ISSN 1995-4255, Contemporary Problems of Ecology, 2023, Vol. 16, No. 6, pp. 758–762. © Pleiades Publishing, Ltd., 2023.
Russian Text © The Author(s), 2023, published in Sibirskii Ekologicheskii Zhurnal, 2023, No. 6, pp. 832–838.

Possible Reasons for the Decrease in the Abundance of the Musk Deer *Moschus moschiferus* L. (Cetartiodactyla, Moschidae) in the Ussuriysky Nature Reserve

M. V. Maslov[a], *, M. N. Litvinov[b], **, E. A. Litvinova[c], *, and T. O. Markova[a], ******

[a] *Federal Scientific Center of the East Asia Terrestrial Biodiversity, Far Eastern Branch, Russian Academy of Sciences, Vladivostok, 690022 Russia*

[b] *Severtsov Institute of Ecology and Evolution, Russian Academy of Sciences, Moscow, 119071 Russia*

[c] *Autonomous Nonprofit Educational Organization of Higher Education International Veterinary Academy, Dzerzhinsky, Moscow oblast, 140090 Russia*

**e-mail: nippon_mvm@mail.ru*

***e-mail: mnlitvinov@rambler.ru*

****e-mail: litvinovakat@mail.ru*

*****e-mail: martania@mail.ru*

Received March 22, 2023; revised March 31, 2023; accepted April 5, 2023

Abstract—Forty-five-year-long observations of variations in the musk deer abundance in the Ussurisky Nature Reserve are summarized. An analysis of winter route censuses (WRC) has made it possible to assume that these variations are related to the emergence of a new predator, the sable. The decrease in the musk deer abundance in the reserve occurred simultaneously with an increase in the sable abundance and a decrease in abundance of alternative food supplies for medium-sized and small predators. From the early 2000s to the present, the musk deer abundance in the reserve has remained at a level of only "presence" of the species in the fauna.

Keywords: musk deer, sable, hare, predator, victim, winter route census, track-making activity, track counts, abundance, Ussurisky Nature Reserve

DOI: 10.1134/S1995425523060161

INTRODUCTION

Uncontrolled snare hunting of musk deer *Moschus moschiferus* Linnaeus, 1758 over most of its range has caused a widespread decline in its abundance, which began in the 1990s and continues (Prikhodko, 2003). V.A. Zaitsev (2006) points out that, since 1990, the decline in the abundance of musk deer is due not only to overhunting, but also to the enormous transformation of habitats as a result of poorly controlled logging. The situation is aggravated by poaching with nooses during felling. In addition to habitat damage, logging involves the construction of roads that increase the accessibility of forest habitats for poachers.

The Ussuriysky State Nature Reserve of the Far Eastern Branch, Russian Academy of Sciences, is located in the southwestern region of the Sikhote-Alin Ridge on the southern slopes of the Przhevalsky Ridge (43°33′–43°47′ N, 132°16′–132°47′ E). Until 1972, the area of the reserve was 16679 ha of forests, almost unchanged by human activity: the "old territory." In 1973, it was increased by almost 2.5 times and amounted to 40432 ha. Currently, the territory of the reserve is part of the Federal State Budgetary Institution Land of the Leopard.

The dominant species in most forest types is korean pine (*Pinus coraiensis* Siebold et Zucc.) (41.6%), followed by ayan spruce (*Picea ajanensis* (Lindl. et Gord.) Fisch. ex Carr.) (23.2%), bud-scale fir (*Abies nephrolepis* (Trautv.) (6%), whole-leaved fir (*A. holophylla* Maxim.) (4.9%), mongolian oak (*Quercus mongolica* Fisch. ex Ledeb.) (4.9%), amur linden (*Tilia amurensis* Rupr.) (4.7%), manchurian ash (*Fraxinus mandshurica* Rupr.) (3.1%), flat-leaved birch (*Betula platyphylla* Sukacz.) (2.1%), japanese elm (valley) (*Ulmus japonica* (Rehd.) Sarg.) (2%), and trembling poplar (*Populus tremula* L.) (1.5%); other species make up 6% (Zhabyko, 2006).

Until 2022, there was no buffer zone around the Ussuriysky Nature Reserve, so logging of varying intensity was carried out constantly. In particular, intensive logging close to the border of the reserve was carried out from 1990 to 2008 in areas of watersheds and in cedar–fir plantations for about 40 km in length. The negative impact of these loggings on the distribu-

tion and abundance of all ungulate species is indicated in the work of M.V. Maslov (2008, 2012).

Hunting (commercial and sports) in the reserve is prohibited by law, and poaching is a criminal offense. The few cases of poaching registered in a protected area cannot have a significant impact on the abundance of ungulates. Despite the above, the downward trend in the abundance of musk deer noted in many publications (Prikhodko, 2003; Maslov and Litvinov, 2005; Zaitsev, 2006; Litvinov, 2008; Danilkin, 2009; etc.) is also observed on the territory of the reserve.

The purpose of this study is to analyze the change in the abundance of musk deer in the Ussuriysky Nature Reserve for the period from 1975 to 2020.

MATERIALS AND METHODS

The registration of ungulates in the reserve was carried out in the specified time period according to generally accepted methods (Formozov, 1932; Malyshev, 1936; Pereleshin, 1950; etc.) on permanent routes along the "white trail" (winter route census (WRC)), 70 km in length, i.e., suitable for comparison, and in some cases they were supplemented by the use of materials from counts on ranger paths. Due to the fact that animal track counts provide not the abundance value, but track-making activity, in the future it is track-making activity that is meant when we talk about the abundance.

The white trail of the reserve from 1974 to 2012 consisted of two segments: the southern circle (36 km) and the northern circle (34 km), which passed through the old territory. Forest management maps were used when laying the routes. The content of land types along the trail was as close as possible to the area of these types throughout the reserve, taking into account the steepness and exposure of the slopes. Accounting data were entered into tables, and the number of intersections of tracks of one type or another was noted for each kilometer of the route. Thus, when processing survey data, it is possible to identify suitable and unsuitable sections of routes for each of the types.

The main material for this work was collected on the old territory, along which the stationary route of the WRC was laid (Fig. 1).

When identifying types of habitats suitable for musk deer, based on literature data (Matyushkin, 1974; Zaitsev, 1982; Bromley and Kucherenko, 1983; Prikhodko, 2003) and our own observations, it was found that areas with a predominance of dark coniferous species on steep slopes and watersheds in the upper reaches of watercourses flowing into the Komarovka River can be considered optimal for the species to inhabit. Floodplains occupied by broad-leaved forests sections of the routes were not taken into account when calculating the abundance of musk deer. In accordance with this approach, we considered 20 km

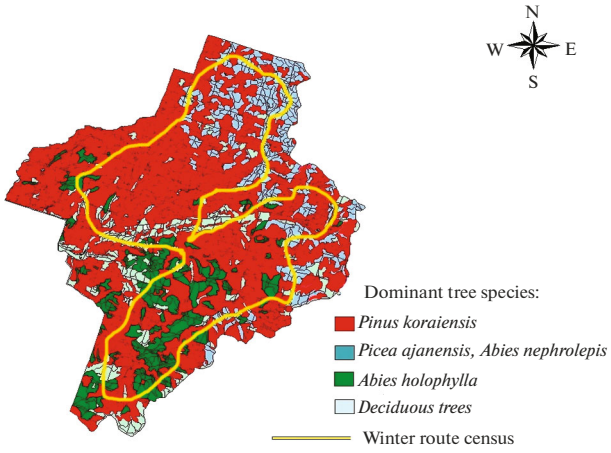

Fig. 1. Map of the old territory of the Ussuriysky Nature Reserve, indicating the dominant species and the white trail (WRC).

on the northern circle and 20 km on the southern one suitable for habitation. Ranger paths in the reserve are laid mainly along the valleys of rivers and other watercourses and cover the habitats of musk deer *M. moschiferus* only in their upper reaches.

Since the white hare *Lepus timidus* Linnaeus, 1758 and manchurian hare *Lepus mandshuricus* Radde, 1861 are the main victims of predators capable of preying on musk deer, we also provide data on the abundance of hares.

Tracks of the sable *Martes zibellina* Linnaeus, 1758 and hares were noted along the entire routes, because animals of these species fairly evenly inhabit all types of land presented in the reserve.

RESULTS

Data on the abundance of musk deer, hares, and sable on the survey routes are shown in Table 1. For the convenience of analysis, we have divided the study period into separate segments.

In 1975–1986, there were 3 to 12 crossings of musk deer tracks per 10 km of the white trail. In optimal habitats, their number reached 17–20, with the maximum figures occurring in 1975–1976. By the end of the selected period, the abundance decreased to 4–5 crossings per 10 km of the route in optimal habitats.

Sables were observed in the reserve in the period 1981–1986. Solitary sable tracks were recorded during censuses along the white trail in 1981 and 1986, and later sable tracks were recorded constantly (see Table 1). In 1989–1990, from 16 to 18 sable tracks per 10 km of the route were recorded on the same routes.

In the period 1987–1991, an increase in the abundance of both species of hares (manchurian and white hare) was noted. According to the winter route census data, the total abundance of these species reached

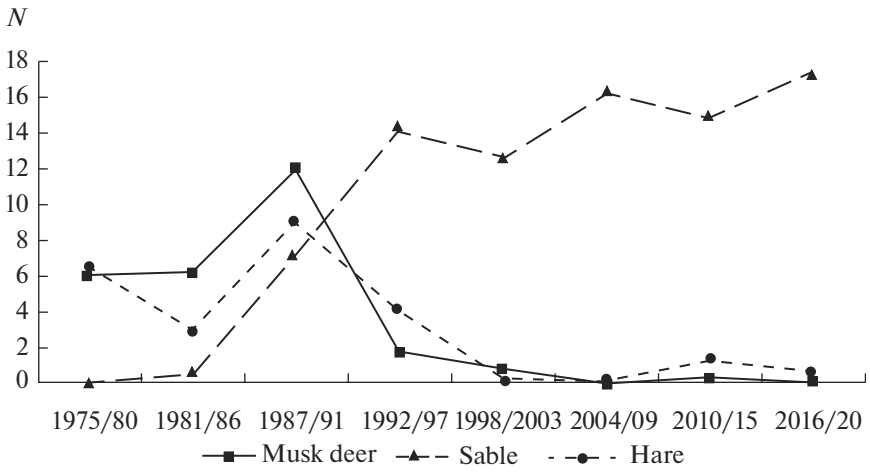

Fig. 2. Abundance dynamics of the musk deer, sable, and hare according to WRCs in the Ussuriysky Nature Reserve for 1975 to 2020: N is the number of tracks per 10 km, Md is the musk deer, Sbl is the sable, and H is the hare (the total abundance of two species).

peak levels (15–20 tracks of both species per 10 km of the route) in 1988. The availability of food supply for medium-sized and small predators made it possible to reduce their impact on the musk deer. If, in 1986, 7 tracks of musk deer were recorded per 10 km of the white trail (up to 12 in optimal biotopes), then in 1989–1990 there were 18–20 (up to 40 in optimal biotopes).

By 1995–1996, the abundance of sable reached 23–25 per 10 km of the route. These data revealed statistically significant differences in the average abundance of sables on the survey routes between 1981–1986 and 1992–1997 ($t_{st} = 3.16$; $p \le 0.05$). The abundance of musk deer in the reserve began to decline after 1991 (Fig. 2.), which is consistent with the situation throughout the entire range of the species. By 1995–1996, the number of musk deer tracks decreased to 3–5 per 10 km of the route in habitats suitable for the species. Analysis revealed a significant decrease in the average abundance of musk deer on the survey routes in the period 1992–1997 when compared to 1975–1980 ($t_{st} = 3.17$; $p \le 0.01$). In the same period, the number of tracks of both species of hares decreased to 2–3 per 10 km of the route. The situation was aggravated by large-scale logging along the boundaries of the reserve, which led to the destruction of the habitats of the species and an increase in poaching in the adjacent territory.

Table 1. Average abundance (number of tracks per 10 km) of musk deer, sables, and hares according to WRCs in the Ussuriysky Nature Reserve from 1975 to 2020

Years	Md	Sbl	Wh	Mh
1975–1980	6.0 (10.2)	0	3.4	2.9
1981–1986	6.2 (9.5)	0.3	1.7	1.2
1987–1991	12.0 (22.2)	7.2	3.0	5.6
1992–1997	1.7 (5.3)	14.2	1.2	2.9
1998–2003	0.8 (2.5)	12.5	0.1	0
2004–2009	0.03 (0.3)	16.3	0	0
2010–2015	0.2 (0.2)	14.8	0.3	1
2016–2020	0.1 (0.1)	17.2	0.3	0.3

Md, musk deer (in brackets, per 10 km of habitable territory); Sbl, sable; Wh, white hare; and Mh, manchurian hare.

Until 1999, tracks of musk deer were recorded annually on counting routes (from 1 to 4 per 10 km in typical habitats). Since 2000, the musk deer, in single specimens, has been encountered no more than once every 2–3 years; that is, it was present as a species. The low abundance of musk deer during this period is evidenced by objective data obtained with the help of digital camera traps.

As part of the Amur Tiger Programme (*Panthera tigris altaica*) in the Russian Far East, from May 2009 to May 2010, a matrix of 40 Leaf River digital camera traps (Vibrashine Leaf River Outdoor Products, United States) was installed, with 4 rows of digital camera traps parallel to one another. The area of the territory occupied by digital camera traps was 4.1 km^2 (Rozhnov et al., 2012). During the year of continuous observations, 654 photographs of potential victims of the Amur tiger were noted, of which only one was a photograph of a musk deer. This situation has continued until 2020. The abundance of sable in the same time interval was at the level of 15–20 tracks per 10 km; it reached 25–30 tracks per 10 km in 2006–2007.

DISCUSSION

The main enemies of the musk deer in the Russian Far East are the lynx *Lynx lynx* Linnaeus, 1758 and marten *Martes flavigula* (Boddaert, 1785). The number of lynxes (number of tracks per 10 km of the route)

in the specified period of time varied from 0.3 to 1.3; i.e., it was practically on the same level. According to long-term data—according to all types of records and expert assessment—from 5 to 8 lynxes constantly live on the territory of the reserve; i.e., the abundance of animals of this species was at a constant level throughout the study period. The marten is a common small species in the reserve. During the indicated period, its abundance remained at a relatively constant level, from 0.2 to 0.7 tracks per 10 km of the route. The maximum abundance of lynx and marten relate to the period of almost complete absence of musk deer in 2000–2010.

Some authors consider the fox *Vulpes vulpes* Linnaeus, 1758, sables, and raptors secondary enemies of the musk deer (Silakov et al., 2006; Zaitsev, 2016; etc.). Foxes are rare in the reserve and inhabit sparse stands in the floodplains of large watercourses, mainly in the peripheral parts of the territory. Of the large raptors capable of hunting musk deer, the hawk-eagle *Spizaetus nipalensis* (Hodgson, 1836) is found in the reserve. During the period of long-term observations, no more than 2–3 pairs of annually nesting eagles were found (Kharchenko and Maslov, 2013).

The abundance of one of the "minor" enemies of the musk deer, the sable, changed especially strongly during the observation period. Sables were first noted in the reserve in 1981, and they began to be regularly registered in the records in 1985. By 1990, up to 15 crossings of tracks (3–4 specimens) were recorded per 10 km of the route. Since 1990, the abundance of sables has increased even more, reaching in some years 10–12 specimens (more than 30 crossings of tracks) per 10 km of the route, and it continues to stay at this level. It is noteworthy that, parallel with the increase in the abundance of sable, the abundance of musk deer began to decrease. If the beginning of the process coincides with the situation in the entire range of the musk deer, then subsequent events make us think about the reasons that prevent the subsequent restoration of the abundance of this species. We believe that the increase in the abundance of sables is one of the main things preventing the restoration of the abundance of musk deer in the reserve.

Published data have shown incidences of sables hunting for musk deer in winter (Zyryanov and Kozhechkin, 1990; Oleinikov and Zaitsev, 2014; Argunov and Tirsky, 2022); however, in our opinion, the greatest harm is caused by the hunting of young animals in the summer. Unfortunately, the absence of tracks and the small size of the calves do not allow us to reliably record such facts, especially since the remains are quickly disposed of during the warm period. An objective assessment of the complex impact on small ungulates in the reserve is also difficult due to the high degree of disposal. Bear tracks are regularly observed near the dead ungulates in the spring. During the study period, only 12 cases of death of musk deer were recorded on the territory of the reserve: 4 proven deaths from marten predation, 1 from tiger predation, 1 from emaciation, and 1 from poaching (Maslov and Kovalev, 2013).

One of the factors aggravating the situation may be the decrease in the abundance of species of hare (manchurian and white hare). As is known, the abundance of white hares is subject to cyclical fluctuations; in the Far Eastern Federal District, cycles last up to 30 years along with an increase in amplitude; "small" cycles with a smaller amplitude are observed at intervals of 4–6 years (Erdakov and Pereyaslovets, 2020). According to the WRC data, the abundance of manchurian hare in the territory of the reserve changed with approximately the same frequency. The total abundance of these species peaked in 1988 and 1993 (15–20 and 12 tracks per 10 km of route). In the subsequent period until 2020, the expected increase in numbers did not occur; at present, hares are not registered during accounting work every year. The analysis revealed a significant decrease in the average abundance of hares on the counting routes by the period of 2015–2020 when compared with 1987–1991 ($t_{st} = 3.17$; $p \leq 0.01$). Thus, for medium and small predators, the food base has been significantly reduced.

It is noteworthy that, up to 1991, the abundance of musk deer varied within certain limits, but did not fall below five specimens per 10 km of routes, despite the presence of common predators (lynx, marten, fox, and hawk-eagle); that is, the predator–prey system was in a degree of balance. However, after the appearance of a new predator, sable, and a decrease in the abundance of hares, the abundance of musk deer decreased critically and continues to be at the level of "presence" of the species in the fauna, when the abundance can be judged only due to the episodic presence of tracks on the counting routes.

CONCLUSIONS

The reasons for such a long and deep decline in the abundance of musk deer in the protected area, along with the general trend in the species range, can only be epizootics or the influence of predators. It can be assumed that, in the absence of hares, the pressure of all predators on musk deer increased significantly, which could aggravate the situation.

We believe that, along with the decline in the abundance of musk deer in the territory surrounding the reserve, it was sable predation that was one of the reasons for its decline in the Ussuriysky Nature Reserve. Only more in-depth studies will make it possible to confirm or refute this hypothesis.

FUNDING

This work was carried out within the framework of State Task of the Ministry of Science and Higher Education of the Russian Federation no. 121031000120-9.

COMPLIANCE WITH ETHICAL STANDARDS

Conflict of interest. The authors declare that they have no conflicts of interest.

Statement of the welfare of animals. The article does not contain any studies involving animals in experiments performed by any of the authors.

REFERENCES

Argunov, A.V. and Tirsky, D.I., Cases of sable (*Martes zibellina*, Carnivora, Mustelidae) hunting on musk deer (*Moschus moschiferus*, Cetartiodactyla, Moschidae) in Yakutia, *Zool. Zh.*, 2022, vol. 101, no. 6. pp. 703–708.

Bromley, G.F. and Kucherenko, S.P., *Musk deer, Kopytnye yuga Dal'nego Vostoka SSSR (Ungulates in the Southern Far East of the Soviet Union)*, Moscow: Nauka, 1983, pp. 72–95.

Danilkin, A.A., Game animal resource management: Principles and methods, *Vestn. Okhotoved.*, 2009, vol. 6, no. 1, p. 56.

Erdakov, L.N. and Pereyaslovets, V.M., Long-term cycle of the mountain hare population dynamics, *Vestn. Sev.-Vost. Fed. Univ.: Biol. Nauki*, 2020, vol. 1, no. 75, pp. 5–16.

Formozov, A.N., Formula for quantitative census of mammals based on their tracks, *Zool. Zh.*, 1932, vol. 2, no. 2, pp. 66–69.

Kharchenko, V.A. and Maslov, M.V., New data on breeding of the mountain hawk-eagle *Spizaetus nipalensis* in the Ussuri Reserve, *Russ. Ornitol. Zh.*, 2013, vol. 22, no. 849, pp. 465–469.

Litvinov, M.N., Features of formation of the ruminant ungulates fauna in the Ussurisky Nature Reserve, in *Zhivotnyi i rastitel'nyi mir Dal'nego Vostoka* (Fauna and Flora of the Far East), Ussuriysk: Ussuriisk. Gos. Pedagog. Univ., 2008, no. 11, pp. 127–131.

Malyshev, V.I., Quantitative mammals track census, *Vestn. Dal'nevost. Fil. Akad. Nauk SSSR*, 1936, no. 16, pp. 177–179.

Maslov, M.V., Effect of logging on the behavior, distribution, and density of ungulates in the Ussurisky Nature Reserve, *Materialy II Mezhdunarodnoi nauchnoi konferentsii "Sovremennye problemy regional'nogo razvitiya"* (Proc. II Int. Sci. Conf. "Current Issues of Regional Development"), Birobidzhan: Inst. Kompleksn. Analiza Reg. Probl. Dal'nevost. Otd. Ross. Akad. Nauk, 2008, pp. 27–29.

Maslov, M.V., Transformation of natural habitats and change of the populations condition of hoofed animals of the Ussuriysk Reserve and adjacent territories under the influence of the anthropogenic press, *Nauchn. Vedomosti Belgorod. Gos. Univ., Ser. Estestv. Nauki*, 2012, vol. 21, no. 140, pp. 82–88.

Maslov, M.V. and Kovalev, V.A., The basic causes of death in hoofed mammals in the Ussuri Reserve and in the adjacent territory, *Contemp. Probl. Ecol.*, 2013, vol. 6, pp. 121–127.

Maslov, M.V. and Litvinov, M.N., The experience of complete census of ungulates in the Ussurisky Nature Reserve, *Materialy VII Dal'nevostochnoi konferentsii po zapovednomu delu* (Proceedings of the VII Far Eastern Conference on Nature Reserve Activities), Birobidzhan, 2005, pp. 169–171.

Matyushkin, E.N., Issues of interactions between marten (*Martes flavigula* Badd.) and musk deer (*Moschus moschiferus* L.) in the Middle Sikhote-Alin and the history of formation of their biocenotic relationship, in *Teriologia (Theriology)*, Novosibirsk: Nauka, 1974, pp. 227–252, vol. 2.

Oleynikov, A.Yu. and Zaitsev, V.A., A sable (*Martes zibellina*) hunting after a musk deer (*Moschus moschiferus*), *Byull. Mosk. O-va Ispyt. Prir., Otd. Biol.*, 2014, vol. 119, no. 6, pp. 20–28.

Pereleshin, S.D., Analysis of the formula for quantitative census based on mammals' tracks, *Byull. Mosk. O-va Ispyt. Prir., Otd. Biol.*, 1950, vol. 55, no. 3, pp. 17–20.

Prikhodko, V.I., *Kabarga. Proiskhozhdenie, sistematika, ekologiya, povedeniye i kommunikatsiya* (Musk Deer: Origin, Systematics, Ecology, Behavior and Communication), Moscow: GEOS, 2003, pp. 1–443.

Rozhnov, V.V., Naidenko, S.Y., Hernandez-Blanco, J.A., Lucarevskiy, V.S., Sorocin, P.A., Maslov, M.V., Litvinov, M.N., and Kotlyar, A.K., Seasonal changes in the abundance of Amur tiger preys: An experience of applying a matrix photocameras, *Zool. Zh.*, 2012, vol. 91, no. 6, pp. 746–756.

Silakov M. B., Smirnov M. N., Eremenko E. A. Spatial organization and age and sex structure of musk deer populations (*Moschus moschiferus moschiferus* Linneus, 1758) in the central Western Sayan Mountains, *Materialy Mezhdunarodnoi konferentsii "Problemy populyatsionnoi ekologii zhivotnykh"* (Proc. Int. Conf. "Issues of Population Ecology of Animals"), Tomsk, 2006, pp. 177–179.

Zaitsev, V.A., Marten. Musk deer. Moose, in *Rastitel'nyi i zhivotnyi mir Sikhote-Alinskogo zapovednika* (Flora and Fauna of the Sikhote-Alin Nature Reserve), Moscow: Nauka, 1982, pp. 238–272.

Zaitsev, V.A., *Kabarga: ekologiya, dinamika chislennosti, perspektivy sokhraneniya, seriya "Sokhraneniye redkikh vidov fauny Rossii"* (Musk Deer: Ecology, Population Dynamics, and Conservation Prospects, Series "Conservation of Rare Species in Russia's Fauna"), Moscow, 2006.

Zaitsev, V.A., Effect of a "new" predator, the Mountain Hawk Eagle (*Nisaëtus nipalensis*), on the choice of resting places by the Musk Deer (*Moschus moschiferus*), *Zool. Zh.*, 2019, vol. 98, no. 6, pp. 691–705.

Zhabyko, E.V., Forest vegetation, in *Flora, rastitel'nost' i mikobiota zapovednika "Ussuriiskii"* (Flora, Vegetation and Mycobiota of the Ussuri Nature Reserve), Vladivostok: Dal'nauka, 2006, pp. 15–29.

Zyryanov, A.N. and Kozhechkin, V.V., Cases of sables attacking musk deer, in *Voprosy Okhotovedeniya v Sibiri* (Hunting in Siberia), Krasnoyarsk, 1990, pp. 69–74.