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Thick-stemmed wood fern *Dryopteris crassirhizoma* Nakai in the diet of sika deer *Cervus nippon* (Temm.) in south of the Primorskiy region

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Abstract. This study considers the role of a herbaceous plant species, the thick-stemmed wood fern *Dryopteris crassirhizoma* Nakai, in the winter diet of sika deer inhabiting the Ussuriysky Nature Reserve and the adjacent territory. Our long-term field surveys (2004–2020) have reliably confirmed that overwintering green fronds of wood fern are one of the most preferred food items of sika deer in autumn and winter. In spring and summer, we rarely observed deer browsing on this plant. The consumption of fern reduces the impact of deer on tree and shrub regeneration.

Keywords: thick-stemmed wood fern, *Dryopteris crassirhizoma*, sika deer, *Cervus nippon*, nutrition, food selectivity, fern fronds, Ussuriysky Nature Reserve.

Щитовник толстокорневищный *Dryopteris crassirhizoma* Nakai в питании пятнистого оленя *Cervus nippon* (Temm.) юга Приморского края

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Аннотация. В данной работе рассматривается роль травянистого растения папоротника *Dryopteris crassirhizoma* Nakai в зимнем рационе пятнистого оленя, населяющего Уссурийский заповедник и прилегающую территорию. Наши многолетние полевые исследования (2004–2020 гг.) надежно подтвердили, что зимующие зеленые вайи папоротника являются одним из наиболее предпочитаемых кормов пятнистого оленя в осенне-зимний период. В весенне-летнее время нами отмечены лишь редкие случаи поедания этого растения. Использование папоротника снижает воздействие оленей на возобновление древесно-кустарниковой растительности.

Ключевые слова: щитовник толстокорневищный, *Dryopteris crassirhizoma*, пятнистый олень, *Cervus nippon*, питание, пищевая избирательность, вайи папоротника, Уссурийский заповедник.

Introduction

One of the recent trends in ecosystem research is the study of relationships between faunal and floral species, including the assessment of the impact that ungulates exert on forest vegetation. There is extensive prior research estimating the quantity of available tree/branch food that constitutes the major part in the winter diets of *Capreolus pyqargus* (Pall.), *Cervus nippon* (Temm.), and *Cervus elaphus* (L.) in forest biocenoses of the south of the Russian Far East (Bromley, Kucherenko 1983; Darman 1986; Gaponov 1991; Prisyazhnyuk, Prisyazhnyuk 1974; Konkov 2015; etc.). However, there is still little data on the shares of specific herbaceous plant species in the winter diet of deer.

After the sika deer *Cervus nippon* (Temm.) was introduced in the Ussuriysky Nature Reserve (release with subsequent winter feeding) in the 1970s, its abundance in the area of introduction exceeded 120 individuals per 1,000 ha. With the high concentration of deer in such a small area, their pressure on tree/shrub and herbaceous vegetation sharply increased (Moskalyuk et al. 1999). As track density surveys show, the sika deer is currently the most abundant ungulate species in the reserve, reaching 27.5 individuals per 10 km transect; the abundances of *Sus scrofa* (L.) and *Capreolus pyqargus* (Pall.) are almost equivalent, 3.6 and 4.0 per 10 km transect; and the abundance of *Cervus elaphus* (L.) amounts to 3.1 per 10 km transect.

Numerous publications provide data on the feeding ecology of sika deer, its habitat use and distance of daily movements (Prisyazhnyuk, Prisyazhnyuk 1974; Putman 1993; Chadwick et al. 1996; Sheremetyev, Prokopenko 2005; Aramilev 2009; Igota et al. 2009; Maslov 2012; Maslov, Bogatov 2017; etc.). The species has been reported to exhibit high feeding plasticity and good adaptation to food shortage due to its high capacity to consume low-value foods (Hofmann 1989; Feldhamer, Demarais 2009).

Our study of the browsing impact of sika deer on the forest ecosystems of the Ussuriysky Nature Reserve has been under way since 1998 until present (Maslov, Fedina 2010; Maslov 2011; Maslov 2012; etc.). In the winter season of 2004–2005, we for the first time recorded cases of sika deer browsing on thick-stemmed wood fern *Dryopteris crassirhizoma* Nakai within the area of the reserve. This occurred during a survey of ungulate abundance, when the members of the survey team encountered tracks of groups of deer that had dug out fern fronds from under the snow in different biotopes of the reserve (Maslov 2011; Maslov 2012). In the winter season of 2020–2021, we also observed some facts indicating the consumption of fern by *Cervus elaphus* and *Capreolus pyqargus*, and launched the study to assess its share in the diet of these ungulates.

The aim of the study was to determine the share of the fern *D. crassirhizoma* in the diet of sika deer (at the current stage) in the Ussuriysky Nature Reserve, which is now included in the territory of the Land of the Leopard national park. The reserve occupies a total area of 40,432 ha and is located at the coordinates of 43°40′00″N and 132°30′00″E.

Materials and methods

To assess the share of the fern *D. crassirhizoma's* in the diet of sika deer and the associated feeding patterns in the autumn and winter of 2019–2020, studies were carried out in the area of the Ussuriysky Nature Reserve and the adjacent territory. For tracking animals in winter, we used the standard methods (Nasimovich 1948; etc.) with some modifications to adapt them to our goals (Aramilev 2003; Maslov 2012).

In November 2019, feeding trails were tracked for 10 different groups of sika deer whose sizes varied from 3 to 10 individuals. These deer groups inhabited the upper reaches of the Komarovka River drainage basin (the left tributary of the Razdolnaya River), with their habitat ranges not overlapping. The groups were selected randomly. For each group, a kilometre-long segment of the feeding trail of an individual moving at the farthest distance left or right of the group was

Table 1

Results of tracking along sika deer feeding trails in the Ussuriysky Nature Reserve in November 2019 (n = 10)

Таблица 1

Результаты тропления кормовых ходов пятнистых оленей на территории Уссурийского заповедника (ноябрь 2019, n = 10)

No.	Consumed plant species	Consumed parts	Total number of feeding instances per 10 km transect	
			Absolute number	%
1.	*Dryopteris crassirhizoma* Nakai	*f, r*	346	23.3
2.	*Ulmus sp.*	*ai, ug*	84	5.7
3.	*Carpinus cordata* Blume	*ai, ug*	37	2.5
4.	*Corylus mandshurica* Maxim.	*st, sh, ai, r*	93	6.3
5.	*Populus sp.*	*st, sh*	24	1.6
6.	*Salix sp.*	*st, ai, ug*	71	4.9
7.	*Actinidia sp.*	*yl, sh*	143	9.6
8.	*Micromeles alnifolia* (Siebold et Zucc.) Koehne	*rsp, ug*	3	0.2
9.	*Phellodendron amurense* Rupr.	*lsh, ug, up, fr*	5	0.3
10.	*Acer barbinerve* Maxim.	*st, lsh*	112	7.5
11.	*A. mono* Maxim.	*rsp, ug, lsh*	53	3.6
12.	*A. ukurunduense* Trautv. et Mey.	*rsp, ug, lsh, st*	42	2.8
13.	*A. tegmentosum* Maxim.	*rsp, ug, lsh, st*	64	4.3
14.	*Aralia elata (Miq.)* Seem.	*st, up*	9	0.6
15.	*Eleutherococcus senticosus* (Rupr. et Maxim.) Maxim.	*st, lsh*	203	13.7
16.	*Tilia sp.*	*rsp, ug, lsh, st*	111	7.5
17.	*Fraxinus mandshurica* Rupr.	*tsh, ug*	48	3.2
18	*Ligustrina amurensis* Rupr.	*rsp, ug, lsh, st*	36	2.4
Total			1483	100

Note: Consumed parts of plants are as follows: *f*, fronds; *up*, upper part; *st*, stems; *sh*, shoots; *lsh*, lateral shoots; *tsh*, terminal shoots; *ai*, annual increment; *rsp*, root sprouts; *ug*, undergrowth; *yl*, young lianas; *r*, roots; *fr*, fruit

examined in detail; feeding instances (facts of browsing on the plant or fresh bites of the plant) were recorded (Table 1).

Transects were laid in spruce/fir and Korean pine/broadleaf forests on slopes of various aspects, including floodplains of watercourses; equivalence of the transects was evaluated using a GPS receiver. The total length of the transects was 10 km (n = 10). The depth of the snow cover during the study period varied from 5 to 15 cm.

During the winter season of 2019–2020, observations were conducted in other biotopes of the Ussuriysky Nature Reserve and in the adjacent territory. More than 50 km with signs of sika deer's activity were covered. During the hunting season of 2020, data on stomach contents of sika deer captured in the territory adjacent to the reserve were collected from interviews with hunters.

Results and discussion

As an analysis of the tracking survey data showed, sika deer of all groups utilized green fronds of *D. crassirhizoma* as food, with more recorded feeding instances than any other plant (Table 1).

The most preferred plant species along the feeding trails tracked were *Eleutherococcus senticosus*, *Actinidia* sp., *Acer barbinerve*, *Tilia* sp., *Corylus mandshurica*, *Ulmus* sp., etc. Most of them are common in the types of forest formations prevalent in the reserve, being an abundant and available food supply

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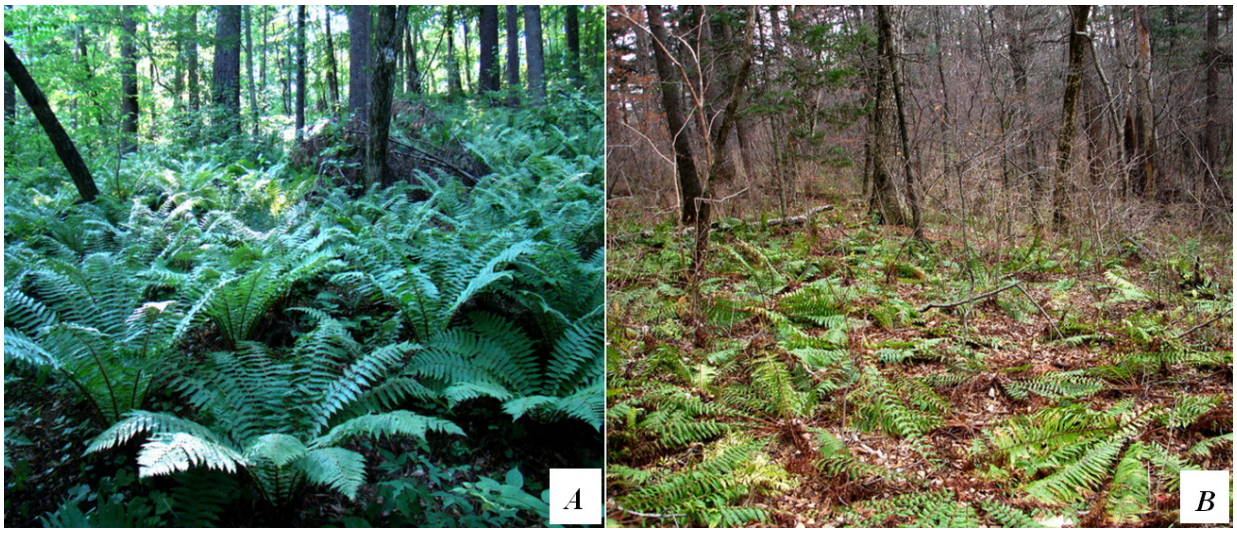

Fig. 1. Thick-stemmed wood fern *Dryopteris crassirhizoma* Nakai in the Ussuriysky Nature Reserve and the Komarovskoe forestry, the Right Komarovka River floodplain: (A) growing season; (B) non-growing season

Рис 1. Щитовник толстокорневищный *Dryopteris crassirhizoma* Nakai в Уссурийском заповеднике и Комаровском лесничестве, пойма реки Правая Комаровка: (A) вегетационный период; (B) вневегетационный период

throughout the non-growing period or only in winter. Furthermore, deer also eat foods from the ground such as acorns, fruit of *Phellodendron amurense* and tree and shrub litter.

In the Ussuriysky Nature Reserve, the fern *D. crassirhizoma* is found everywhere. It is most abundant in Korean pine/broadleaf, Manchurian fir/broadleaf, spruce/broadleaf and silver fir/broadleaf forest formations, which make up 75.7% of the forest cover in the reserve (Azbukina, Vasil'eva 2006). The fern overwinters with green fronds that die off after young ones emerge (Fig. 1: A, B).

Intensive consumption of *D. crassirhizoma* by browsing sika deer is observed since the end of the growing season and throughout winter, snow depth permitting. In October and November, deer mostly nibble leaf blades (pinnae), leaving bare rachises (stalks). As depth of snow cover increases, the feeding pattern changes. Animals partially stick their heads in the snow and tear fronds out of the basal rosette, eating not only pinnae, but also larger fragments. Thus, browsed fern stalks can often be found along deer's trails.

During the hunting season of 2020, the stomachs of two adult sika deer (male and female) captured in the adjacent territory were dissected at our request. A significant part of their contents consisted of a green mass where fragments of *D. crassirhizoma* were present in large numbers. Usually, the amount of fern consumed by deer is markedly reduced as the snow cover depth increases to 40 cm or more. In rare cases, sika deer were observed digging out fern at a snow depth greater than 60 cm (Fig. 2: A–D). During this period, their diet is dominated by branches, although some sika deer groups utilize wild boars' feeding grounds, which allows them to find food on the ground with the lowest energy expenditure.

The share of fern in deer's diet begins to decrease only with the emergence of young vegetation. In spring and summer, we rarely observed cases of browsing on this plant: in spring, uncurled fern fronds (fiddleheads) are utilized by deer as food; in summer, leaf blades.

As part of the programme for the study and conservation of the Amur tiger in the Russian Far East, digital camera traps (Reconyx and Leaf River) have been deployed in the Ussuriysky Nature Reserve since 2008. The images obtained after processing all photographs taken have confirmed the facts indicating that sika deer utilizes *D. crassirhizoma* as food (Fig. 3: A, B).

Fig. 2. Patterns of consumption of thick-stemmed wood fern parts by feeding sika deer: (A) stalks (rachises) with leaf blades completely nibbled off; (B) upper parts of fronds and partially pinnae browsed; (C) fern fronds (pinnae, upper and lower parts of leaf) are torn out of the basal rosette and partially browsed; (D) signs of digging and eating of wood fern (arrows indicate fern fragments)

Рис. 2. Способы потребления частей *Dryopteris crassirhizoma* при кормлении пятнистого оленя: (A) стержни (рахисы) с полностью откушенными листовыми пластинками; (B) объедены верхние части вайи и частично листовые пластинки; (C) листья папоротника (листовые пластинки, верхняя и нижняя части листа) вырваны из прикорневой розетки и частично съедены; (D) признаки раскапывания и поедания папоротника (стрелками указаны фрагменты папоротника)

Conclusions

Our observations have reliably confirmed the active utilization of the fern *D. crassirhizoma*—an herbaceous plant—as a food item in sika deer diet. According to available data on the sika deer feeding ecology, this fern species has not previously been reported as a forage plant in the south of the Russian Far East, including the territory of the Lazovsky Nature Reserve (Prisyazhnyuk, Prisyazhnyuk 1974; Makovkin 1999; Sheremetyev, Prokopenko 2005).

After the termination of winter feeding of sika deer, which was carried out from 1950

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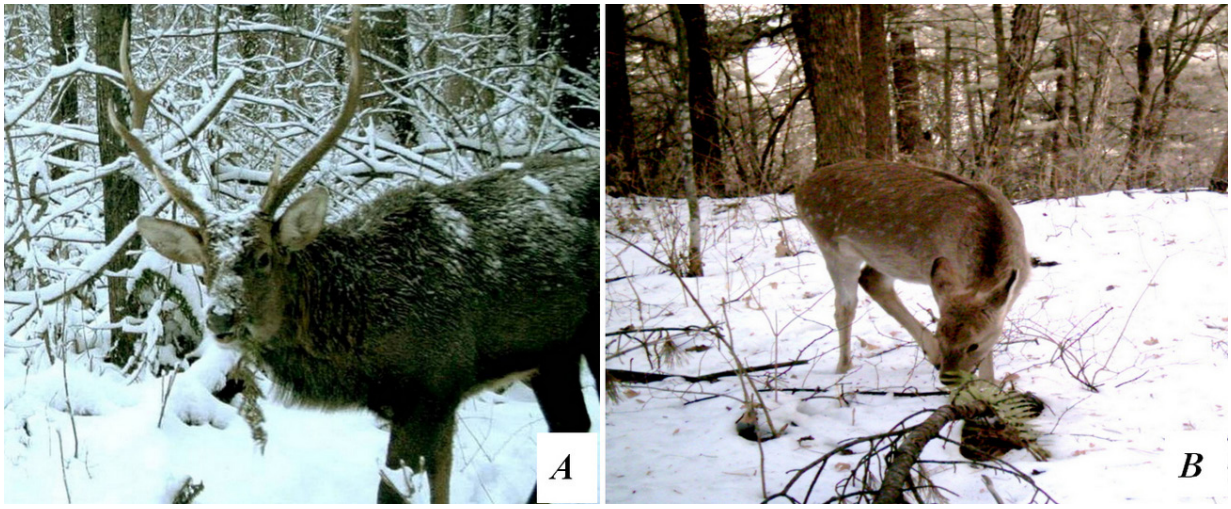

Fig. 3. Sika deer browsing on thick-stemmed wood fern: (A) an adult male in the Komarovskoe forestry, Ussuriysky Urban Okrug, November 15, 2009, photographed with a Reconyx camera trap; (B) a young female in the Suvorov forestry, Shkotovsky District, May 11, 2009, photographed with a Leaf River camera trap

Рис. 3. Пятнистый олень, использующий в питании *Dryopteris crassirhizoma*: (A) взрослый самец в Комаровском лесничестве. Уссурийский городской округ. 15 ноября 2009 г., сфотографирован фотоловушкой Reconyx; (B) молодая самка в Суворовском лесничестве Шкотовского района, 11 мая 2009 г., сфотографирована фотоловушкой Leaf River

to 1970, their dispersal and feeding adaptation began in the conditions of Korean pine/broadleaf forests of the Ussuriysky Nature Reserve, where *D. crassirhizoma* is one of the most common species of the herbaceous stratum. We do not have sufficient information as to the point in time after the introduction when deer began to utilize this fern as food; however, overwintering green fronds of *D. crassirhizoma* currently continue to be one of the most preferred items in the diet of this ungulate species in the study area in autumn and winter. We have rarely recorded cases of browsing on this plant in spring and summer. The consumption of fern reduces deer browsing impact on tree and shrub regeneration.

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