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Investigation and Analysis on Diversity of Lucanidae spp. in Fanjing Mountain National Nature Reserve

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Abstract Lucanidae spp. in Fanjing Mountain National Nature Reserve were collected and investigated. A total of 65 specimens were examined. They belong to 26 species (including subspecies) in 13 genera. The richness reached 41.53%, with obvious diversity characteristic. According to the survey results, the vertical distribution of Lucanidae spp. in Fanjing Mountain was divided into foothill belt, low mountain belt, low-middle mountain belt, middle mountain belt and sub-alpine belt.

Key words Lucanidae, Taxonomy, Diversity, Fanjing Mountain National Nature Reserve

1 Introduction

Insects are an important part of forest ecosystem, and their diversity is the key to maintaining the stability of forest ecosystem. Analytical research on local insects is inseparable for scientific evaluation of the conservation effectiveness of forest ecosystem in national nature reserves.

Lucanidae belongs to Scarabaeoidea in Coleoptera. Data shows that Lucanidae contains more than 1 800 species in more than 100 genera. Lucanidae spp. are distributed across the world, mainly in subtropical and tropical regions, and 60% of them are distributed in Asia. The body of Lucanidae spp. is bright and beautiful, and is easy to distinguish. Their appearance is complex and interesting, and has high viewing value. There is significant sexual dimorphism and male polymorphism in Lucanidae spp. Some species are bright and metallic. Mandibles of most males are quite developed, with many decorative small teeth, which have great ornamental value. Fig. 1 shows male of *Cyclommatus elsae* Kriesche. Fig. 2 shows female of *C. elsae* Kriesche. Fig. 3 shows male of *Dorcus hopei hopei* Saunders. Fig. 4 shows female of *D. hopei hopei* Saunders.

Larvae of Lucanidae spp. feed on deadwood. They can accelerate the material cycle and energy flow of ecosystem, with unique niche. Adults of Lucanidae spp. have fighting phenomena during feeding and courtship, and are classic creatures of sexual selection theory. Most adults and larvae of Lucanidae spp. strictly choose forest as a habitat. They are an important indicator of the health status of forest ecosystems. Therefore, Lucanidae spp. have become a hot spot for insect research.

Fanjing Mountain, as a national nature reserve, has the characteristics of insect diversity and stable ecosystem[1]. Currently, there has been no investigation on the diversity of insects in the Fanjing Mountain National Nature Reserve. Therefore, the author had been in the Fanjing Mountain National Nature Reserve for six times from January 2016 to July 2018 to collect insect specimens and investigate the diversity of Lucanidae spp., so as to provide basic data for the cataloging of insect diversity in the Fanjing Mountain National Nature Reserve and make some contribution to the protection of forest ecosystems in national nature reserves.

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2 Natural environment of Fanjing Mountain

Fanjing Mountain National Nature Reserve (108°45′55″ - 108°48′30″ E, 27°49′50″ - 28°1′30″ N) is located in the junction of Jiangkou, Yinjiang and Songtao, three counties in Tongren City, northeastern Guizhou Province. The annual average temperature is 13.1 - 14.7℃. The average temperature of the hottest month (July) is 25.3℃, and the average temperature of the coldest month (February) is 2℃. The temperature decreases with the increase of the terrain. The annual frost-free period is 270 - 278 d. The annual sunshine hours are 900 - 1 170 h. The annual precipitation is 1 100 - 2 600 mm. The relative humidity is 80% in average. Fanjing Mountain National Nature Reserve has the best preserved and most typical virgin forest at the same latitude. The forest coverage rate is 90%, which four climatic zones and five vertical soil types. The vertical distribution of soil types shows obvious regularity: mountain yellow red soil below 500 m above sea level, mountain yellow soil 500 - 1 400 m above sea level, mountain yellow brown soil 1 400 - 2 000 m above sea level, mountain dark forest soil 2 000 - 2 200 m above sea level, and mountain scrubby-meadow soil more than 2 200 m above sea level. Within the scope of the reserve, due to changes in vertical height of the mountain (the highest peak is 2 570 m, and the relative height difference is 2 000 m), there are also forest types of medium-temperate nature although Fanjing Mountain is located in the mid-subtropical zone. Fanjing Mountain has obvious vertical spectrum of vegetation: evergreen broad-leaves forest belt below 1 300 m above sea level, evergreen deciduous mixed forest belt 1 300 - 2 200 m above sea level, and sub-alpine coniferous and broad-leaved mixed forest and scrubby meadow belt 2 200 m above sea level.

In the geographical division of animals, Fanjing Mountain is in the transitional area of the Palearctic realm and the Oriental realm. Insect fauna is dominated by Oriental species, and a certain number of Palearctic species exist[1]. Fanjing Mountain National Nature Reserve has complex wetland, and the ecological environment is superior. It provides a superior habitat and breeding ground for all kinds of insects.

Fig. 1 *Cyclommatus elsae* Kriesche (male)

Fig. 2 *Cyclommatus elsae* Kriesche (female)

Fig. 3 *Dorcus hopei hopei* Saunders (male)

Fig. 4 *Dorcus hopei hopei* Saunders (female)

3 Survey methods

3.1 Sampling method In the daytime, the collection of insect specimens was mainly carried out by the searching method or shaking-off method. At night, insects were collected by light trapping method.

3.2 Survey route Around the eastern route of Fanjing Mountain, from the foot to the top, Lucanidae spp. were collected. The situation of Lucanidae spp. at all altitudes in the protected area was investigated. The scope of the investigation was extended as much as possible.

3.3 Specimen production After the collected insects were smoked by absolute ethanol or naturally died, they were inserted with appropriate specimen needles through the right elytra, and their posture was adjusted. The specimens prepared were put into the specimen box.

3.4 Specimen identification Identification of Lucanidae spp. was carried out referring to *Stag Beetles of China* or under the guidance of relevant experts. Most of the identification work was helped by Mr. Chen Changqing, one of the authors of *Stag Beetles of China*.

4 Survey results

4.1 Species composition of Lucanidae in Fanjing Mountain According to the statistics, a total of 15 genera and 27 species (subspecies) were recorded in *Stag Beetles of China* and *Insects in Fanjing Mountain*. It can be seen that the resources of Lucanidae spp. in Fanjing Mountain are very rich. The diversity feature is obvious. In the investigation, a total of 65 specimens of Lucanidae spp. were obtained (Table 1). They belong to 26 species (including subspecies) in 13 genera, four species in *Lucanus Scopoli*, seven species in *Dorcus MacLeay*, two species in *Falcicornis Planet*, one species in *Ceurchus MacLeay*, two species in *Prismognathus Motschulsky*, one species in *Serrognathus Motschulsky*, one species in *Cyclommatus Parry*, one species in *Himaloaesalus Huang & Chen*, one species in *Prosopocoilushope*, one species in *Platycerus Geoffroy*, one species in *Kirchnerius Schenk*, one species in *Pseudorhaetus Planet*, and three species in *Neolucanus Thomson*.

Table 1 Survey results of Lucanidae spp. in Fanjing Mountain Natural Nature Reserve

No.	Genus	Species	Number of specimens	Proportion//%
1	*Lucanus*	*Lucanus fanjingshanus* Huang & Chen	1	1.54
		Lucanus liuyei Huang & Chen	1	1.54
		Lucanus fairmairei Planet	15	23.08
		Lucanus thibetanus ssp.	1	1.54
2	*Dorcus*	*Dorcus liyingbingi* Huang & Chen	2	3.08
		Drocus daedalion Didier & Seguy	4	6.15
		Dorcus hopei hopei Saunders	4	6.15
		Dorcus haitschunus Didier & Seguy	1	1.54
		Dorcus yaksha gracilicornis Benesh	1	1.54
		Dorcus antaeus Hope	2	3.08
		Dorcus semenowi Jakowlew	2	3.08
3	*Falcicornis*	*Falcicornis mellianus* Kriesche	1	1.54
		Falcicornis songianus Didier & Seguy	2	3.08
4	*Ceruchus*	*Ceruchus yangi* Imura & chen	2	3.08
5	*Prismognathus*	*Prismognathus* davidis Deyrolle	2	3.08
		Prismognathus haojiani Huang & Chen	1	1.54
6	*Serrognathus*	*Serrognathus titanus* ssp.	1	1.54
7	*Cyclommatus*	*Cyclommatus scutellaris elsae* Kriesche	2	3.08

(To be continued)

(Continued)

No.	Genus	Species	Number of specimens	Proportion//%
8	*Himaloaesalus*	*Himaloaesalus satoi* Araya & Yoshitomi	1	1.54
9	*Prosopocoilus*	*Prosopocoilus forficula* Thomson	2	3.08
10	*Platycerus*	*Platycerus mandibularis* Imura	2	3.08
11	*Kirchnerius*	*Kirchnerius yangi* Fukinuki	1	1.54
12	*Pseudorhaetus*	*Pseudorhaetus sinicus sinicus* Boileau	1	1.54
13	*Neolucanus*	*Neolucanus sinicus* Saunders	2	3.08
		Neolucanus sp.	9	13.85
		Neolucanus perarmatus Didier	2	3.08

4.2 Distribution characteristics of Lucanidae spp. in Fanjing Mountain Due to the large elevation difference in the Fanjing Mountain, the vertical zoning of climate, soil and vegetation is obvious. Insects living in Fanjing Mountain also have obvious vertical distribution characteristics. Referring to the distribution method of Yang Chenjin's *Investigation Report on Insects in Fanjing Mountain*, according to the species, quantity and location of insects collected, the vertical distribution of Lucanidae spp. in Fanjing Mountain is divided into foothill belt, low mountain belt, low-middle mountain belt, middle mountain belt and sub-alpine belt.

4.2.1 Foothill. Foothill belt (below 600 m above sea level) mainly refers to agricultural land and secondary vegetat6ion. Vegetation is evergreen broad-leaved forest that represents the subtropical zone, dominated by Fagaceae, Lauraceae, Magnoliaceae and Theaceae, supplemented by Elaeocarpaceae, Hamamelidaceae, Symplocaceae, secondary Chinese fir forests, masson pines, bamboo forests and secondary shrubs. Because of intense human activities, most of the native vegetation has disappeared. Agricultural land, mainly rice fields, is mostly distributed near villages. In this belt, a total of five species in five genera of Lucanidae (*Falcicornis mellianus* Kriesche, *Aegus chelifer* MacLeay, *Dorcus hopei hopei* Saunders, *Serrognathus titanus* ssp. and *Prosopocoilus forficula* Thomson) were collected.

4.2.2 Low mountain belt. Low mountain belt (600 – 1 200 m above sea level) refers to the low mountain area where the mountain begins to rise. It belongs to the north subtropical climate. The vegetation is mainly evergreen broad-leaved forest, including Fagaceae, Magnoliaceae and Theaceae. This area is less destroyed by human activities, so the original state is preserved and the inset species are quite abundant. In this belt, a total of 11 species from 8 genera of Lucanidae (*Drocus daedalion* Didier & Seguy, *Cyclommatus scutellaris elsae* Kriesche, *Serrognathus titanus* ssp., *Cerucchus yangi* Imura & chen, *Neolucanus sinicus* Saunders, *Neolucanus* spp., *Pseudorhaetus sinicus sinicus* Boileau, *Dorcus hopei hopei* Saunders, *Prosopocoilus forficula* Thomson and *Falcicornis mellianus* Kriesche) were collected.

4.2.3 Low-middle mountain belt. Low-middle mountain belt (1 200 – 1 900 m above sea level) has a low temperature and a warm temperate climate. Fanjing Mountain has risen sharply here, with layer upon layer and steep slopes. The ecological environment is extremely different. The vegetation is evergreen deciduous mixed forest, represented by *Cyclobalanopsis glauca* (Thunb.) Oerst., *Cyclobalanopsis stewardiana* and *Quercus engleriana*. The weather here is cold, the man-made damage is less, the originality is stronger, and the number of most insects is significantly reduced. However, Lucanidae spp. are abundant. In this belt, a total of 12 species in six genera (*Lucanus fanjingshanus* Huang & Chen, *Drocus daedalion* Didier & Seguy, *Falcicornis songianus* Didier & Seguy, *Himaloaesalus satoi* Araya & Yoshitomi, *Ceruchus yangi* Imura & chen, *Prismognathus haojiani* Huang & Chen, *Prismognathus davidis* Deyrolle, *Dorcus semenowi* Jakowlew, *Dorcus haitschunus* Didier & Seguy, *Dorcus antaeus* Hope, *Lucanus liuyei* Huang & Chen and *Lucanus thibetanus* ssp.) were collected.

4.2.4 Middle mountain belt. Middle mountain belt (1 900 – 2 100 m above sea level) has steep terrain, frosty and snowy weather, and high humidity. There is no summer throughout the year. The vegetation is deciduous broad-leaved forest, and the upper part is mossy short forest, represented by rhododendron, maple, cherry and rowan. Since the vegetation is basically not destroyed by humans, the originality is very strong, but the number and species of insects are drastically reduced. In this belt, a total of 6 species from 4 genera of Lucanidae (*Platycerus mandibularis* Imura, *Drocus daedalion* Didier & Seguy, *Dorcus liyingbingi* Huang & Chen, *Dorcus yaksha gracilicornis* Benesh, *Lucanus fairmairei* Planet and *Ceruchus yangi* Imura & chen) were collected.

4.2.5 Sub-alpine belt. Sub-alpine belt (2 100 m above sea level) has extremely steep terrain, deep canyon, high altitude, long snow cover, less sunshine, numerous clouds, and large winds, and it has a typical sub-alpine cold and humid climate. The vegetation is dominated by hemlock, rhododendron and moss. It is inaccessible, undestroyed, and has a strong originality, but the number of insects is small. In this belt, two species from two genera of Lucanidae (*Lucanus fairmairei* Planet and *Prismognathus davidis* Deyrolle) were collected.

4.3 Diversity characteristics of Lucanidae spp. in Fanjing Mountain

4.3.1 High abundance. In the investigation, a total of 65 specimens of Lucanidae spp. were collected. They belong to 26 species (including subspecies) in 13 genera. The numerical species richness (the number of species in a certain number of individuals or biomass) reaches 41.53%. At the taxonomy level of genus, the richness is 20%. Therefore, Fanjing Mountain National Nature Reserve is rich in Lucanidae resources.

4.3.2 Relative concentration of dominant species. According to the survey results, *Lucanus fairmairei* Planet has the highest abundant, accounting for 23.08%, with obvious advantage, followed by an unidentified new species (*Neolucanus* sp.), accounting for 13.85%.

4.3.3 Relative evenness. The survey found that there were 11 species of which the specimens accounted for 1.54% of the total, 11 species of which the specimens accounted for 3.08% of the total, two species of which the specimens accounted for 6.15% of the total, one species of which the specimens accounted for 13.85% of the total and one species of which the specimens accounted for 23.08% of the total. In other words, the abundance of all the species except two species differed slightly.

In short, Lucanidae spp. have high abundance in Fanjing Mountain National Nature Reserve. The larvae of Lucanidae spp. have high requirements for vegetation, reflecting the excellent and healthier forest environment of Fanjing Mountain.

5 Conclusions and discussion

Fanjing Mountain has rich Lucanidae resources. It is a region with abundant Lucanidae spp., and it has brought together more Lucanidae spp. with weak migration ability in Sichuan and Chongqing. The Jinfo Mountain in the Wuling Mountains also has the same Lucanidae species, such as *Dorcus lvbu* Huang & Chen and *Prismognathus sinicus* Bomans. At the same time, there are differences between the two. For example, *Lucanus liuyei* Huang & Chen is distributed in both Jinfo Mountain and Fanjing Mountain; *Lucanus fanjingshanus* Huang & Chen is currently only found in Fanjing Mountain; *Lucanus szetschuanicus* Hanus is found in Jifo Mountain, but Fanjing Mountain is not distributed; *Lucanus fairmairei* Planet is distributed in Fanjing Mountain but not in Jinfo Mountain; *Prismognathus haojiani* Huang & Chen exists in Fanjing Mountain, but it has not been found in Jinfo Mountain. Fanjing Mountain has a unique location. It is an area worthy of further research from perspectives of geographical features and biodiversity.

This survey was self-funded by the author, with limited funds. Coupled with heavy academics, there was no enough time to investigate further. The best way to collect Lucanidae spp. is the light trapping method. However, due to the internal protection of Fanjing Mountain, this method has been forbidden since 2017, producing great impact on this survey. It needs further investigation. Many Lucanidae species or some male (female) specimens were absent in this survey. For example, *Lucanus thibetanus* ssp. had only female specimen; and *Stag Beetles of China* records the existence of *Dorcus lvbu* Huang & Chen, but it was not found in this survey.

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