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Species Composition and Population Dynamics of Dominant Dendrophagous Moths (Lepidoptera) in St. Petersburg and Its Environs

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Abstract—The paper summarizes new and literature data on the species composition, trophic relationships, and population dynamics of phyllophagous lepidopterans dominant on woody plants in St. Petersburg and its environs (Russia). Most of these species have concealed larvae (e.g., leaf miners and leaf rollers), and some of them are invasive. The data were accumulated during approximately a hundred years of observations and field collections. Concealed species form the dominant group within the studied complex of phyllophagous moths in St. Petersburg and Leningrad Province (27 species from 13 families). Changes in the composition of dominant pests of the dog rose, bird cherry, elm, poplar, and other woody plants have been recorded. Outbreaks of some species, such as *Phyllonorycter salicicolella* (Gracillariidae), *Archips rosana* (Tortricidae), *Leucoma salicis*, *Lymantria monacha*, and *Orgyia antiqua* (Erebidae), were recorded during the XX century but since about 1980 the population density of these species has remained at a very low level. Another group of species, which includes *Phyllonorycter populifoliella* (Gracillariidae), *Batrachedra praeangusta* (Batrachedridae), *Acleris bergmanniana*, and *Epinotia abbreviana* (Tortricidae), demonstrated a sharp increase in population density in the 1990–2000s, a phenomenon which had not been observed before. The possible causes of such population dynamics are discussed. The dominant species of phyllophagous micro-lepidopterans, including some recent invaders (e.g., *Cameraria ohridella* and *Phyllonorycter issikii*, Gracillariidae) and adventive species (e.g., *Ph. populifoliella* and *Ph. acerifoliella*, Gracillariidae) pose a serious threat to woody plants in St. Petersburg and Leningrad Province.

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Pests and disease agents damaging woody plants are invariably present in urban vegetation. The total diversity of woody plants in St. Petersburg, together with those kept in botanical gardens, amounts to about 2000 species. Of these, 76% of the urban plantings are formed by the small-leaved lime *Tilia cordata* (Mill.) (26%), the European white elm *Ulmus laevis* (Pall.) (10%), the Norway maple *Acer platanoides* (L.) (10%), the silver birch *Betula pendula* (Roth.) (10%), poplars *Populus* spp. (9.7%), the green ash *Fraxinus pennsylvanica* (Marsh.) (6.7%), and the common oak *Quercus robur* (L.) (2.6%) (Moshchenikova, 2011). By contrast, the forest ecosystems of St. Petersburg and Leningrad Province mostly consist of other tree species: the Scots pine *Pinus sylvestris* (L.), the Norway spruce *Picea abies* (L.), birches *Betula* spp. (L.), the common aspen *Populus tremula* (L.), and the grey alder *Alnus incana* (L.). The peculiar composition of the urban woody vegetation determines the specific features of the complexes of dendrophagous insects in the urban environment, including the potentially catastrophic outbreaks of invasive pests (Izhevsky and Mozolevskaya, 2008; Selikhovkin, 2010; Selikhovkin et al., 2011; Mozolevskaya, 2012). The most conspicuous pests in the parks and urban plantings of various regions of Russia belong to the group of phyllophagous lepidopterans, including the leaf-mining, leaf-rolling, and leaf-tying species. Several invasive and adventive pests, in particular mining moths of the family Gracillariidae including the locust digitate leaf-miner *Parectopa robiniella* (Clemens, 1863) (Gninenko, 2002; Antyukhova, 2010), *Macrosaccus robiniella*

(Clemens, 1859) (Gninenko and Rakov, 2010), the horse-chestnut leafminer *Cameraria ohridella* (Deshka et Dimić, 1986), the lime leafminer *Phyllonorycter issikii* (Kumata, 1963) (Gninenko and Kozlova, 2008; Mozolevskaya, 2012), and the poplar leaf blotch miner *Phyllonorycter populifoliella* (Treitschke, 1833) (Bondarenko, 2008; Selikhovkin, 2010) have formed outbreaks in Russia. The lime leafminer and the horse-chestnut leafminer have also appeared in St. Petersburg (Selikhovkin et al., 2012, 2016a, 2016b).

Data on the dominant pest species whose outbreaks pose a threat to the urban green plantings are of great practical significance. However, the biological features and population dynamics of some phyllophagous lepidopteran species present in St. Petersburg, especially those with a concealed mode of life, are only scantily known or not known at all.

In view of the above, the goal of this work was to summarize the available data on the population dynamics and trophic associations of phyllophagous Lepidoptera in St. Petersburg and its environs. The specific tasks included collection of data on the species composition of this group, its changes, and cases of population densities of some species increasing to the level posing a threat to the vegetation, and also quantitative interpretation of the results.

MATERIALS AND METHODS

The pest complexes of woody plants in St. Petersburg have been studied by researchers from St. Petersburg State Forest Technical University (SPSFTU), the Zoological Institute of the Russian Academy of Sciences (ZIN), and some other institutions since the second half of the XIX century. Monitoring of the population state of the most common dendrophagous insects in the city and suburbs of St. Petersburg started in the early XX century. This work continued in the XXI century; since 2009, observations have been carried out on a regular basis, including route surveys and examination of permanent test plots, performed 2–3 times a year in 5 areas located in several city parks of St. Petersburg.

Research was mainly focused on the phyllophagous Lepidoptera developing on woody plants and having a concealed mode of life. According to the classification of Gerasimov (1952), this group includes "… leaf rollers living in rolled or tied leaves…" and "… leaf miners living inside leaves or leaf stalks." The lepidopteran larvae tying and rolling leaves, and also those living in cases (Gerasimov, 1952), are sometimes regarded as an intermediate group between free-living and concealed forms; however, we consider all such species to be concealed phyllophages.

Our retrospective analysis of the species composition of pests and their population dynamics was based on the published data, unpublished material, expert assessments made by researchers from the Department of Forest Protection, Wood Science and Hunting of SPSFTU, scientific reports, and forest pathology examination results. A considerable part of the data used in this paper was obtained from the extensive archives of the department, including unpublished observations and results of various surveys of pests of woody plants.

The material of ZIN collections was used for identification of some species of mining moths and for characterizing their distribution in the past.

Besides the authors, expert data assessment was performed by A.L. Lvovsky (ZIN), B.G. Popovichev, and L.N. Shcherbakova (SPSFTU).

Quantitative interpretation of data was based on the criteria used in forest pathology for revealing considerable population growth or, in some cases, outbreaks of pests.

According to the classical works (*Monitoring…*, 1965; Varley et al., 1978; Berryman, 1990), a significant increase in the pest population density (i.e., an outbreak) should be recorded if at least 10% of trees are damaged by the given species within an area of at least 1 ha, and at least 10% of leaves are damaged on these trees. Correspondingly, we considered three criteria: damage extensity (the percentage of trees showing signs of damage by the given pest), damage intensity (the percentage of damaged leaves or damaged leaf surface, calculated only for the damaged trees), and the area in which these parameters were recorded. The extensity and intensity of pest damage were evaluated using a three-point scale, as shown in Table 1 (Selikhovkin and Kozlov, 2000; Selikhovkin, 2009).

The sources included in our analysis usually contained certain estimates of the degree of damage to trees due to a particular pest species or a group of species. The level of damage caused by concealed pests was often characterized by the percentage of damaged leaves, less frequently by the percentage of infested trees and the degree of damage to their crowns. Many publications, reports, and other sources did not specify the exact method of calculation; besides, different quantitative parameters of damage were commonly used in different periods of research. In view of all these factors, such parameters as extensity and intensity are quite conditional and in many cases are based only on expert assessments. The area of infestation may be difficult to estimate in the urban environment due to the fragmented pattern of vegetation; therefore, we used a conditional method of calculation in which 50 trees or 100 shrubs corresponded to an area of 1 ha.

The pest species were identified based on adults, and the results were then compared with the larval morphology and the nature of damage to plants, in order to estimate the damage intensity. In some cases, preliminary identification was performed only by the characteristic signs of damage.

The main criteria for estimating the pest population density were the extensity and intensity of damage, and in some cases also the ecological density, i.e., the number of larvae per unit mass of leaves.

In 2009–2017, we carried out regular examinations of maples, elms, oaks, birches, and lime trees two or three times a year (from the last third of May to the beginning third of June, in mid-July, and in late August) in the Forestry Academy Park, Moscow Victory Park, and Alexander Park (Pushkin). Five test plots were marked out in each park, and 5 trees of each species were selected within each plot. For each tree, pest damage was determined by examination of 5 or 6 branches collected with a 5-m long extensible pruning shears from the lower of middle part of the crown.

For monitoring the lime leafminer, we used separate test plots whose location was determined by the species composition of lime trees. Besides, in 2016 and 2017 we performed additional studies of the population dynamics of the horse-chestnut leafminer and the larch casebearer *Coleophora sibiricella* Falkovitsh, 1972.

The population density was characterized by the ecological density, i.e., the number of larvae or mines per 100 g of leaves (wet weight) (Bondarenko et al., 2001) and, in some cases, by the mean number of mines per leaf in a given tree.

To determine the ecological population density, annual surveys of the phyllophagous pests of elms *Ulmus* spp., oak *Quercus robur* L., limes *Tilia* spp., maple *Acer platanoides* L., and birches *Betula* spp. were carried out at five randomly selected sites in the Forestry Academy Park (Vyborgsky District), Moscow Victory Park (Moskovsky District), and Alexander Park (Pushkinsky District), starting from 2009. At each site, we examined 1 tree of each species and collected 6 branches from its crown at heights of 4–8 m. The diameter of each branch was measured with an accuracy of 1.0 mm, and the larvae feeding on the branch were identified and counted. Data for each tree were processed separately (Selikhovkin et al., 2012). The calculations were based on the regression equations describing the relation between the total wet weight of leaves (mg) and the branch diameter (mm) for the trees of St. Petersburg (Bondarenko et al., 2001).

Table 1. Scales of extensity and intensity (%) of damage cased by phyllophagous insects

Points	Extensity*	Intensity**
1	from 10 to 29	from 10 to 29
2	from 30 to 59	from 30 to 59
3	60 and more	60 and more

The mean values were calculated based on data for the trees and leaves showing the same type of damage; * extensity is the percentage of trees showing signs of damage; ** intensity is the percentage of damaged leaves or damaged leaf surface calculated for the damaged trees.

The classification and nomenclature of pest taxa follow the *Catalogue of the Lepidoptera of Russia* (2008).

RESULTS

The species composition of concealed lepidopteran pests in St. Petersburg and Leningrad Province and the known cases of significant increase in their density are shown in Table 2. Such cases have been recorded for 33 species, including 13 species of leaf and needle miners and 14 species of leaf-rolling and leaf-tying forms. Larvae of 3 species develop in wood, and 3 other species are conobionts that mainly occur in Leningrad Province.

These data, especially the material collected before the early 1990s, are far from being complete. It is highly probable that outbreaks of some species did take place in the past but remained undocumented. In particular, according to verbal accounts by specialists, some outbreaks of the archaic sun moths *Eriocrania* spp. (Eriocraniidae), the leafroller moths *Archips crataeganus* (Hübner, [1799]) and *A. rosana* (Linnaeus, 1758) (Tortricidae), the black-dotted groundling *Stenolechia gemmella* (Linnaeus, 1758) (Gelechiidae), the lime bent-wing moth *Bucculatrix thoracella* (Thunberg, 1794) (Bucculatricidae) on limes, the apple leaf miner *Lyonetia clerkella* (Linnaeus, 1758) (Lyonetiidae) on bird cherry, and also casebearers (Coleophoridae) that occurred in St. Petersburg were never recorded in publications or other documents. These cases remained unnoticed because the damage intensity was relatively low and had no substantial effect on the host plants.

Leafminers of the family Gracillariidae form a considerable part of the phyllophagous moth complex in St. Petersburg. Particularly notable are two invasive species which, as mentioned above, have only recently appeared in St. Petersburg: the lime leafminer *Phyllonorycter issikii* and the horse-chestnut leafminer *Cameraria ohridella*. The history of their expansion over European Russia is well known (Shchurov and Rakov, 2011; Ermolaev, 2012; Meshkova and Mikulina, 2013; Ermolaev and Rubleva, 2017).

The lime leafminer was first recorded in St. Petersburg in 2000 (Popovichev, 2007), and its population density noticeably increased in 2002, 2008, and 2013 (Table 2). The species has two annual generations in the region but the third generation is likely to appear in years with a hot summer. In the latter case, its population density would abruptly increase to 4 mines per leaf and more, and the resulting damage would negatively affect the lime plantings (Ermolaev and Zorin, 2011).

The horse-chestnut leafminer was first recorded in St. Petersburg by A.L. Lvovsky in 2013, and the species reached noticeable densities in 2014 (Popovichev, 2016; Selikhovkin et al., 2016b, 2017).

One of the most important pests from the leafminer family is the poplar leaf blotch miner *Phyllonorycter populifoliella*. The biology of this moth is well known (Polezhaev, 1934; Rumyantsev, 1934; Bondarenko, 2008; Selikhovkin, 2010; Selikhovkin et al., 2012). The species was only relatively recently found in St. Petersburg, the first reliable record being published by Lvovsky (1994). Its outbreak in 1992–1999 (Selikhovkin, 2010; Selikhovkin et al., 2012) must have led to the spread of poplar cytosporosis and mass mortality of poplars in the environs of St. Petersburg in 2000–2005. No cases of significantly increasing population density of *Ph. populifoliella* have been observed in St. Petersburg and Leningrad Province since 1999 but its abundance remains at a considerable level. Its mines can be easily found in practically any poplar stand. Although the species became known in St. Petersburg only in the recent decades, our examination of the ZIN material revealed a single male that had been collected by A.M. Gerasimov on 24.IX.1936, off a willow stem in a "Polish cemetery" on the outskirts of Leningrad (apparently the former Vyborgskoe Roman Catholic cemetery near Arsenalnaya Street). The identity of this male as *Ph. populifoliella* was confirmed by us based on genital morphology. Since this was the only specimen, the population density of the species may have been very low in the past. It is also possible that the species was initially associated with willows, which were recorded earlier as its host plants in Moscow (Rumyantsev, 1934). This leafminer must have become a noticeable species in St. Petersburg as the result of large-scale planting of poplars after the WWII. It may even be hypothesized that some other populations preferring poplars were introduced with planting stock and became dominant in the region. At any rate, *Ph. populifoliella* can presently be considered an adventive species in St. Petersburg, if not a native one.

The maple midget *Phyllonorycter acerifoliella* (Zeller, 1839) was first recorded in St. Petersburg during our surveys in 1998. This pest was rarely found in the subsequent years, but in 2009–2011 it mined up to 10% of maple leaves in some city parks (Selikhovkin et al., 2016a, 2016b). However, the ZIN material of this species includes only a small collection made by N.N. Filipjev in Mikhailovsky Garden in 1922, several specimens collected by A.M. Gerasimov in the environs of Leningrad in 1927, 1931, and 1933 (some of them were reared from maple), and single specimens collected by A.L. Lvovsky in the Forestry Academy Park in 1987. It may be concluded that the maple midget was present in St. Petersburg and its environs in the past, but it was rare and thus remained unrecorded. Later the species became more abundant, either as the result of changing ecological conditions or due to additional dispersal over the city together with new maple plantings.

The aspen leaf blotch miner *Phyllonorycter apparella* (Herrich-Schäffer, 1855), mostly developing in mines on aspen leaves, abruptly increased its population density in 2014 in practically all the districts of Leningrad Province, in the environs of St. Petersburg, in the south of Finland (Selikhovkin et al., 2016a, 2016b), and also in Novgorod Province.

Table 2. Population density of concealed moth species in St. Petersburg and Leningrad Province

Pest species	Year	Region*	Host plant**	Ext	Int	Source of data
Family ERIOCRANIIDAE						
Eriocrania semipurpurella (Stephens, 1835)	2000	1, 2, 4	Bet	2	1	Authors' data
	2008	1	Bet	2	2	
	2009	1	Bet	2	1	
E. cicatricella (Zetterstedt, 1839)	2002	1	Bet	2	2	
Family BUCCULATRICIDAE						
Bucculatrix thoracella (Thunberg, 1794)	2011	1	Til	2	2	Authors' data
Family GRACILLARIIDAE						
Cameraria ohridella Deschka et Dimič, 1986	2015	1	Aes	1	2	Selikhovkin et al., 2016a, 2016b, 2017
	2016	1		2	3	
	2017	1–4, 6		2	2	
Gracillaria syringella (Fabricius, 1794)	1934–1935, 1939–1940, 1946–1949, 1953–1954	1, 2	Sr, Sv	3	1	Archive data; Beloselskaya, 1955
	2003–2004	1, 2	Sr, Sv	2	2	Authors' data
Phyllonorycter apparella (Herrich-Schäffer, 1855)	1994, 1998	2	Pt	2	2	Selikhovkin et al., 2016a, 2016b, 2017
	2014	1–6	Pt	3	3	
	2015	1–6	Pt	2	3	
Ph. acerifoliella (Zeller, 1839)	1998–2004	1	Ace	2	1	Authors' data
Ph. populifoliella (Treitschke, 1833)	1991	1–6	Pp	2	2	Bondarenko, 2008; Selikhovkin, 1996, 2010, 2011
	1992–1998	1–6	Pp	3	3	
	1999	1–6	Pp	3	2	
Ph. salicicolella (Sircom, 1848)	1927–1928	2	Bet	3	2	Rimsky-Korsakov, 1929; Rimsky-Korsakov and Gusev, 1938
Ph. issikii (Kumata, 1963)	2002	1	Til	1	1	Authors' data
	2008, 2013	1		1	1	Selikhovkin et al., 2012; Timofeeva, 2014, 2015
Family YPONOMEUTIDAE						
Yponomeuta cagnagella (Hübner, [1813])	1996	1	Euo	1	1	Authors' data; Shcherbakova, 1998, 1999
Y. evonymella (Linnaeus, 1758)	1954	4	Pad	3	3	Archive data; *Research Activity Report*..., 1990
	1955, 1956	1, 4	Pad	3	3	
	1966	1, 2, 4	Pad	3	3	
	1993	1, 2	Pad	2	3	Authors' data
	1994–1995	1, 2, 4	Pad	3	3	
	1996	1	Pad	2	3	
	2003–2005	1,2	Pad	2	3	
	2008	1	Pad	1	1	
	2013	4	Pad	1	3	Selikhovkin and Musolin, 2013
	2014–2015	1, 2	Pad	1	2	Authors' data

Table 2. (Contd.)

Pest species	Year	Region*	Host plant**	Ext	Int	Source of data
Family YPSOLOPHIDAE						
Ypsolopha vittella (Linnaeus, 1758)	1998	1	Ulm	3	1	Denisova, 2009
	2000	1	Ulm	3	2	
	2001	1	Ulm	3	3	
	2002	1	Ulm	3	2	
Family LYONETIIDAE						
Lyonetia clerkella (Linnaeus, 1758)	2002	1, 2, 4	Pad	2	3	Selikhovkin et al., 2012
Family BATRACHEDRIDAE						
Batrachedra praeangusta (Haworth, 1828)	2006	1	Pp	3	3	Authors' data; Podolyatskaya, 2011
	2007	1	Pp	1	2	
	2008	1	Pp	3	3	
Family COLEOPHORIDAE						
Protocryptis sibiricella (Falkovitsh, 1965); in 1974 and 1975 recorded as *Coleophora laricella* (Hübner, [1822])	1974–1975	2	Lar	2	1	Golutvina and Golutvin, 1980; Kataev and Golutvina, 1983
	1997–1999	1, 3	Lar	2	2	
Suireia milvipennis (Zeller, 1839) and/or *Haploptilia serratella* (Linnaeus, 1761)	2009–2011	1	Bet	1	1	Authors' data; Timofeeva, 2015
Family GELECHIIDAE						
Stenolechia gemmella (Linnaeus, 1758)	2004	1	Que	2	1	Archive and authors' data; Myasnikova and Podolyatskaya, 2009; Lukmazova, 2010; Podolyatskaya, 2011
	2005	1	Que	2	2	
	2006	1	Que	2	3	
	2007	1	Que	2	2	
	2008	1	Que	2	3	
	2011	1	Que	3	3	Authors' data
	2014	1	Que	2	3	
Family SESIIDAE						
Sesia apiformis (Clerck, 1759)	2009	1	Pp, Pt, Aln	1	1	Selikhovkin, 2009b
Family COSSIDAE						
Cossus cossus (Linnaeus, 1758)	1962	1	Pp	2	3	Archive data
Family TORTRICIDAE						
Acleris forsskaleana (Linnaeus, 1758)	1993	1	Ace	3	2	Archive and authors' data
	2003	1	Ace	2	1	
A. bergmanniana (Linnaeus, 1758)	2004	1, 2	Ros	2	3	Authors' data
	2013	1, 2	Ros	2	2	
Archips rosana (Linnaeus, 1758)	1954	1, 2	Ros, Crt, Syr	2	1	Beloselskaya, 1955
	1971–1973	1, 2	Ros	2	1	Archive and authors' data
	1974–1975	1, 2	Ros	2	2	
	1976–1977	1, 2	Ros	2	1	

Table 2. (Contd.)

Pest species	Year	Region*	Host plant**	Ext	Int	Source of data
Epinotia abbreviana (Fabricius, 1794)	2002	1	Ulm	3	3	Denisova, 2009
	2003–2004	1	Ulm	3	2	
	2005–2006	1	Ulm	3	1	
E. cruciana (Linnaeus, 1761)	1933	1	Sal	1	1	Selishchenskaya, 1938
E. nisella (Clerck, 1759)	1935	1, 2, 4	Pt	1	1	Selishchenskaya, 1938
	1992	6	Pp, Pt	1	1	Selikhovkin, 1994, 2011
	2006	1	Pp	1	1	Authors' data; Podolyatskaya, 2011
	2008	1	Pp	1	1	
Gypsonoma minutana (Hübner, [1799])	1991	2, 6	Pt, Pp	2	1	Selikhovkin, 1994
	1992	2, 6		3	2	
Cydia illutana (Herrich-Schäffer, 1851)	1974	2	Lar	2	1	Golutvina and Golutvin, 1980; Kataev and Golutvina, 1983
	1975	2	Lar	2	1	
C. strobilella (Linnaeus, 1758)	1920	5	Pic	3	2	Kadoshnikov, 1929; Nosyrev, 1940
	1924	4	Pic	2	1	Tyulyupaeva, 1928
	1928	5	Pic	2	2	Kadoshnikov, 1929; Yatsentkovsky, 1931; Talman and Yatsentkovsky, 1938
	1930	3	Pic	2	2	Rimsky-Korsakov and Gusev, 1938
	1931	3	Pic	2	2	Kurentsov, 1935
	1934	4	Pic	2	2	Talman and Yatsentkovsky, 1938; Nosyrev, 1940
	1938	1, 2, 4	Pic	2	2	
	1978–1979	2	Pic	3	3	Kataev and Golutvina, 1983
	1993	2	Pic	3	3	Archive data; Bondarenko, 2009
	2008	2	Pic	3	3	
	2016	2	Pic	3	3	Archive data
Syricoris siderana (Treitschke, 1835)	1997	1	Spi	2	3	Authors' data
Tortrix viridana Linnaeus, 1758	1933	1	Que	3	3	Selishchenskaya, 1938
	1934	1	Que	3	2	
	1944–1945	1	Que	3	3	Archive and authors' data
	1946	1	Que	3	2	
	1951	1	Que	3	1	Shcherbakova, 1998, 1999
	1952–1953; 1955–1956, 1965	1	Que	3	2	
	1966	1	Que	3	3	Archive and authors' data
	1970	1	Que	3	2	
	1971–1972	1	Que	3	2	Shcherbakova, 1998, 1999
	2000–2001	1	Que	3	3	Authors' data
	2002	1	Que	3	2	
	2007	1	Que	1	1	Lukmazova, 2010

Table 2. (Contd.)

Pest species	Year	Region*	Host plant**	Ext	Int	Source of data
	2008	1	Que	3	3	Myasnikova and Podolyatskaya, 2009; Podolyatskaya, 2011
	2010–2011	1	Que	1	1	Authors' data
	2012	1	Que	2	2	
	2013	1	Que	2	3	
	2014	1	Que	2	2	
	2015	1	Que	1	1	
Zeiraphera isertana (Fabricius, 1794)	2008	1	Que	1	1	Authors' data; Podolyatskaya, 2011
	2016	1	Que	1	1	Authors' data
Family PYRALIDAE						
Dioryctria abietella (Denis et Schiffermüller, [1775])	1926	5	Pic	3	3	Yatsentkovsky, 1931
	1931	3	Pic	1	2	Berezina, 1935
	1938	2, 4	Pic	1	1	Nosyrev, 1940

* Regions: 1, St. Petersburg including the suburban districts of Shuvalovo, Pushkin, Pavlovsk, and Petrodvorets; 2, west and south of Region 1, including Sosnovyi Bor, Siverskaya, Lisino-Korpus, and Mga; 3, other districts in the south of Leningrad Province, including Luga; 4, the Karelian Isthmus; 5, eastern part of Leningrad Province east of the Mga River; 6, other districts in the south and west of Leningrad Province, including Slantsy and Kingisepp.

Ext and int are the damage extensity and intensity assessed by the 3-point scale (see Table 1).

** Host plants: Ace, *Acer platanoides* L. (Norway maple); Aes, *Aesculus hippocastanum* L. (horse chestnut); Aln, *Alnus incana* (L.) Moench. (grey alder); Bet, *Betula* spp. (birch); Crt, *Crataegus* spp. (hawthorn); Euo, *Euonymus europaeus* L. (European spindle-tree); Fra, *Fraxinus* spp. (ash); Lar, *Larix* spp. (larch); Mal, *Malus domestica* Borkh. (apple tree); Pic, *Picea abies* (L.) (Norway spruce); Pad, *Prunus padus* L. (bird cherry); Pp, *Populus* spp. (poplar); Pt, *Populus tremula* L. (common aspen); Que, *Quercus robur* L. (common oak); Ros, *Rosa* spp. (dog rose); Sal, *Salix* spp. (willow); Sor, *Sorbus aucuparia* L. (rowan); Spir, *Spiraea* spp. (spirea); Sr, *Syringa vulgaris* L. (common lilac); Sv, *Syringa josikaea* J. Jacq. ex Rchb. (Hungarian lilac); Til, *Tilia* spp. (lime); Ulm, *Ulmus* spp. (elm).

The long-streak midget *Phyllonorycter salicicolella* (Sircom, 1848), mostly developing in mines on willows, was earlier recorded as a pest (see Table 2). Now the species is regularly, though in small numbers, found in various regional collections of miner moths. Its population density was not included in our analysis.

One more pest of this family is the sycamore slender *Caloptilia hemidactylella* (Denis et Schiffermüller, 1775) (*Forest Pests*, 1955). Its larvae develop on maple, bending the leaf margin into a conical shelter. Unfortunately, our attempts at rearing the adult have been unsuccessful so far; therefore the identity of our material remains to be confirmed. The species was constantly recorded starting with 2000; its population density was relatively low, with no more than 10% of leaves damaged, but larvae tentatively identified as *C. hemidactylella* were found on 1 out of 2–3 branches even under the most adverse weather conditions of the cold summer of 2017. Moreover, we occasionally found isolated maple trees on which all the leaves were damaged by this moth. The ZIN collections include four specimens of *C. hemidactylella* reared by A.L. Lvovsky in 2010 from mines collected on maple in Sosnovka Park. In view of these findings, our preliminary identification of material as *C. hemidactylella* appears quite reliable.

The lilac leafminer *Gracillaria syringella* (Fabricius, 1794) regularly increases its population density and causes mass damage to lilac plants. The role of this pest became noticeable after the WWII when various lilac species started to be used in landscaping of St. Petersburg and garden plots. According to our data, regularly pruned lilac plants suffer the greatest damage from the pest.

Of moths of the family Coleophoridae, great numbers of the western larch casebearer *Coleophora laricella* were recorded on larch in Leningrad Province in 1927 and 1928 (Rimsky-Korsakov, 1929). Now, however, the presence of this species not only in Leningrad Province but in Russia as a whole is doubted (*Catalogue*…, 2008). It is highly probable that the pest reported by M.N. Rimsky-Korsakov was in fact *Protocryptis sibiricella*, a fairly common species in St. Petersburg and Leningrad Province (Golutvina and Golutvin, 1980; Kataev and Golutvina, 1983; Chapchikova, 2017).

Increased population densities of other casebearer moths, *Haploptilia serratella* and/or *Suireia milvipennis*, were observed on birch in 2009 and 2010. Considerable damage to birch trees by casebearers was also recorded earlier (Rimsky-Korsakov and Selishchenskaya, 1949), but the exact species of the pest and the years of outbreaks remain unknown.

One more quite common species forming outbreaks in St. Petersburg and Leningrad Province is the bird-cherry ermine *Yponomeuta evonymella* (Linnaeus, 1758) (family Yponomeutidae), which damages only bird cherry. Although these plants can easily recover even after complete defoliation, during outbreaks the trees get completely covered with the weblike nests and totally lose their ornamental value. In 1996, the outbreak of the bird-cherry ermine coincided with that of the spindle ermine *Yponomeuta cagnagella* (Hübner, [1813]), which damaged spindle plants.

Members of the family Ypsolophidae have not been previously recorded as pests of plantings in St. Petersburg and Leningrad Province. The trophic associations of this family are poorly known. Two species, *Ypsolopha vittella* (Linnaeus, 1758) on elms and *Y. sequella* (Clerck, 1759) on maples, are practically ubiquitous but a significant increase in population density has been recorded only for *Y. vittella* (Denisova, 2009).

The polyphagous apple leaf miner *Lyonetia clerkella* (family Lyonetiidae) usually has low density. However, in 2002 its population abruptly increased in St. Petersburg and Leningrad Province, and in that year all the bird cherry leaves were damaged, with up to 3 mines per leaf. It should be noted that observations of this pest have been carried out regularly since 1920, and on an annual basis during the last 40 years, but no such event has been ever recorded before.

The poplar cosmet *Batrachedra praeangusta* (Haworth, 1828) (family Batrachedridae) was found in St. Petersburg in considerable numbers only once, in 2006–2008. An intense outbreak of this species was recorded in Slantsevsky District of Leningrad Province in 1990–1992 (Selikhovkin, 1994, 1996). It is quite possible that undocumented outbreaks of this pest also occurred in St. Petersburg before 2000.

The black-dotted groundling *Stenolechia gemmella* (Linnaeus, 1758) (family Gelechiidae) is an important permanent pest of oaks in the parks of St. Petersburg. We and our colleagues have repeatedly observed cases of considerable population growth of this species in different parts of St. Petersburg since 1992 (Lukmazova, 2010; Podolyatskaya, 2011), but in the last three years the pest density became very low.

The family Tortricidae has the greatest number of species (12) that periodically reach a significant level of abundance in the study region (Table 2). The most conspicuous member of this family in St. Petersburg is the green oak tortrix *Tortrix viridana* Linnaeus, 1758. Cases of significant increase of its population density in St. Petersburg have been recorded since 1933. The pest totally destroyed the young oak foliage in 1933, 1944, 1945, 1966, 2000, 2001, and 2013.

The rose tortrix *Archips rosana* was recorded in 1954 (Beloselskaya, 1955) on roadside and park plantings of the beach rose *Rosa rugosa* Thunb. and the dog rose *Rosa canina* L. High population densities of this moth were observed from 1971 to 1977, after which not a single case of significant population growth was detected. Instead, an abrupt increase in the population density of another, biologically similar tortrix species, the yellow rose button moth *Acleris bergmanniana* (Linnaeus, 1758), was recorded twice in the same dog rose plantings.

High population densities of the brown elm bell *Epinotia abbreviana* (Fabricius, 1794) were observed by us for several years on elms in St. Petersburg. No previous cases of such an increase have been recorded.

Significant densities of the grey poplar bell *Epinotia nisella* (Clerck, 1759) have been periodically recorded on poplar and aspen since 1935. However, observations of this species have been quite irregular.

Several species of tortrix moths, namely *Acleris forsskaleana* (Linnaeus, 1758), *Epinotia cruciana* (Linnaeus, 1761), *Gypsonoma minutana* (Hübner, [1799]), *Syricoris siderana* (Treitschke, 1835), and *Zeiraphera isertana* (Fabricius, 1794), were only once or twice recorded as conspicuous pests. It should be noted that considerable population growth of all the four species in Leningrad was noticed by various authors during the first half and the middle of the XX century (Rimsky-Korsakov, 1929; Rimsky-Korsakov and Gusev, 1938; Selishchenskaya, 1938; Beloselskaya, 1955; *Forest Pests*, 1955).

Table 3. Ecological density of *Tortrix viridana* L. in parks of St. Petersburg and its environs in 2009–2017

Locality	2009	2010	2011	2012	2013	2014	2015	2016	2017
Forestry Academy Park (Vyborgsky District)	11.0 ± 1.6	+	18.0 ± 3.4	52.2 ± 6.6	38.0 ± 6.1	16.7 ± 2.7	+	+	+
Moscow Victory Park (Moskovsky District)	+	+	16.3 ± 4.1	27.62 ± 5.4	17.2 ± 3.0	20.8 ± 3.9	+	+	+
Alexander Park (Pushkinsky District)	+	25.7 ± 6.6	24.4 ± 4.6	66.0 ± 8.8	38.3 ± 5.2	65.6 ± 7.0	+	+	+

+ the species was recorded but its ecological density was below the significant level.

Only fragmentary data are available on the pests of larch cones and seeds in St. Petersburg and Leningrad Province. The larch piercer *Cydia illutana* (Herrich-Schäffer, 1851) is known to be present in the region but a significant increase in its density was recorded only in 1974–1975 (Golutvina and Golutvin, 1980; Kataev and Golutvina, 1983). The population dynamics of the spruce seed moth *C. strobilella* (Linnaeus, 1758), a widespread pest of spruce cones, has been monitored quite regularly but locally, in particular in tree seed orchards and in the Lisino forest farm.

The following species were regularly recorded in considerable numbers in the permanent test plots: *Tortrix viridana* on oaks, *Epinotia abbreviana* on elms, *Eriocrania* spp. on birches, *Haploptilia serratella* and/or *Suireia milvipennis* on birches, *Phyllonorycter acerifoliella* on maples, *Ph. issikii* on limes, and species of the genus *Ypsolopha* on elms and maples.

Annual surveys carried out in these plots showed that the pest populations had low densities in 2009–2017. At densities of 10 larvae per 100 g of leaves and less, the density estimates are considered unrepresentative and cannot be used in comparative analysis. Correspondingly, we took into account only significant values and their standard deviations. The population density of the green oak tortrix was considerable in 2009–2014; the highest values were observed in the parks with prevalence of old oaks, i.e., in the Forestry Academy Park and especially the Alexander Park (Table 3).

Epinotia abbreviana was recorded during all the surveys but its population density was always below the significant level. The densities of *Eriocrania* spp. and *Haploptilia serratella* and/or *Suireia milvipennis* on birch increased only in 2009 and 2012 and reached the threshold values of 10–11 ind./100 g of leaves. A noticeable increase in the density of the lime leafminer *Phyllonorycter issikii* was recorded only in Moscow Victory Park in 2013 (10.1 ± 4.8 ind./100 g of leaves). *Phyllonorycter acerifoliella* was first found by us in 1998 but it was reliably identified only in 2010 when its population density was high. In the subsequent years the species had low density even though its mines were recorded annually from 2013 to 2017.

Ypsolopha sequella was found by us every year in all the examined maple trees but its density usually remained not higher than 3 ind./100 g of leaves, and reached 5.0 ± 0.9 ind./100 g of leaves only once, in the Forestry Academy Park in 2012. The population density of *Y. vittella* on elms was still lower while its highest values were also observed in the Forestry Academy Park in 2011 and 2012, reaching 3.1 ± 0.7 and 2.2 ± 0.8 ind./100 g of leaves, respectively. The latter species was not found in the permanent test plots in 2015.

Moths of the genus *Ypsolopha* damaging oak, lime, and birch trees were not identified to species. They were rarely recorded and their population density did not exceed 1.1–1.2 ind./100 g of leaves.

The group of free-living phyllophagous moths includes several well-known species (Table 4).

Regular and quite frequent outbreaks were characteristic of the looper moths *Erannis defoliaria* (Clerck, 1759) and *Operophtera brumata* (Linnaeus, 1758) (family Geometridae). A significant increase in the population density of the buff-tip *Phalera bucephala* (Linnaeus, 1758) (family Notodontidae) and the noctuids *Amphipyra pyramidea* and *Cosmia trapezina* (family Noctuidae) was recorded repeatedly, and that of the nun moth *Lymantria monacha* and the rusty tussock moth *Orgyia antiqua* (family Erebidae), only once. The white satin moth was a very common species in St. Petersburg from 1938 to 1971, and its outbreaks inflicting heavy damage to host plants were

Table 4. Population density of free-living moths in St. Petersburg and Leningrad Province

Pest species	Year	Region	Host plant	Ext	Int	Source of data
			Family GEOMETRIDAE			
Bupalus piniaria (Linnaeus, 1758)	1971	4	Pin	3	3	*Results*…, 2000
	1976, 1981–1982	4	Pin	2	2	
	1983	4	Pin	2	3	
	1993	3, 4	Pin	2	2	
	1994–1995	3, 4	Pin	3	3	
	1996–1997	3, 4	Pin	2	2	
	1998	3, 4	Pin	2	1	
Erannis defoliaria (Clerck, 1759)	1992	1	Ulm, Til, Que, Bet	2	2	Shcherbakova, 1998, 1999
	1993	1	Fra, Que, Til, Ulm, Bet	3	3	
	1994	1		3	3	
	1995	1		2	3	
	1996–1997	1	Ulm, Til, Que, Bet	2	2	
	2007	1	Ulm, Til, Fra	2	2	Lukmazova, 2010
	2008	1		2	1	
Operophtera brumata (Linnaeus, 1758)	1900–1901	1	Mal, Bet	2	2	Shreiner, 1902
	1948–1950	1	Ulm, Til, Que, Bet	2	2	Archive data
	1951–1952	1		3	2	
	1953, 1956	1		2	2	
	1992	1		1	1	Shcherbakova, 1999
	1993	1	Fra, Que, Til, Ulm, Bet	3	3	
	1994–1995	1		3	3	Shcherbakova, 1998, 1999
	2007	1	Ulm, Til, Fra	3	2	Lukmazova, 2010
	2008	1		3	1	
			Family NOTODONTIDAE			
Phalera bucephala (Linnaeus, 1758)	1937	1–3	Bet	2	2	Selishchenskaya, 1938
	1938	1–3	Bet	2	2	
	1947	1–3	Bet	2	2	*Research Activity Report*, 1990
	1947	1–3	Bet	2	2	
	2008	1–3	Ulm	1	1	Authors' data
			Family NOCTUIDAE			
Amphipyra pyramidea (Linnaeus, 1758)	1992	1	Ulm, Til, Que, Bet	2	2	Shcherbakova, 1998, 1999
	1993	1	Fra, Que, Til, Ulm, Bet	2	2	
	1994	1		1	1	
	2008	1	Ulm, Til, Fra	1	1	Lukmazova, 2010
Cosmia trapezina (Linnaeus, 1758)	1992–1993	1	Fra, Ulm, Til, Que, Bet	2	2	Shcherbakova, 1999
	1994	1		1	1	Shcherbakova, 1998, 1999

Table 4. (Contd.)

Pest species	Year	Region	Host plant	Ext	Int	Source of data
Panolis flammea (Denis et Schiffermüller, 1775)	1928	2, 3	Pin	3	3	Talman and Yatsentkovsky, 1938
	1979–1980	3	Pin	2	2	Gorokhovnikov et al., 1984; Lebedeva and Gorokhovnikov, 1984; *Results*…, 2000
			Family EREBIDAE			
Leucoma salicis (Linnaeus, 1758)	1935	1	Pp	2	1	Selishchenskaya, 1938
	1936	1	Pp	2	2	
	1937	1	Pp	3	2	
	1938	1	Pp	2	1	
	1971	1	Pp	2	1	Authors' data
Lymantria monacha (Linnaeus, 1758)	1926	5	Pin	2	1	Yatsentkovsky, 1931
Orgyia antiqua (Linnaeus, 1758)	1931	1, 2 ,4	Bet	2	2	Kurentsov, 1935
	1983	4	Bet	1	2	Kutenkova, 1986; *Results*…, 2000

Ext and int are the damage extensity and intensity assessed by the 3-point scale (see Table 1). Host plants: Pin, *Pinus sylvestris* (L.) (Scots pine); other designations as in Table 2.

recorded in 1935–1938 and 1971. However, during the last 45 years the species has been difficult to find in the city, and no population growth has been documented in Leningrad Province.

DISCUSSION

Concealed phyllophages (27 species) form the prevalent group in the studied complex of phyllophagous lepidopterans in St. Petersburg. This group also demonstrated the most significant changes in the species composition. Particularly notable is the recent appearance of two aggressive invaders of the family Gracillariidae: the horse-chestnut leafminer *Cameraria ohridella* and the lime leafminer *Phyllonorycter issikii*. Their current population density in St. Petersburg and Leningrad Province is not very high, but some of the infested horse chestnut trees had up to 12 mines per leaf (Martirova, 2017; Selikhovkin et al., 2017). Of other members of Gracillariidae, the poplar leaf blotch miner *Phyllonorycter populifoliella* can be regarded as an adventive species in St. Petersburg. One more apparently adventive species, *Ph. acerifoliella*, regularly occurs on maples and poses a potential threat to the plantings.

Of special interest is the change of dominant pests of some trees. In particular, *Acleris bergmanniana* has appeared on the dog rose instead of *Archips rosana*. The currently common species which have not reached significant densities in St. Petersburg in the past are *Lyonetia clerkella* on bird cherry, *Epinotia abbreviana* on elm, and *Batrachedra praeangusta* on poplar. At the same time, *Phyllonorycter salicicolella*, *Leucoma salicis*, and *A. rosana* have not been recorded in considerable numbers in St. Petersburg for many decades. A noticeable increase in the population density of *Lymantria monacha* was recorded only once, nearly a century ago, and that of *Orgyia antiqua*, only twice, in 1931 and 1983. During the past 30–40 years, larvae or adults of these species have been very hard to find in St. Petersburg and Leningrad Province.

The absence of previous records of outbreaks of *Ph. salicicolella* may be partly explained by the difficulty in identification of this species. The other species can be quite reliably identified based on adults; *L. monacha* and *O. antiqua*, also based on larvae, and *B. praeangusta*, on the damage pattern. No essential changes in the climate conditions or trophic resources have occurred in the study region, and it remains unknown why some species have not increased their abundance for a long time.

One of the possible factors of increasing activity of some pest may be the rise in temperatures during the vegetation season in St. Petersburg (Table 5). During the last 100 years, the mean monthly temperature of May, July, August, and September has increased by about 2 degrees, and that of June, by 1 degree Celsius.

Table 5. Mean monthly temperatures during the vegetation period in St. Petersburg, °C

Years	May	June	July	August	September
2009	12.1	15.0	18.2	16.8	13.9
2010	13.4	15.5	24.4	19.7	12.3
2011	11.0	17.5	22.5	17.7	13.1
2012	12.7	15.3	19.5	16.3	12.9
2013	14.4	19.8	19.0	18.6	12.1
2014	13.0	15.0	21.2	18.8	13.5
2015	11.8	15.9	16.9	18.3	14.0
2016	14.7	16.4	19.0	17.2	12.9
2017	9.4	13.6	16.5	17.4	12.5
2000–2017	12.1	15.8	19.8	17.8	12.5
1961–1990	10.9	15.6	17.7	16.2	11.0
1931–1960	9.9	15.4	18.4	16.8	11.2
1901–1930	9.8	14.9	18.0	15.7	10.8

This increase has been quite steady. In the last two years, the temperatures of May–August were considerably lower than the average values for 2000–2017. Correspondingly, in these years we observed local population growth only in two species: the cock's-head bell *Zeiraphera isertana* (in 2016) and the recent invader *Cameraria ohridella* (see Tables 2 and 5).

Another factor of changes in the complex of phyllophagous moths is the changing composition of the urban vegetation. In particular, extensive planting of poplars after the WWII conditioned the outbreak of *Phyllonorycter populifoliella* and the spread of *Batrachedra praeangusta*, whereas the relatively recent planting of horse chestnuts facilitated the invasion of the horse-chestnut leafminer.

In conclusion, it should be noted that the significance of phyllophagous moths (first of all the concealed forms) in St. Petersburg is currently increasing. Several warm vegetation seasons are likely to be accompanied by abrupt population growth of a number of species, in particular the recent invaders: the horse-chestnut leafminer *Cameraria ohridella*, the lime leafminer *Phyllonorycter issikii*, the probably adventive maple midget *Ph. acerifoliella*, and also some other species whose population density has increased only in the recent years.

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