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Application of Moran-Ricker model for analysis of *Bupalus piniarius* L. population dynamics

L.V. Nedorezov
University of Nova Gorica, Slovenia
E-mail: lev.nedorezov@ung.si

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Abstract
Statistical method of analysis of population time series in considered in current publication. This method is based on analysis of dynamics of non-linear ecological model parameter estimations in time, and devoted to investigation of influence of changing of weather conditions on population dynamics. Estimations of model parameters were obtained for all parts (which contains 12 measured values each) of initial sample. For the approximation of sub-samples the well-known Moran – Ricker model (Moran, 1950; Ricker, 1954) of isolated population dynamics was used. This model was used for the approximation of dataset of pine looper moth (*Bupalus piniarius* L.) dynamics in Germany (total sample size is 58; Schwerdtfeger, 1957, 1968). Estimation of model parameters were obtained with least squares method. Analyses of tendencies of model parameter estimations showed that there are no reasons for rejecting hypotheses about the equalities of regression line angles to zero. It gives the base for conclusion about the absence of serious changing in weather conditions in Germany during considering time interval (60 years).

Keywords population dynamics; *Bupalus piniarius*; estimation; model parameters; climate change.

1 Introduction

Various climatic factors have strong influence on insect population dynamics (Uwarov, 1931; Isaev et al., 2009; Vorontsov, 1978; Berryman, 1981; Schwerdtfeger, 1957, 1968; Tonnang, 2009, 2010 and others). Within the framework of climatic theory (Uwarov, 1931; Rafes, 1968) all observed in nature fluctuations of insect populations were explained from the standpoint of influence of various climatic factors.

Influence of climatic factors has a complex nature, and can be realized as in direct way as in indirect way (as changing of influence of other components of ecosystem – through the changing of influence of parasites, predators, competitors, food plants etc.). And these inluences must be taked into account under the constructing of various forecasts (Kondakov, 1974; Isaev et al., 2009; Tonnang et al., 2010; Nedorezov, 2012 a, b; Nedorezova and Nedorezov, 2012).

It is obvious that changing of living conditions for population (first of all, changing of climatic characteristics) leads to changing of basic population characteristics as productivity of individuals, death rates, intensity of influence of self-regulative mechanisms, intensity of interaction between various components of ecosystems etc.). Thus, if we have a model which gives suitable approximation of existing empirical datasets, then for sufficient big time series differences between estimations of models parameters obtained for initial part of the sample and tail of the sample, must be confidently different (in a result of changing of weather conditions for a long time interval and respective changing of living conditions for individuals).

For any fixed integer values m and r (which are less than sample size N) it is possible to estimate model parameters using sub-sample x_r, $x_{r+1},\ldots,$ x_{r+m}, where $r \geq 1$, $r+m \leq N$. Obtained estimations of model parameters are the characteristics of population dynamics on the respective time interval (for $m+1$ years). These estimations of model parameters for all possible values of r form new time series, and for these time series we can find tendencies (linear regressions). If hypotheses of the equivalence of coefficients of incline of straight regression lines to zero can be rejected, it gives the background for conclusion that weather conditions were changed in considering time interval. If these hypotheses cannot be rejected, it means that (possible) changing of weather conditions hasn't confident influence onto population dynamics (but it doesn't mean that weather conditions didn't change at all). In this last case we can conclude that all observed fluctuations of model parameters have pure demographic nature or can be explained as results of used techniques of field measurements.

If we use for the approximation of datasets the well-known Moran – Ricker model (Moran, 1950; Ricker, 1954; Nedorezov and Utyupin, 2011):

$$y_{k+1} = a y_k e^{-b y_k}, \qquad (1)$$

where y_k is population size (or population density) at k th time moment (year); parameter a is equal to maximum value of coefficient of birth rate (coefficient of birth rate can be determined as relation of values of population densities of two nearest generations); parameter b is a coefficient of self-regulation (Nedorezov and Utyupin, 2011; Nedorezov, 2012 a, b). The initial sample contains the values of stochastic variables, thus estimations of model (1) parameters (which are determined as combinations of elements of considering initial sample) are also the values of any stochastic variables (Tamburino et al. 2012; Sharma and Raborn, 2011; Griebeler, 2011). Respectively, it allows applying of statistical methods for the analyses of these new samples (time series which are organized by the estimations of model parameters a and b obtained for all sub-samples with fixed values m and r) and for the determination of its trends.

Program described above for analyses of trends of estimations of model parameters (and determination of character of influence of weather condition changing on population dynamics regimes) may have several difficulties. First of all, the practice of the use of non-linear mathematical models for the approximation of empirical datasets shows (see, for example, Nedorezov and Sadykova, 2010; Nedorezov et al., 2008; Tonnang et al., 2009, 2010; Nedorezov, 2012 a, b) that even for short time series (10-15 values) models of the type (1) can give bad approximation. It determines by the behavior of the sequence of deviations between theoretical (model) trajectory and empirical time series (Draper and Smith, 1986, 1987).

The second, sometimes approximation of short time series with models of the type (1) leads to long-term calculations (in particular, in a result of selection of initial values of parameters for iteration process). The third, if model gives sufficient approximation for some parts of initial sample and gives insufficient approximation for other parts of the sample there appears a question – can we use all obtained estimations of model parameters (for the determination of trends) or we have to use part of them which correspond to sufficient approximations only?

In current publication model (1) was used for fitting of the sub-samples of time series of pine looper moth (*Bupalus piniarius* L.) population dynamics. For every sub-sample sequence of deviations between model trajectory and real data were analyzed by several statistical tests. Sets of deviations were tested for Normality (Kolmogorov – Smirnov test, Lilliefors test, Shapiro – Wilk test; Bolshev and Smirnov, 1983; Lilliefors, 1967;

Shapiro et al., 1968), for equivalence of averages to zero, and for absence/existence of serial correlation (test of series, Durbin – Watson test; Draper and Smith, 1986, 1987).

For some cases Durbin – Watson criterion doesn't allow obtaining a conclusion about absence or presence of serial correlation in a sequence of residuals. For these cases behaviour of auto-correlation function was analyzed. Even for cases when Durbin – Watson criterion showed that there is no serial correlation in a sequence of residuals, auto-correlation function was analyzed too: this test allows finding of the correlation of the first order only. For the identification of dependencies with time lag 2, 3 or more we have to use auto-correlation function.

For sequences of estimated values of model parameters linear regressions were built, and hypotheses of the equivalence of angles of linear regression lines to zero were tested with Theil criteria (Theil, 1950; Hollander, Wolfe, 1973). As it was shown for various combinations of sub-samples of time series of model coefficients there are no reasons to reject Null hypotheses about the equivalence of angles to zero. It allows conclusion about the absence of confident influence of climate changing on population dynamics (Germany, 1881-1940; Schwerdtfeger, 1957, 1968).

2 Methods of Time Series Analysis

Let x_1, $x_2, \ldots, x_N$ be an initial time series, N is number of years (sample size), and x_k is a population density at k th year. For every sub-sample of the type x_r, $x_{r+1}, \ldots,$ x_{r+m}, $r, m \geq 1$, $r + m \leq N$ (we put $m = 11$ for every analyzed sub-sample) the values of Moran – Ricker model (1) parameters $a^* = a^*(r)$, $b^* = b^*(r)$, and $y_1^* = y_1^*(r)$ were estimated with the following condition:

$$Q(r, m, a^*, b^*, y_1^*) = \min_{a,b,y_1} \sum_{j=r}^{r+m} (x_j - f(j, a, b, y_1))^2 , \qquad (2)$$

where y_1 is initial value for the population density in model (1), $f(j, a, b, y_1)$ is the respective value obtained with model (1) for concrete values of parameters a, b, and initial value y_1: $f(r, a, b, y_1) = y_1$, $f(r+1, a, b, y_1) = y_2$ and so on. In (2) a^*, b^*, and y_1^* are the estimations of parameters (initial value of population density is unknown parameter which must be estimated with existing sample) which give us a minimum. Use of formula (2) means that in the set of all trajectories of model (1) we have to find the best one which is closest to our sample.

In a result of approximation of all subsets of considering time series, we have $N - m$ values of estimations of parameters a and b: we get two new time series: $a_1, \ldots,$ a_{N-m} and $b_1, \ldots,$ b_{N-m}. But as it was pointed out above, we cannot exclude the situation when we can't use all elements of these new samples for obtaining confidence results about the tendencies of population parameters chaging. It depends on the properties of the sequences of the residuals between theoretical (model) results (which were obtained with estimated model parameters) and empirical datasets.

Deviations must have Normal distribution with zero average (more precisely, the respective hypotheses couldn't be rejected for selected significance level). For this reason Kolmogorov – Smirnov test, Lilliefors test, and Shapiro – Wilk test were used (Bolshev and Smirnov, 1983; Lilliefors, 1967; Shapiro et al. 1968). In the sequence of residuals the serial correlation cannot be also observed (Draper, Smith, 1986, 1987). If use of one or other statistical criteria allowed rejecting the respective hypothesis (hypothesis about equivalence of average to zero, hypothesis about absence of serial correlation etc.), then we had reasons to conclude that model isn't suitable for fitting of the respective subset. And we concluded that model (1) is suitable for fitting of any sub-sample if all used criterions didn't allow rejecting of respective Null hypotheses.

It is important for the analysis of influence of weather conditions onto population dynamics to give analyses of tendencies of estimations of parameters a and b in time. It is obvious that values $a_1, \ldots, a_{N-m}$ and $b_1, \ldots, b_{N-m}$ are stochastic numbers. But it is very difficult to present any truthful hypothesis about the distribution of deviations between elements of these time series and respective real values of population parameters. Thus, for checking tendencies of these time series non-parametric Theil criterion was used (Theil, 1950; Hollander, Wolfe, 1973). If this criterion allows rejecting the hypothesis about equivalence of coefficient of incline of regression line to zero, then we have background for the conclusion that there is no confidence influence of external factors onto population dynamics. If we have no reasons for rejecting of this hypothesis it means that selected conditions of analysis (selected model, selected size of subsets etc.) don't allow proving that population dynamics had serious changing in time.

Let g be a coefficient of incline of linear regression line. In considering situation checking of the hypothesis $H_0 : g = 0$ (vs. alternative hypothesis $H_1 : g \neq 0$) we have to provide with non-parametric Theil criteria (Theil, 1950; Hollander and Wolfe, 1973):

$$C = \sum_{i<j}^{N} c(x_j - x_i),$$

where $c(z)$ is determined by the next formula:

$$c(z) = \begin{cases} 1, \textit{npu } z > 0, \\ 0, \textit{npu } z = 0, \\ -1, \textit{npu } z < 0. \end{cases}$$

For big samples the following statistics

$$C^* = \frac{C}{(N(N-1)(2N+5)/18)^{0.5}}$$

(when hypothesis H_0 is truthful) has Normal distribution with parameters $(0,1)$ asymptotically. Critical value for statistics C^* for 5% significance level is equal to 1.96 approximately.

Remark 1. One of very important items is selection of value of the length of sub-sample. If we put $m = 11$ it means that sub-sample size is equal to 12. Thus, for the estimation of one of three unknown parameters of model (1) we have four real values. It means that confidence of obtained results can be insufficient. On the other hand, increase of the amount of m leads to decrease of the number of cases when model gives sufficient approximation of sub-samples (from the standpoint of applied statistical criterions). When m is close to 30, we can obtain a situation when model cannot give sufficient fitting of real values – time interval is rather long, and sufficient for confident changing of model parameters. Anyway, full investigation of considering situation requires analysis of tendencies for various values of m, but it can lead to extremely big time of calculations.

Remark 2. The second important problem is selection of mathematical model for fitting of considering datasets. It's known that now we haven't criterions for model selection (before comparison of theoretical and empirical datasets). It is possible to point out several indirect criterions (like ability of dynamical regimes which can be observed in model, number of previous success results of application of model to various datasets and so on) but these criterions cannot give guarantee that in concrete situation good results will be observed too. Thus, for obtaining confidence results it is better to use various mathematical models.

3 Used Datasets

In current publication well-known datasets by F. Schwerdtfeger (1957, 1968) on fluctuations of pine looper moth (*Bupalus piniarius* L.) densities in Germany were used. These time series can be free downloaded in Internet (NERC Centre for Population Biology, Imperial College (1999) The Global Population Dynamics Database, N 3759). Datasets are presented in units «number of larvae per squared meter of forest floor in December”. The total number of elements in the sample is 58 ($N = 58$); values of density for 1911 and 1912 are absent.

4 Results

As it was pointed out above, estimations of Moran – Ricker model (1) parameters were obtained for sub-samples, and every sub-sample contains 12 real values ($m = 11$). If we hadn’t gaps in sub-sample (i.e. sub-sample didn’t contain gap corresponding to 1911 and 1912), estimations of model parameters characterize population dynamics on the respective 12-years time interval. If the gap (1911 and 1912) was inside the sub-sample, estimations of model parameters characterize population dynamics on the respective 14-years time interval. Results of approximation of all sub-samples by Moran – Ricker model (1) and results of statistical analyses of all sets of residuals are presented in tables 1, 2 and 3.

In table 3 there are the results of testing of Null hypotheses when respective values of autocorrelation function are equal to zero. It was obtained that for $r = 12,13,19,34$ (table 3) we have to reject hypotheses about the absence of dependencies in sequences of residuals: for $r = 12,13,19$ and 5% significance level values of autocorrelation function are confidently differed from zero for time lag 3. For $r = 13,34$ and the same significance level values of autocorrelation function are confidently differed from zero for time lag 4. Taking into account that for all considering situations Null hypotheses about Normality of sets of deviations cannot be rejected (table 2), we get background for conclusion that in considering cases we can observe dependencies in sequences of residuals. Note that for $r = 19$ Durbin – Watson criterion showed that there is no serial correlation in sequence of residuals.

Finally, in 20 cases model (1) gives good approximation of analyzing sub-samples. Results of approximation of sub-samples $a = a(r)$ and $b = b(r)$, and linear regression lines are presented on figures 1 and 2:

$$a(r) = 0.0018r + 1.8057, \ R^2 = 0.0007,$$

$$b(r) = -0.0034r + 0.6819, \ R^2 = 0.0074.$$

As we can see, coefficients of inclines of both straight lines are rather small. Coefficient of first line $a(r)$ is positive: maximum of population birth rate has tendency for increasing (Fig. 1). Coefficient of the second line $b(r)$ has the tendency for decreasing: it means that intra-population competition between individuals decreases (Fig. 2). Consequently, increasing of one coefficient and decreasing of another one mean that environmental conditions become better for population: for every fixed value of current generation the next generation becomes bigger in time.

Table 1 Estimations of model (1) parameters for all subsets*

N	x_0	a	b	$Q_{\min}$	$\bar{x}$	$(N-1)s_x^2$
1	$1.18 \cdot 10^{-3}$	3.73	1.55	5.233	0.59	5.767
2	$4.65 \cdot 10^{-3}$	3.70	1.71	5.098	0.56	5.864
3	$1.62 \cdot 10^{-2}$	3.74	1.68	5.007	0.60	5.910
4	$5.69 \cdot 10^{-2}$	3.77	1.70	4.991	0.65	5.694
5	0.93	0.93	$5.36 \cdot 10^{-16}$	5.356	0.65	5.707
6	1.30	0.86	$5.36 \cdot 10^{-16}$	4.386	0.65	5.690
7	1.93	0.88	0.14	2.850	0.64	5.766
8	2.47	1.75	1.23	0.845	0.58	4.771
9	$9.83 \cdot 10^{-2}$	1.26	$1.94 \cdot 10^{-16}$	1.305	0.51	2.320
10	0.14	1.23	$1.68 \cdot 10^{-16}$	1.262	0.58	2.761
11	0.23	1.25	0.14	1.733	0.62	2.562
12	0.28	1.41	0.43	2.402	0.60	2.725
13	0.28	4.79	2.50	2.601	0.60	2.740
14	0.90	2.13	1.31	2.587	0.60	2.686
15	0.89	4.21	2.69	2.538	0.55	2.658
16	$4.69 \cdot 10^{-2}$	3.51	2.08	2.360	0.51	2.735
17	0.78	0.92	$7.59 \cdot 10^{-17}$	2.372	0.51	2.716
18	1.01	0.87	$1.71 \cdot 10^{-16}$	1.835	0.50	2.797
19	1.37	0.78	$1.17 \cdot 10^{-16}$	0.931	0.48	2.966
20	1.70	0.73	0.13	0.243	0.41	2.850
21	1.22	1.05	0.84	0.133	0.29	1.189
22	0.60	3.61	5.74	0.193	0.24	0.356
23	$5.77 \cdot 10^{-2}$	1.19	$3.64 \cdot 10^{-17}$	0.256	0.25	0.472
24	$2.03 \cdot 10^{-4}$	2.01	$4.48 \cdot 10^{-17}$	0.319	0.39	2.677
25	$2.81 \cdot 10^{-9}$	6.04	1.25	0.473	0.47	3.059
26	$2.22 \cdot 10^{-6}$	3.84	1.19	1.053	0.48	3.039
27	$9.02 \cdot 10^{-5}$	3.10	1.29	1.753	0.47	3.149
28	$4.20 \cdot 10^{-4}$	3.02	1.52	2.250	0.46	3.227
29	$1.34 \cdot 10^{-3}$	3.05	1.72	2.467	0.46	3.188
30	$3.90 \cdot 10^{-3}$	3.14	1.95	2.693	0.47	3.144
33	0.11	3.17	2.00	2.698	0.51	2.953
34	0.77	0.93	$5.34 \cdot 10^{-16}$	2.579	0.55	2.807
35	0.93	0.99	0.11	2.555	0.61	2.859
36	1.07	1.35	0.47	4.422	0.73	4.647
37	$1.96 \cdot 10^{-3}$	2.02	$5.76 \cdot 10^{-16}$	4.891	1.04	17.540
38	$2.15 \cdot 10^{-7}$	6.18	0.51	2.418	1.12	19.671
39	$6.50 \cdot 10^{-5}$	3.94	0.53	8.266	1.07	20.026
40	$1.20 \cdot 10^{-3}$	3.29	0.57	11.320	1.07	20.026
41	$7.86 \cdot 10^{-3}$	3.04	0.63	13.685	1.09	19.574
42	$3.22 \cdot 10^{-2}$	2.94	0.70	15.560	1.11	19.193
43	$9.71 \cdot 10^{-2}$	2.93	0.74	15.982	1.16	18.424
44	0.28	2.92	0.79	16.608	1.20	17.664
45	1.78	0.95	$1.98 \cdot 10^{-16}$	17.159	1.34	17.978
46	2.22	0.91	$6.57 \cdot 10^{-15}$	15.182	1.39	17.420
47	3.02	0.92	$5.03 \cdot 10^{-2}$	12.043	1.34	18.284
48	4.47	1.13	0.24	5.349	1.21	18.351
49	2.77	2.12	0.97	2.964	0.89	6.793

* N is a number of subset; x_0 is estimation of initial point for the respective subset; a, b are the estimations of model (1) parameters; $Q_{\min}$ is respective value of functional form (2); $\bar{x}$ is average for respective subset; $(N-1)s_x^2$ is sum of squared deviations (real values from averages) for the same samples.

Table 2 Results of analyses of sets of deviations*

N	$\bar{e}$ ±SE	KS	SW	DW	ST
1	-0.094±0.197	0.144/p>0.2	0.925/p=0.327	1.132	6,6,4,0.067
2	-0.039±0.196	0.195/p>0.2	0.852/p=0.039	1.164	5,7,4,0.076
3	-0.012±0.195	0.262/p>0.2	0.832/p=0.022	1.259	5,7,5,0.197
4	-0.002±0.194	0.260/p>0.2	0.818/p=0.015	1.267	4,8,6,0.533
5	0.004±0.201	0.325/p<0.15	0.819/p=0.015	1.37	4,8,5,0.279
6	0.003±0.182	0.212/p>0.2	0.897/p=0.144	1.682	4,8,5,0.279
7	-0.011±0.147	0.188/p>0.2	0.901/p=0.165	2.125	4,8,6,0.533
8	-0.006±0.080	0.193/p>0.2	0.902/p=0.170	1.644	4,8,6,0.533
9	-0.040±0.099	0.141/p>0.2	0.942/p=0.531	1.109	6,6,5,0.175
10	-0.015±0.098	0.179/p>0.2	0.919/p=0.274	1.497	5,7,6,0.424
11	-0.004±0.115	0.168/p>0.2	0.930/p=0.375	1.359	6,6,6,0.392
12	-0.0009±0.135	0.165/p>0.2	0.964/p=0.836	1.064	5,7,5,0.197
13	0.002±0.140	0.147/p>0.2	0.915/p=0.250	0.868	5,7,5,0.197
14	0.0002±0.140	0.192/p>0.2	0.882/p=0.094	0.837	6,6,4,0.067
15	-0.003±0.139	0.289/p>0.2	0.813/p=0.013	0.708	4,8,3,0.024
16	-0.005±0.134	0.200/p>0.2	0.899/p=0.153	0.658	6,6,4,0.067
17	0.008±0.134	0.224/p>0.2	0.895/p=0.137	0.766	4,8,3,0.024
18	0.017±0.118	0.280/p>0.2	0.898/p=0.149	1.028	4,8,3,0.024
19	0.013±0.084	0.229/p>0.2	0.912/p=0.230	1.669	4,8,5,0.279
20	-0.019±0.043	0.157/p>0.2	0.928/p=0.356	1.493	4,8,4,0.109
21	0.0007±0.032	0.168/p>0.2	0.939/p=0.483	1.952	5,7,5,0.197
22	-0.0003±0.038	0.160/p>0.2	0.911/p=0.221	0.432	5,7,5,0.197
23	-0.022±0.044	0.137/p>0.2	0.947/p=0.598	0.424	5,7,3,0.015
24	-0.104±0.038	0.139/p>0.2	0.961/p=0.802	0.179	2,10,3,0.182
25	-0.139±0.043	0.113/p>0.2	0.965/p=0.858	0.083	2,10,4,0.455
26	-0.087±0.085	0.216/p>0.2	0.880/p=0.087	1.706	3,9,4,0.200
27	-0.042±0.115	0.233/p>0.2	0.866/p=0.057	1.227	3,9,4,0.200
28	-0.023±0.130	0.235/p>0.2	0.871/p=0.068	0.982	4,8,4,0.109
29	-0.010±0.137	0.265/p>0.2	0.871/p=0.068	0.912	5,7,4,0.076
30	-0.004±0.143	0.217/p>0.2	0.857/p=0.045	0.846	6,6,4,0.067
33	-0.0001±0.143	0.213/p>0.2	0.849/p=0.036	0.894	5,7,4,0.076
34	0.003±0.140	0.163/p>0.2	0.885/p=0.100	1.0	5,7,4,0.076
35	-0.0001±0.139	0.163/p>0.2	0.896/p=0.139	1.038	5,7,4,0.076
36	0.003±0.183	0.196/p>0.2	0.869/p=0.064	0.863	4,8,4,0.109
37	-0.316±0.167	0.309/p<0.2	0.724/p=0.001	0.257	2,10,3,0.182
38	-0.292±0.103	0.184/p>0.2	0.903/p=0.171	0.520	2,10,4,0.455
39	-0.149±0.246	0.321/p<0.15	0.745/p=0.002	1.389	2,10,4,0.455
40	-0.073±0.292	0.274/p>0.2	0.822/p=0.017	1.183	3,9,4,0.200
41	-0.044±0.322	0.239/p>0.2	0.868/p=0.062	1.042	4,8,4,0.109
42	-0.030±0.343	0.180/p>0.2	0.873/p=0.071	0.942	6,6,4,0.067
43	-0.015±0.348	0.179/p>0.2	0.855/p=0.043	0.943	5,7,4,0.076
44	-0.010±0.355	0.187/p>0.2	0.820/p=0.016	0.916	4,8,4,0.109
45	0.002±0.361	0.253/p>0.2	0.815/p=0.014	1.085	4,8,4,0.109
46	-0.006±0.339	0.188/p>0.2	0.882/p=0.094	1.289	4,8,4,0.109
47	-0.013±0.302	0.194/p>0.2	0.895/p=0.139	1.656	4,8,5,0.279
48	0.010±0.201	0.232/p>0.2	0.892/p=0.125	1.666	5,7,6,0.424
49	-0.009±0.150	0.266/p>0.2	0.765/p=0.004	1.635	4,8,7,0.788

* N is a number of subset; $\bar{e}$ ±SE is average for deviations plus-minus standard error; KS is value of Kolmogorov – Smirnov test and respective probability; SW is value of Shapiro – Wilk test and respective probability; DW is value of Durbin – Watson criteria for the respective subset; ST is result of application of the serial test: first and second numbers correspond to deviations with different signs, third number is the number of sets of deviations with one and the same signs, fourth number is the respective (cumulative) probability (Swed Frieda and Eisenhart, 1943).

Table 3 Values of autocorrelation function for some sequences of residuals*

	Time lag			
	1	2	3	4
1	0.378/0.309/1.225	-0.188/0.347/0.541	-0.295/0.361/0.816	-0.388/0.376/1.032
6	0.092/0.332/0.278	-0.583/0.287/2.031	-0.229/0.368/0.624	-0.283/0.392/0.724
7	-0.082/0.332/0.247	-0.258/0.342/0.755	-0.077/0.377/0.205	-0.359/0.381/0.941
8	0.072/0.332/0.217	-0.627/0.275/2.278	-0.54/0.318/1.696	0.149/0.404/0.368
9	0.383/0.308/1.243	-0.278/0.34/0.82	-0.475/0.333/1.43	-0.448/0.365/1.229
10	0.243/0.323/0.75	-0.418/0.321/1.303	-0.442/0.339/1.305	-0.321/0.387/0.831
11	0.278/0.32/0.869	-0.577/0.289/1.999	-0.647/0.288/2.244	-0.317/0.387/0.818
12	0.414/0.303/1.363	-0.495/0.307/1.611	-0.824/0.214/3.85	-0.577/0.334/1.729
13	0.55/0.278/1.975	-0.263/0.341/0.77	-0.747/0.251/2.977	-0.728/0.28/2.604
19	0.059/0.333/0.177	-0.654/0.267/2.446	-0.841/0.204/4.119	0.146/0.404/0.363
20	0.245/0.343/0.713	-0.538/0.319/1.689	-0.341/0.384/0.89	0.013/0.447/0.03
21	-0.015/0.378/0.039	-0.507/0.352/1.44	-0.29/0.428/0.677	-0.027/0.5/0.055
26	-0.191/0.491/0.389	-0.537/0.487/1.103	---	---
27	0.272/0.43/0.632	-0.462/0.443/1.043	-0.621/0.452/1.373	---
28	0.467/0.361/1.292	-0.186/0.439/0.424	-0.66/0.375/1.759	-0.49/0.503/0.974
29	0.528/0.321/1.646	-0.009/0.408/0.023	-0.504/0.386/1.306	-0.549/0.418/1.318
34	0.472/0.294/1.607	-0.134/0.35/0.382	-0.615/0.298/2.065	-0.762/0.264/2.882
35	0.439/0.3/1.466	-0.187/0.347/0.538	-0.608/0.3/2.026	-0.594/0.328/1.808
36	0.49/0.291/1.685	0.04/0.353/0.112	-0.276/0.363/0.761	-0.503/0.353/1.425
41	0.44/0.299/1.472	-0.283/0.339/0.833	-0.558/0.314/1.778	-0.339/0.384/0.883
42	0.506/0.287/1.76	-0.13/0.351/0.372	-0.305/0.36/0.846	-0.422/0.37/1.14
46	0.323/0.315/1.024	-0.375/0.328/1.144	-0.512/0.325/1.577	-0.436/0.367/1.186
47	0.132/0.33/0.401	-0.298/0.337/0.884	-0.257/0.365/0.705	-0.462/0.362/1.275
48	0.165/0.329/0.503	-0.041/0.353/0.117	-0.249/0.366/0.682	-0.586/0.331/1.772

*In all cells of the table there are the values of autocorrelation function/ with respective errors/ and values of Student's test.

In first case we have $C = -4$. For the second case C is equal to 3. When sample size is equal to 20 we have $P\{|C| \geq 60\} = 0.054$, thus, there are no reasons for rejecting Null hypotheses about equivalence of coefficients of straight line inclines to zero. It means that observed tendencies in coefficients changing are not confident.

In figures 3 and 4 there are the tendencies of changing of model parameters for all obtained estimations:

$$a(r) = 9 \cdot 10^{-5} r + 2.3858,\ R^2 = 8 \cdot 10^{-7},$$

$$b(r) = -0.0134r + 1.2055,\ R^2 = 0.0335.$$

As we can see, in this situation the similar situation with tendencies of model parameters is observed: maximum of birth rate increases and intra-population competition decreases. For both variants we have $C = -35$, $C^* = -0.32097$ and $C = -59$, $C^* = -0.54106$. For 5% significance level (double-sided criterion) critical level for statistics C^* is 1.96. Thus, we have the inequality $|C^*| < 1.96$, and cannot reject the Null hypotheses. Like in previous case the observed tendencies are not confident.

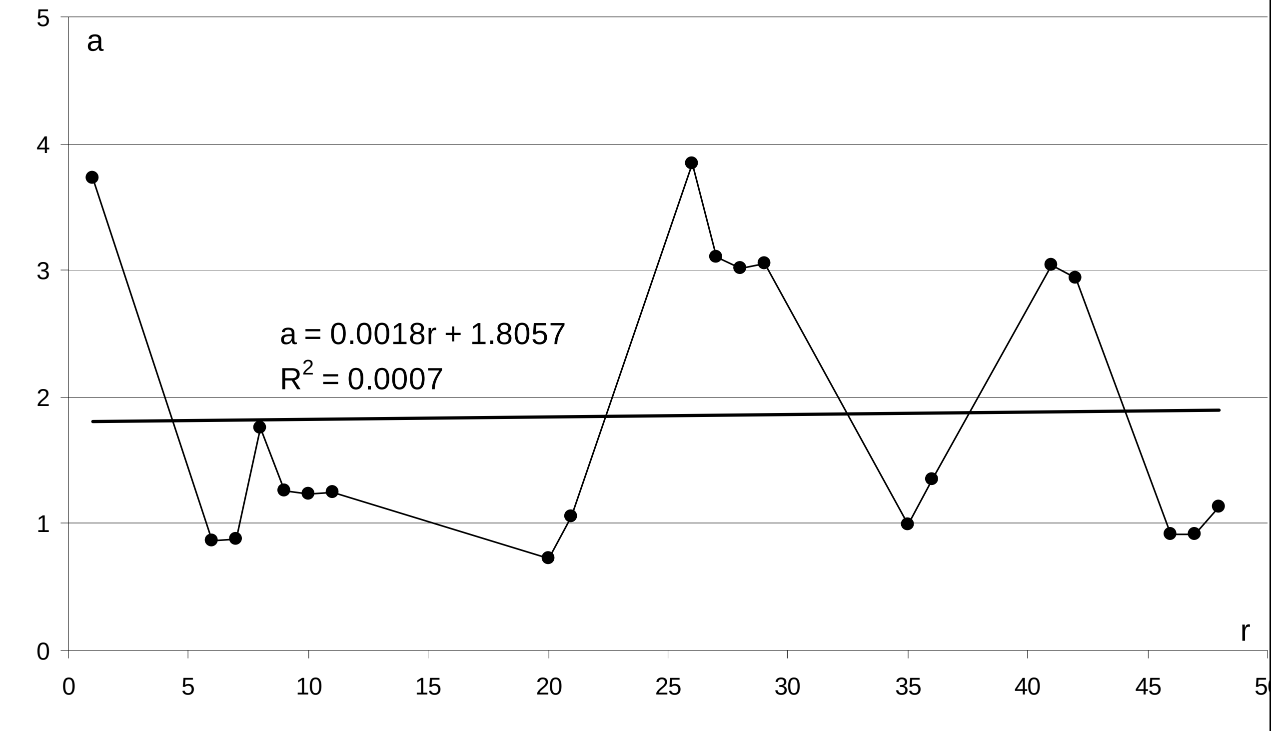

Fig. 1 Changing of parameter $a = a(r)$ for the cases when model (1) gives suitable fitting for the respective sub-samples.

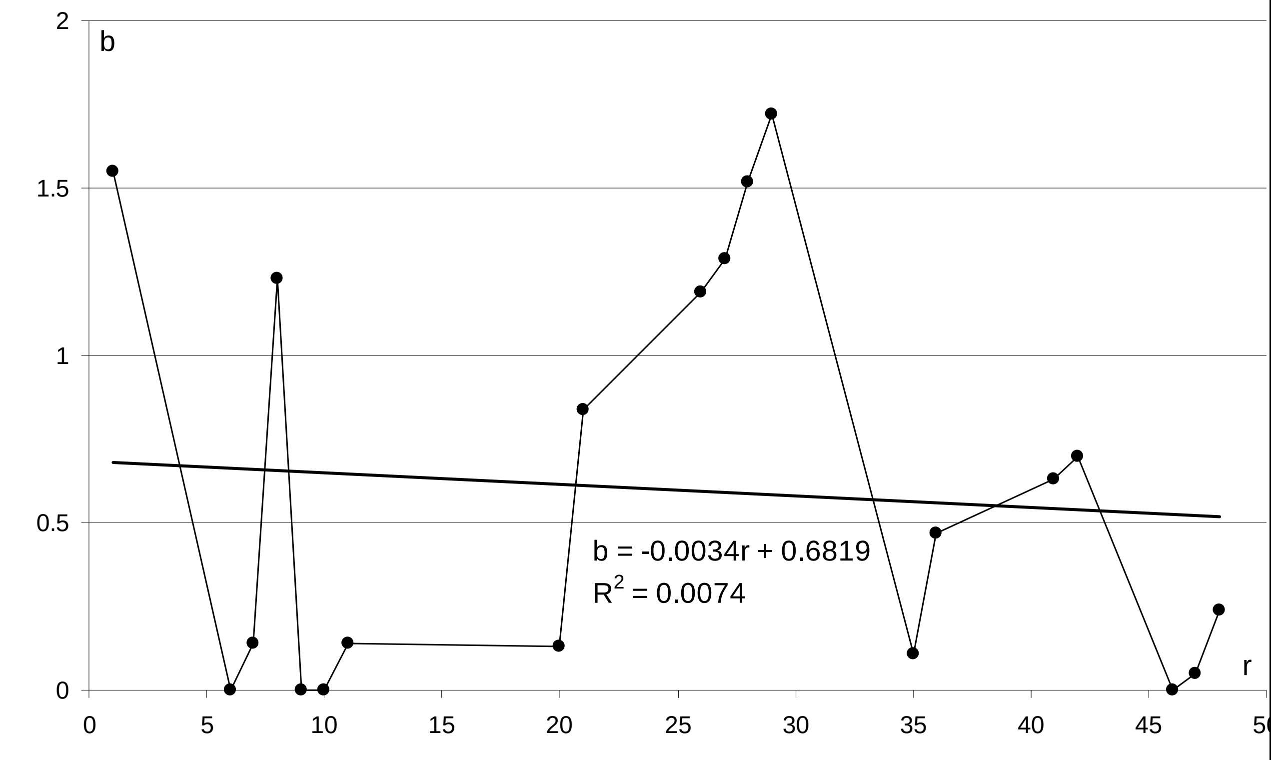

Fig. 2 Changing of parameter $b = b(r)$ for the cases when model (1) gives suitable fitting for the respective sub-samples.

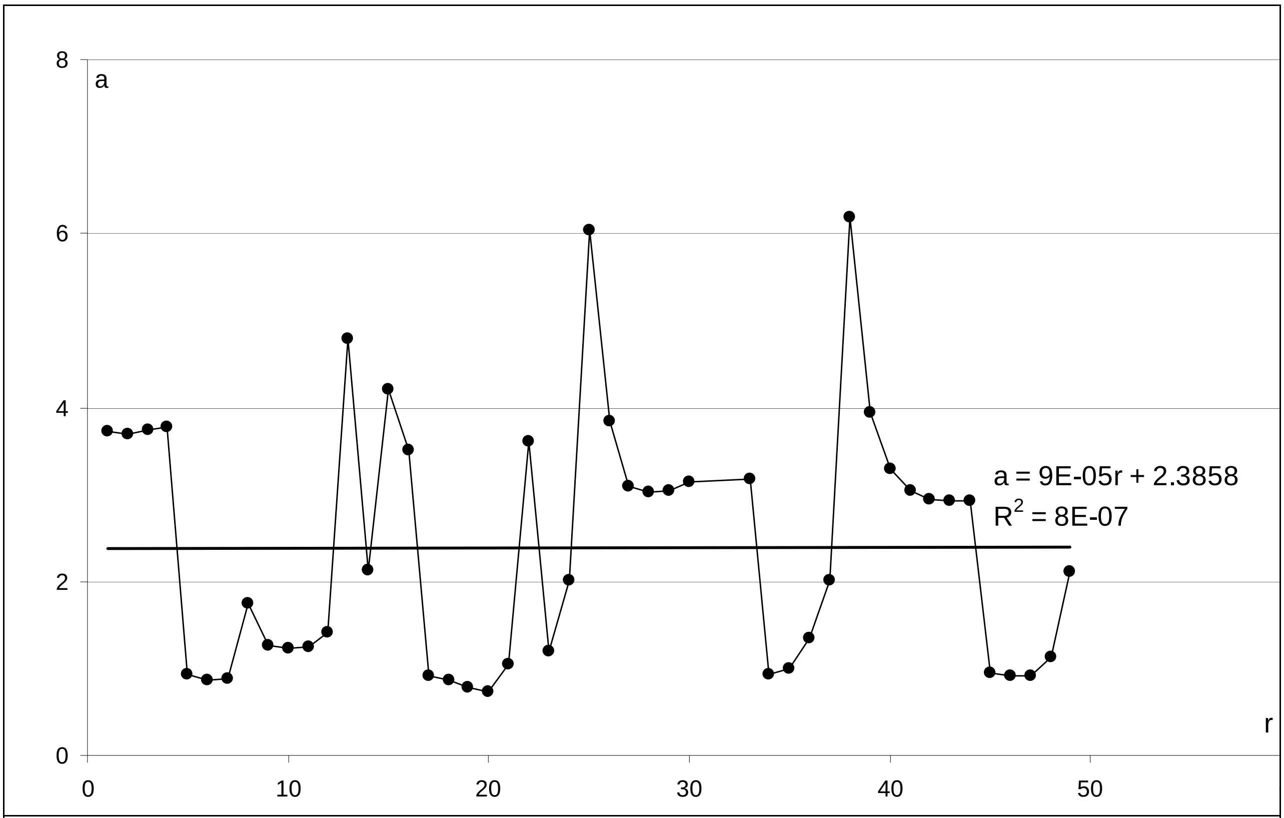

Fig. 3 Changing of parameter $a = a(r)$ for all cases when model (1) gives suitable or unsuitable fitting for sub-samples.

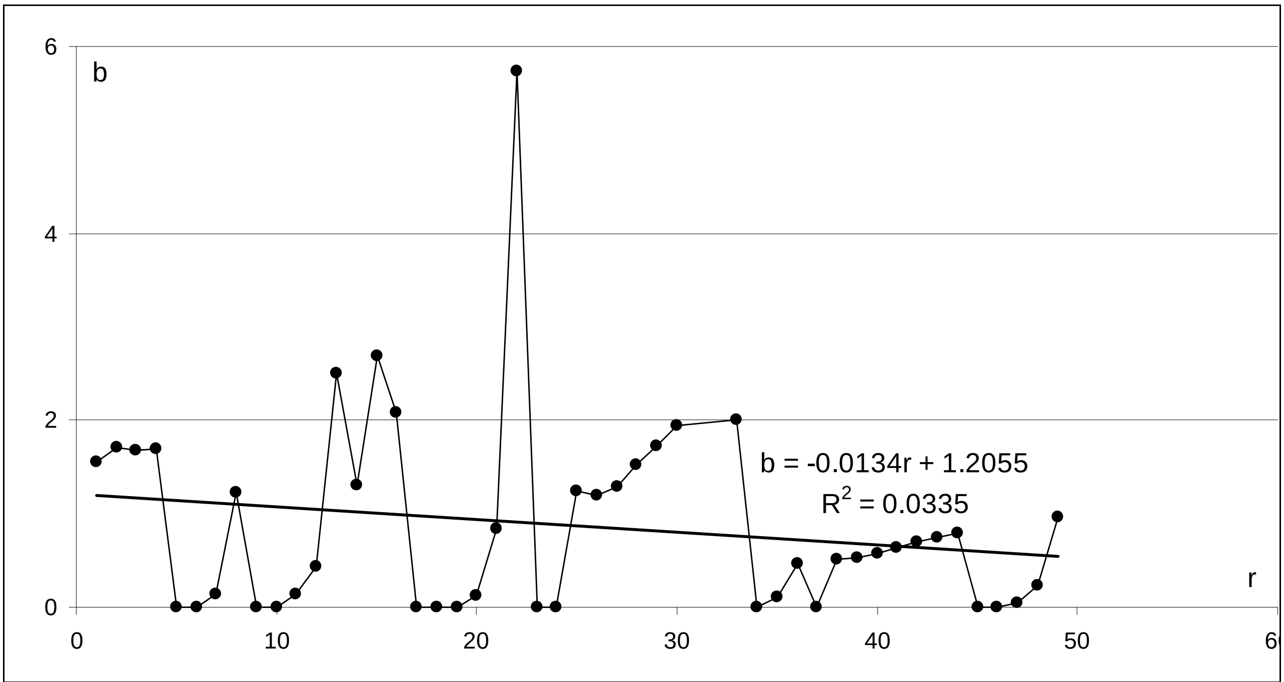

Fig. 4 Changing of parameter $b = b(r)$ for all cases when model (1) gives suitable or unsuitable fitting for sub-samples.

5 Conclusion

It is rather simple idea which was considered in current publication. For the analysis of influence of changing of weather conditions initial sample (on changing of population size or population density in time) was transformed with the use of non-linear mathematical model (Moran – Ricker model) to some other time series; and these new time series (which were formed by estimations of basic population parameters) were analyzed with known statistical methods. Considered in current publication the time series on fluctuations of pine looper moth density in Germany (Schwerdtfeger, 1957, 1968) was transformed into two new time series – changing in time of maximum of population growth rate and coefficient of intra-population competition (coefficient of self-regulation). Analysis of these time series showed that there are no reasons for conclusion that changing of external conditions (during 60 years) had confidence influence onto basic population characteristics.

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