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DYNAMICS OF EUROPEAN PINE SAWFLY FOCI AREA IN THE STANDS OF LOW DNIEPER REGION IN 2010–2017

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Dynamics of European pine sawfly (EPS) foci area in Low Dnieper region in 2010–2017 has been analyzed. The main outbreak parameters in six forest and forest & hunting enterprises of the region have been estimated. Area of EPS foci with the threat of forest damage over 25 % was from 499.3 ha in the State Enterprise "Ochakivske FHE" and 991.0 ha in the State Enterprise "Kakhovske FE" up to almost 5,000 ha in the State Enterprise "Tsurupinske FHE". For eight years one can distinguish only one EPS outbreak with the maximum in 2012 in the forest fund of all analyzed forest enterprises, except State Enterprise "Velykokopanivske FHE" with the maximum in 2013. Duration of a period with the threat of forest damage over 50 % during EPS outbreak did not exceed three years. Evaluation of the mean score of stand threat from EPS damage was suggested, which gives the possibility to compare outbreak dynamics in the forest fund of different forest enterprises not taking into account the absolute values of foci area. The reasons for the possible increase of outbreak duration in the region are considered.
K e y w o r d s: European pine sawfly (*Neodiprion sertifer* Geoffr.) (EPS), outbreak of mass propagation, focus of mass propagation, specific focus area, score of the stand damage threat.

Introduction. Analysis of long-term data on dynamics of foliage browsing insects' foci area in the forest fund of Ukraine in 1947–1977 has revealed that the probability of their outbreaks in the Steppe zone is almost twice higher than in the Forest-Steppe zone. Among these pests, European sawfly (*Neodiprion sertifer* Geoffr.) is in the first place by severity and duration of outbreaks (Meshkova 2002). Larvae of European pine sawfly consume two years old pine needle, which can bring to stand weakening at high insect population density and to stand mortality in a result of high needle losses (Reference book 1988). Research in different regions show (Meshkova 2002, 2009, Meshkova et al. 2009, Meshkova & Davydenko 2010, Meshkova & Kolienkina 2016) that European pine sawfly outbreaks usually develop cyclically at intervals of 9–12 years, and outbreak duration depends on environmental conditions.

It was found that over 40 % of European pine sawfly foci area falls on Kherson region (Meshkova 2002). Its considerable part belongs to Low Dnieper region, where massive afforestation was started over 60 years ago (Shevchuk et al. 2006). Almost 95 % of forest fund in Low Dnieper region is represented by pure pine plantations, which play a very important ecological role but grow in extremely unfavorable climatic conditions, on the southern timberline (Nazarenko 2000). European pine sawfly was found there for the first time in 1965 (Bekosipov 1956). As the stands grew, their attraction for this pest increased. So for 1992–2006 in comparison with 1981–1991, the average annual European pine sawfly foci area in the stands of Kherson region has increased by 5.4 times (by 20,970 hectares) (Nazarenko 2012).

Usually, the outbreak of monovoltinous insects lasts no more than seven years, and dangerous for forest population density is registered no more than two years in succession (Meshkova 2009, Reference book 1988). However, since the 80's, the cyclicity of European pine sawfly population dynamics with expressed years of maximum and minimum disrupted. Since 2001, the area of European pine sawfly foci in Kherson region exceeded 40 thousand hectares (which is almost equal to the area of pine stands in the region), despite regular forest treatment with chemical or viral preparations (Nazarenko 2012).

Due to the necessity to develop the strategy of forest protection, the analysis of current dynamics of European pine sawfly foci area in artificial stands of Low Dnieper region is very important, particularly taking into account such area distribution by crown damage threat.

The aim of the research was the evaluation of parameters for European pine sawfly outbreak dynamics in the Low Dnieper region in 2010–2017.

Materials and methods. To analyze European pine sawfly outbreak dynamics, statistical reporting materials for 2010–2017 from the State Enterprises (SE) "Velykokopanivske Forest & Hunting Economy" (FHE), "Holoprystanske FHE", "Zburyivske FHE", "Kakhovske Forest Economy" (FE) and "Tsurupinske FHE" (Kherson Regional Administration of Forest & Hunting Management), SE "Ochakivske FHE" (Mykolaiv Regional Administration of Forest & Hunting Management), as well as from the State Specialized Forest Protection Enterprise (SSFPE) "Khersonlisozahyst" were used.

Pine stand area in the forest fund of mentioned forest and forest & hunting enterprises was calculated using the forest inventory database of Production Association "Ukrderzhlisproekt" (as of 01.01.2011).

Severity, incidence (probability) and intervals between outbreaks of European pine sawfly in the forest fund of mentioned forest and forest & hunting enterprises have been evaluated (Meshkova 2009).

Outbreak severity was calculated as mean annual area and specific area of European pine sawfly foci in the forest fund of mentioned forest and forest & hunting enterprises. Specific foci area was evaluated as the ratio of absolute foci area (in hectares) to pine stands area in the forest fund of mentioned enterprises (thousand hectares) (Meshkova 2002).

Outbreak incidence (probability) in the forest fund of certain forest and forest & hunting enterprises was calculated as the ratio of the number of outbreak years to the duration of an investigated period, years (in percent) (Meshkova 2009).

The mean interval between outbreaks (years) was calculated as the ratio of an investigated period to the number of outbreaks during this period.

Statistical analysis of data was carried out by standard methods of Basic statistics and ANOVA (Atramentova & Utevskaja 2008) using *Microsoft Excel*.

In view of the differentiated assessment of stand damage threat within the foci of European pine sawfly mass propagation in recent years, we suggest to evaluate the *mean score of stand threat* by this pest (1):

$$T = \frac{(a_1 * 1 + a_2 * 2 + a_3 * 3 + a_4 * 4)}{(a_1 + a_2 + a_3 + a_4)}, \quad (1)$$

where T is the mean score of stand damage threat; a_1, a_2, a_3, and a_4 – the stand area with certain threat level: up to 25 %, 26–50 %, 51–75 % and over 75 %, respectively. According to this, score 1 corresponds to the up to the 25 % threat, score 2 – 26–50 %, score 3 – 51–75 %, and score 4 – over 75 %.

Results and discussion. Analysis of European pine sawfly outbreak severity for 2010–2017 shows (Table 1), that SE "Tsurupinske FHE" and SE "Holoprystanske FHE" (9,261.8 and 7,678.1 hectares, respectively) are on the first places by annual foci area.

Maximal area of European pine sawfly foci was also the highest in the forest fund of these enterprises, it exceeded 1.7 and 1.1 times the mean annual area in SE "Holoprystanske FHE" and SE "Tsurupinske FHE", respectively.

Mean annual area of European pine sawfly foci in SE "Zburyivske FHE" and SE "Kakhovske FE" was almost similar (3,515.3 and 3,081.5 hectares) but maximal foci area exceeded mean annual area 2 and 1.3 times, respectively. Both parameters were the lowest in SE "Ochakivske FHE".

The highest area of forests with pine as the main forest forming species belongs to SE "Holoprystanske FHE", SE "Tsurupinske FHE" and SE "Velykokopanivske FHE" (over 10 thousands of hectares in each). Such area is the lowest in SE "Ochakivske FHE". Maximal area of European pine sawfly foci exceeded the area of pine stands in two forest enterprises (SE "Zburyivske FHE" and SE "Holoprystanske FHE") (see Table 1). It may be explained by the location of some foci in unclosed pine plantations and in mixed pine stands, as well as by the increase of pine stand area after the last forest inventory.

Table 1

European pine sawfly outbreak severity in the forest fund of the state forest enterprises and forest & hunting enterprises of the Low Dnieper region (2010–2017)

State forest enterprises and forest & hunting enterprises	Pine stand area, hectares	Foci area, hectares					
		maxi-mal	specific	mean annual			
				total	including with stand damage threat*		
					до 25 %	26–50 %	51–75 %	>75 %
“Velykokopanivske FHE”	10,262.3	7,830.0	613.9	6,299.8	4,865.9 / 67.6	1,783.3 / 24.8	791.0 / 3.1	757.3 / 4.5
“Holoprystanske FHE”	12,843.8	13,030.0	597.8	7,678.1	6386.6 / 83.2	1,377.0 / 15.7	693.0 / 1.1	0.0 / 0.0
“Zburyivske FHE”	5,922.3	7,035.0	593.6	3,515.3	3,010.6 / 85.6	1,099.3 / 11.7	445.0 / 1.6	294.0 / 1.0
“Kakhovske FE”	4,185.9	3,912.0	736.2	3,081.5	2,090.1 / 67.8	534.6 / 17.3	56.9 / 1.9	399.9 / 13.0
“Tsurupinske FHE”	12,839.3	10,460.0	721.4	9,261.8	7,110.4 / 76.8	2,355.3 / 19.1	1,034.5 / 2.8	1,610.0 / 2.2
“Ochakivske FHE”	3,709.1	1,800.0	278.4	1,032.8	848.3 / 82.1	238.8 / 11.6	138.0 / 3.3	122.5 / 3.0

*denominator is the part of total mean annual foci area, %.

Taking into account the available data concerning pine stand area in the forest fund of analyzed enterprises, specific area of European pine sawfly foci has been calculated. It was significantly the lowest in SE “Ochakivske FHE” (278.4 ha per 1000 ha of pine stands) and ranged from 593.6 (SE “Zburyivske FHE”) to 736.2 (SE “Kakhovske FE”) hectares per 1000 hectares of pine stands.

Analysis of annual foci area of European pine sawfly distribution by the level of stand damage threat shows that from 67.6 to 85.6 % of this area belonged to plots, which are not pest foci by definition, they are only the plots where this insect occurs. It is accepted (Reference book 1988) that forest protection is necessary only if the threat of stand damage exceeds 30 %. Since the requirements of statistical reporting distinguish the gradation of such threat “26–50 %”, “51–75 %” and “over 75 %”, let us consider an appropriate distribution of European pine sawfly foci area in the pine stands of the Low Dnieper region.

As we can see from Table 1, the stands with the threat of damage by European pine sawfly 26–50 % were from 11.6 and 11.7 % from annual foci area in SE “Ochakivske FHE” and SE “Zburyivske FHE” to 24.8 % from annual foci area in SE “Velykokopanivske FHE”. The stands with the threat of damage by European pine sawfly 51–75 % make up 1.1–3.3 % from annual foci area in analyzed forest enterprises. The stands with the threat of damage by European pine sawfly over 75 % were not found at all in SE “Holoprystanske FHE”, had the largest area (13 % from annual foci area of this pest) in SE “Kakhovske FE”, and in other forest enterprises such stands occupied 1–4.5 % from annual foci area of European pine sawfly (see Table 1).

Considering that stand treatment with insecticides or viral preparations is prescribed only in the case of stand damage threat exceeds 30 % (by statistical reporting – not less than 26 %), we have calculated the total area of European pine sawfly foci with the threat of stand damage over 25 % (that is the sum of areas with a threat of 26–50, 51–75 and over 75 %), and with the threat of stand damage over 50 % (that is the sum of areas with a threat of 51–75 and over 75 %), that is the accumulation. Then we sorted analyzed forest enterprises by foci area with stand damage threat over 75 % (Fig. 1).

Both the annual foci area (see Table 1) and the area of foci with different levels of stand damage threat were the highest in SE “Tsurupinske FHE”, SE “Velykokopanivske FHE” and SE “Holoprystanske FHE” (see Fig. 1).

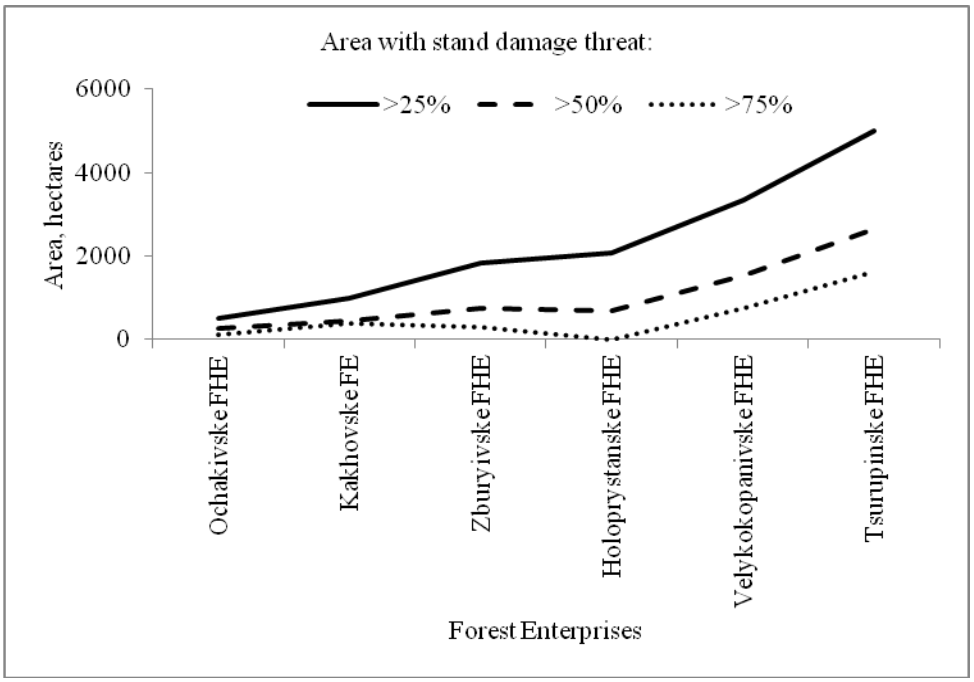

Fig. 1 – European pine sawfly foci area with stand damage threat over 25, 50 and 75 % in the forest fund of the State Forest Enterprises and Forest & Hunting Enterprises of the Low Dnieper region (2010–2017)

It can be seen that as the threat of stand damage over 25 % increases, the difference between the area with the threat of stand damage over 25 % and over 50 % increases too. The total European pine sawfly foci area with the threat of stand damage over 25 % was from 499.3 hectares in SE "Ochakivske FHE" and 991 hectares in SE "Kakhovske FE" to almost 5,000 hectares in SE "Tsurupinske FHE". It is such areas one must take into account during the planning of forest treatment with insecticides.

Evaluation of dynamics of stand damage threat in European pine sawfly foci, taking into account their distribution by damage threat level and calculation the mean score of stand damage threat show that 2012 was the outbreak maximum in all analyzed forest enterprises, except SE "Velykokopanivske FHE", where it was 2013 (Fig. 2).

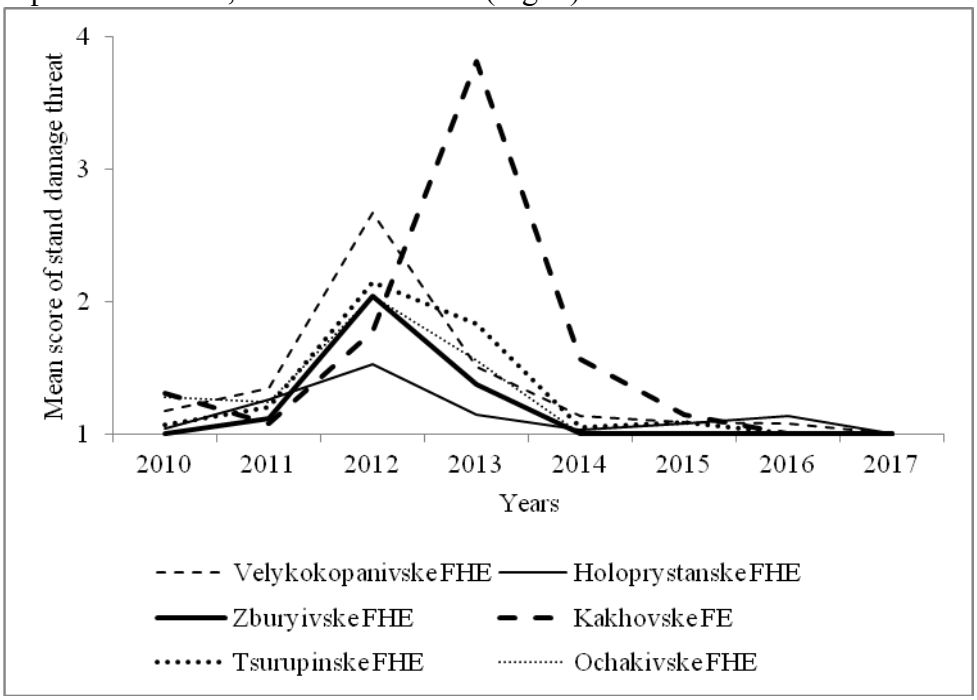

Fig. 2 – Dynamics of mean score of stand damage threat in European pine sawfly foci in the forest fund of the State Forest Enterprises and State Forest & Hunting Enterprises of the Low Dnieper region (2010–2017)

In the forest fund of all analyzed forest enterprises, the mean score of stand damage threat was less than 1.5 points and did not exceed 1.1 points in 2015–2017. All differences in dynamics of European pine sawfly outbreak were revealed in 2012–2014. So in 2012, the stand damage threat reached 2.7 points for SE "Velykokopanivske FHE", 2.14 points for SE "Tsurupinske FHE", 2 points for SE "Zburyivske FHE" and SE "Ochakivske FHE", 1.8 points for SE "Kakhovske FE", and 1.5 points for SE "Holoprystanske FHE". In 2013, the mean score of stand damage threat has decreased in the forest fund of all forest enterprises, except SE "Kakhovske FE", where it has increased up to 3.8 points and was still quite high (1.6 points) in 2014 (see Fig. 2).

Analysis of Fig. 2 shows that European pine sawfly population and the respective threat of stand damage increased in SE "Kakhovske FE" slower than in the stands of other forest enterprises, reached the maximum one year later and decreased also slowly. Quick growth and decline of stand damage threat were characteristics for SE "Velykokopanivske FHE", and quick growth and slow decline for SE "Tsurupinske FHE" and SE "Ochakivske FHE".

Thus, the submission of stand survey results in the form of dynamics of the mean score of stand damage threat makes it possible to compare the outbreak dynamics of European pine sawfly in different stands not taking into account the absolute foci area.

In order to explain the differences in outbreak dynamics of European pine sawfly in different stands, foci area was differentiated by stand damage threat level (with accumulation) (Fig. 3).

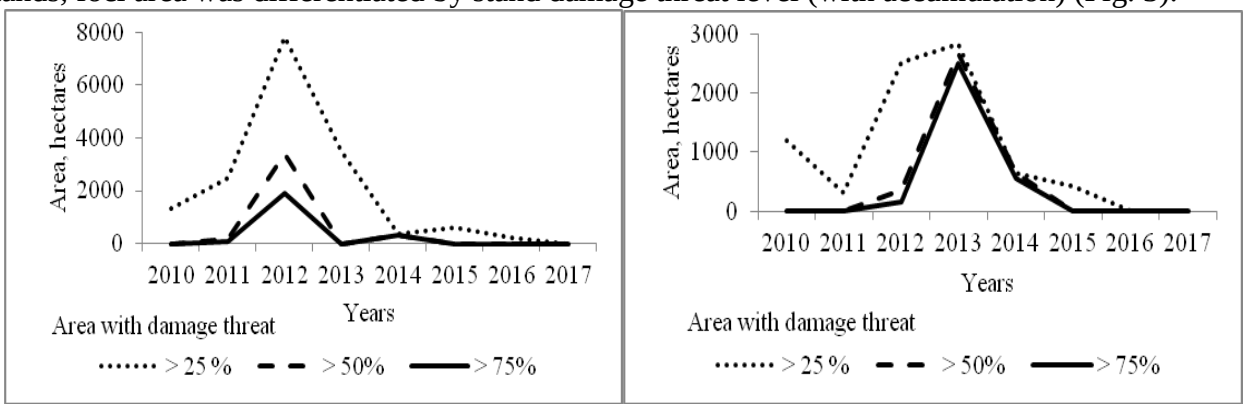

Fig. 3 – Dynamics of European pine sawfly foci area with stand damage threat over 25, 50 and 75 % in the forest fund of SE "Velykokopanivske FHE" (left) and SE "Kakhovske FE" (right) (2010–2017)

So in the forest fund of SE "Velykokopanivske FHE", the area of European pine sawfly foci with stand damage threat over 25 % exceeded 1,000 ha even in 2010, but stands with damage threat over 50 % and moreover 75 % were absent (see Fig. 3, left). In 2011, the foci area with stand damage threat over 25 % increased almost twice, and in 2012, the foci area with stand damage threat over 25 %, 50 and 75 % has increased in the forest fund of this enterprise. In 2013, the distribution of foci area was similar to 2011, and in 2014–2017, stand damage threat over 25 % was assessed for the relatively small area.

In SE "Kakhovske FE", the foci of European pine sawfly with stand damage threat over 50 % and over 75 % were revealed only in 2012–2014 with the maximum in 2013 (see Fig. 3, right). However, European pine sawfly foci area with stand damage threat over 25 % was registered from 2010 to 2015.

Because of availability of detailed data on European pine sawfly foci area only for 8 years, parameters of outbreak duration, intervals between outbreaks and outbreak frequency (probability) were calculated only as an implementation of the methodical approach. At the same time, even such limited sample shows certain peculiarities.

Thus, in the forest fund of all analyzed enterprises, there is the high probability (87.5–100 %) of European pine sawfly propagation up to stand damage threat 25 % (Table 2). The probability of 26–50 % stand damage is less in all analyzed enterprises than stand damage threat below 25 % (it is similar in SE "Velykokopanivske FHE"), and probability of 51–75 % stand damage is less than its 26–50 % damage.

Table 2

Probability of European pine sawfly outbreaks with different stand damage threat in the forest fund of the State Forest Enterprises and State Forest & Hunting Enterprises of the Low Dnieper region

State forest enterprises and forest & hunting enterprises	Outbreak probability (%) with stand damage threat:			
	up to 25 %	26–50 %	51–75 %	over 75 %
SE "Velykokopanivske FHE"	87.5	87.5	25.0	37.5
SE "Holoprystanske FHE"	100.0	87.5	12.5	–
SE "Zburyivske FHE"	100.0	37.5	12.5	12.5
SE "Kakhovske FE"	87.5	62.5	37.5	37.5
SE "Tsurupinske FHE"	100.0	75.0	25.0	12.5
SE "Ochakivske FHE"	100.0	50.0	25.0	25.0

Analysis of foci area of European pine sawfly shows only one outbreak for eight years in the forest of all analyzed forest enterprises (see Fig. 3). Two periods with damage increase up to 25 % (Fig. 4) can be connected with foci area redistribution by threat of stand damage in the years before and after outbreak maximum.

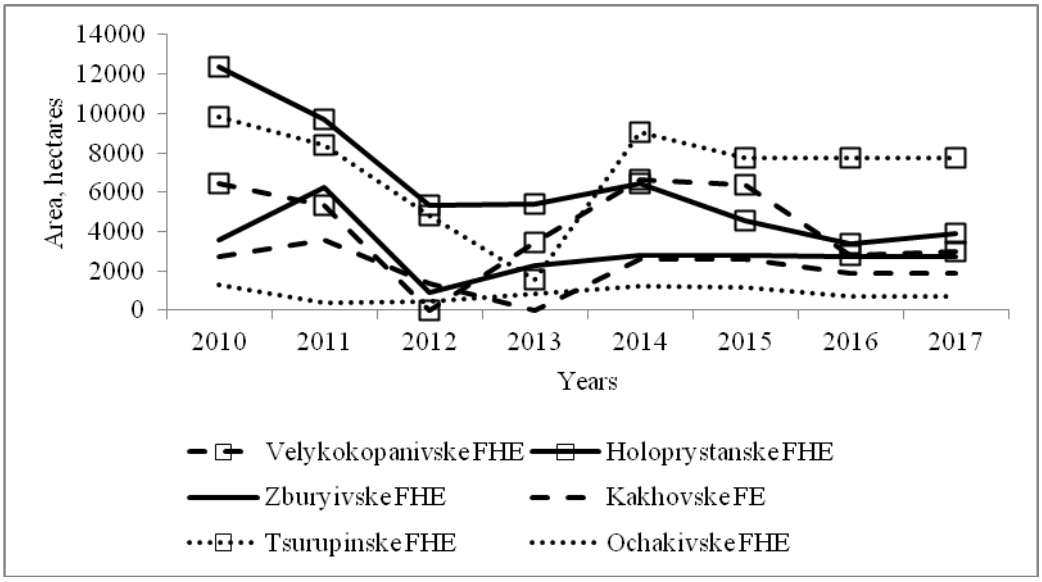

Fig. 4 – Dynamics of European pine sawfly foci area with stand damage threat up to 25 % in the forest fund of the State Forest Enterprises and State Forest & Hunting Enterprises of the Low Dnieper region (2010–2017)

Analyzed data show that the interval between European pine sawfly outbreaks in the Low Dnieper region makes at least eight years. It respects to publications on this pest population dynamics (Meshkova 2009, Meshkova & Kolienkina 2016).

Period with high stand damage threat (over 50 %) during European pine sawfly outbreak did not exceed three years (see Fig. 3), while the stands with damage threat below 25 % exist almost always.

Forest treatment with chemical insecticides or with viral preparations later than it was necessary could be one of the causes for outbreaks lengthening (Meshkova & Nazarenko 2011a). Such delay may be the result of unfavorable weather conditions or complications with the agreement with respective offices. In result of such lateness, the most healthy and fertile specimens survive, population increases the next year, and outbreak lengthened (Meshkova & Davydenko 2000).

The second cause of European pine sawfly outbreak lengthening is a diversity of relief and forest site conditions even in one forest stand. Therefore pest population density increases in different years in different plots, which gives the impression of a permanent outbreak in the forest or even in the region (Meshkova & Nazarenko 2002, 2011b).

The third cause consists in holding the foci "in the account" after their collapse.

The fourth, and the main cause, in our opinion, is connected with indication in the reports the whole area with European pine sawfly presence (and this pest is always present in pine forest!), while the foci are the plots with increased pest population, which can cause stand damage over 30 % (Reference book, 1988).

Conclusions. By European pine sawfly foci area in the Low Dnieper region, the leading places belong to SE "Tsurupinske FHE" and SE "Holoprystanske FHE", and the last place belongs to SE "Ochakivske FHE".

European pine sawfly foci area with stand damage threat over 25 % is from 499.3 ha in SE "Ochakivske FHE" and 991.0 ha in SE "Kakhovske FE" to almost 5,000 ha in SE "Tsurupinske FHE".

In the forest fund of the most of the analyzed forest enterprises, the maximum of the outbreak was registered in 2012, and only in SE "Velykokopanivske FHE" it was in 2013. For eight years only one outbreak clearly stands out. The length of periods with stand damage threat over 50 % does not exceed three years.

Evaluation of the mean score of stand threat from European pine sawfly damage gives the possibility to compare outbreak dynamics in the forest fund of different forest enterprises not taking into account the absolute values of foci area.

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ДИНАМІКА ПЛОЩ ОСЕРЕДКІВ РУДОГО СОСНОВОГО ПИЛЬЩИКА В НАСАДЖЕННЯХ НИЖНЬОДНІПРОВ'Я У 2010–2017 рр.

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Проаналізовано динаміку площ осередків масового розмноження рудого соснового пильщика (РСП) у Нижньодніпров'ї за 2010–2017 рр. Визначено основні параметри спалахів у шести лісогосподарських і лісомисливських підприємствах регіону. Площа осередків РСП із загрозою пошкодження насаджень понад 25 % становила від 499,3 га у ДП «Очаківське ЛМГ» та 991,0 га у ДП «Каховське ЛГ» до майже 5000 га у ДП «Цюрупинське ЛМГ». За вісім років у лісовому фонді всіх проаналізованих підприємств вирізняється один період спалаху РСП з максимумом у 2012 р, лише у ДП «Великокопанівське ЛМГ» – у 2013 р. Тривалість періоду із загрозою насадженням понад 50 % під час масового розмноження РСП не перевищувала трьох років. Запропоновано розраховувати середній бал загрози пошкодження насаджень РСП, що дає змогу порівняти динаміку площ осередків у лісовому фонді різних підприємств, не беручи до уваги абсолютних значень площі осередків. Розглянуто причини можливого подовження спалахів масового розмноження РСП у регіоні.

Ключові слова: рудий сосновий пильщик (*Neodiprion sertifer* Geoffr.) (РСП), спалах масового розмноження, осередок масового розмноження, питома площа осередку, бал загрози пошкодження насаджень.

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ДИНАМИКА ПЛОЩАДЕЙ ОЧАГОВ РЫЖЕГО СОСНОВОГО ПИЛИЛЬЩИКА В НАСАЖДЕНИЯХ НИЖНЕДНЕПРОВЬЯ В 2010–2017 гг.

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Проанализирована динамика площадей очагов массового размножения рыжего соснового пилильщика (РСП) в Нижнеднепровье за 2010–2017 гг. Определены основные параметры вспышек в шести лесохозяйственных и лесоохотничьих предприятиях региона. Площадь очагов РСП с угрозой повреждения насаждений свыше 25 % составляла от 499,3 га в ГП «Очаковское ЛОХ» и 991,0 га в ГП «Каховское ЛХ» до почти 5000 га в ГП «Цюрупинское ЛОХ». За восемь лет в лесном фонде всех проанализированных предприятий выделяется один период вспышки РСП с максимумом в 2012 г., лишь в ГП «Великокопанивское ЛОХ» – в 2013 г. Продолжительность периода с угрозой насаждениям свыше 50 % во время массового размножения РСП не превышала трех лет. Предложено рассчитывать средний балл угрозы повреждения насаждений РСП, что позволяет сравнивать динамику площади очагов в лесном фонде разных предприятий, не принимая во внимание абсолютных значений площади очагов. Рассмотрены причины возможного увеличения продолжительности вспышек массового размножения РСП в регионе.

Ключевые слова: рыжий сосновый пилильщик (*Neodiprion sertifer* Geoffr.) (РСП), вспышка массового размножения, очаг массового размножения, удельная площадь очага, балл угрозы повреждения насаждений.

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