Phenological Prediction of Forest Pest-Defoliators

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The methodology for predicting phenological events are useful for predicting the seasonal development of insects in the current year, for analyzing terms and rate variation of insect population development in different years, and for comparing different geographical and ecological insect populations after terms and rate of different stages of seasonal development.

A mathematical sense of the proposed approach is in the determination of such period (*n* days) in the year temperature course, the average temperature of which allows to complete development of a particular stage of insect for the same *n* days. The values of *n* are determined by graphical solution of the system of two or more empirical equations, where one equation characterizes the heat resources of a geographical region and the others define the heat demands of biological objects (Podolskij 1967)

The heat requirements of insects are represented as curves that show the dependency of certain stage of instar development duration (*n* days) on the mean air temperature during the period of this development (*T*). Such curves are called "phonological" curves.

The basis of such curves are data on the developmental dates for objects obtained at constant temperatures in the laboratory as well as data obtained from field investigations or from the literature (Meshkova 2001a,b,c,d). Datasets for many years or for different points were plotted in the graphs and trend lines $n=f(T)$ were constructed (Fig.1,2).

Heat resources of a region were represented in such a way that it was possible to determine the mean air temperature for any time interval in a season. The net of heat resources consists of lines; every line is marked by the mean date for a respective period (for example, <<15.IV>>, <<25.VI>>). Every line consists of points whose coordinates are determined from values for 10 day periods. To build the net of heat resources, auxiliary tables were calculated for different geographical regions from data on mean air temperature over many years (Meshkova 2001 b). If necessary, intermediate lines can be built by graphical or analytical means.

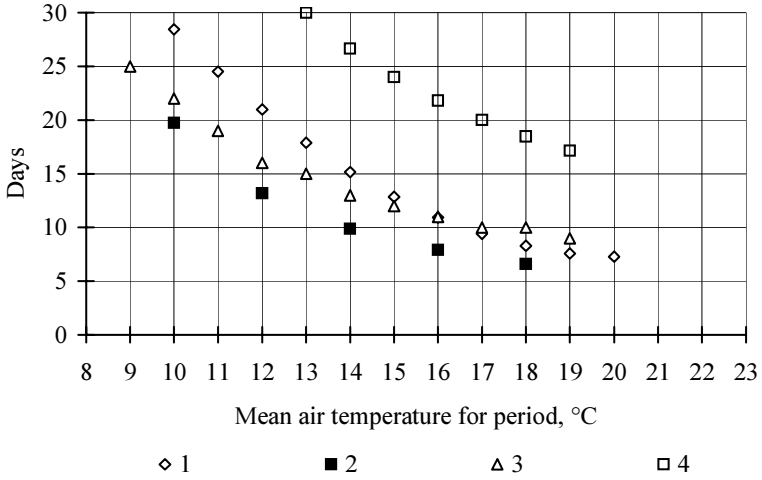

Figure 1.—Phenological curves for eggs development: 1 – *Lymantria dispar* L.; 2 – *Operophthera brumata* L.; 3 – *Tortrix viridana* L. 4 – *Archips crataegana* Hb.

For a graphical solution of the system of equations that describe heat demands of insects and heat availability, the net of heat resources and the phenological curve must be plotted at the same coordinates. One must find the line of heat resources that starts from the beginning date of a given stage and the point of its intersection with the phenological curve for that stage. Then the ordinate of the intersection point is equal to the number of days which are necessary for this stage to complete its development. The results of such estimations are represented as phenological calendars for a region (Meshkova 2001a, b, c, d).

It is known that air temperature growth temp depends on latitude and longitude. It transits over 0°C in Lviv (49°49' N, 23°57'E) on March 14 and in Kharkiv (49°58' N, 36°08'E) on March 22, but it

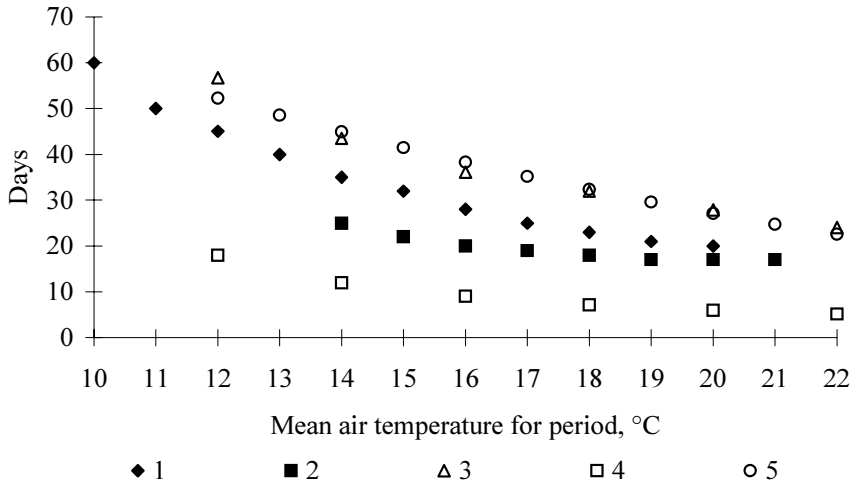

Figure 2.—Phenological curves for larvae development: 1 – *Neodiprion sertifer* Geoffr.; 2 – *Operophthera brumata* L.; 3 – *Panolis flammea* L.; 4 – *Archips crataegana* Hb.; 5 – *Euproctis chrysorrhoea* L.

transits over 10°C 6 days earlier in Kharkiv (24.IV), than in Lviv (30.IV). If winter moth eggs begin development on March 15, then larvae will hatch 42 days later in the Crimea and 57 days later in Kharkiv. If eggs begin development on April 15, then larvae will hatch almost simultaneously (two days difference) in Lviv and Kharkiv.

Based on analysis of data from many years, winter moth egg development begins on April 1 in Simferopol (44°41'N, 34°08'E) and larvae would appear there in 30 days or on May 1, on May 5, in Lviv, and on May 9 in Kharkiv. According to calculations, then larvae will pupate 24 days after April 1, that being May 25 in Simferopol, 25 days after May 5, or May 30 in Lviv, 23 days after May 9, or June 1 in Kharkiv.

However the suggested method can be used only for predicting insect development during the first part of the summer; after the solstice, the role of photoperiod in their development becomes more important. For example, the timing of winter moth swarming does not depend on the completion of larval feeding, but rather it coincides with the end of the vegetation period at a given point. Therefore, winter moth swarming is observed earlier in the northern regions and later in the southern regions.

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