Natural cycles in the Northern Baikal region

Tatiana Ananina[1*], *Alexander* Ananin[1,2], *Mikhail* Ovdin[1], and *Vadim* Kozulin[1]

[1]FSE United Administration of Barguzinsky State Nature Biosphere Reserve and Zabaikalsky National Park, 71, Lenina street, Ust-Barguzin, Republic of Buryatia, 671624, Russian Federation
[2]Institute of General and Experimental Biology SB RAS, 6, Sakhyanovoj street, Ulan-Ude, 670047, Russian Federation

Abstract. The authors of the article present the results of an analysis of the cyclicity of long-term numerical series of meteorological parameters (average annual air temperature, total annual precipitation) and six long-term numerical series of short-lived animal species from different taxonomic groups: ground beetles, small rodents and passerine birds living in similar biotopes of the low-mountain part of Barguzinsky ridge (territory of the Barguzin State Natural Biosphere Reserve). The cyclic components of long-term observation series lasting 33-67 years were studied by Fourier spectral analysis. Periodograms and cyclic sequences of model species coincide in most cases. In all species, high-frequency 2-3 year cycles predominate, while mid-frequency 4-8 year and low-frequency 9-19 year cycles are of secondary importance. Statistically significant correlations between cyclicity in the long-term abundance series of model animal species and the cyclicity of annual precipitation and average annual temperature have been identified. Reliable correlations between the cyclicity of Wolf numbers and the cyclicality of meteorological parameters are shown. Solar activity has an indirect effect on the cyclicity of natural processes in the Northern Baikal region.

1 Introduction

Over the period of its existence, the Barguzin State Natural Biosphere Reserve has accumulated a large array of primary accounting data on meteorological parameters, phenology and population dynamics of a number of fauna representatives. Currently, databases collected over a period of 60 years or more are systematized and subjected to statistical processing.

We live in a cyclical world. The environment around us is a huge oscillatory system with a wide variety of cycles. The problem of explaining the cyclicity of species still does not have a clear solution [1-2]. The reason why researchers study the cyclical mechanism of natural processes is to understand their consequences for the existence of ecosystems.

The dynamics of animal numbers has long been in the center of scientific interests - factors that influence population fluctuations are analyzed, and forecasts of expected changes are made. A number of scientists consider long-term fluctuations in the number of species as components of a single natural process and consider them an adaptation to

* Corresponding author: t.l.ananinar@mail.ru

changing environmental conditions [3-5]. The reasons for the cyclical nature of animal populations are multifaceted and can be associated with abiotic, intrapopulation factors, predation, food availability, diseases, etc. [5-7]. We assume that populations of animals of different taxonomic status, but living in similar habitats, are affected by the same environmental factors, which themselves are also cyclical. Based on this hypothesis, the cyclical nature of the population dynamics of these animals, namely the duration of the cycles, will also be similar.

The purpose of our research: to consider and identify the features of natural cycles using the example of long-term numerical series of the abundance of animals of different taxonomic groups and basic elements of weather in the Northern Baikal region.

2 Materials and methods

Research was carried out on the territory of the Barguzinsky Nature Reserve on permanent sites and routes in the high altitude section of the lower part of the mountain forest belt of the Barguzinsky ridge (N54˚21'10.8" E109˚39'29.1 - N54˚23'06.5" E109˚43'54 ,6"). The most abundant species of animals from different classes, but living in similar habitats, were selected as model ones: the Warbler *Phylloscopus inornatus* Bluth, 1842 (Passeriformes, Silvidae) and the Bluetail *Tarsiger cyanurus* Pal., 1773 (Passeriformes, Muscicapidae), red-backed vole *Myodes rutilus* (Pal., 1779) (Rodentia, Cricetidae) and red-gray vole *Myodes rufocanus* Sund., 1846 (Rodentia, Cricetidae), ground beetles *Carabus odoratus (barguzinicus)* Shil., 1996 and *Calathus micropterus* Duft., 1812. For the analysis, we used databases of quantitative records of animals for the periods: (1963-2023) in rodents, (1984-2022) in birds, (1988-2020) in ground beetles and (1955-2022) changes in meteorological parameters. Material was collected using generally accepted methods of capture [. 8, 9, 10]. Weather observations were carried out at the "Davsha" weather station. Characteristics of long-term numerical series of animals and meteorological parameters are presented in Table 1.

Table 1. Statistical characteristics of long-term series of numbers of model animal species and meteorological parameters (ground beetles, rodents – specimens per 100 catches/day; birds – specimens/km^2).

View	N, year	Number, M±m	σ	Cv, %
Car. odoratus	33	20.2±2.8	15.9	78.7
Cal. micropterus	33	11.4±1.9	11.9	103.5
M. rutilus	60	3.6±0.4	3.0	83.0
C. rufocanus	60	1.6±0.3	2.4	150.0
P. inornatus	38	32.6±3.2	19.6	60.3
T. cyanurus	38	7.2±0.9	5.7	79.1
Average annual temperature	67	-3.3±0.1	1.2	36.3
The level of annual precipitation	67	427.7±11.1	89.7	21.0

Note. n – number of years of observations, M – average, m – error of the average, σ – square deviation, Cv – coefficient of variation

When studying long-term numerical series of animal abundance, we used indirect methods of analysis. The fact is that numerical time sequences have a specific property - they are not stationary, not linear, and contain hidden periodic components that are not noticeable in the graphs of long-term numerical series. The fast Fourier transform method allows us to identify the entire set of hidden periodic components (Statistica 6.0 software) [11]. The essence of the method is to transform a long-term numerical series - transferring it from a time scale to a frequency scale. In the final table of the results of the periodogram analysis, we limited ourselves to the parameters period, frequency and density, since it is

these characteristics that make a significant contribution to the cyclic behavior of the series. The periodogram shows the power distribution of periods by frequency. The density in the periodogram is the power spectral density (PSD), which allows you to analyze the spectral characteristics of the series.

To exclude random periods, the periodogram was modified by smoothing using the moving average method in the Data Analysis package Microsoft Excel 7.0. and constructing a histogram that clearly shows which period values are the most frequent.

After the transformation procedure, the cyclicity of long-term series was assessed. Here we specify the concept of the terms “periodicity” and “cyclicity” of natural processes. In this matter, we adhere to the approach of A.A. Maksimov [12], where “periodicity” is considered as a sequence of data with strict intervals, and “cyclicity” is the alternation of data without clear fixed intervals, but close to average values. The calculations took into account statistically reliable values of periods that fit at least two or three times into the length of the analyzed series.

Spearman's rank correlation analysis was carried out with cyclic series of animals and meteorological parameters (average annual temperature, level of annual precipitation) modified during the analysis.

3 Results

The results of Fourier spectral analysis of long-term series of meteorological parameters are presented in Figure 1.

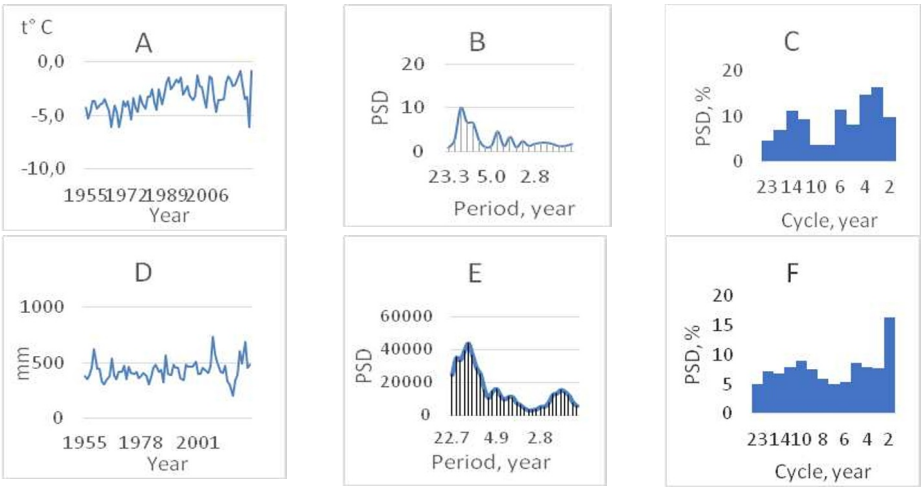

Fig. 1. Characteristics of the cyclicity of long-term series of average annual air temperature (A, B, C) and the level of average annual precipitation (D, E, F) in the Northern Baikal region. Designations: A, D – long-term dynamics of primary data; B, E – periodograms; C, F – cyclic series.

The temperature regime of the average annual temperature (A) during the analyzed period increased (R^2 = 0.3154) at a stationary level of annual precipitation (D). Periodograms (B, E) demonstrate left-sided asymmetry, which indicates an increased power of long periods of meteorological parameters in low frequencies. In the cyclic series of average annual temperature, 3-4 year cycles dominate, and atmospheric precipitation - 2 year cycles. A significant presence of 9-14 year cycles was noted. Correlation analysis of the cyclicity of average annual temperature and precipitation levels with Wolf numbers confirmed significant relationships (r = - 0.3987, p = 0.001 and r = - 0.3331, p = 0.01).

Increased levels of average annual precipitation and temperature were observed at minimum solar activity.

The nature of the cyclical dynamics of the number of model animal species is reflected in Figures 2-4.

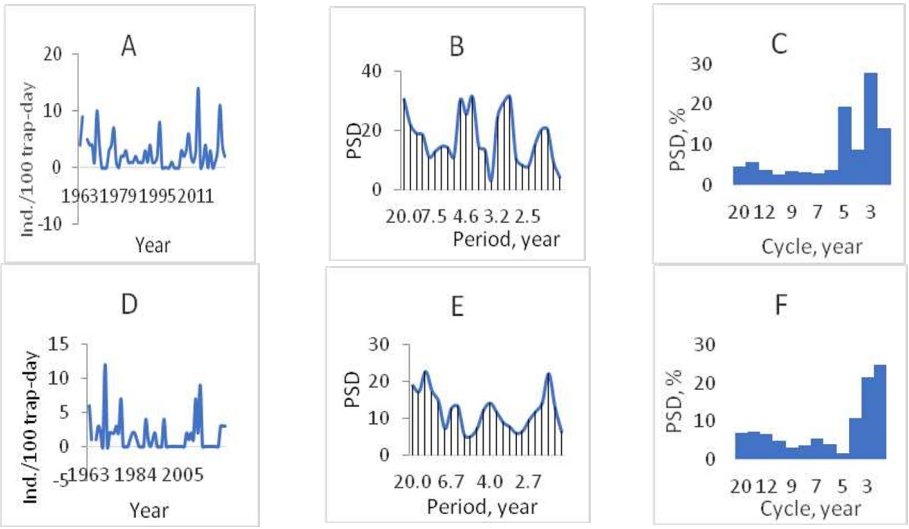

Fig. 2. Characteristics of the cyclicity of long-term numerical series of small rodents *Myodes rutilus* (A, B, C) and Craseomys rufocanus (D, E, F). Designations as in Figure 1.

There is no trend in the dynamic numerical series of red-backed and red-gray voles. The periodogram curves of both species show 4 peaks in the high, low, and mid frequency bands. In the cyclic series of the red-backed vole, 3 and 5 year cycles predominate, and the red-gray vole – 2-3 year cycles. Correlation analysis of the cyclicity of red-backed and red-gray voles with hydrometeorological parameters showed close relationships: with average annual temperature ($r = 0.5460$ and $r = 0.4866$, $p = 0.001$) and annual precipitation ($r = 0.3518$, $p = 0.01$ and $r = 0.6839$, $p = 0.001$).

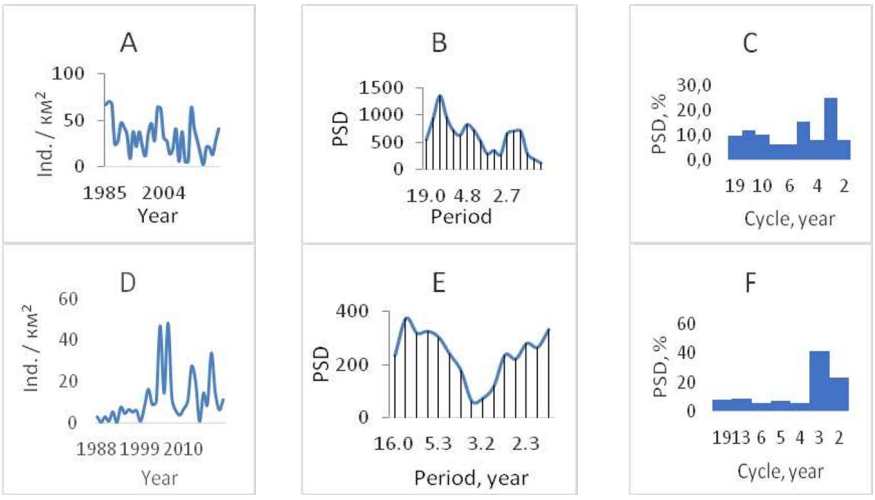

Fig. 3. Characteristics of the cyclicity of long-term numerical series of birds *Phylloscopus inornatus* (A, B, C), *Tarsiger cyanurus* (D, E, F). Designations as in Figure 1.

No trends were identified in the dynamic numerical series of the abundance of the Eastern Bluebird and Bluetail. The most powerful peaks in the periodograms of both species are recorded in the low frequency band; in the bluetail, they are also recorded in the high frequency band. In the cyclic series of both species, the 3-year cycle predominates. Correlation analysis of cyclicity showed significant connections between the lightning and the temperatures ($r = 0.4517$, $p = 0.01$), bluetail – with temperature ($r = 0.5138$, $p = 0.001$) and precipitation ($r = 0.3636$, $p = 0.001$).

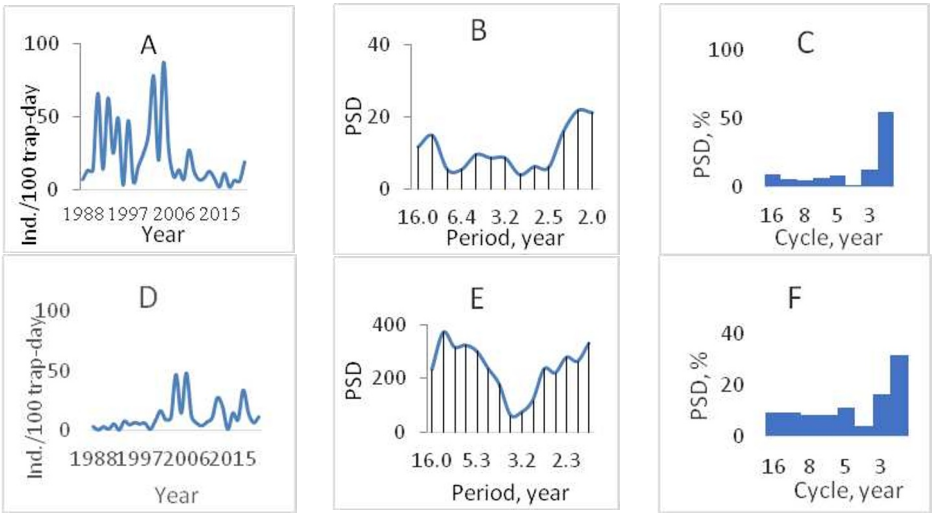

Fig. 4. Characteristics of the cyclicity of long-term numerical series of abundance of ground beetles *C. odoratus* (A, B, C), *Cal. micropterus* (D, E, F). Designations as in Figure 1.

In the dynamic numerical series of *C. odoratus* there is a trend towards a decrease in abundance ($R^2 = 0.1248$), and *Cal. micropterus* – increase ($R^2 = 0.1309$). The highest peak amplitudes in the periodograms of both types are observed in the low and high frequency bands. In the cyclic series of both species, the 3-year cycle dominates. Correlation analysis of cyclicity showed a very high relationship between *C. odoratus* and annual precipitation amounts, ($r = 0.9360$, $p = 0.001$), in *Cal. micropterus*, no connections with hydrothermal parameters were identified.

4 Discussion

The paper presents an analysis of the dynamic numerical series of six widespread and most well-studied animal species subjected to annual population counts on permanent routes and sites in the Barguzinsky Nature Reserve. The spectral Fourier transform method made it possible to identify a complete set of periods and establish their magnitude and amplitude ratio, and in the process of modifying the periodogram, obtain a cyclic model of the time series. The advantage of this type of analysis is also that there are no restrictions on the length of the series. The periodogram is also built on short series. We believe that the disadvantage of this method is that the cyclic model is descriptive in nature, it is difficult to interpret, and it does not reveal the reasons for the formation of the cyclical nature of the time series.

Despite the fact that the model species we selected have different taxonomic status, the similarity in the cyclicity of long-term numerical series is obvious. All histograms of the spectral density of animals, including histograms of meteorological parameters,

demonstrate left-sided asymmetry, which indicates a non-uniform frequency distribution. The histograms show the cycles that make the greatest contribution to the cyclical behavior of the series. In all model numerical series, 2-3 year cycles dominate, and less often 4 year cycles. There are also 9-14 year long and 5-8 medium cycles, which occupy a subordinate role. Correlation analysis of primary long-term numerical series of animals with external environmental factors did not show significant reliable connections, in contrast to the correlation analysis of cyclicity, i.e. series subjected to spectral analysis and then modification.

5 Conclusion

Based on the results of ours and the research of other authors [5, 12], we conclude that heliocosmic processes indirectly act as “conductors” of the Earth’s natural cycles. By influencing the atmosphere, they set weather cycles, and these, in turn, form the population cycles of animals.

A feature of cyclical processes in the Northern Baikal region is the presence of a high proportion of short 2 and 3 year cycles both in hydrothermal parameters and in long-term numerical series of very different animal species. The presence of smaller shares of long (9–19 year) and medium (4–8 year) cycles was also noted.

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