# Pros and cons of climate change for forest phytophagous insects

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# Introduction

Climate change is to increase the temperature, $CO_2$ concentration, the frequency of drought, fires, and hurricanes.
A temperature affects insect survival and development directly and indirectly through the availability and quality of food.
Acceleration of insect development will bring to increase the number of generations and negative affect the health condition of trees.
At the same time, in the zone of winter, spring, summer, and autumn, insects are adapted to hibernate in the most protected places and in the least vulnerable stage.
The main signal to change the rate of development (acceleration, slowdown) or diapause is most often the length of the day (photoperiod), less often - temperature level and food quality.
An increase in temperature without changing the photoperiod may ambiguously affect the survival and harmfulness of phytophagous species

The aim of this paper was to assess a possible reaction to climate change of forest phytophages with different types of seasonal development.

## Methods

Partially published author’s data for almost 50-year-old on phytophagous insects of oak (*Quercus robur* L.) and pine (*Pinus sylvestris* L.) were used.

Current and predicted temperature in the Kharkiv region are used here (the northeastern part of Ukraine on the border of the forest-steppe and steppe, 50º00 'N, 36º10' E).

In analysis, classification of foliage browsing insects by the types of seasonal development considering voltinism, hibernating stage and summer diapause were used (Meshkova 2009).

The deadlines for the development of individual stages of insects were analyzed taking into account the type of seasonal development, the deadlines of the appearance after hibernation, and termination of active development in autumn.

When calculating the deadlines for the development of stages, which appeared after the end of hibernation, the evaluated dependences of their duration from temperature and the sum of temperature were used (Meshkova 2009).

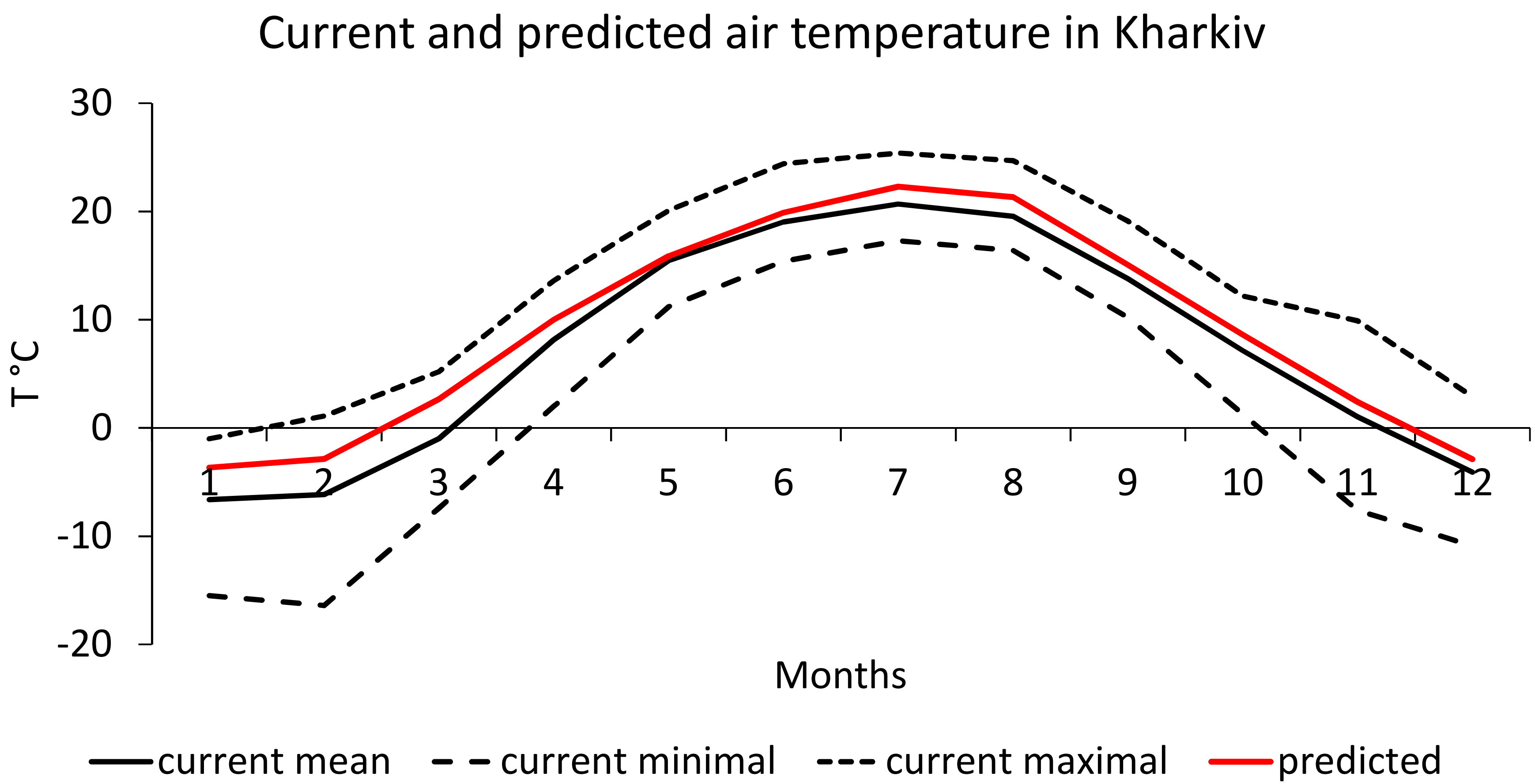
Date and the day from the 1st January for a stable transition of daily air temperature up and down through 0ºC, 5ºC, 10ºC and 15ºC for different periods and predicted by modified A1B climate change scenario for Kharkiv

| Limits of transi-tion | 1892–2000 | | | 1981–2010 | | | 2021–2050* | | |
|---|---|---|---|---|---|---|---|---|---|
| | start | end | length | start | end | length | start | end | length |
| 0ºC | 17.03 76 (15–99) | 27.11 326 (296–348) | 251 | 15.03 75 | 20.11 325 | 251 | 9.03 69 | 4.12 339 | 271 |
| 5ºC | 1.04 95 (74–113) | 26.10 300 (280–332) | 206 | 1.04 92 | 27.10 301 | 210 | 25.03 85 | 29.10 303 | 219 |
| 10ºC | 23.04 113 (97–129) | 30.09 277 (261–295 | 165 | 24.04 115 | 10.10 284 | 170 | 18.04 109 | 17.10 291 | 183 |
| 15ºC | 8.05 136 (114–158) | 10.09 253 (239–274) | 118 | 11.05 132 | 11.09 255 | 124 | 10.05 131 | 17.09 261 | 131 |

*Shvidenko et al. 2018

There is a tendency towards an increase in temperature in all months, an earlier beginning of the growing season, a later completion, and a longer duration.

At the same time, even several decades ago, in some years, the timing of these events was beyond the predicted values. This indicates the ability of phytophagous insects to adapt to predicted climate changes.



In accordance with our classification (Meshkova 2009), foliage browsing insects were divided into groups by hibernating stage: group 1 – egg hibernates (larvae feeding in spring), group 2 – larva hibernates (feeding in spring and at the end of vegetation, for example, *Dendrolimus pini* L., *Euproctis chrysorrhoea* L.), group 3 – pupa hibernates (larvae feeding in spring or in summer-autumn), and group 4 – eonymph hibernates (larvae feeding in summer-autumn, for example, *Diprion pini* L.). Subgroups differ by the presence of summer diapause: subgroup 1a – summer diapause of eggs transits to winter diapause (*Tortrix viridana* L.); subgroup 1b – summer diapause of pupae or eonymph, swarming in autumn, winter diapause of eggs (*Operophtera brumata* L., *Neodiprion sertifer* Geoffr.); subgroup 3a – summer diapause of pupae transits to winter diapause (*Panolis flammea*); subgroup 3b – winter diapause of pupae transits to summer diapause (*Bupalus piniarius* L.).

Representatives of groups 1–3 are monovoltine throughout the entire range, and representatives of group 4 are known to have different variants of cycles.

**Each group will have a specific response to climate change.**

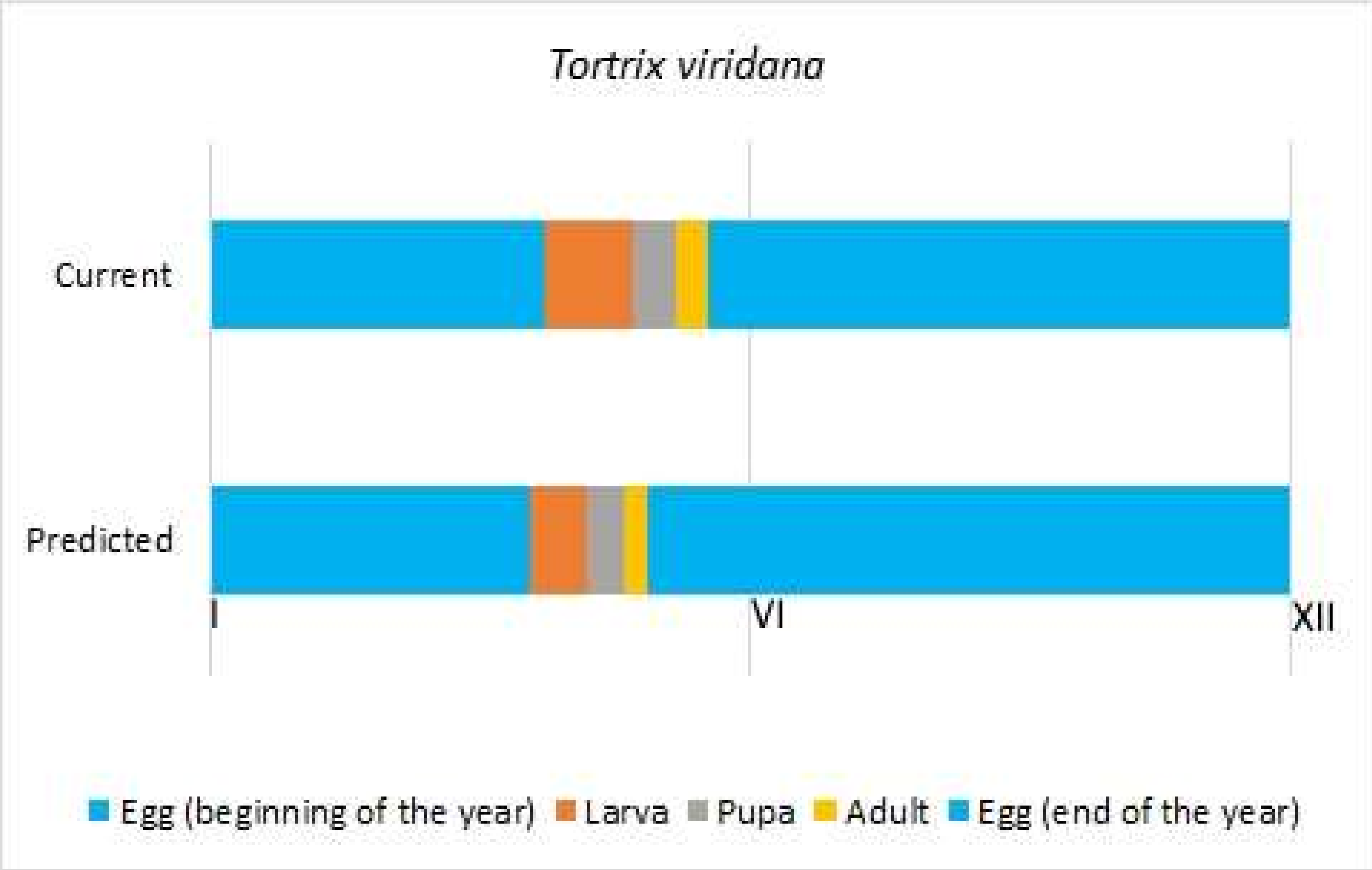
# Patterns of seasonal development for foliage browsing insects

| Group by seasonal development | Species | Gene-ration | Hibernating stage | Sum-mer dia-pause | Months of larvae feeding | Dates of active development |
|---|---|---|---|---|---|---|
| 1a | Tortrix viridana Linnaeus, 1758 | 1 year | Egg | – | V | D10s – D10s +DD |
| 1b | Operophtera brumata (Linnaeus, 1758) | 1 year | Egg | Pupae | V | D10s – D5au |
| 1b | Neodiprion sertifer (Geoffroy, 1785) | 1 year | Egg | Eo-nymph | V | D10s – D15 au |
| 2 | Euproctis chrysorrhoea (Linnaeus, 1758) | 1 year | Larvae | – | IV–VI, VII–IX | D10s – D10au |
| 2 | Dendrolimus pini (Linnaeus, 1758) | 1–2 years | Larvae | – | VIII–IX, IV–VI | D10s – D10au |

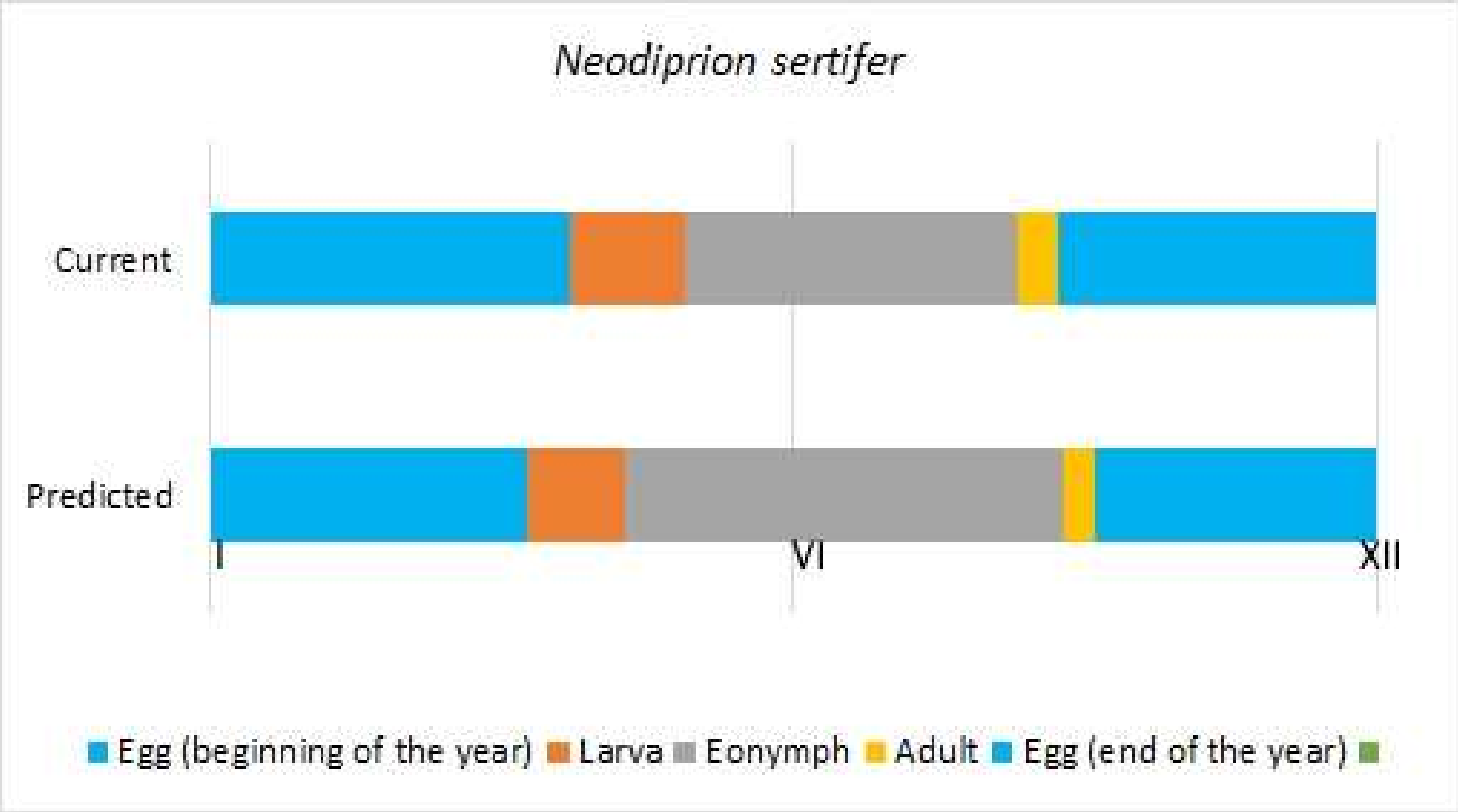
# Patterns of seasonal development for foliage browsing insects (continuation)

| Group by seasonal development | Species | Gene-ration | Hibernating stage | Sum-mer dia-pause | Months of larvae feeding | Dates of active development |
|---|---|---|---|---|---|---|
| 3a | Panolis flammea (Denis & Schiff., 1775) | 1 year | Pupae | – | V–VI | D10s – D10s+DD |
| 3b | Bupalus piniaria (Linnaeus, 1758) | 1 year | Pupae | – | VI–IX | solstice – D15au |
| 4 | Diprion pini (Linnaeus, 1758) | 1 – 2 / year | Eo-nymph | Eo-nymph | V–VI, VIII–IX | D10s – D15au |

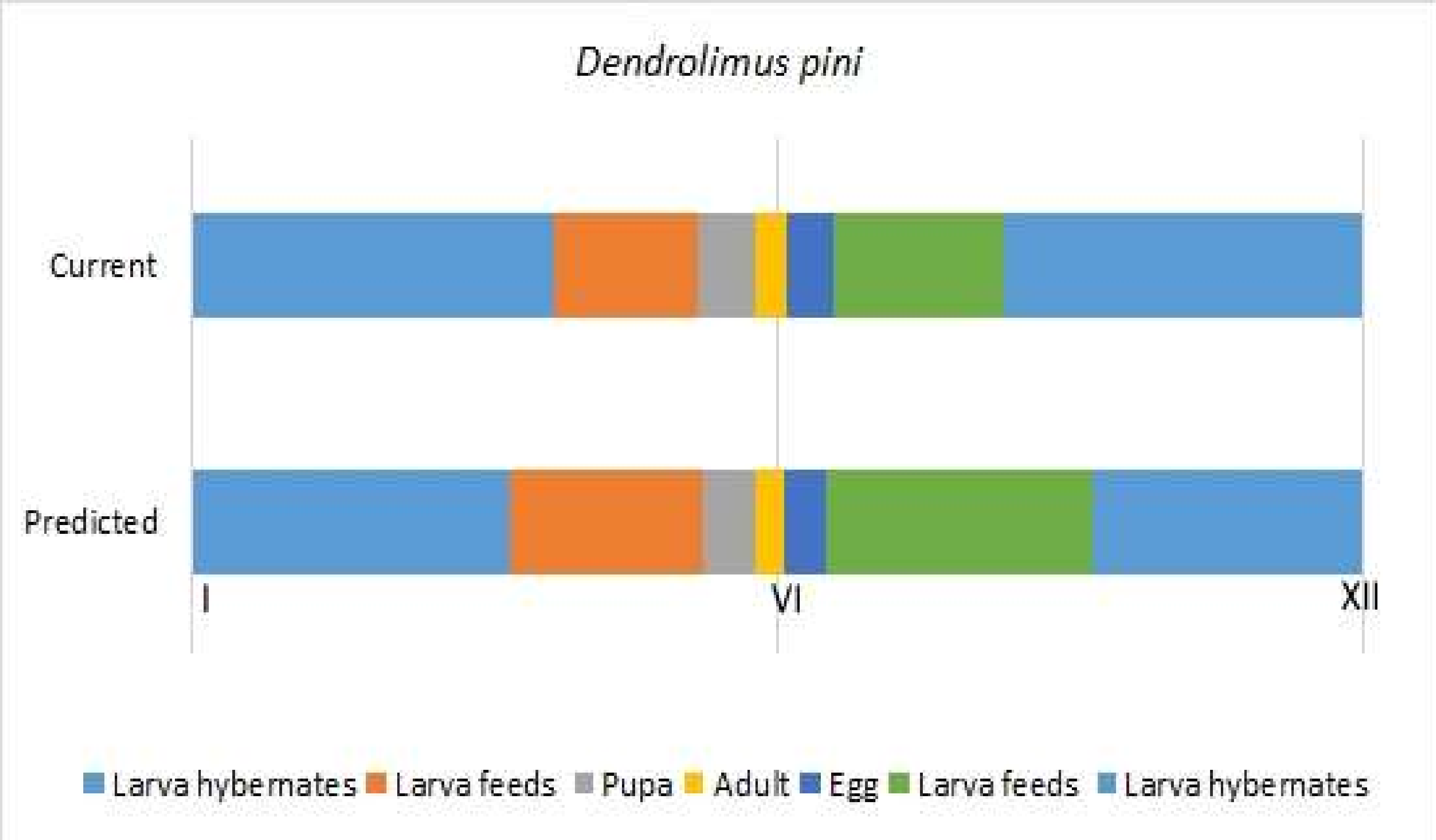
Notes: – D5s – Date of stable transition of daily temperature over 5 ºC in spring
D10s – Date of stable transition of daily temperature over 10 ºC in spring
D10au – Date of stable transition of daily temperature below 10 ºC in autumn
DD – degree days



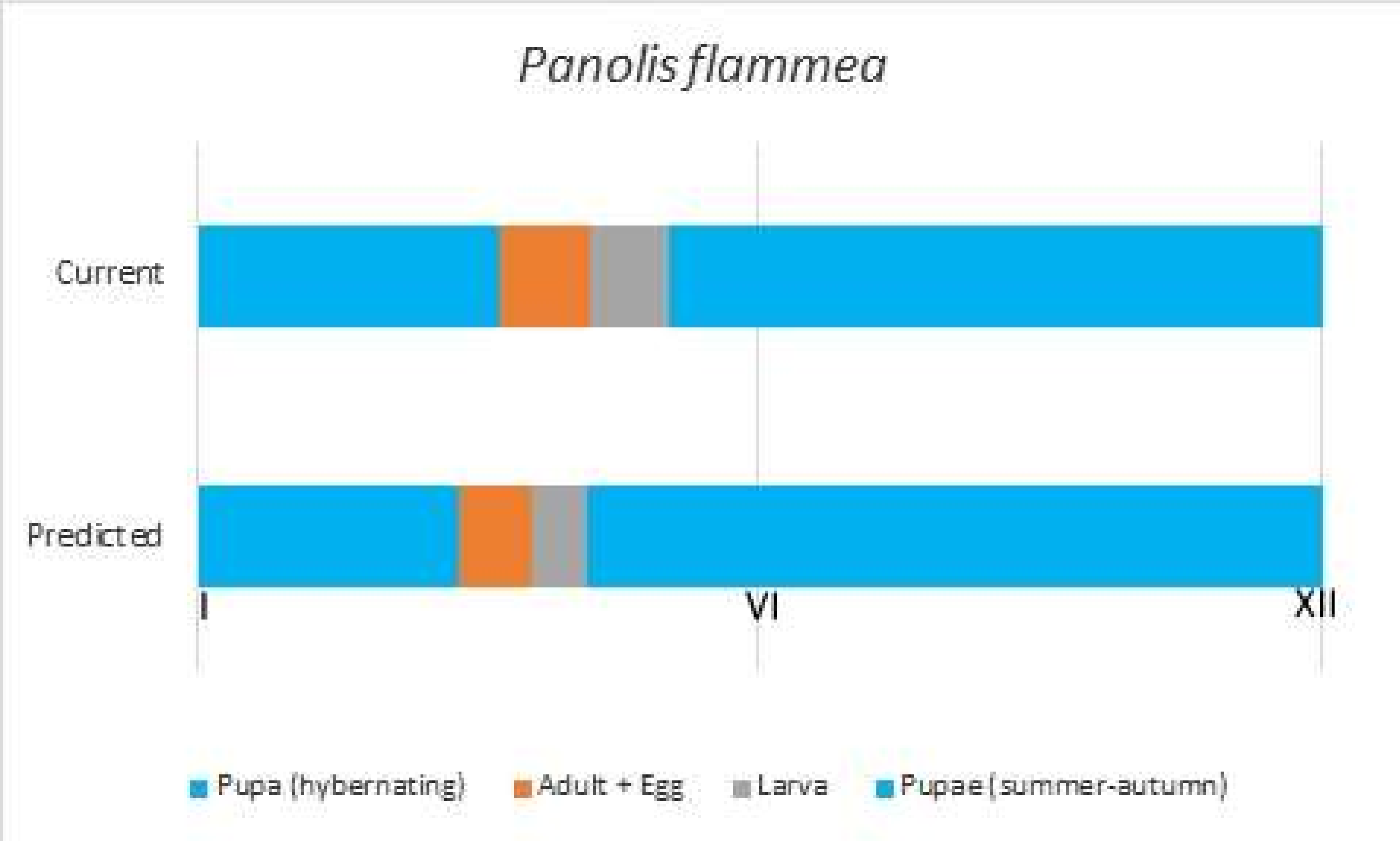

I, VI, XII - months



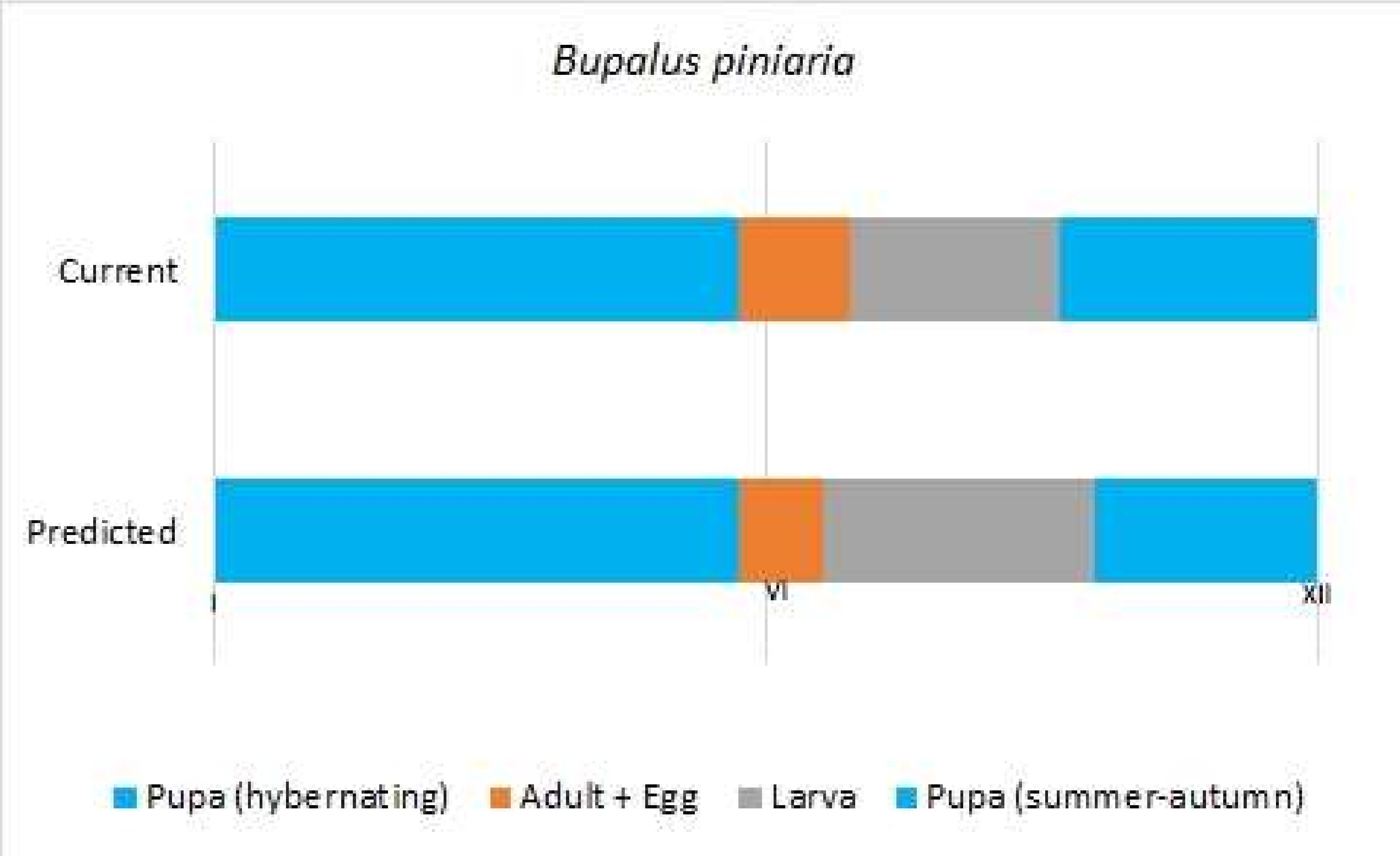

I, VI, XII - months



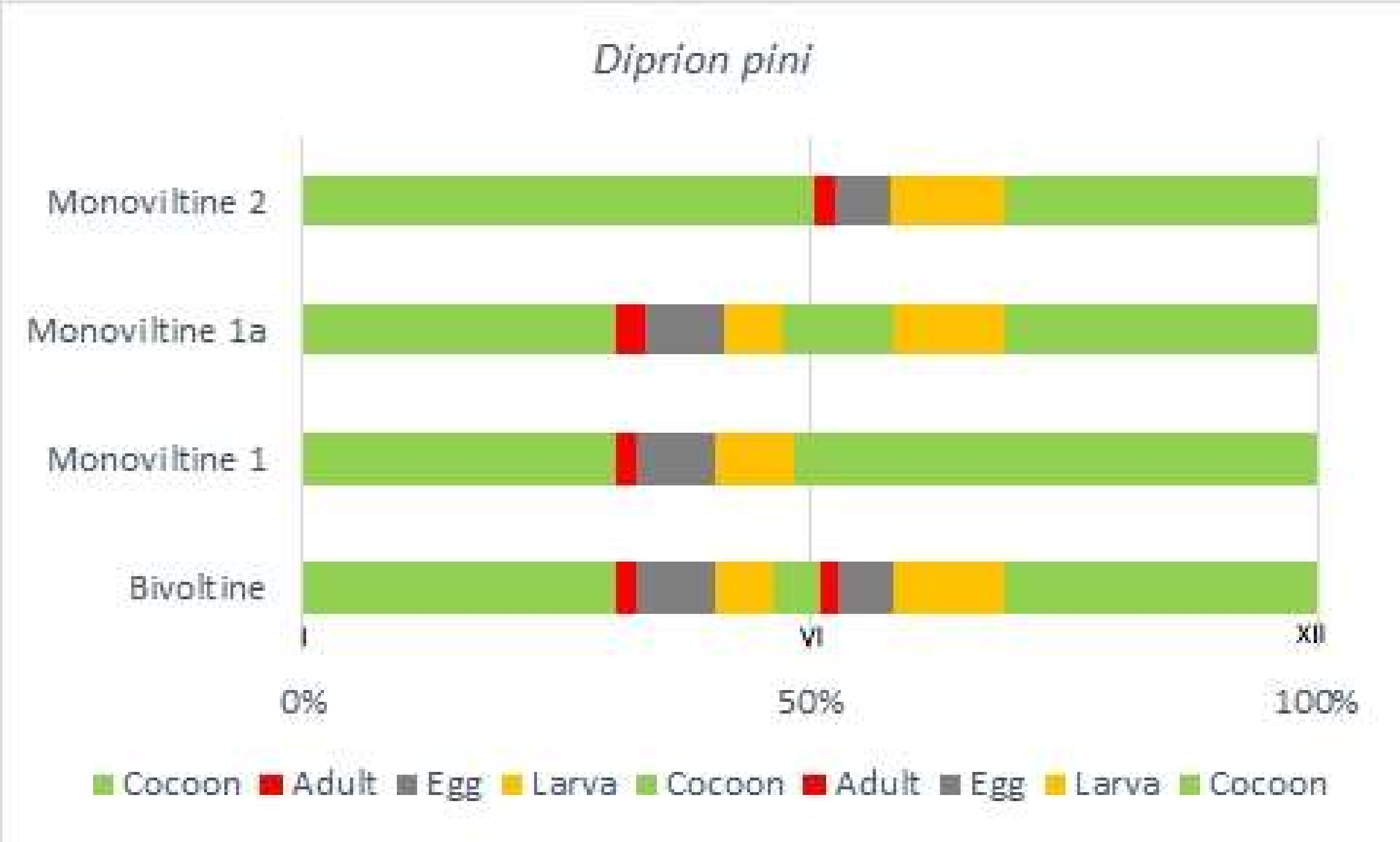

I, VI, XII - months




I, VI, XII - months




I, VI, XII - months




I, VI, XII - months

**Conclusions**

The adaptation of forest phytophagous insects to climate change can occur by

– accelerated development (development of additional generations);
– expanding the range of host plants;
– changing location of individual stages;
– spread to new territory.

Species that are monophages throughout their current range will remain monophages.

Species that now have more than one generation in the south of the range will be able to increase their number in other parts of it as it warms.

Changes in the timing and rate of development of phytophages will depend on the type of seasonal development, and the survival rate and harmfulness will depend on the synchronicity with the appearance of foliage and entomophages.

The harmfulness of phytophages will increase with an increase in their voltinism and with an increase in the vulnerability of trees under conditions of aridity and anthropogenic pressure and will decrease as a result of a decrease in the size of insects and their fertility during rapid development.

Wintering of individuals at stages that are not adapted to new combinations of temperature and photoperiod can also be negative results of climate change.

# Thanks for attention!!!