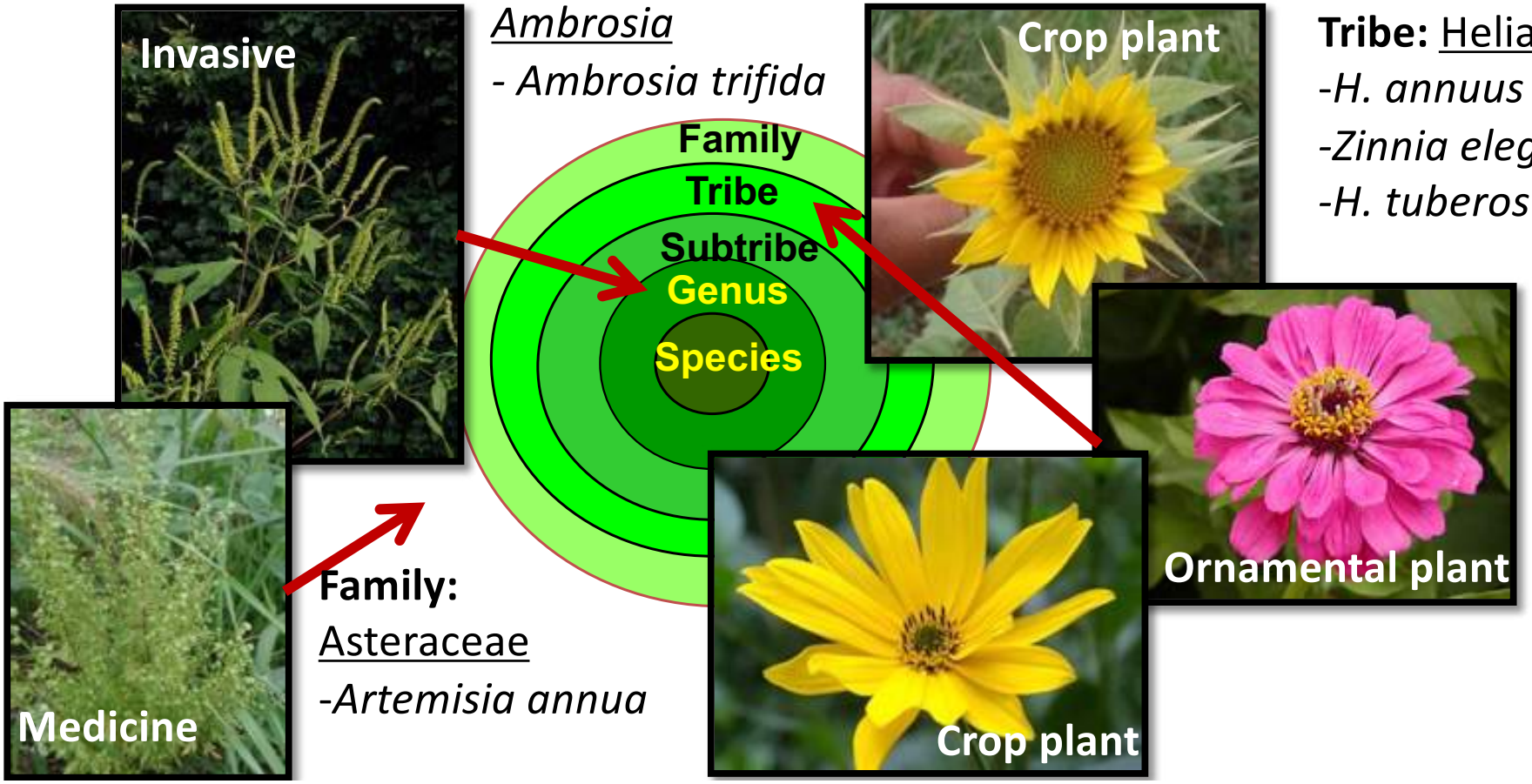
- This knowledge allows implementing a more targeted release and management strategies to optimize biocontrol efficacy.

Potential risks: direct non-target effects

... but is it safe?

need for host-specificity tests: **but how to compose the test plant list?**

The closer the relatedness of the plant species the more likely it is attacked



Host range and host specificity tests (2014-17)

(1) Under controlled conditions (quarantine lab)

- Transfer of
  - adults ➔ oviposition **preference**
  - eggs/larvae ➔ **performance**

In total some 50 tests 2014 – 2017
- 6 ragweed species
- 4 ornamentals
- 4 sunflower varieties,
- 9 native endangered species

Müller-Schärer *et al.*,in prep.

(2) Under open field conditions in areas with *Ophraella*

(3) Field survey on non-target plants in CH and I in areas with *Ophraella*

20 species
3 exotic
14 native
3 crop

Cohorts of test plant exposures across the season, i.e.

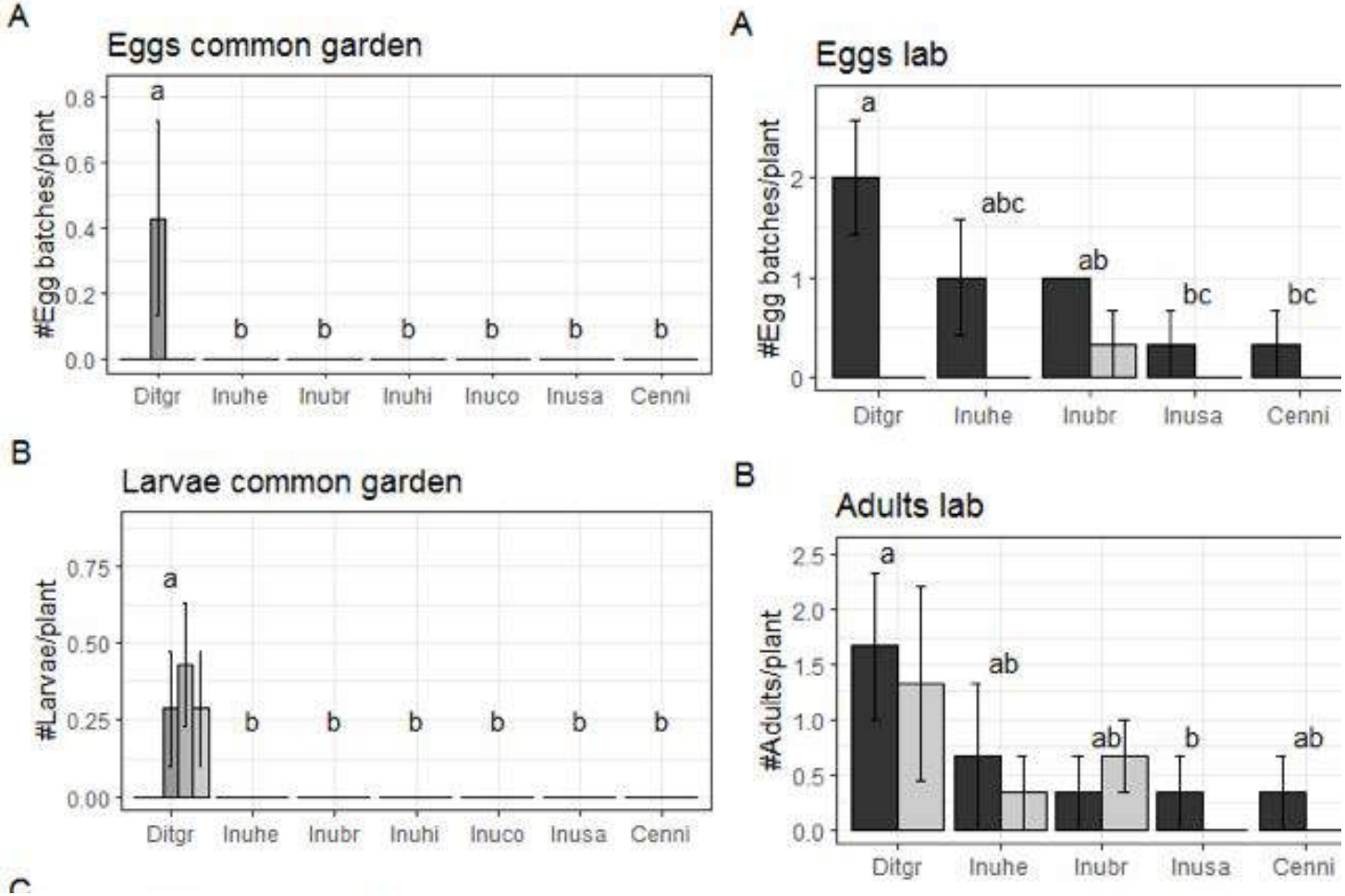
- from high ragweed/low beetle early in the season
- to no ragweed/high beetle settings late in the season

Augustinus et al. 2020; Müller-Schärer *et al.*,in prep.

No evidence of substantial non-target effects by *O. communa* on European native plant species that are taxonomically closely related to ragweed

Augustinus *et al.*,2020, Neobiota

- Eggs only on *Dittrichia graveolens*
- Adult damage on *Inula helvetica*
- Damage (roughly) follows phylogenetic relatedness
- **Follow-up studies are needed**



EVOLUTIONARY STUDIES

The **fundamental area of uncertainty** associated with **biocontrol introductions** are
→ potential evolutionary changes post-release

Biocontrol introductions offer an exciting opportunity, given
- the ample knowledge available on source populations and their genetic make-up,
- the number and size of introductions.,
- Furthermore, intentional releases allow specific manipulations for introductions and redistributions

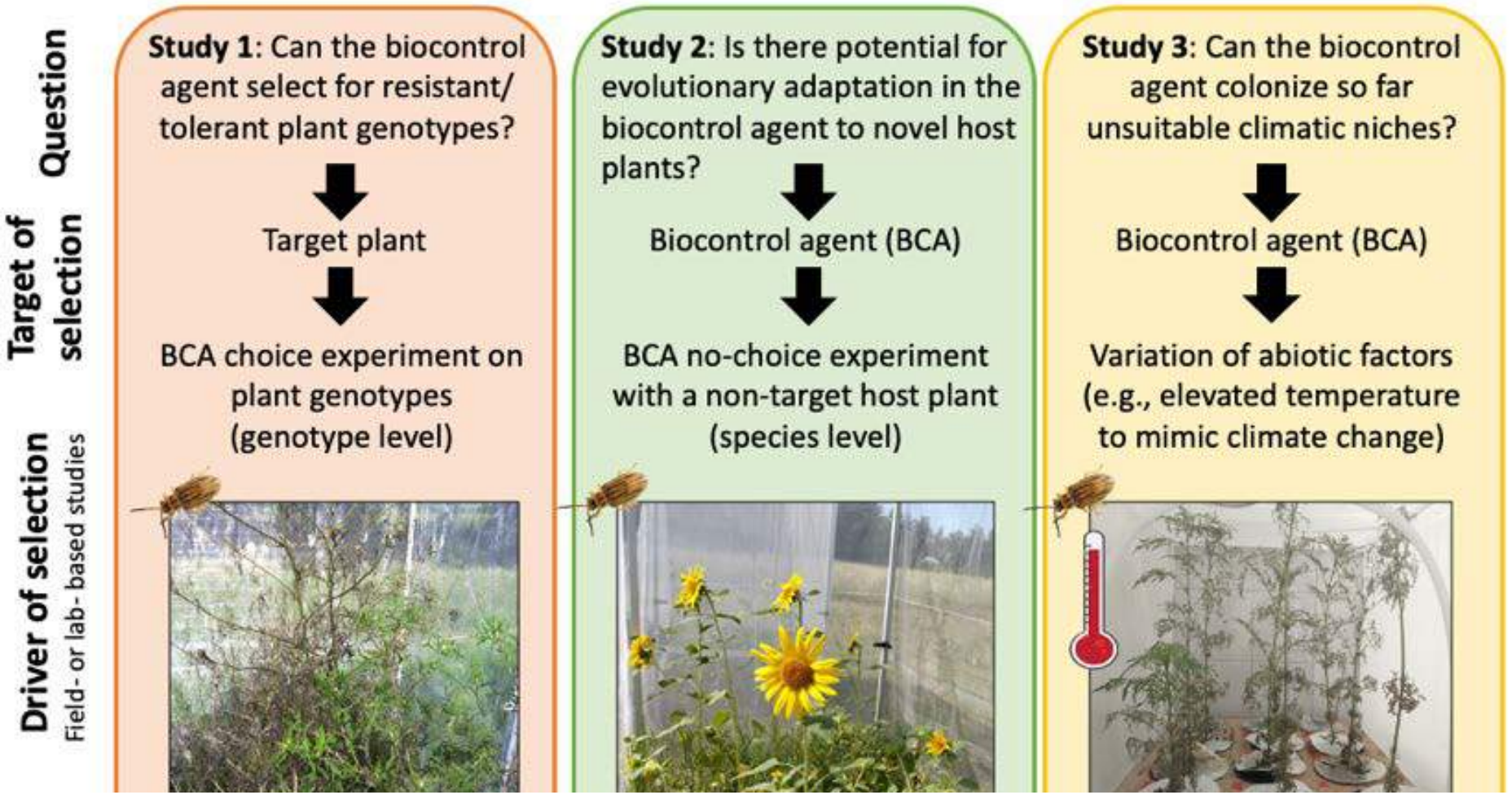
Great - but yet unexplored - scope

to learn from such post-release studies

We miss pre-release studies of how biocontrol candidates might evolve upon release in a new environment

Three key examples relevant for biocontrol efficacy and safety (biocontrol agent = BCA = beetle; target = ragweed)

Müller-Schärer *et al*. 2020 Curr Opin Insect Sci



Study 2: Selection of sunflower on beetle populations

x 8

1200 ind./cage

Aug. 2017, we released eggbatches larvae, pupae & adults

x 4

800 ind./cage

8-10 generations

2017 | **2018** | **2019**

Is there any differences at the phenotypic and genomic levels after 10 generations of evolution on sunflower?

- No beetles left in the sunflower cages after 7 beetle generations
- No effect of beetle origin, but of host plant species in both years
- Host range espansion vs. host shift

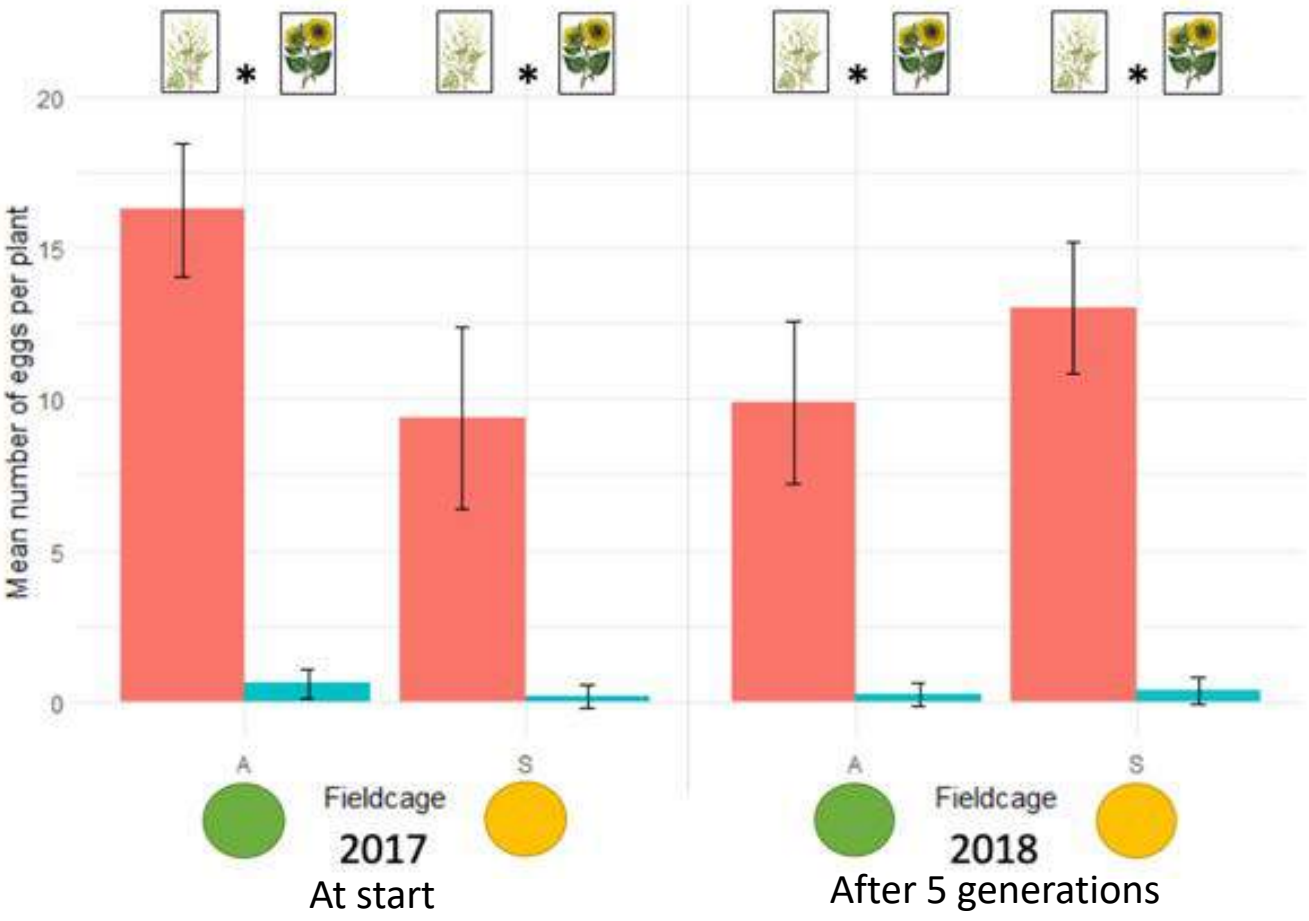
Bioassay in the Qlab
Adult host choice and larval performance

+

Poolsequencing
Investigate the variants involved in adaptation

Müller-Schärer *et al*. 2020, Curr Opin Insect Sci
Bouchmousse & Litto *et al*.,in prep

Ophraella phenotying: adult host choice



Does –over time- *Ophraella* from the ragweed vs. sunflower cages differ in their host choice and performance on the two **host plants**?

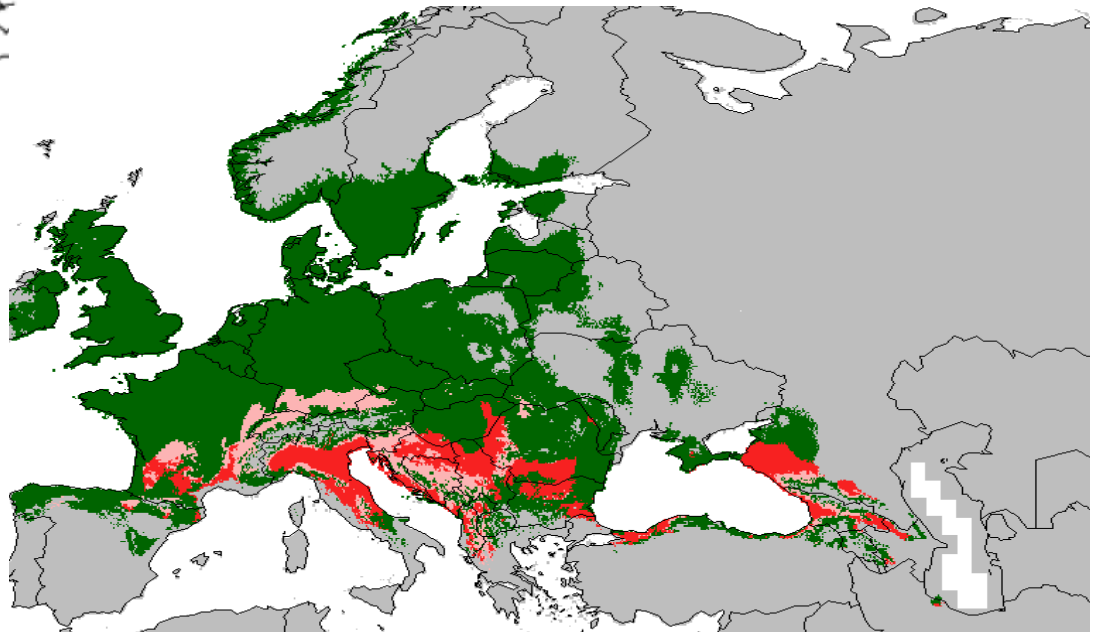
Plant species tested
Ambrosia
Sunflower

Litto *et a*l. on-going

Significant effect of the plant species tested in both years, but not of beetle origin

Study 3: Assessing phenotype – environment correlations

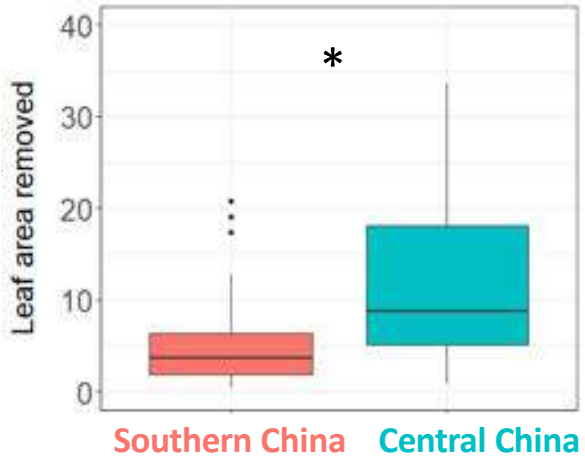
- Native and introduced ranges
- 12 populations (4 per range)
- Latitudinal gradients in each range



Can we find *Ophraella* populations to cover highly infested ragweed areas presently not suitable?

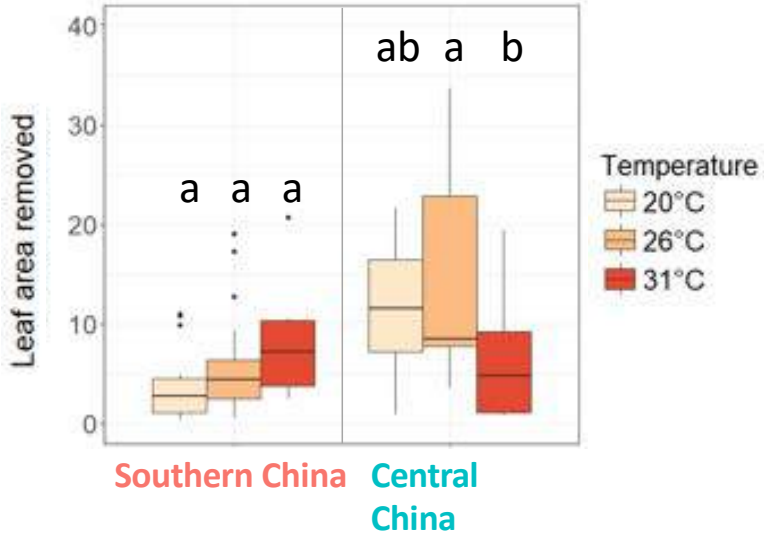
Some first results

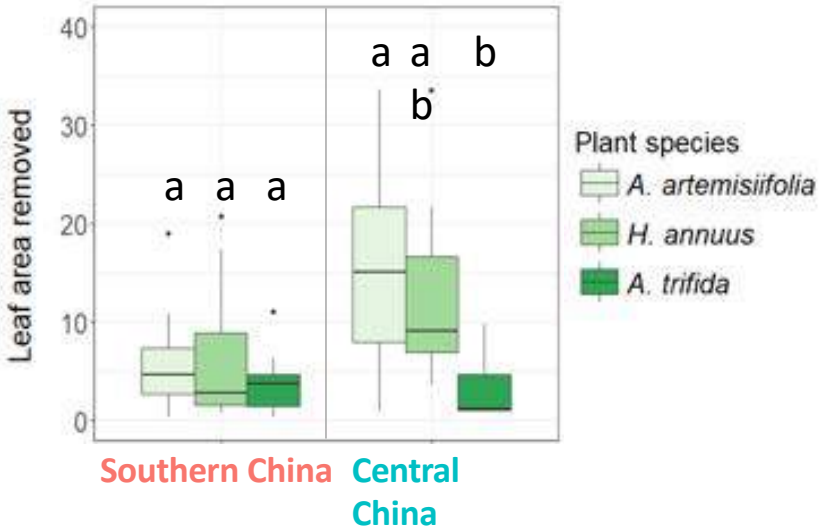
Leaf area removed (cm²)



Larvae from Central as compared to Southern China
- feed more
- feed less at 31°C than at other temperatures
- feed less on *A. trifida*.

➢ **Strong effects of *Ophraella* population origin assessed by phenotyping; genomics data to come**





IN CONCLUSION

Such studies assess the evolvability, i.e. the **potential** for rapid evolution to both novel abiotic and biotic conditions, and for

both the ragweed and the biocontrol agent

- Understanding the evolvability **pre-release** will make species interaction - and thus biological control – (i) more efficient, and (ii) further increase its safety.
- **Post-release evaluation** will ideally allow to test the hypotheses established pre-release

We advocate such experimental evolution studies **pre-release** to advance biological control towards a **more predictive and sustainable management strategy, also under climate change.**

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