PNIE PROCEEDINGS OF THE NATIONAL INSTITUTE OF ECOLOGY OF THE REPUBLIC OF KOREA

Original Article

PNIE 2025;6(3):127-134
https://doi.org/10.22920/PNIE.2025.6.3.127
pISSN 2765-2203, eISSN 2765-2211

Seasonal and Forest Type-based Comparison of Nocturnal Insect Diversity Using Bucket Light Traps

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ABSTRACT

Understanding insect diversity is crucial for establishing policies for conservation and ecosystem management. This study investigated seasonal variation in nocturnal insect diversity using bucket light traps across three forest types—coniferous, deciduous, and mixed forests—in Gimje, Jeollabuk-do, Republic of Korea. Surveys were conducted in spring, summer, and fall; 934 species and 13,531 individuals from 14 insect orders were collected. The highest numbers of species and individuals were recorded in summer and in the mixed forest. One-way analysis of variance revealed significant seasonal differences in the numbers of species and individuals ($P<0.05$), whereas forest-type differences were significant only for the number of species between coniferous and mixed forests. These findings suggest that surveys conducted in summer and in mixed forests are most effective for assessing insect diversity. The results provide a foundational reference for improving survey methodologies in the National Ecosystem Survey and for long-term biodiversity monitoring.

Keywords: Bucket light trap, Forest type, Insect diversity, Nocturnal insects, Seasonal variation

Introduction

Insects play a critical role in ecosystems and are widely used as indicators of biodiversity (Basset *et al.*, 2012; Samways, 2007; Thomas, 2005). Their distribution and number of individuals are influenced by various factors, including season, forest type, climate, and environmental change, all of which serve as important indicators for evaluating ecosystem health and stability (Kremen *et al.*, 1993). Therefore, accurate assessment and monitoring of insect diversity are essential for establishing policies for conservation and ecosystem management (Andersen, 1999; Didham *et al.*, 2012).

Among various methods for surveying insects, light traps are commonly used to capture nocturnal insects because of their efficiency (Intachat & Woiwod, 1999). Light traps utilize the phototactic behavior of insects and are particularly useful in studies on community structure and seasonal variation of nocturnal species (Frank, 1988). However, survey results may be influenced by trap placement, survey timing and location, and duration of operation (Yela & Holyoak, 1997). Therefore, standardization of trap setup and collection protocols is necessary for clarify the differences in insect diversity by season and forest type (Thomas, 2005).

The bucket light trap is advantageous because of its lightweight design, allowing for easy installation and high sampling efficiency across various environments (Brown

Received July 5, 2025; **Revised** July 24, 2025; **Accepted** July 25, 2025

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et al., 2000). This study was conducted as part of a methodological improvement initiative for the terrestrial insect components of the National Ecosystem Survey. It aimed to compare insect diversity according to season and forest type using bucket light traps and to provide guidelines for optimal trap deployment in terms of timing and location. The results of this study are expected to serve as a valuable foundation for standardizing insect monitoring and evaluating ecosystem changes.

Materials and Methods

Survey period and sites

Surveys were conducted in spring (May), summer (July), and autumn (September). Forest types were categorized as coniferous, deciduous, and mixed. The study was conducted in the areas surrounding Moaksan and Guseongsan in Gimje, Jeollabuk-do. For each forest type, three surveys were conducted per season, totaling nine surveys (27 traps; Table 1).

Survey method

The surveys followed the National Ecosystem Survey guidelines. Bucket light traps (BL, 12 W) were operated using timers set from 20:00 to 24:00, and samples were collected the following morning. The collected specimens were stored on-site and transported to the laboratory for identification.

Sample processing and statistical analysis

The specimens were identified by taxonomic experts and were categorized into the orders Lepidoptera, Coleoptera, Hymenoptera, Diptera, and Hemiptera. One-way analysis of variance (ANOVA) was used to compare the

Table 1. Survey period and sites of bucket light traps

Survey round	Survey date	Season	Forest type	Coordinates
1st	May 29, 2023	Spring	Coniferous	N 35.72082, E 127.0663
			Mixed	N 35.72187, E 127.0639
			Deciduous	N 35.71802, E 127.0655
2nd	May 30, 2023	Spring	Coniferous	N 35.72537, E 127.0648
			Mixed	N 35.72651, E 127.0658
			Deciduous	N 35.72775, E 127.0682
3rd	May 31, 2023	Spring	Coniferous	N 35.71260, E 127.0567
			Mixed	N 35.71271, E 127.0590
			Deciduous	N 35.71223, E 127.0600
4th	July 11, 2023	Summer	Coniferous	N 35.72082, E 127.0663
			Mixed	N 35.72187, E 127.0639
			Deciduous	N 35.71802, E 127.0655
5th	July 12, 2023	Summer	Coniferous	N 35.72537, E 127.0648
			Mixed	N 35.72651, E 127.0658
			Deciduous	N 35.72775, E 127.0682
6th	July 30, 2023	Summer	Coniferous	N 35.74209, E 127.0274
			Mixed	N 35.74589, E 127.0296
			Deciduous	N 35.74667, E 127.0272
7th	September 14, 2023	Autumn	Coniferous	N 35.72082, E 127.0663
			Mixed	N 35.72187, E 127.0639
			Deciduous	N 35.71802, E 127.0655
8th	September 15, 2023	Autumn	Coniferous	N 35.72537, E 127.0648
			Mixed	N 35.72651, E 127.0658
			Deciduous	N 35.72775, E 127.0682
9th	September 16, 2023	Autumn	Coniferous	N 35.74209, E 127.0274
			Mixed	N 35.74589, E 127.0296
			Deciduous	N 35.74667, E 127.0272

number of species and individuals by season and forest type, followed by Scheffe's post hoc test. Statistical significance was set at $P<0.05$, and SPSSWIN v.28.0 (IBM Co., Armonk, NY, USA) was used for all analyses.

Results

Overall summary

In total, 13,531 individuals representing 934 species from 129 families and 14 orders were recorded. The mixed forest yielded 720 species and 5,139 individuals across 13 orders and 99 families; the deciduous forest yielded 645 species and 4,559 individuals from 11 orders and 97 families; and the coniferous forest yielded 580 species and 3,833 individuals from 11 orders and 87 families.

In the coniferous forest, 222 species and 815 individuals were recorded in spring, 341 species and 1,673 individuals in summer, and 280 species and 1,345 individuals in autumn. In the mixed forest, 333 species and 1,112 individuals were recorded in spring, 440 species and 2,452 individuals in summer, and 336 species and 1,575 individuals in autumn. In the deciduous forest, 238 species and 1,091 individuals were found in spring, 398 species and 2,090 individuals in summer, and 306 species and 1,378 individuals in autumn. In all seasons, the mixed forest had the highest numbers of species and individuals, whereas the coniferous forest had the lowest numbers (Table 2).

Seasonal status of the taxonomic groups

In spring, 432 species and 3,018 individuals were recorded, with Lepidoptera being dominant (315 species and 2,413 individuals), followed by Coleoptera (59 species and 315 individuals), Hymenoptera (28 species and 70 individuals), Hemiptera (12 species and 32 individuals), and Trichoptera (6 species and 130 individuals).

In summer, 567 species and 6,215 individuals were recorded, with Lepidoptera being dominant (427 species and 5,037 individuals), followed by Coleoptera (59 species and 317 individuals), Hymenoptera (34 species and 661 individuals), Hemiptera (25 species and 134 individuals), and Neuroptera (7 species and 20 individuals).

In autumn, 474 species and 4,298 individuals were recorded, with Lepidoptera being dominant (310 species and 3,391 individuals), followed by Hymenoptera (63 species and 400 individuals), Diptera (28 species and 108 individuals), Coleoptera (28 species and 76 individuals), and Hemiptera (18 species and 73 individuals; Table 3).

Forest type status of the taxonomic groups

In the coniferous forest, 580 species and 3,833 individuals were recorded. Lepidoptera was dominant (406 species and 2,915 individuals), followed by Coleoptera (68 species and 202 individuals), Hymenoptera (42 species and 425 individuals), Hemiptera (21 species and 104 individuals), and Diptera (16 species and 41 individuals).

In the mixed forest, 720 species and 5,139 individuals were recorded. Lepidoptera was dominant (540 species and 4,207 individuals), followed by Coleoptera (68 species and 276 individuals), Hymenoptera (48 species and 417 individuals), Hemiptera (22 species and 55 individuals), and Trichoptera (15 species and 83 individuals).

In the deciduous forest, 645 species and 4,559 individuals were recorded. Lepidoptera was dominant (471 species and 3,719 individuals), followed by Coleoptera (68 species and 230 individuals), Hymenoptera (39 species and 289 individuals), Hemiptera (26 species and 80 individuals), and Diptera (17 species and 52 individuals; Table 4).

Statistical analysis

Seasonal comparison

The average number of species was highest in summer (265.67), followed by autumn (204.33) and spring (156.22). Similarly, the average number of individuals was highest in summer (690.56), followed by autumn (477.56) and spring (335.33; Table 5).

One-way ANOVA indicated significant differences among seasons in the number of species ($F=22.319$, $P<0.05$) and individuals ($F=25.476$, $P<0.05$; Table 6).

Scheffe's post hoc tests revealed significant differences in the number of species between spring and summer ($P<0.001$), spring and autumn ($P<0.025$), and summer and autumn ($P<0.004$). Significant differences were also observed in the number of individuals between spring and summer ($P<0.001$), spring and autumn ($P<0.031$), and summer and autumn ($P<0.001$; Table 7).

Comparison among forest types

The average number of species was highest in the mixed forest (243.89), followed by deciduous forests (203.89) and coniferous forests (178.44). Similarly, the average number of individuals was highest in mixed forest (571.00), followed by deciduous forests (506.56) and coniferous forests (425.89; Table 8).

One-way ANOVA showed significant difference in the number of species by forest type ($F=3.691$, $P<0.040$); however, no significant differences were noticed in the number of individuals ($F=1.520$, $P=0.239$; Table 9).

Post hoc tests for the number of species indicated significant difference between coniferous and mixed forests ($P<0.042$), whereas no significant differences were observed between coniferous and deciduous forests or deciduous and mixed forests. No significant differences were observed in the number of individuals among any of the forest-type pairs (Table 10).

Table 2. Overall summary of the survey results

Season	Taxa	Coniferous forest	Mixed forest	Deciduous forest	Total
Spring	Order	9	9	11	12
	Family	53	57	62	78
	Species	222	333	238	432
	Individual	815	1,112	1,091	3,018
Summer	Order	10	10	9	12
	Family	53	62	57	84
	Species	341	440	398	567
	Individual	1,673	2,452	2,090	6,215
Autumn	Order	8	8	8	9
	Family	46	47	41	65
	Species	280	336	306	469
	Individual	1,345	1,575	1,378	4,298
Total		11 orders, 87 families, 580 species, and 3,833 individuals	13 orders, 99 families, 720 species, and 5,139 individuals	11 orders, 97 families, 645 species, and 4,559 individuals	14 orders, 129 families, 934 species, and 13,531 individuals

Table 3. Overview of taxonomic groups by season

Taxa	Spring		Summer		Autumn		Total	
	No. of species	No. of individuals	No. of species	No. of individuals	No. of species	No. of individuals	No. of species	No. of individuals
Ephemeroptera	1	2	2	9	-	-	3	11
Mantodea	-	-	-	-	2	2	2	2
Plecoptera	2	21	2	14	-	-	4	35
Orthoptera	1	2	3	4	6	79	10	85
Phasmatodea	1	1	1	1	-	-	2	2
Embioptera	-	-	1	1	-	-	1	1
Hemiptera	12	32	25	134	18	73	45	239
Megaloptera	1	3	-	-	-	-	1	3
Neuroptera	1	1	7	20	2	11	7	32
Coleoptera	59	315	59	317	28	76	110	708
Hymenoptera	28	70	34	661	63	400	87	1,131
Diptera	5	28	3	7	28	108	32	143
Trichoptera	6	130	3	10	17	158	23	298
Lepidoptera	315	2,413	427	5,037	310	3,391	607	10,841
Total	432	3,018	567	6,215	474	4,298	934	13,531

-, not applicable.

Discussion

Seasonal analysis showed that summer had the highest number of species (567 species) and individuals (6,215 individuals), followed by autumn (474 species and 4,298 individuals) and spring (432 species and 3,018 individuals). Compared to spring and autumn, summer showed approximately 31.2% and 19.6% higher number of species and 105.9% and 44.6% higher number of individuals than those in autumn and spring, respectively.

By forest type, the mixed forest had the highest number of species (720 species) and individuals (5,139 individu-

Table 4. Overview of taxonomic groups by forest type

Taxa	Coniferous forest		Mixed forest		Deciduous forest		Total	
	No. of species	No. of individuals	No. of species	No. of individuals	No. of species	No. of individuals	No. of species	No. of individuals
Ephemeroptera	1	2	-	-	2	9	3	11
Mantodea	-	-	2	2	-	-	2	2
Plecoptera	4	20	3	5	2	10	4	35
Orthoptera	7	38	2	32	6	15	10	85
Phasmatodea	-	-	2	2	-	-	2	2
Embioptera	-	-	1	1	-	-	1	1
Hemiptera	21	104	22	55	26	80	45	239
Megaloptera	1	1	1	1	1	1	1	3
Neuroptera	3	11	3	8	5	13	7	32
Coleoptera	68	202	68	276	68	230	110	708
Hymenoptera	42	425	48	417	39	289	87	1,131
Diptera	16	41	13	50	17	52	32	143
Trichoptera	11	74	15	83	8	141	23	298
Lepidoptera	406	2,915	540	4,207	471	3,719	607	10,841
Total	580	3,833	720	5,139	645	4,559	934	13,531

-, not applicable.

Table 5. Descriptive statistics of the number of species and individuals by season

Factors		Mean	Standard deviation	Standard error	Minimum	Maximum
Number of species	Spring	156.22	26.00	8.67	121.00	206.00
	Summer	265.67	48.27	16.09	199.00	347.00
	Autumn	204.33	25.17	8.39	180.00	253.00
	Total	208.74	56.60	10.89	121.00	347.00
Number of individuals	Spring	335.33	57.12	19.04	246.00	415.00
	Summer	690.56	152.44	50.81	473.00	991.00
	Autumn	477.56	85.87	28.62	363.00	598.00
	Total	501.15	180.42	34.72	246.00	991.00

Table 6. Analysis of variance for number of species and individuals by season

Factors		Sum of squares	df	Mean square	F	*P*-value
Number of species	Between groups	54,163.630	2	27,081.815	22.319	<0.05
	Within groups	29,121.556	24	1,213.398	-	-
	Total	83,285.185	26	-	-	-
Number of individuals	Between groups	575,336.963	2	287,668.481	25.476	<0.05
	Within groups	271,000.444	24	11,291.685	-	-
	Total	846,337.407	26	-	-	-

-, not applicable.

Table 7. Scheffe's post hoc multiple comparison for number of species and individuals by season

Dependent variable	(I) Season	(J) Season	Mean difference (I–J)	Std. error	*P*-value	95% Confidence interval	
						Lower bound	Upper bound
Number of species	Spring	Summer	–109.44444	16.42084	<0.001	–152.2826	–66.6063
		Autumn	–48.11111	16.42084	<0.025	–90.9492	–5.2730
	Summer	Spring	109.44444	16.42084	<0.001	66.6063	152.2826
		Autumn	61.33333	16.42084	<0.004	18.4952	104.1714
	Autumn	Spring	48.11111	16.42084	<0.025	5.2730	90.9492
		Summer	–61.33333	16.42084	<0.004	–104.1714	–18.4952
Number of individuals	Spring	Summer	–355.22222	50.09255	<0.001	–485.9019	–224.5426
		Autumn	–142.22222	50.09255	<0.031	–272.9019	–11.5426
	Summer	Spring	355.22222	50.09255	<0.001	224.5426	485.9019
		Autumn	213.00000	50.09255	<0.001	82.3203	343.6797
	Autumn	Spring	142.22222	50.09255	<0.031	11.5426	272.9019
		Summer	–213.00000	50.09255	<0.001	–343.6797	–82.3203

Table 8. Descriptive statistics of number of species and individuals by forest type

Factors		Mean	Standard deviation	Standard error	Minimum	Maximum
Number of species	Coniferous forest	178.44	36.64	12.21	121.00	228.00
	Mixed forest	243.89	62.30	20.77	165.00	347.00
	Deciduous forest	203.89	52.33	17.44	132.00	290.00
	Total	208.74	56.60	10.89	121.00	347.00
Number of individuals	Coniferous forest	425.89	146.84	48.95	246.00	622.00
	Mixed forest	571.00	218.93	72.98	327.00	991.00
	Deciduous forest	506.56	156.23	52.08	328.00	788.00
	Total	501.15	180.42	34.72	246.00	991.00

Table 9. Analysis of variance for number of species and individuals by forest type

Factors		Sum of squares	df	Mean square	F	*P*-value
Number of species	Between groups	19,591.185	2	9,795.593	3.691	<0.040
	Within groups	63,694.000	24	2,653.917	-	-
	Total	83,285.185	26	-	-	-
Number of individuals	Between groups	95,152.296	2	47,576.148	1.520	0.239
	Within groups	751,185.111	24	31,299.380	-	-
	Total	846,337.407	26	-	-	-

-, not applicable.

als), followed by the deciduous forest (645 species and 4,559 individuals) and coniferous forest (580 species and 3,833 individuals). Compared to coniferous and deciduous forests, the mixed forest showed approximately 24.1% and 11.6% more species and 34.1% and 12.7% more individuals respectively.

Statistical analysis by season revealed significant differences in both the number of species and number of individuals. Specifically, significant differences were observed between spring and summer ($P<0.001$), spring and

Table 10. Scheffe's post hoc multiple comparison for number of species and individuals by forest type

Dependent variable	(I) Forest type	(J) Forest type	Mean difference (I–J)	Standard error	*P*-value	95% Confidence interval	
						Lower bound	Upper bound
Number of species	Coniferous forest	Mixed forest	–65.44444	24.28496	<0.042	–128.7982	–2.0907
		Deciduous forest	–25.44444	24.28496	0.585	–88.7982	37.9093
	Mixed forest	Coniferous forest	65.44444	24.28496	<0.042	2.0907	128.7982
		Deciduous forest	40.00000	24.28496	0.277	–23.3537	103.3537
	Deciduous forest	Coniferous forest	25.44444	24.28496	0.585	–37.9093	88.7982
		Mixed forest	–40.00000	24.28496	0.277	–103.3537	23.3537
Number of individuals	Coniferous forest	Mixed forest	–145.11111	83.39915	0.240	–362.6798	72.4576
		Deciduous forest	–80.66667	83.39915	0.632	–298.2354	136.9021
	Mixed forest	Coniferous forest	145.11111	83.39915	0.240	–72.4576	362.6798
		Deciduous forest	64.44444	83.39915	0.745	–153.1243	282.0132
	Deciduous forest	Coniferous forest	80.66667	83.39915	0.632	–136.9021	298.2354
		Mixed forest	–64.44444	83.39915	0.745	–282.0132	153.1243

autumn ($P<0.025$), and summer and autumn (number of species: $P<0.004$; number of individuals: $P<0.001$). These findings suggest that surveys conducted in summer are more effective for identifying insect diversity. Therefore, it is advisable to include summer sampling in biodiversity monitoring programs (Samways, 2007; Yela & Holyoak, 1997). In particular, when conducting multi-season surveys, including summer as a core period can enhance compliance with the National Ecosystem Survey guidelines and improve the monitoring of ecosystem changes (Didham *et al.*, 2012; Kremen *et al.*, 1993).

Regarding forest types, a significant difference in the number of species was observed between coniferous and mixed forests, but no significant differences were found between other forest types. These findings suggests that mixed forests are more favorable for surveying insect communities and securing higher diversity (Andersen, 1999; Brown *et al.*, 2000). Consequently, mixed forests with both coniferous and deciduous components are recommended as priority sites for insect diversity assessments.

Additionally, variations in the number of species and individuals were observed even within the same forest type, depending on the diversity of vegetation and understory development. These results align with previous studies emphasizing the importance of understory vegetation for insect diversity (Thomas, 2005). Therefore, in mixed forests, survey sites with well-developed understory vegetation, including shrubs and herbaceous plants, should be prioritized for more effective biodiversity assessment.

In conclusion, this study clearly demonstrated differences in nocturnal insect diversity by season and forest type. The findings provide a scientific basis for biodiversity monitoring and ecosystem assessment. In particular, the effectiveness of surveys conducted in mixed forests among forest types and during summer among seasons was validated, highlighting the potential for standardizing insect monitoring protocols and improving national survey guidelines.

However, this study has several limitations. First, the results were based on data collected during a single year, which may not capture inter-annual variability in insect diversity. Second, forest types were classified without accounting for fine-scale habitat variables such as understory structure, canopy cover, and vegetation age, which could influence insect assemblages.

Future studies should incorporate multi-year data and include more detailed assessments of microhabitat characteristics. Additionally, identifying indicator species for each forest type would strengthen biodiversity assessment frameworks and contribute to more effective insect-based conservation strategies. These efforts would support ongoing improvements to national biodiversity monitoring guidelines and facilitate evidence-based conservation planning.

Author Contributions

Conceptualization: YGH, EJH. Data curation: YGH, STY. Formal analysis: YGH. Funding acquisition: EJH, STY. Investigation: YGH, STY. Methodology: YGH. Project administration: EJH, STY. Resources: EJH, STY. Supervision: EJH. Validation: YGH, EJH. Visualization: YGH. Writing – original draft: YGH. Writing – review & editing: YGH, EJH.

Conflict of Interest

The authors declare that they have no competing interests.

Funding

This work was supported by a grant from the National Institute of Ecology (NIE) funded by the Ministry of Environment (MOE) of the Republic of Korea (NIE-A-2023-01).

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