Avian Ecol. Behav. 15, 2009: 23-31

Relationship between weather conditions, crops of Siberian pine nuts, and irruptions of Siberian Nutcrackers *Nucifraga caryocatactes macrorhynchos* C.L. Brehm in Siberia and Europe

Alexander A. Ananin[1] & Leonid V. Sokolov[2]

Abstract: Ananin, A.A. & Sokolov, L.V. (2009): Relationship between weather conditions, crops of Siberian pine nuts, and irruptions of Siberian Nutcrackers *Nucifraga caryocatactes macrorhynchos* C.L. Brehm in Siberia and Europe. Avian Ecol. Behav. 15: 23-31.

Summer numbers of Nutcrackers *Nucifraga caryocatactes* in Barguzinsky Nature Reserve (Eastern Siberia) and their trapping figures in Russia, Estonia, Latvia, and Ukraine are positively related to the crops of Siberian pine (*Pinus sibirica*) nuts averaged across Siberia during the previous year. Only numbers of wintering Nutcrackers are positively related to the current crops in Barguzinsky Nature Reserve. No such relationship was found for the autumn numbers. A retrospective analysis showed a significant correlation of Siberian pine crops with summer NAO (North Atlantic Oscillation) and NP (North Pacific Pattern) indices in the years of the three-year cycle of crops. Autumn numbers of Siberian Nutcrackers captured in Europe were related to March and May NAO index values recorded two years before.

Key words: Siberian Nutcracker, *Nucifraga caryocatactes macrorhynchos*, irruptive migration, invasion, autumn numbers, North Atlantic Oscillation (NAO) index, climate.

Address: [1]A.A. Ananin: Barguzinsky State Biosphere Reserve, 670045 Ulan-Ude, Russia. E-mail: a_ananin@mail.ru

[2]L.V. Sokolov: Biological Station "Rybachy", Zoological Institute, 199034 St. Petersburg, Russia. E-mail: leonid-sokolov@mail.ru

Received 13 April 2006 / Received in revised form 20 June 2006/ Accepted 26 June 2006.

1. Introduction

Siberian Nutcracker *Nucifraga caryocatactes macrorhynchos* C.L. Brehm is a specialised consumer of Siberian pine nuts. They occur in their diet throughout the year, and in autumn and winter are nearly the sole food item in the areas where masses of Siberian Nutcrackers occur. Cached nuts are also used for feeding the young during breeding. Nestlings receive exclusively kernels of pine nuts (Reymers 1959, Vorobyev 1982, Cramp & Perrins 1993).

A clear foraging specialisation of Nutcrackers should cause, as in most stenophagous species, a dependence of their numbers on the crops of Siberian pine nuts. This relationship has been reported by many authors (Formozov 1933, Reymers 1966, Kumari 1972, Vorobyev 1982 etc.). Nutcrackers are redistributed across the range of Siberian pine as a result of their summer and autumn movements. Migration time is not constant across the years. Summer movements usually occur between early July – early August, and autumn movements in mid September – late October. Autumn passage peaks when the nuts ripen (Filonov 1961, Vorobyev 1982). It is assumed that annual movements of Nutcrackers are mainly aimed at finding areas with good crops (Bibikov 1948, Mezhenny 1964, Reymers 1966, Kischinski 1968, Rogacheva 1992, Vartapetov 1998, Tsybulin 1999). Noskov et al. (2005) believe that juvenile Nutcrackers have in their annual cycle a period of obligatory increased locomotory activity that causes redistribution of the birds across a large area.

It is usually assumed that Siberian Nutcrackers perform aperiodic mass long-distance migration from the north to the south and from the east to the west, caused by Siberian pine crops failing in large areas. Noskov & Rymkevich (2005) claimed that increased migratory activity during food shortage is a typical behavioural feature of many birds, Nutcracker including, with the nomadic type of migratory behaviour. However, already Johansen (1912) saw the cause of mass migration of Nutcrackers not only in nut crops failing, but also in the increase of bird numbers due to successful breeding in the previous years. Reymers (1954) also suggested that mass irruptions of Nutcrackers were preceded by the years of good Siberian pine crops. However, no detailed studies of the relationship between Nutcracker numbers and the crops of Siberian pine nuts and weather conditions in Siberia in the current and previous years have been performed.

The aim of this study is to investigate the concrete relationship between weather conditions, Siberian pine crops, and irruptions of Nutcrackers in Siberia and Europe.

2. Material and methods

We analysed long-term observation data on the numbers of Nutcrackers in Barguzinsky Nature Reserve (54°01´ – 54°56´N; 109°31´ – 110°17´E). This nature reserve is situated along the eastern coast of Lake Baikal on the western slopes of Barguzinsky mountain range.

Counts of Nutcrackers in Barguzinsky Nature Reserve were made in constant transects in the first half of summer, in autumn and winter in 1984-2004, following the standard methodology (Ravkin 1967). We also used autumn trapping data in Rybachy-type traps at the field stations in Estonia, Latvia, Kaliningrad Region of Russia, and Ukraine. The data collected in Estonia (Kabli field station, 58°01´N, 24°27´E, 1971-2000), Latvia (Pape field station, 56°11´N, 21°03´E, 1967-2000) and in Ukraine (Kiev Region, 50°38´N, 30°32´E, 1976-1997), were kindly provided by the colleagues from the respective countries. The data on long-term trapping at Fringilla field station located in the Russian part of the Courish Spit on the Baltic coast (55°05´N, 20°44´E) were taken from the database of the Biological Station "Rybachy". Besides, we used the published data on the crops of Siberian pine (scores) from different parts of Siberia (Nekrasova 1961, Nesvetaylo 1987, Vorobyev 1999) and the relevant unpublished data stored at Barguzinsky Nature Reserve.

To find out the relationships between Siberian pine crops, Nutcracker numbers and the weather variables, we primarily used the NAO index. Usually the monthly NAOI values are used as summary characteristics of the weather situation in Europe. NAOI is calculated as the difference between the normalized sea-level pressure at the Azores and Iceland (Hurrell et al. 2001). Positive NAOI values indicate a weather in Europe during winter and early spring when warm air masses move from the Atlantic and cause higher temperature and precipitation in northwest Europe (Hurrell 1995). To the contrary, negative NAOI values indicate weaker westerlies and thus lower temperature and precipitation in this part of Europe. Monthly NAO indices are archived at the National Oceanic and Atmospheric Administration's Climate Prediction Center website (www.cpc.ncep.noaa.gov/data/teledoc/nao.html).

We have shown elsewhere that a significant relationship between NAOI and seasonal air temperature persists not only for Europe but for Siberia as well (Sokolov et al. 2003). An important factor that influences Siberia climate are North Atlantic lows that cross it in winter, spring, and summer. Atlantic lows that go through Scandinavia and central European Russia may enter Siberia. A shift towards more southern trajectories (through southern Russia and Central Asia) changes both temperatures and precipitation (Chaplygina 1970, Perevedentsev et al. 1994).

Apart from this, two eastern atmospheric centres influence the weather in Eastern Siberia in summer: Aleutian minimum and Siberian high (Chaplygina 1970, Perevedentsev et al. 1994). Therefore, several other global circulation indices may be used to characterise weather conditions in Siberia: NP (North Pacific Pattern), WP (West Pacific Pattern), POL (Polar/Eurasia Pattern), PT (Pacific Transition Pattern), ASU (Asia Summer Pattern), and some others. We used the NP index as the most relevant one for summer conditions in Eastern Siberia.

To test the hypothesis that mass irruptions of Nutcrackers are related to the weather conditions and to the crops of Siberian pine nuts, we compared time series of counts in Siberia and captures in Europe and Siberian pine crops in different parts of Siberia by Kendall rank correlation. We used the statistical package Statistica 5.0.

3. Results and discussion

Our retrospective correlation analysis showed a significant relationship between crops of Siberian pine nuts and summer NAOI values during all years of the three-year cycle of pine fruitage in Western and Central Siberia (Tab. 1). In the southern part of Eastern Siberia the relationship with NAO is weaker, here the southeastern monsoons start to play a role, as shown by the relationship with the North Pacific Pattern (Tab. 2).

Summer numbers of Nutcrackers in Barguzinsky Nature Reserve were positively related to the crops of the previous, not the current year (Tab. 3). A similar correlation was found for the autumn captures in the Baltic area. The current crops only influenced the numbers of Nutcrackers wintering in Barguzinsky Nature Reserve. Numbers of Nutcrackers trapped in autumn in the Eastern Baltic varied between 0 and 201, in Ukraine between 0 and 59 (Tab. 4). The strongest annual variation was

Table 1. Relationship between crops of Siberian pine in Western and Central Siberia and NAOI (Kendall correlation coefficient: *p < 0.05).

Month	Index NAO		
	Current year	Current year – 1	Current year – 2
January	-0.040	0.091	-0.068
February	-0.255*	-0.065	0.004
March	-0.147	0.186	-0.052
April	0.079	-0.052	-0.048
May	-0.057	-0.039	0.222*
June	0.215*	-0.236*	0.217*
July	0.014	0.131	-0.001
August	-0.044	-0.060	-0.008
September	0.006	0.228*	-0.098
October		0.126	-0.173
November		0.132	0.075
December		0.225*	-0.225*

Table 2. Relationship between crops of Siberian pine in Eastern Siberia and NP index (Kendall correlation coefficient: *p < 0.05).

Month	Index NP		
	Current year	Current year – 1	Current year – 2
January	0.100	-0.043	0.149
February	-0.053	0.091	0.053
March	-0.107	-0.087	0.064
April	0.186	-0.042	-0.038
May	0.018	-0.084	-0.128
June	-0.083	0.206*	-0.183
July	0.078	-0.231*	0.334*
August	-0.052	0.173	-0.155
September	0.079	0.069	-0.240*
October		0.027	-0.139
November		0.013	0.033
December		0.179	-0.222*

Table 3. Relationship of summer, autumn, and winter numbers of Siberian Nutcrackers and the crops of Siberian pine nuts in Eastern Siberia (Kendall correlation coefficient: *p < 0.05).

Siberian pine crops (scores)	Summer numbers in Barguzinsky Nature Reserve	Autumn numbers in Barguzinsky Nature Reserve	Autumn numbers in the Baltic area	Winter numbers in Barguzinsky Nature Reserve
Current year	0.018	0.126	-0.017	0.441*
Current year – 1	0.450*	0.025	0.407*	-0.108
Current year – 2	0.133	0.075	0.177	-0.262

Table 4. Numbers of Siberian Nutcrackers captured during autumn passage in the Baltic area and in Ukraine.

Year	Kabli (Estonia)	Pape (Latvia)	Courish Spit (Russia)	Baltic area pooled	Kiev Region (Ukraine)
1957			0	0	
1958			1	1	
1959			0	0	
1960			0	0	
1961			32	32	
1962			4	4	
1963			3	3	
1964			0	0	
1965			0	0	
1966			0	0	
1967		2	1	3	
1968		13	176	189	
1969	0	1	2	3	
1970	0	1	0	1	
1971	5	11	29	45	
1972	1	0	1	2	
1973	4	5	14	23	
1974	0	0	0	0	
1975	7	192	2	201	
1976	1	2	0	3	
1977	30	97	52	179	2
1978	0	10	0	10	10
1979	0	3	0	3	3
1980	13	63	20	96	10
1981	4	2	4	10	0
1982	0	0	0	0	0
1983	0	2	0	2	0
1984	3	1	1	5	0
1985	22	122	16	160	6
1986	3	49	0	52	
1987	1	3	0	4	0
1988	1	16	0	17	19
1989	0	0	1	1	0
1990	0	1	0	1	1
1991	10	139	4	153	2
1992	5	5	1	11	16
1993	0	0	1	1	0
1994	0	12	0	12	0
1995	5	32	11	48	0
1996	2	2	1	5	4
1997	0	0	1	1	0
1998	10	97	80	187	59
1999	0	1	0	1	0
2000	0	0	0	0	0
2001			0	0	
2002			1	1	
2003			0	0	
2004			0	0	
2005			0	0	
All years	127	884	458	1470	119
Mean	4	27	10	31	5
S.D.	6.87	48.25	28.66	59.40	12.87

recorded in Latvia (one-way ANOVA: $F_{3,134} = 3.74$, $p = 0.013$; if the Latvian site is omitted, $F_{2,101} = 0.70$, $p = 0.50$). Correlation between autumn numbers of Nutcrackers at different stations was very high (Tab. 5). We have elsewhere demonstrated by autocorrelation function that the long-term series of autumn captures of this species on the Courish Spit shows no periodicity (Sokolov et al. 2002). Peaks of Nutcracker numbers in the Baltic area occur after varying numbers of years (Fig. 1, Tab. 4).

Table 5. Correlation of autumn Siberian Nutcracker numbers at different Eastern European sites (Kendall correlation coefficient: *p < 0.05; **p < 0.01; ***p < 0.001).

Site (country)	Pape (Latvia)	Courish Spit (Russia)	Kiev Region (Ukraine)
Kabli (Estonia)	0.609***	0.667***	0.498***
Pape (Latvia)		0.286*	0.457**
Courish Spit (Russia)			0.409**

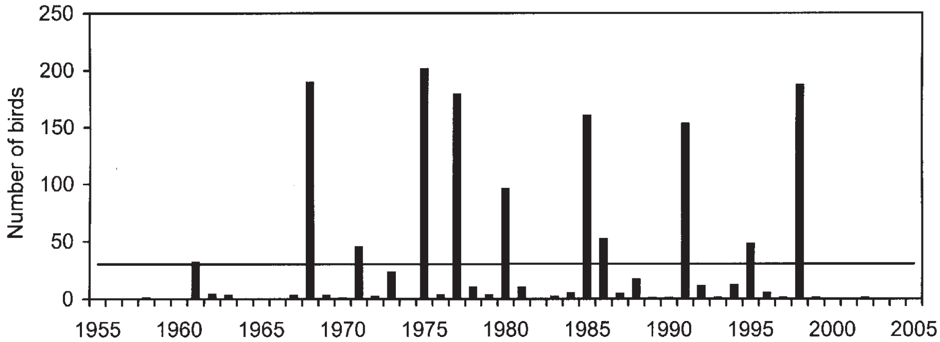

Figure 1. Long-term dynamics and trend of the numbers of Nutcrackers captured at autumn passage in the eastern Baltic.

Autumn trapping figures in Europe, mainly in the Baltic area, were significantly related to winter and spring-summer NAOI values of the previous year and two years earlier when the three-year fruitage cycle of Siberian pine starts (Fig. 2, Tab. 6).

Fruitage of Siberian pines is the process since the inception of reproductive organs until ripening of seeds. The crops of cones and nuts is the final stage. The generative organs of Siberian pines are incepted in July and August, florescence occurs in June or July next year and lasts for 3-7 days, the seed bugs are fertilised one year after pollination, and then the seeds are formed within 50-60 days. The whole process takes ca. 28 months (Nekrasova 1961, 1972).

Siberian pines bear seeds annually, with very rare exceptions. The periodicity of crops is manifested not in the strict succession of good and bad years, but rather in the periods of higher and lower crops (Nekrasova 1961, 1972). The crops depends on many factors, mainly on the weather conditions during pollination. Cool and wet

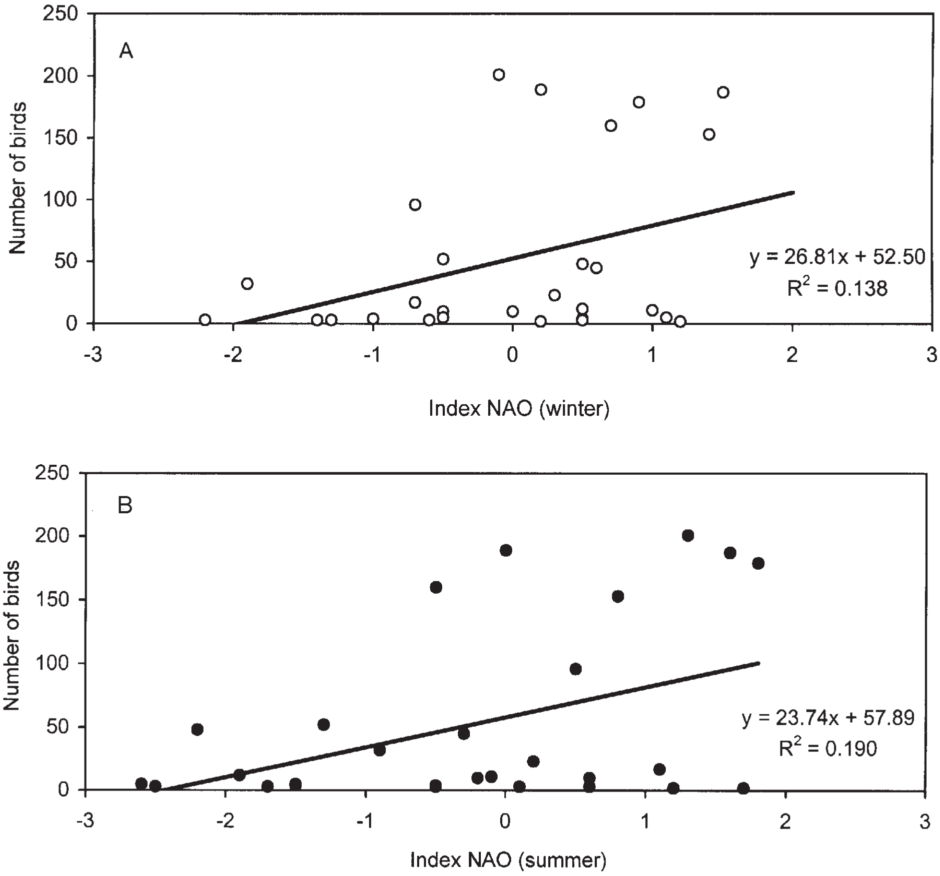

Figure 2. Relationship between the numbers of Nutcrackers captured at autumn passage in the eastern Baltic with NAO index values of the previous year (A) and two years before (B). Only the years with >1 capture are included.

weather during inception of generative germs is unfavourable for the crops, whereas the development of cones is hampered by dry conditions. The weather in June, July, and August of all the three years when the crops are formed, is of utmost importance (Nekrasova 1972, Nesvetaylo 1987).

The dynamics of formation of female embryos and the mean air temperature and humidity in July and August are directly related. It permits to forecast the future crops of Siberian pine on the basis of residuals of mean temperature and humidity in August. The 'flowers' and female cones of the previous year are sensitive to temperature and air humidity, cannot tolerate frosts, droughts, prolonged rains with cold spells that significantly decrease or even completely destroy the crops. A tentative forecast of Siberian pine crops may be made two years in advance by the analysis of the weather conditions during inception of the generative organs. A wet summer

Table 6. Relationship between autumn Siberian Nutcracker trapping numbers in Europe and NAOI in the current and previous years (Kendall correlation coefficient: *$p < 0.05$).

Month	Index NAO		
	Current year	Current year – 1	Current year – 2
January	0.045	0.101	0.042
February	-0.105	-0.034	-0.077
March	0.065	0.157	0.218*
April	-0.157	-0.165	0.022
May	0.074	-0.051	0.220*
June	0.112	-0.107	0.096
July	0.136	-0.121	0.039
August	0.110	-0.135	0.041
September	0.007	-0.125	0.117
October		-0.077	0.019
November		-0.165	0.030
December		-0.185	0.104

with strong winds is a sign of poor crops two years later. After a dry and warm summer, one can expect a good crops in two years (Nekrasova 1961, 1972).

Our results show a significant relationship between the global atmospheric circulation indices (NAO, NP), weather conditions in summer during the three-year year fruitage cycle of Siberian pine, pine crops and seasonal numbers of Nutcrackers both in Siberia and in Europe.

Acknowledgments

The data on Nutcracker numbers at European field stations were kindly provided by several colleagues (Janis Baumanis †, Agu Leivits, Anatoly M. Poluda, Vladislav D. Yefremov, Mikhail Y. Markovets, Anatoly P. Shapoval). The study was partly supported by Russian Foundation for Basic Research (grant no. 06-04-48774 to L.V.S.).

References

Ananin, A.A. & Ananina, T.L. 2002. Long-term dynamics of climatic parameters. Proc. Barguzinsky State Biosphere Reserve 8: 9-27 (in Russian).

Ananina, T.L. 2002. Long-term dynamics of soil and water regimens. Proc. Barguzinsky State Biosphere Reserve 8: 27-38 (in Russian).

Bibikov, L.I. 1948. To the ecology of the Nutcracker. Proc. Pechoro-Ilychsky State Nature Reserve 4: 89-112 (in Russian).

Chaplygina, A.S. 1970. Fluctuations of zone circulation of atmosphere in the Northern hemisphere in the former half in the 20th century. Questions of Geography 79: 68-81 (in Russian).

Cramp, S. & Perrins, C. 1993. The Birds of the Western Palearctic. Vol. 7. Oxford Univ. Press, Oxford – New York.

Filonov, K.P. 1961. Local nomadism of some winter birds on the northeastern Baikal coast. Proc. Buryatsky State Pedagogical Inst. 24: 69-77 (in Russian).
Formozov, A.N. 1933. Crops of Siberian pine nuts, irruptions of Siberian Nutcrackers (*Nucifraga caryocatactes macrorhynchos* Brehm) to Europe and fluctuations of Red Squirrel (*Sciurus vulgaris* L.) numbers. Bull. Zoology Res. Inst. Moscow Univ. 1: 64-70 (in Russian).
Johansen, H.E. 1912. The nature of Tomsk in 1911. N.I. Orlova Publ., Tomsk (in Russian).
Kischinski, A.A. 1968. The birds of the Kolyma Plateau. Nauka, Moscow (in Russian).
Kumari, E.V. 1972. Irruption of Siberian Nutcrackers to Europe in autumn 1969. Proc. Baltic Comm. Study Bird Migr. 7: 58-81 (in Russian).
Mezhenny, A.A. 1964. Biology of Nutcrackers (*Nucifraga caryocatactes macrorhynchos*) in southern Yakutia. Zool. zhurnal 43: 1679-1687 (in Russian).
Nekrasova, T.P. 1961. Crops of the Siberian pine in Western Siberia. Publ. Siberian Branch of Soviet Acad. Sci., Novosibirsk (in Russian).
Nekrasova, T.P. 1972. Biological basis of fruitage of Siberian pine. Nauka, Novosibirsk (in Russian).
Nesvetaylo, V.D. Long-term dynamics of reproduction activity and radial growth of Siberian pine in the stands near villages in the subzone of southern taiga. Ekologiya 6: 19-25 (in Russian).
Noskov, G.A., Rezvyi, S.P., Rychkova, A.L. & Smirnov, O.P. 2005. On irruptions of Siberian Nutcrackers *Nucifraga caryocatactes macrorhynchos* L. in northwestern Russia and in adjacent regions. In: Iovchenko, N.P. (ed.) Ornithological studies in the Ladoga area. St. Petersburg Univ. Press, St. Petersburg: 61-81 (in Russian).
Noskov, G.A. & Rymkevich, T.A. 2005. Forms of migratory activity in the annual cycle of birds. In: Iovchenko, N.P. (ed.) Ornithological studies in the Ladoga area. St. Petersburg Univ. Press, St. Petersburg: 18-60 (in Russian).
Perevedentsev, Y.P., Ismagilov, N.V. & Shantalinsky, K.M. 1994. Centres of atmospheric activity and their relationship with macrocirculation processes in the Northern hemisphere. Meteorology and Hydrology 3: 43-51 (in Russian).
Ravkin, Y.S. 1967. To the survey methods of birds in forest landscapes. In: The nature of pestholes of tick-borne encephalitis in the Altai. Nauka, Novosibirsk: 43-51 (in Russian).
Reymers, N.F. 1954. To the biology of Nutcrackers in southern Baikal area. Zool. Zhurnal 33: 1358-1362 (in Russian).
Reymers, N.F. 1959. Breeding of thin-billed Nutcrackers in central Siberia. Zool. Zhurnal 38: 907-915 (in Russian).
Rogacheva, H. 1992. The birds of Central Siberia. Husum: Husum Druck u. Verlagsges.
Sokolov, L.V., Markovets, M.Y., Yefremov, V.D. & Shapoval, A.P. 2002. Irregular migration (irruptions) in six bird species on the Courish Spit on the Baltic Sea in 1957-2002. Avian Ecol. Behav. 9: 39-53.
Sokolov, L.V., Kosarev, V.V., Fedoseeva, N.V., Markovets, M.Y., Shapoval, A.P. & Yefremov. V.D. 2003. Relationship between autumn numbers of the Coal Tit *Parus ater*, air temperatures and North Atlantic Oscillation index. Avian Ecol. Behav. 11: 71-88.
Tsybulin, S.M. 1999. The birds of Northern Altai. Nauka, Novosibirsk (in Russian).
Vartapetov, L.G. 1998. The birds of northern taiga of West Siberian plain. Nauka, Novosibirsk (in Russian).
Vorobyev, V.N. 1982. The Nutcracker and its relationships with the Siberian pine (An attempt of quantitative analysis). Nauka, Novosibirsk (in Russian).
Vorobyev, V.N. 1999. Reproductive chronology of conifers: programme and methods. Siberian Ecol. Journal 6: 117-123 (in Russian).