Attribution of Estonian phyto-, ornitho- and ichtyophenological trends with parameters of changing climate

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Abstract

We summarised trends of phyto-, ornitho- and ichtyophenological time series gathered during the last half a century in Estonia and analysed their relations with selection of climate parameters. 943 phenological time series with best observation quality from the period of 1948–1999 were selected for the analysis. Linear regression of phenological time series indicates that in total more than 80% of phenological phases have advanced during springtime. Significant values of phytophenological and ornithophenological phases have advanced 5–20 days and ichtyophenological phases have advanced 10–30 days. Estonian mean air temperature has become significantly warmer in spring and at the same time slight decrease in air temperature has been detected in autumn. Growing season has become significantly longer in the maritime climate area in West-Estonia.

Analysis of attribution of phenological trends indicates that studied trends of phenophases and climate parameters are first and foremost related to changes of North Atlantic Oscillation Index (NAOI) during winter months (Jan–March). Correlations between them reach up to the level of 0.9. Although the impact of winter NAOI on the phases decreases towards summer, the trends of studied phases still remain high. Apparently trends of later phases and climate parameters are not affected only by changes of winter NAOI as since April and May other air masses coming from Eastern directions

are dominating in the area of the Baltic Sea. These circulation indexes do not have significant changes during study period. Therefore the reasons behind the trends of phenophases in the end of spring and beginning of summer are elsewhere, like in temperature inertia caused by changing winter and spring and direct consequences of human impact like land use, heat islands or pollution.

Introduction

Estonian phenological studies show that spring has advanced significantly and winter has become shorter, other seasons do not have many significant changes. This contributes to phenological studies in Europe (Ahas 1999; Ahas et al., 2002; Chmielewski and Rötzer, 2001; Menzel, 2000;) and other regions (Beaubien and Freeland, 2000; Chen et al., 2000), that also report significant changes in seasonal development of nature. Trends have different values in different geographical regions, the Baltic Sea region and Western Europe has the highest rate of changes.

The Objective of the current study is to summarize phenological trends recorded in different observation networks during the last half a century in Estonia and to attribute studied trends with changes in regional climate.

1. Materials and methods

We have gathered and evaluated the majority of Estonian systematically recorded phyto-, ornitho-, and ichtyophenological time-series into one database. The minimal length of 35 years of the observation series during the period of 1951–1999 is the main criteria for phyto- and ornithophenological time-series to be suitable for analysis. The number of observed years for ichthyophenological time series was only 25, because of more fragmented observation data. All together 753 time-series (one phase of one species observed in one station) of trees and bushes (409), fruit trees and berry bushes (185), field crops (220), potatoes (75) and grasses (49) have been used.

2. Results

Plants

There have been remarkable changes in the beginning dates of phytophenological phases in Estonia. The results of linear regression analysis show that 85.5% of (644) phytophenological time-series have advanced (Fig. 1), majority of them occur in spring half of year. Statistically significant trends show that 138 time-series have advanced 10…15 days; 112 time-series 5…10 days and 53 time-series 15…20 days during studied 49 years. The 32 time-series that advanced more than 20 days are all statistically significant ($p<0.05$). 151 time-series have advanced 0…5 days, but trends are not significant. 14.5 % of phytophenological time-series have delayed, 20 of them have a statistically significant trend with a delay of 10…30 days. Delayed time-series that have significant trends are mostly autumn phases like ripening of fruit, colouring and falling of leaves.

Spatial distribution of phenological trends shows that western-Estonian maritime climate has advanced more than it has in continental inland areas and Northern Estonia. For example the ear of rye has advanced 10…12 days in western and 2…4 days in eastern Estonia. It is important to remember that in many cases the spatial differences in phenology in Estonia are smaller than the ones resulting from local natural peculiarities like microclimate, relief, soil or observation error etc.

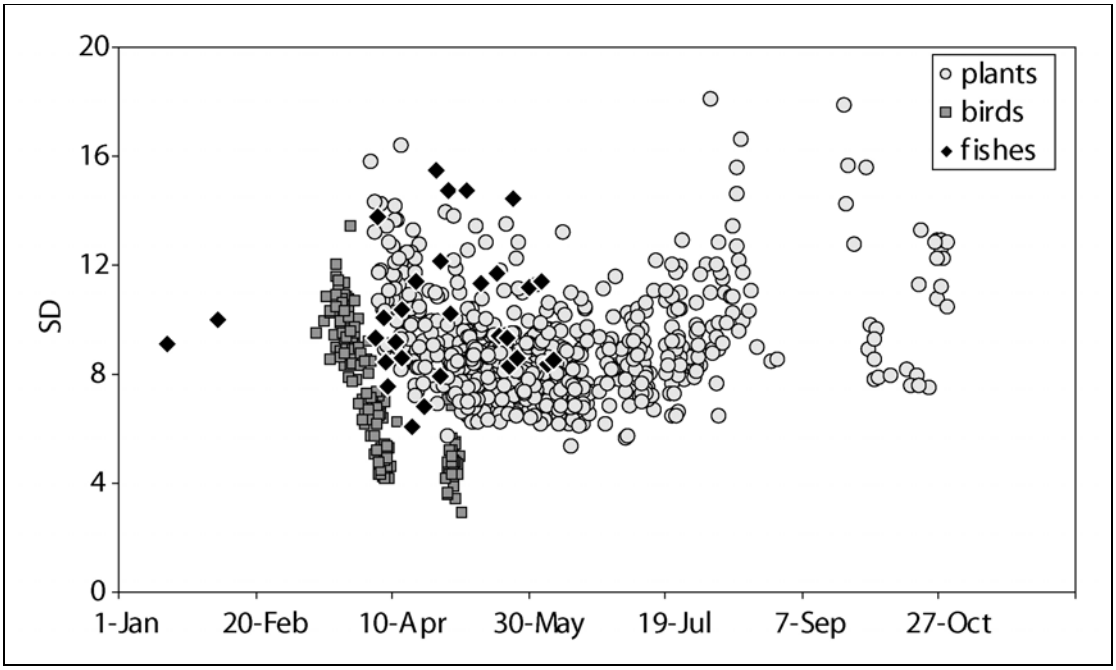

Fig 1. Temporal distribution of 943 studied phyto-, ornitho-, and ichtyophenological time-series and their standard deviatio

<u>Birds</u>

The arrival dates of Eurasian skylark, white wagtail, barn swallow, chaffinch and lapwing in spring has advanced remarkably, but majority of trends are not statistically significant. Statistically significant changes show that 15 time-series have advanced 5…10 days and 12 time-series 10…15 days. Studied database shows that birds whose arrival date is earlier in spring have the biggest trends. For example, the biggest significant changes occurre in the arrival of Eurasian skylark and lapwing.

Most of ornithophenological time-series, which have advanced 0…5 and 5…10 days, are not statistically significant. 20 ornithophenological phases have delayed up to 10 days; arrival dates of barn swallow in some stations in Eastern and Southern Estonia have statistically significant shifts towards later.

Arrival trends of Eurasian skylark have a clear spatial distribution: in southern Estonia they have advanced 6…14 days, which is a significant change, in northern Estonia the changes are smaller, in the range of 0…-8 and the trends are not significant. Spatial distribution of trends similar to Eurasian skylark is also noticeable in the arrival of lapwing and white wagtail. The change in the arrival time of the chaffinch is bigger and reliable on the western coast; the arrival trends of barn swallow do not possess clear spatial regularity.

Fishes

Changes in phenological phases describing events in the life cycle of fishes are relatively smaller than changes in phyto- and ornithophenological time-series. In case of fish phases, statistically significant changes can be found only among the advanced phases (Fig. 1). Four ichthyophenological phases have advanced reliably: the end of pike first spawn in Vagula Lake for 12 days, the end of ruff spawn in Vilusi for 28 days, the end of bream first spawn in Vilusi for 26 days and migration of local smelt in Vilusi for 19 days. Generally the majority of trends are not statistically significant and their slopes are divided evenly between advancing and delaying.

In case of ichthyophenological phases, the spatial regularities have not been detected (Ristkok, 1974) as the distribution of observation stations is fragmented, and small lakes and rivers and big lakes and rivers have very diverse hydrological regime and phenology.

3. Phenological trends and changing climate

For attribution of phenological trends with changing climate we studied correlations between studied time series and selection of climate factors. Studied climate factors have strong trend of warming mainly in winter and springtime, which decrease since the end of June. For example the date of exceeding mean air temperature over 0º has advanced up to 25 days, and 15º reached by the end of June has not changed. Geographically, the warming of mean air temperature during spring period is higher in inland and South-Estonia, growing season on the other hand is significantly longer on the islands of West-Estonia. While analysing correlations it became evident that phytophenological phases correlate better with air temperature, ornithophenological with NAOI and fish phases have weaker correlations with mentioned parameters.

The strongest trend among the early spring phases is characteristic to the beginning of birch sap bleeding. This phase has strong correlations with climate parameters during winter. For example correlation coefficient of birch sap bleeding is up to 0.9 with permanent exceeding of mean daily temperature 0º; -0.8 with NAO index of February and -0.7 with mean temperature of February.

Phytophenological phases with beginning dates in spring, from the middle of April to the third decade of May have strongest correlations with mean air temperature of April, those correlation coefficients are up to -0.8. There are also strong correlations with the date of reaching 100º active temperatures, which in Türi (central Estonia) begins on an average on 16th of May. In comparison to early spring phases the impact of NAO on spring phases is significantly smaller (r = -0.4…-0.6).

Since May, the correlations between the date of reaching sums of active temperatures and phenophases are considerably increasing. For example the phases of the end of May like the beginning of flowering of rowan and apple tree have correlation coefficients up to 0.9 with the date of reaching the sum of 200º of active temperatures and 0.9 with the date of reaching the sum of 100º of active temperatures. Correlations of those phases with NAO indexes are lower, -0.5...-0.6.

Correlations of autumn phases with studied climate parameters and circulation indices are relatively low. The end of vegetation of rye, which in Türi starts on an average on 29th October, is the only autumn phase which has correlation with NAOI. The correlation with NAOI of October is 0.6. Correlations with studied climate parameters are similarly small for colouring and falling of leaves (birch, apple, maple), only a weak correlation can be detected with mean monthly temperatures (r < 0,5).

Arrival time of migratory birds is not only influenced by natural conditions of the arrival spot but also by conditions of wintering area and migration route. Apparently therefore arrival times of birds have stronger correlation with circulation indexes than with local weather parameters like air temperature. Circulation indexes like NAOI describe weather conditions of larger areas. Correlation of arrival times of 5 studied migratory bird species with NAO index is higher in early spring and decreases with evolvement of spring. For example: correlation of skylark arriving averagely on 23. March with NAOI is highest in March (r = -0.75); correlation of barn swallow arriving averagely on 2. May with NAOI of April is only -0.4. Birds' arrival has also a relevantly strong connection with air temperature rise over 0º.

4. References

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