Spatial demo-genetic model for studying phenomena observed during introduction of the ragweed leaf beetle *Zygogramma suturalis* F. in the South of Russia

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History of biological system

Ambrosia artemisiifolia L.
XVIII-XIX – Europe
1910th – South of Russia
1940th – outbreak in SU
1980th – modern period

Zygogramma suturalis F.
1978 – Stavropol Krai
1984 – North Caucasus
1986 – Palearctics

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(ZIN RAS, St. Petersburg)
Author of the biological method for suppression of common ragweed

Obse

- Solitary p ation

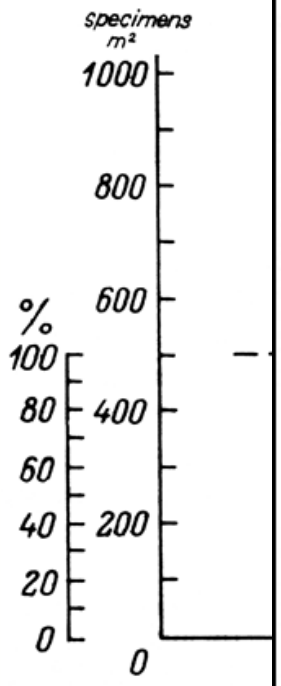


Fig 2. Solitary popu
induced wave of the
1, 2 – theoretical es
of the experimenta
June 9th, 1985. Ax
point (measured pe
axes: left, reduction
of beetles per squa
Vechernin, 1986).

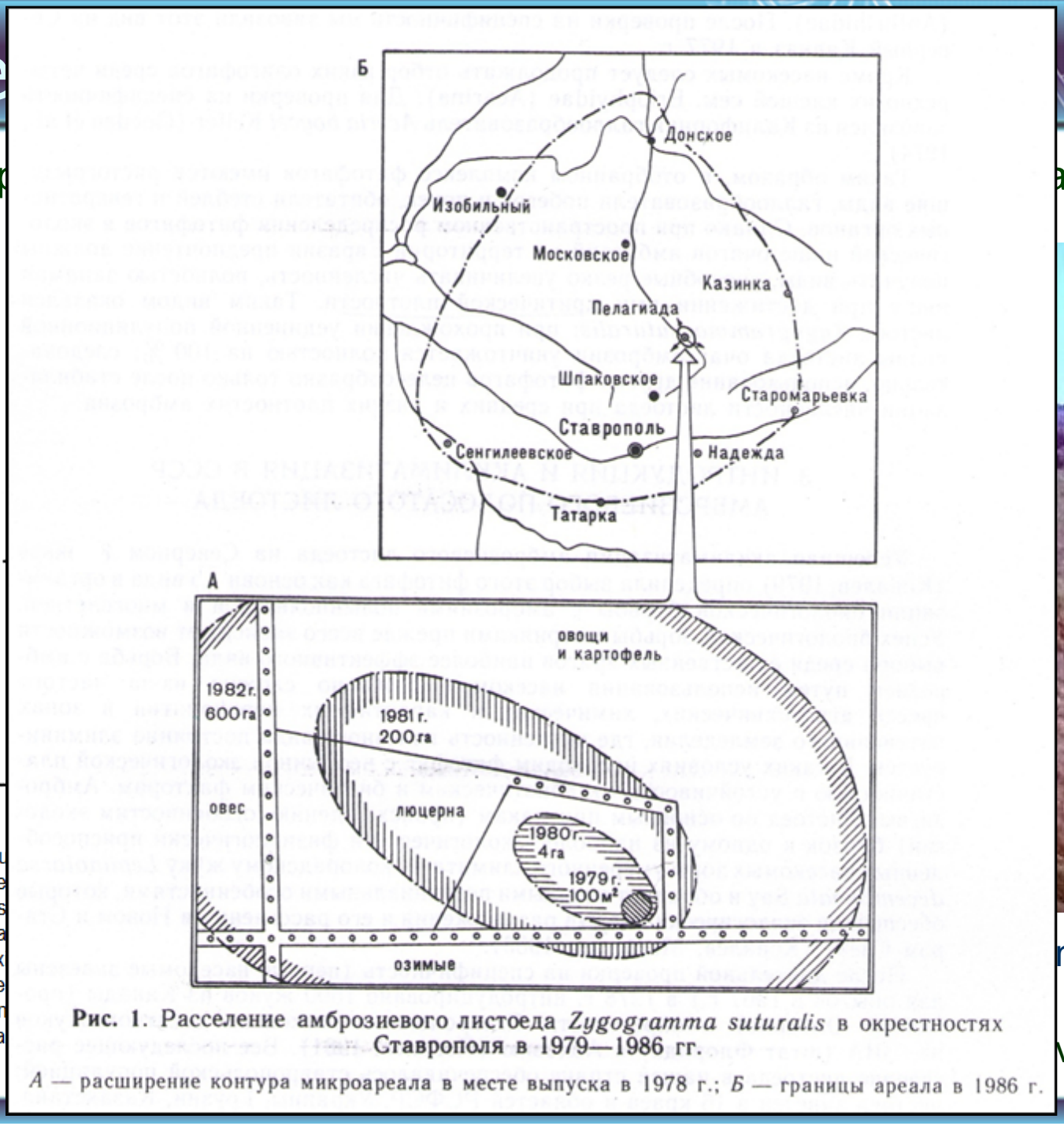


Рис. 1. Расселение амброзиевого листоеда *Zygogramma suturalis* в окрестностях Ставрополя в 1979—1986 гг.

А — расширение контура микроареала в месте выпуска в 1978 г.; *Б* — границы ареала в 1986 г.

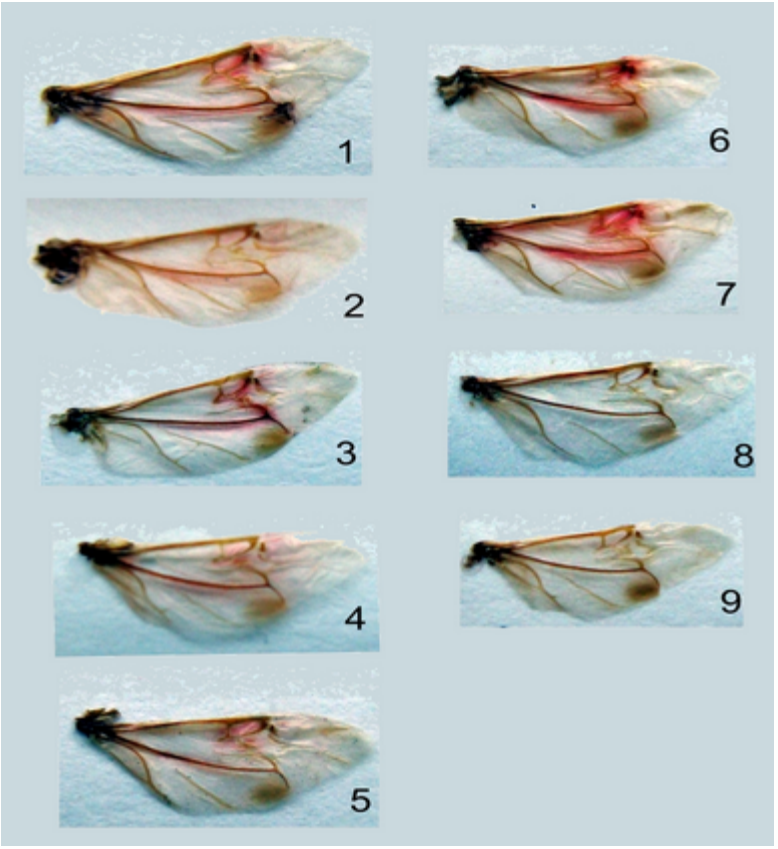
nt

valev 2004)

Observed phenomena

- Rapid (within 5-6 years) development of flight of the ragweed leaf beetle

Flying subspecies *Zygogramma suturalis volatus* Kovalev (Kovalev 1989; Kovalev 2004)



Changes in axillary apparatus including development of wing muscles and axillary sclerites (Kovalev 1989; Brodsky 1989; Kovalev 2004; Arzanov 2012)

Specific demands to the model

- Explicit description of spatial dynamics
- Considering both random (diffusion) and active directed movements of phytophage population density, stimulated by heterogeneity of food resource (trophotaxis)
- Accounting for spatial heterogeneity by marking plots unfit for vegetation
- Ability to keep track of changes in genetic structure of phytophage population
- Accounting for the Allee effect (Allee 1931; Stephens, Sutherland, 1999) in phytophage population
- Universality, applicability to broad class of similar systems

We combine explicit modelling of animal spatial behaviour (Govorukhin et al 2000; Arditi et al 2001; Tyutyunov et al 2002; 2009; Sapoukhina 2003) with demogenetic equations of V.A. Kostitzin (1936; 1937; 1938; 1938a)

Spati

$$\frac{\partial R}{\partial t} = F$$

$$\frac{\partial P}{\partial t} = F$$

$$f_{ff}\left(N_{ff}, N\right)$$

$$f_{fp}\left(N_{ff}, N\right)$$

$$f_{pp}\left(N_{ff}, N\right)$$

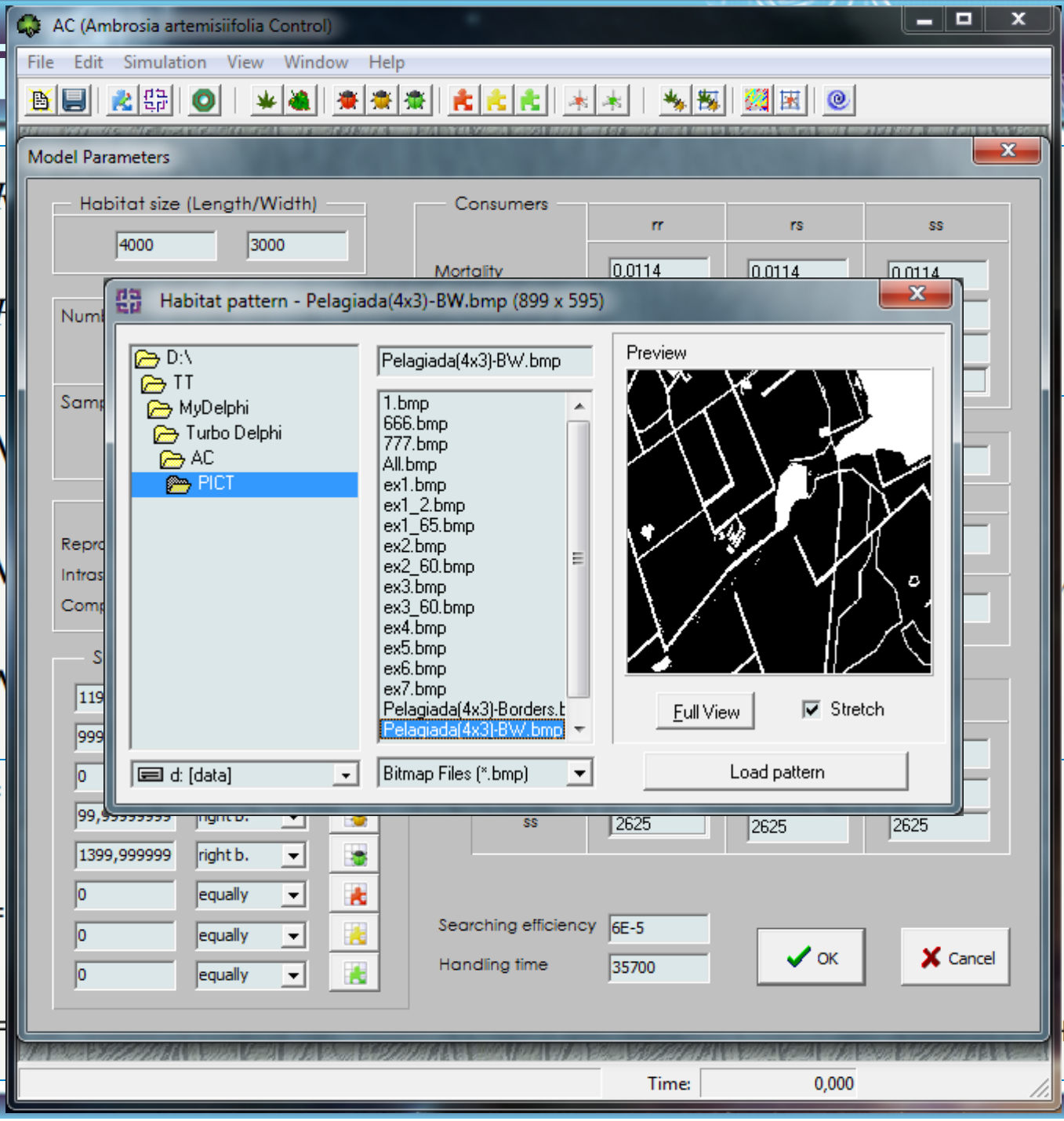
$$\frac{\partial S_{ff}}{\partial t} =$$

$$\frac{\partial S_{fw}}{\partial t} =$$

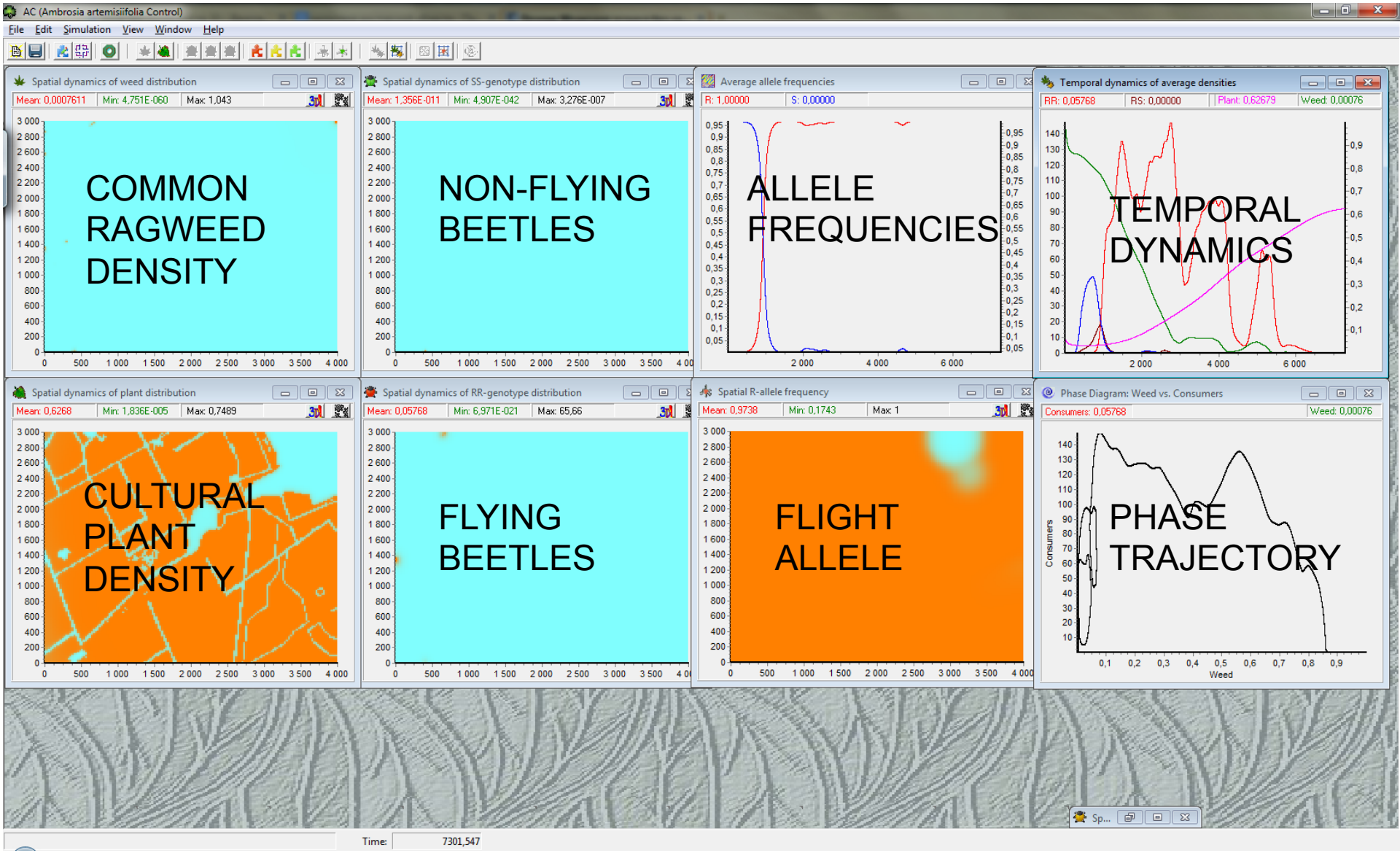
$$\frac{\partial S_{ww}}{\partial t} =$$

$$N_{ww} N_{fw} N_{ww}$$

$$+ N_{ww}$$



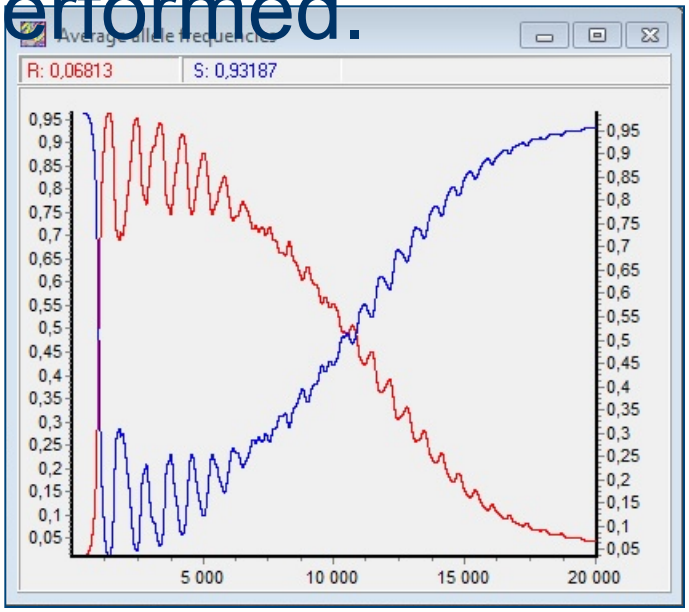
Simulations



Supplementary simulations

- Without Allee effect (*A*=0) → flight evolution is negligibly slow
- Homogeneous release of beetles → no SPW and → no control
- Lowering weed growth decreases SPW effect of weed control
- Extremely low production of ragweed → beetles can't establish
- Increased habitat fragmentation → 'walkers' replace 'flyers'

In order to elucidate the factors that determine efficiency of biomethod and accelerate the evolution in the model, additional simulations have been performed.



Conclusions

- Model correctly reproduces qualitative dynamics of the system
- Phytopage SPW is a key factor of biomethod efficiency
- SPW accelerated development of flight of *Z. suturalis* in Russia
- SPW formation requires plots with high ragweed density
- SPW enhances the excluding effect of the competing plant
- Cultural plants prolongate SPW effect of weed extermination

Thank you for attention!