Article

Fluctuations of population dynamics model parameters: View on the problem of climate change

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

Received 26 August 2012; *Accepted 29 September 2012*; *Published online 1 December 2012*
IAEES

Abstract
In current publication the statistical method of analysis of population time series in considered. This method is based on analysis of dynamics of non-linear ecological model parameter estimations in time, and devoted to investigation of influence of change of weather conditions on population dynamics (on the other words, it is devoted to analysis of climate change from the standpoint of separated population dynamics). Estimations of model parameters were obtained for parts (which contains 12 values each) of initial sample. For the approximation of sub-samples the well-known Kostitzin model of population size changing in time was used. It was used for the approximation of dataset of pine looper moth (*Bupalus piniarius* L.) dynamics in Germany (total sample size is 58). Estimation of model parameters were obtained with known 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 change in weather conditions in Germany during analyzing time interval (60 years).

Keywords population dynamics; estimation; model parameters; climate change.

1 Introduction

Climatic factors have strong influence on insect population fluctuations (Isaev et al., 2009; Vorontsov, 1978; Berryman, 1981; Schwerdtfeger, 1957, 1968; Tonnang, 2009, 2010 and others). This influence 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, food plants etc.). Taking it into account, we can conclude that attempts to find strong direct correlations between population size changing in time and dynamics of any weather factor (or group of weather factors) haven’t a good base and perspectives. On the other hand such attempts can be very useful for constructing various forecasts (Kondakov, 1974; Isaev et al., 2009; Tonnang et al., 2010; Nedorezov, 2012 a, b; Nedorezova, Nedorezov, 2012).

It is naturally to assume that changing of living conditions (including changing of climatic characteristics) leads to changing of some population characteristics (productivity, death rates of individuals, intensity 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).

For any fixed integer values m and r (which are less than sample size) it is possible to estimate model parameters using sub-sample x_r, x_{r+1},…, x_{r+m}, where $r \geq 1$, $r+m \leq N$, where N is sample size. Obtained estimations of model parameters are the characteristics of population dynamics on the respective time interval. 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. In this last case all observed fluctuations of model parameters have pure demographic nature or can be explained as results of provided measurements.

If we use for the approximation of datasets the well-known Kostitzin model (Kostitzin, 1937; Nedorezov, Utyupin, 2011):

$$y_{k+1} = \frac{a y_k}{1 + b y_k}, \tag{1}$$

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, Utyupin, 2011; Nedorezov, 2012 a, b). The initial sample contains the values of stochastic variables, thus estimations of model (1) parameters (determined as combinations of elements of initial sample) are also the values of any stochastic variables (Tamburino, La Morgia, Venturino, 2012; Sharma, Raborn, 2011; Griebeler, 2011). Finally, it allows applying statistical methods for the analyses of these new samples and for the determination of its trends.

Program described above for analyses of trends of model parameters may have several difficulties. First of all, the practice of the use of non-linear mathematical models for the approximation of empirical datasets shows (Nedorezov, Sadykova, 2005, 2008, 2010; Nedorezov, Lohr, Sadykova, 2008; Tonnang et al., 2009, 2010; Nedorezov, 2011 a, b, 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 trajectory (Draper, 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 bad 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 the trends) or we have to use part of them which correspond to sufficient approximations only?

In current publication we use model (1) for fitting the sub-samples of time series of pine looper (*Bupalus piniarius* L.) population dynamics. For every sub-sample sequences of deviations between model trajectory and real data were analyzed. Sets of deviations were tested for Normality (Kolmogorov – Smirnov test, Lilliefors test, Shapiro – Wilk test; Bolshev, Smirnov, 1983; Lilliefors, 1967; Shapiro, Wilk, Chen, 1968), for equivalence of averages to zero, and for absence/existence of serial correlation (test of series, Durbin – Watson test; Draper, Smith, 1986, 1987). 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,..., 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},..., x_{r+m}, $r,m \geq 1$, $r+m \leq N$ (we put $m = 11$ for every analyzed sub-sample) the values of Kostitzin model (1) parameters $a^* = a^*(r)$, $b^* = b^*(r)$, and $y_1^* = y_1^*(r)$ were estimated with the following condition:

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

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.

After the approximation of all subsets of existing time series, we obtain $N-m$ values of parameters a and b: we obtain two new time series: a_1,..., a_{N-m} and b_1,..., b_{N-m}. But as we pointed out above, we cannot exclude the situation when we have no reasons to use all elements of these new samples for obtaining confidence results about the tendencies of population parameters. It depends on the properties of the sequences of the residuals between theoretical (model) results (which were obtained with estimated model parameters) and empirical results.

First of all, 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, Smirnov, 1983; Lilliefors, 1967; Shapiro, Wilk, Chen, 1968). Additionally, in the sequence of residuals the serial correlation cannot be 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 respective 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,..., a_{N-m} and b_1,..., b_{N-m} are stochastic numbers. But it is very difficult to announce 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' criteria 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.

3 Used Datasets

In publication we use well-known datasets by F. Schwerdtfeger (1957, 1968) on fluctuations of pine looper moth (*Bupalus piniarius* L.) densities in Germany. 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" (Fig. 1). The total number of elements in the sample is 58 ($N = 58$); values of density for 1911 and 1912 are absent.

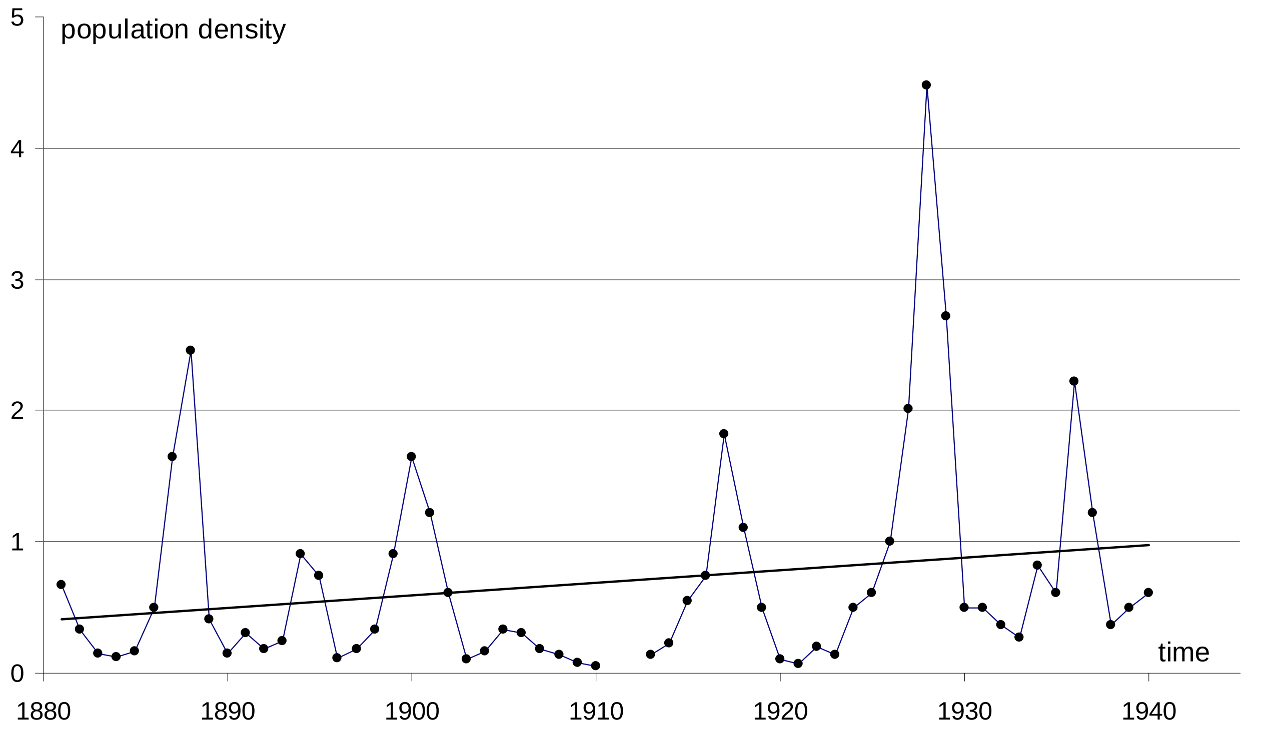

Fig. 1 Changing of pine looper moth density from 1881 to 1940 (red points; Schwerdtfeger, 1957, 1968). Regression line is determined by the equation (3).

Before the use of non-linear mathematical models for fitting of empirical time series we have to solve the following question: can we observe a tendency in population density? For initial sample we have the following regression line (Fig. 1):

$x = 0.009648t + 17.7392$,

(with $R^2 = 0.045$; estimations of values of regression coefficients were obtained with least square method) where x is population density, t is time (years). Average of deviations between regression line and empirical datasets is equal to zero; standard error is equal to 0.1037. Kolmogorov – Smirnov criteria shows that $d = 0.21476$, and even with 1% significance level we have to reject the hypothesis about Normality of the set of deviations. The same result was obtained with Lilliefors' test (Lilliefors, 1967). Shapiro – Wilk test (Shapiro, Wilk, Chen, 1968) gives $W = 0.73642$, and probability that set of deviations corresponds to Normal distribution is less than 10^{-5}.

Thus, there are no reasons for the use of parametric statistical methods (Draper, Smith, 1986, 1987; Lakin, 1990) for checking various hypotheses about values of coefficients of linear regression lines. Let g be a coefficient of incline of 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 methods of statistics. Non-parametric Theil criterion (Theil, 1950; Hollander, Wolfe, 1973) gives the following result:

$$C = \sum_{i<j}^{N} c(x_j - x_i) = 250,$$

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

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

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, $C^* = 1.677$. Critical value for 5% significance level is equal to 1.96 approximately. Thus, we have the inequality $C^* < 1.96$ and no reasons for rejecting Null hypothesis $g = 0$.

Considering sample can be (naturally) divided into two groups: before 1910 (30 values) and after 1913 (up to 1940; 28 values). For first subset the equation of linear regression is following:

$$x = -0.0124t + 23.959,$$

($R^2 = 0.0366$) with $C = -82$. For sample size 30 critical value of statistics C is equal to -111 (for 5% level of significance).

For the second subset the equation of linear regression is following:

$$x = 0.0175t + 32.847,$$

($R^2 = 0.0217$) with $C = 65$. For sample size 28 critical value of statistics C is equal to 100 (for 5% level of significance also). Consequently, in both considering cases there are no reasons for rejecting Null hypotheses about equivalence of coefficient of incline of regression lines to zero, $g = 0$. Note, that in both cases hypotheses H_0 cannot be rejected even with 10% significance level.

4 Results

As it was pointed out above estimations of 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 gaps corresponding to 1911 and 1912), estimations of model parameters characterize population dynamics on the respective 12-years time interval. If the gaps (1911 and 1912) were 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 and results of analyses of sets of residuals are presented in tables 1 and 2.

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

N	x_0	a	b	$Q_{\min}$	$\overline{x}$	$(N-1)s_x^2$
1	0.54	1.016	0	5.749	0.59	5.767
2	0.542	1.0043	0	5.863	0.555	5.864
3	0.575	1.0086	0	5.905	0.603	5.91
4	0.69	0.99	0	5.686	0.652	5.694
5	0.934	0.933	0	5.356	0.651	5.707
6	1.298	0.863	0	4.386	0.653	5.69
7	1.941	0.917	0.202	2.831	0.639	5.766
8	2.45	0.191	0	2.523	0.577	4.771
9	$9.826\cdot10^{-6}$	1.259	$1.764\cdot10^{-16}$	1.305	0.509	2.32
10	0.145	1.226	0	1.262	0.577	2.761
11	0.232	1.244	0.147	1.734	0.615	2.562
12	0.279	1.463	0.578	2.404	0.599	2.725
13	0.437	1.582	0.889	2.685	0.597	2.74
14	0.909	7.359	11.087	2.583	0.604	2.686
15	0.636	0.975	$2.368\cdot10^{-16}$	2.62	0.554	2.658
16	$1.35\cdot10^{-2}$	11.66	17.793	2.393	0.508	2.735
17	0.775	0.923	$6.563\cdot10^{-16}$	2.372	0.51	2.716
18	1.013	0.866	$5.275\cdot10^{-17}$	1.835	0.5	2.797
19	1.372	0.778	3.909	0.931	0.477	2.966
20	1.701	0.756	0.177	0.241	0.413	2.85
21	1.228	1.203	1.711	0.123	0.294	1.189
22	0.268	0.979	0	0.354	0.238	0.356
23	0.0577	1.193	0	0.256	0.249	0.472
24	$2.035\cdot10^{-4}$	2.01	$1.252\cdot10^{-16}$	0.319	0.393	2.677
25	$3.409\cdot10^{-2}$	1.335	$4.344\cdot10^{-17}$	0.949	0.471	3.059
26	$1.387\cdot10^{-7}$	5.897	4.5	1.134	0.485	3.039
27	$1.939\cdot10^{-7}$	7.538	7.627	1.786	0.468	3.149
28	$5.455\cdot10^{-7}$	9.282	11.514	2.267	0.458	3.227
29	2.367	11.129	15.68	2.478	0.464	3.188
30	1.361	13.54	21.452	2.702	0.469	3.144
33	$3.158\cdot10^{-2}$	13.961	22.531	2.706	0.506	2.953
34	0.774	0.934	0	2.579	0.545	2.807
35	0.166	1.19	0	2.569	0.61	2.859
36	0.569	1.044	0	4.596	0.732	4.647
37	$1.958\cdot10^{-3}$	2.017	$2.663\cdot10^{-16}$	4.891	1.044	17.54
38	$1.957\cdot10^{-6}$	5.413	1.23	4.109	1.119	19.671
39	$1.323\cdot10^{-6}$	7.822	2.734	8.882	1.068	20.026
40	$3.885\cdot10^{-5}$	6.851	2.880	11.697	1.068	20.026
41	$6.281\cdot10^{-4}$	6.277	3.05	13.949	1.09	19.574
42	$6.669\cdot10^{-3}$	5.963	3.275	15.755	1.107	19.193
43	$4.445\cdot10^{-2}$	5.976	3.484	16.141	1.159	18.424
44	0.245	6.186	3.875	16.735	1.198	17.664
45	0.539	11.019	6.996	17.306	1.342	17.978
46	2.222	0.909	0	15.182	1.393	17.42
47	3.032	0.932	$6.31\cdot10^{-2}$	12.021	1.341	18.284
48	4.541	1.39	0.563	4.941	1.214	18.351
49	1.265	0.932	0	6.362	0.891	6.793

N is the number of subsets; x_0 is estimation of initial point for the respective subset; a, b are the estimations of model (1) parameters; $Q_{\min}$ is value of functional form (2) for estimated parameters; $\overline{x}$ is average for respective subset; $(N-1)s_x^2$ is sum of squared deviations for the same sample.

Table 2 Results of analyses of sets of deviations

N	$\bar{e}$ ±SE	KS	SW	DW	ST
1	0.00037±0.209	0.299/p<0.2 (p<0.01)	0.6872/p=0.0006	1.225	3,9,4,0.200
2	-0.00003±0.211	0.363/p<0.1 (p<0.01)	0.622/p=0.00016	0.935	2,10,3,0.182
3	0.0001±0.212	0.301/p<0.2 (p<0.01)	0.688/p=0.0006	1.131	3,9,4,0.200
4	0.00009±0.208	0.265/p>0.2 (p<0.05)	0.768/p=0.0041	0.655	4,8,4,0.109
5	0.0036±0.201	0.325/p<0.15 (p<0.01)	0.8187/p=0.01541	1.37	4,8,5,0.289
6	0.0026±0.182	0.212/ p>0.2 (p<0.2)	0.8967/p=0.14379	1.682	4,8,5,0.289
7	-0.0062±0.146	0.199/p>0.2 (p<0.2)	0.8904/p=0.1191	2.16	4,8,6,0.533
8	-0.324±0.098	0.24/p>0.2 (p<0.1)	0.848/p=0.035	0.505	1,11,3,1.0
9	-0.0398±0.099	0.141/p>0.2	0.942/p=0.5305	1.109	6,6,5,0.175
10	-0.015±0.098	0.179/p>0.2	0.9185/p=0.2739	1.592	5,7,6,0.424
11	-0.003±0.115	0.166/p>0.2	0.9303/p=0.3837	1.36	6,6,6,0.392
12	-0.0003±0.135	0.166/p>0.2	0.963/p=0.8196	1.063	5,7,5,0.197
13	0.00004±0.143	0.15/p>0.2	0.9196/p=0.2826	0.95	5,7,5,0.197
14	0.00009±0.14	0.1902/p>0.2	0.8807/p=0.0895	0.8296	5,7,5,0.197
15	0.0007±0.141	0.211/p>0.2 (p<0.2)	0.8789/p=0.08475	0.663	5,7,4,0.076
16	-0.01±0.135	0.176/p>0.2	0.9025/p=0.171	0.68	6,6,4,0.067
17	0.0081±0.134	0.224/p>0.2 (p<0.1)	0.895/p=0.1365	0.791	4,8,3,0.024
18	0.0169±0.118	0.281/p>0.2 (p<0.01)	0.898/p=0.1494	1.018	4,8,3,0.024
19	0.013±0.084	0.229/p>0.2 (p<0.1)	0.9125/p=0.2297	1.669	4,8,5,0.289
20	-0.015±0.042	0.157/p>0.2	0.9357/p=0.4442	1.154	4,8,4,0.109
21	0.0009±0.031	0.149/p>0.2	0.9322/p=0.4044	0.965	6,6,6,0.392
22	-0.00038±0.052	0.213/p>0.2 (p<0.15)	0.8341/p=0.0235	0.793	5,7,5,0.197
23	-0.0222±0.0435	0.137/p>0.2	0.9473/p=0.5983	0.424	5,7,3,0.015
24	-0.1042±0.038	0.139/p>0.2	0.9612/p=0.8016	0.179	1,11,3,1.0
25	-0.0314±0.084	0.172/p>0.2	0.9204/p=0.2897	1.062	5,7,4,0.076
26	-0.0723±0.09	0.216/p>0.2 (p<0.15)	0.8942/p=0.1335	1.348	3,9,4, 0.200
27	-0.0451±0.116	0.222/p>0.2 (p<0.15)	0.8818/p=0.0923	1.18	4,8,4,0.109
28	-0.0286±0.131	0.24/p>0.2 (p<0.1)	0.8814/p=0.0912	1.059	5,7,4,0.076
29	-0.0171±0.137	0.261/p>0.2 (p<0.05)	0.8788/p=0.0846	1.018	6,6,4,0.067
30	-0.011±0.143	0.215/p>0.2 (p<0.15)	0.8663/p=0.0586	0.976	6,6,4, 0.067
33	-0.0069±0.143	0.205/p>0.2 (p<0.2)	0.8586/p=0.047	0.888	5,7,4,0.076
34	0.0025±0.14	0.163/p>0.2	0.8846/p=0.1003	0.999	5,7,4, 0.076
35	-0.0044±0.139	0.172/p>0.2	0.9025/p=0.1706	1.026	5,7,4, 0.076
36	-0.0049±0.187	0.177/p>0.2	0.8717/p=0.0687	0.755	5,7,3, 0.015
37	-0.3161±0.167	0.309/p<0.2 (p<0.01)	0.7236/p=0.0014	0.257	2,10,3,0.182
38	-0.232±0.162	0.154/p>0.2	0.9509/p=0.65	1.841	3,9,4,0.200
39	-0.137±0.256	0.262/p>0.2 (p<0.05)	0.8107/p=0.0124	1.544	3,9,4, 0.200
40	-0.0769±0.297	0.246/p>0.2 (p<0.05)	0.8471/p=0.0338	1.222	3,9,4, 0.200
41	-0.0538±0.325	0.227/p>0.2 (p<0.1)	0.8826/p=0.0948	1.056	5,7,4, 0.076
42	-0.0385±0.345	0.17/p>0.2	0.8774/p=0.0812	0.948	6,6,4, 0.067
43	-0.0196±0.35	0.169/p>0.2	0.8534/p=0.0405	0.949	5,7,4, 0.076
44	-0.0113±0.356	0.226/p>0.2 (p<0.1)	0.8116/p=0.0127	0.921	4,8,4,0.109
45	-0.0019±0.362	0.188/p>0.2	0.8477/p=0.0344	1.032	5,7,5,0.197
46	-0.0063±0.339	0.188/p>0.2	0.8822/p=0.0936	1.289	4,8,4,0.109
47	-0.009±0.302	0.195/p>0.2	0.894/p=0.1325	1.667	4,8,5,0.289
48	0.0129±0.193	0.223/p>0.2 (p<0.15)	0.87/p=0.0656	1.752	4,8,7,0.788
49	-0.0053±0.22	0.242/p>0.2 (p<0.1)	0.813/p=0.0132	1.76	4,8,5,0.289

N is a number of subsets; $\bar{e}$ ±SE are the 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; ST is result of application of the serial test (Swed Frieda, Eisenhart, 1943): 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.

In some cases (when estimations of model parameters are very far from the "biological zone") values of model parameters which correspond to local minima, were used (see tables 1, 3 and 4) for estimating of tendencies.

Table 3 Values of model parameters which are far from "biological zone"

N	x_0	a	b	$Q_{\min}$	$\overline{x}$	$(N-1)s_x^2$
1	$1.093\cdot10^{-21}$	16092.48	18753.79	5.287	0.59	5.767
2	$1.769\cdot10^{-18}$	29810.85	38679.15	5.158	0.555	5.864
3	$9.77\cdot10^{-12}$	5167.83	6561.7	5.063	0.603	5.91
4	$4.623\cdot10^{-10}$	54241.61	69336.23	5.043	0.652	5.694
8	2.46	1024.8	2523.3	0.904	0.577	4.771
22	0.607	38344291887.96	187546040465.67	0.208	0.238	0.356
49	2.718	2748965359569.63	3790829143023.0	3.151	0.891	6.793

Table 4 Results of analyses of sets of deviations when estimations of model parameters are far from "biological zone"

N	$\overline{e}$ ±SE	KS	SW	DW	ST
1	-0.12±0.197	0.14/p>0.2	0.9299/p=0.3788	1.093	5,7,4,0.076
2	-0.064±0.197	0.191/p>0.2	0.8675/p=0.0608	1.127	6,6,4,0.067
3	-0.036±0.196	0.258/p>0.2 (p<0.05)	0.847/p=0.0314	1.222	6,6,5,0.175
4	-0.024±0.195	0.251/p>0.2 (p<0.05)	0.842/p=0.0266	1.233	5,7,6,0.424
8	$1.32\cdot10^{-8}$±0.083	0.249/p>0.2 (p<0.05)	0.833/p=0.0229	1.459	4,8,6,0.533
22	$3.59\cdot10^{-10}$±0.04	0.196/p>0.2	0.877/p=0.0803	0.768	4,8,4,0.109
49	0.0±0.155	0.264/p>0.2 (p<0.05)	0.722/p=0.0014	1.526	3,9,5,0.491

For estimations of parameter a (numbers 6, 7, 10, 11, 19, 26, 38, 46-48; for these cases model (1) is suitable for fitting; fig. 2a; tables 1 and 2) we have the following regression line:

$$a = 0.0213r + 1.4072,\ R^2 = 0.0362,$$

with $C = 13$. For sample size 10 critical values for Theil criterion are following: $P\{C \geq 19\} = 0.054$ (one-side criterion) and $P\{|C| \geq 21\} = 0.072$ (double-side criterion; Theil, 1950; Hollander, Wolfe, 1973). Additionally, $P\{C \geq 13\} = 0.146$. Thus, Theil criterion doesn't allow rejecting the hypothesis $H_0 : g = 0$ for parameter a. Selected method of analysis doesn't allow concluding that changing of external conditions had influence on maximum value of birth rate. Respectively, it gives some reasons to say that during the 60 years of population monitoring of the density of pine looper moth there weren't confident changing of productivity and surviving of individuals.

With the same conditions regression line for parameter b is following (Fig. 2b):

$$b = -0.001r + 1.0877,\ R^2 = 0.0001,$$

with statistics $C = 8$. Like in previous case Theil criterion doesn't allow rejecting the hypothesis $H_0 : g = 0$ for parameter b. It means that we have a certain reason to say that during 60 years the intra-population competition between individuals didn't change.

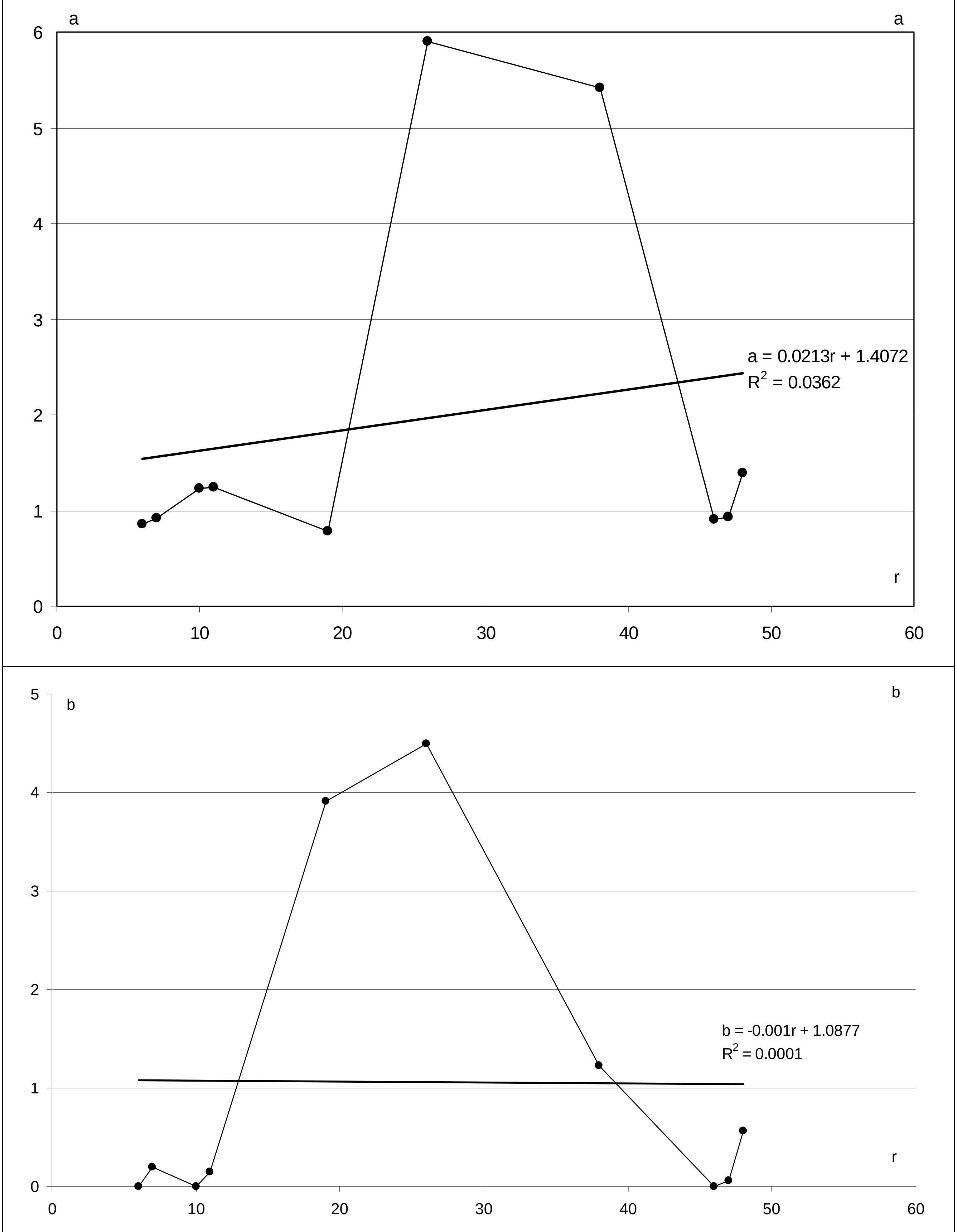

Fig. 2 Changing of parameters a (case a) and b (case b) of model (1) with respect to changing of variable r (for the cases when model with these parameters gives good fitting of the respective subsets of initial sample), and linear regression lines.

Let's consider the case with bigger number of points in samples for estimations of parameters a and b. In some cases (when variable r is equal to 9, 12, 13, 20, 21, 27, 28, 30, 34, 35, 41, 42; table 2) Durbin – Watson criterion cannot give a conclusion about absence or presence of serial correlation. Other criteria showed good results for fitting of the respective sub-samples. Combining both samples we obtain two new time series (fig. 3).

For estimations of parameter a (fig. 3a; tables 1, 2) we have the following regression line:

$$a = 0.067r + 1.4703,\ R^2 = 0.0717,$$

with $C = 45$. For sample size 22 critical values for Theil criterion are following: $P\{C \geq 59\} = 0.051$ (one-side criterion) and $P\{|C| \geq 69\} = 0.054$ (double-side criterion; Theil, 1950; Hollander, Wolfe, 1973). Additionally, $P\{C \geq 45\} = 0.109$. Thus, in considering case Theil criterion doesn't allow rejecting the hypothesis $H_0 : g = 0$ for parameter a. Method of data analysis doesn't allow concluding that changing of external (weather) conditions had influence on maximum value of birth rate. Respectively, it gives some reasons to say that during the 60 years the pine looper moth hadn't confident changes in productivity and surviving of individuals.

With the same conditions regression line for parameter b is following (fig. 3b):

$$b = -0.0451r + 1.5988,\ R^2 = 0.0154,$$

with statistics $C = 43$. Like in previous case Theil criterion doesn't allow rejecting the hypothesis $H_0 : g = 0$ for parameter b, $P\{C \geq 43\} = 0.12$ (Theil, 1950; Hollander, Wolfe, 1973). It means that we have a certain reason to say that during 60 years the intra-population competition between individuals didn't change. In both last cases Null hypotheses cannot be rejected even with 10% significance level.

Let's consider the last case with all obtained estimations of model parameters (tables 1, 2; fig. 4). For all estimations of parameter a (fig. 4a) we have the following regression line:

$$a = 0.0958r + 1.2463,\ R^2 = 0.1266,$$

with $C = 278$ and $C^* = 2.549$. For 5% significance level critical level for statistics C^* is 1.96. Thus, we have the inequality $C^* > 1.96$, and Null hypothesis must be rejected with 5% significance level (double-sided criterion). Taking into account that $P\{|C^*| \geq 2.55\} = 0.0108$ Null hypothesis cannot be rejected with 1% significance level.

Formally, we got a contradiction with results obtained in two previous cases (if we confine ourselves with 5% significance level; and there are no contradictions between results if we choose 1% significance level). In this situation we have to take into account that a lot of parameters used for determination of tendency corresponds to situations when model gives insufficient approximation of respective sub-samples.

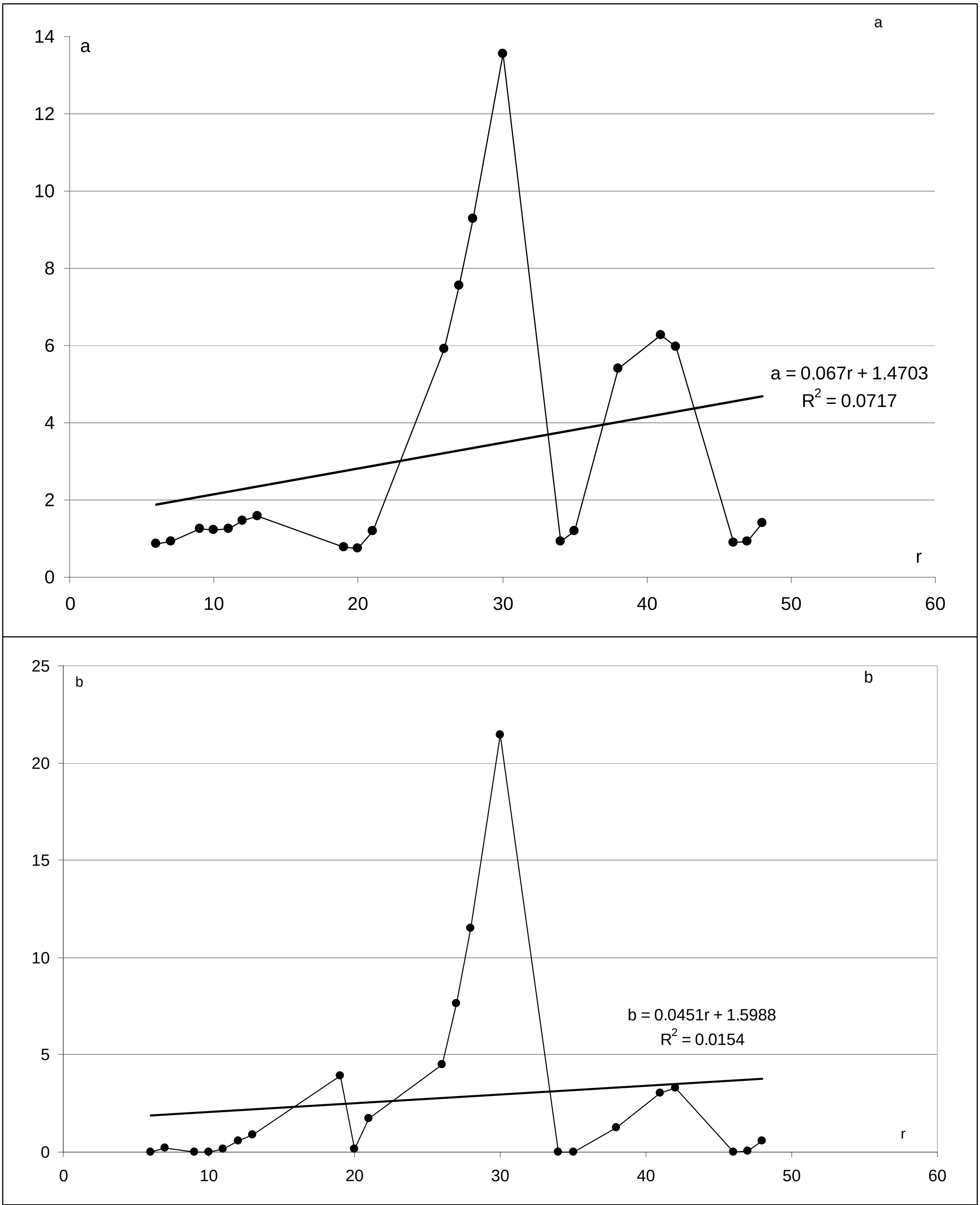

Fig. 3 Changing of parameters a (case a) and b (case b) of model (1) with respect to changing of variable r (for the cases when model with these parameters gives good fitting of the respective subsets of initial sample, plus cases when Durbin – Watson test cannot give a conclusion about existence/absence of serial correlation in sequences of residuals), and linear regression lines.

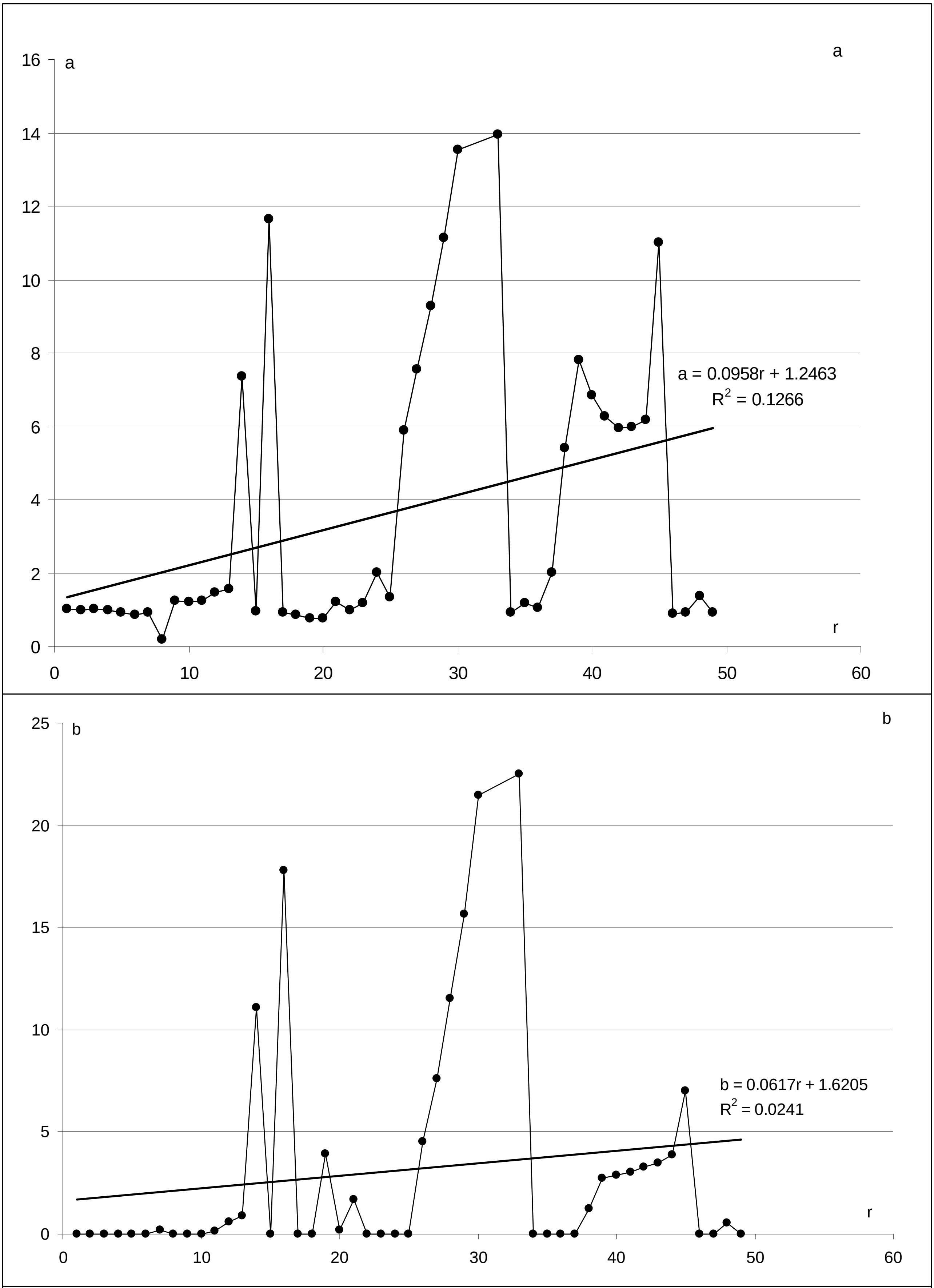

Fig. 4 Changing of parameters a (case a) and b (case b) of model (1) with respect to changing of variable r (for all obtained estimations), and linear regression lines.

On fig. 4b there are values of all estimations of parameter b and the respective regression line which is determined by the following equation:

$$b = 0.0617r + 1.6205\,,\ R^2 = 0.0241,$$

with statistics $C = 278$ and $C^* = 2.549$. Like in previous case with parameter a we have to reject Null hypothesis $H_0 : g = 0$ for parameter b. Thus, if we confine ourselves with 5% significance level we can conclude that there exist some reasons for conclusion that during 60 years weather conditions had been changed, and it led to increase of population birth rate and to increase of intra-population self-regulation.

5 Conclusion

It is the simple idea considered in current publication which is in the base of approach to analysis of population dynamics. Initial sample (on changing of population size or population density in time) transforms with the use of non-linear mathematical model to some other time series; and these new time series are 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 with the use of Kostitzin model into two new time series – changing in time of maximum of population birth rate and coefficient of intra-population competition (coefficient of self-regulation). Analysis of these new 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 if we use for estimation of tendencies parameters which correspond to situations when model gives good fitting of the respective sub-samples. If we use for estimation of tendencies of model parameters all obtained estimations we have unobvious situation: with 5% significance level we have to reject the Null hypotheses (for both population parameters), and we cannot reject the Null hypotheses if we use 1% significance level.

It is important to point out some problems we have when we apply considered method for population dynamics analysis. One or other variant of solution of these problems may have strong influence on final results.

First of all, it is a problem of choosing of mathematical model we assume to use for fitting of time series. In current publication the well-known Kostitzin model (1) was used. This model has very poor set of dynamical regimes (regimes of monotonic stabilization only), and it cannot give us a guarantee that this model is the best one among all other mathematical models. We cannot exclude the situation when with the help of other model (for example, discrete logistic model or Moran – Ricker model which have very rich sets of dynamical regimes) we can obtain better results (when we have smaller number of situations when model isn't suitable for fitting or when checked hypotheses can be rejected with bigger level of significance).

The second problem of considered approach is choosing of the size of sub-samples (number of empirical values we use for estimation of model parameters). If sub-sample size is low the confidence of obtained results isn't big. Increasing of sub-sample size leads to the decreasing of sizes of obtaining new time series (for model parameters). In general case the size of sub-samples must depend on existing initial sample, and main goals of providing investigations.

Acknowledgements

Publication was supported by RFFI grant 11-04-01295.

References

Berryman AA. 1981. Population systems: a general introduction. Plenum Press, New York, USA

Bolshev LN, Smirnov NV. 1983. Tables of Mathematical Statistics. Nauka, Moscow, USSR (in Russian)

Draper NR, Smith H. 1986. Applied Regression Analysis. V.1. Finance and Statistics, Moscow, USSR (in Russian)

Draper NR, Smith H. 1987. Applied Regression Analysis. V.2. Finance and Statistics, Moscow, USSR (in Russian)

Griebeler EM. 2011. Are individual based models a suitable approach to estimate population vulnerability? - a case study. Computational Ecology and Software, 1(1): 14-24

Hollander M, Wolfe DA. 1973. Nonparametric statistical methods. John Wiley and Sons, USA

Isaev AS, Khlebopros RG, Nedorezov LV, et al. 2009. Forest Insect Population Dynamics. KMK, Novosibirsk, Moscow, Russia

Kondakov YuP. 1974. Laws of mass propagations of Siberian pine moth. In: Ecology of Populations of Siberian Forest Animals. 206, 265, Nauka, Novosibirsk, USSR (in Russian)

Kostitzin VA. 1937. La Biologie Mathematique.A. Colin, Paris, France

Lakin GF. 1990. Biometrics. High School, Moscow, USSR (in Russian)

Lilliefors HW. 1967. On the Kolmogorov-Smirnov test for normality with mean and variance unknown. Journal of the American Statistical Association, 64: 399-402

Nedorezov LV. 2011a. Analysis of cyclic fluctuations in larch bud moth populations with discrete-time dynamic models. Biology Bulletin Reviews, 72(2): 407-414

Nedorezov LV. 2011b. Analysis of some experimental time series by Gause: Application of simple mathematical models. Computational Ecology and Software, 1(1): 25-36

Nedorezov LV. 2012a. Chaos and Order in Population Dynamics: Modeling, Analysis, Forecast. LAP Lambert Academic Publishing, Saarbruecken, Germany (in Russian)

Nedorezov LV. 2012b. Modeling and analysis of some methods of entomological data collection. Computational Ecology and Software, 2(2): 83-95

Nedorezov LV, Lohr BL, Sadykova DL. 2008. Assessing the importance of self-regulating mechanisms in diamondback moth population dynamics: Application of discrete mathematical models. Journal of Theoretical Biology, 254: 587–593

Nedorezov LV, Sadykova DL. 2005. A contribution to the problem of selecting a mathematical model of population dynamics with particular reference to the green oak tortrix. Euro-Asian Entomological Journal, 4(4): 263-272

Nedorezov LV, Sadykova DL. 2008. Green oak leaf roller moth dynamics: An application of discrete time mathematical models. Ecological Modelling, 212: 162-170

Nedorezov LV, Sadykova DL. 2010. Analysis of population time series using discrete dynamic models (on an example of green oak leaf roller). Lesovedenie, 2: 14-26

Nedorezov LV, Utyupin YuV. 2011. Continuous-Discrete Models of Population Dynamics: An Analytical Overview. Ser. Ecology. Vip. 95. State Public Scientific-Technical Library, Siberian Branch, Russian Academy of Sciences, Novosibirsk, Russia (in Russian)

Nedorezova BN, Nedorezov LV. 2012. Pine looper moth population dynamics in Netherlands: Prognosis with generalized logistic model. Proceedings of the International Academy of Ecology and Environmental Sciences, 2(2): 70-83

Schwerdtfeger F. 1957. Forstinsekten im Ur- und Nutzwald. Forstzeitschrift, Allgem, Germany.

Schwerdtfeger F. 1968. Okologie der Tiere. 2. Demokologie.Verl. Paul Parey, Hamburg, Berlin, Germany

Shapiro SS, Wilk MB, Chen HJ. 1968. A comparative study of various tests of normality. Journal of the American Statististical Association, 63: 1343–1372

Sharma R, Raborn SW. 2011. Estimating critical abundance thresholds in exploited populations: a simulation approach based on species resilience to disturbance. Computational Ecology and Software, 1(4): 189-207

Swed Frieda S, Eisenhart C. 1943. Tables for testing randomness of grouping in a sequence of alternatives. The Annals of Mathematical Statistics, 14: 66-87

Tamburino L, La Morgia V, Venturino E. 2012. System dynamic approach for management of urban parks: a case study. Computational Ecology and Software, 2(1): 26-41

Theil H. 1950. A rank-invariant method of linear and polynomial regression analysis. 1. Proc. Kon. Ned. Akad. v. Wetensch. A., 53: 386-392

Tonnang H, Nedorezov LV, Owino J, Ochanda H, Löhr B. 2009. Evaluation of discrete host –parasitoid models for diamondback moth and Diadegma semiclausum field time population density series. Ecological Modelling, 220: 1735–1744

Tonnang H, Nedorezov LV, Ovino J, Ochanda H, Lohr B. 2010. Host–parasitoid population density prediction using artificial neural networks: diamondback moth and its natural enemies. Agricultural and Forest Entomology, 12(3): 233-242

Vorontsov AI. 1978. Forest Pathology. Forest Industry, Moscow, USSR (in Russian)