Ph.D. Dissertation of Veterinary Physiology

New habitat for water deer in Northeast China and local community's attitudes towards wildlife, and implications for the conservation of Amur tigers and Amur leopards

중국 동북지역에서 새로 확산된
고라니의 잠재적 서식지와 지역주민들의
야생동물 인식에 관한 연구 및 아무르호랑이
와 아무르표범 보전에 갖는 의미

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Graduate School of Veterinary Medicine

Seoul National University

Veterinary Physiology Major

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수의학박사 학위논문

중국 동북지역에서 새로 확산된 고라니의 잠재적 서식지와 지역주민들의 야생동물 인식에 관한 연구 및 아무르호랑이와 아무르표범 보전에 갖는 의미

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2023 년 2 월

서울대학교 대학원

수의학과 수의생리학 전공

이 영

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Advised by Professor Je-Yoel Cho

Submitting a Ph.D. Dissertation of Faculty of the Graduate School of Seoul National University in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

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이 논문을 수의학 박사 학위논문으로 제출함

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수의학과 수의생리학 전공

이 영

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Abstract

Prey animal and local communities' awareness are one of the important aspects for big cats' conservation. There are multiple small populations of tigers (*Panthera tigris*) and leopards (*Panthera pardus*) across Asia due to the rapid expansion of human populations and the subsequent development of human-dominated landscapes. The habitat patches in northeast China and southwest Primorye of Russia also retain the last population of Amur leopards (*Panthera pardus orientalis*) and a metapopulation of Amur tiger **(***Panthera tigris altaica***).** This region recently became the new habitat for a deer species, water deer (*Hydropotes inermis*), which can become a potential prey species for the big cats; having the baseline knowledge of the water deer and the attitudes of the local community towards wildlife may have important implications for the big cat's conservation. We applied camera trapping, genetic analysis, a species distribution model, and a questionnaire survey to acquire the baseline information.

It is challenging but crucial to combine multiple research techniques when surveying wildlife. The ecology of wildlife, their interactions with the environment, and how the landscape provides a habitat for wildlife are all important aspects of wildlife conservation. The presence of humans in wildlife habitats is crucial to conservation efforts' success and long-term viability. This study focuses on one aspect of wildlife research, but more is needed because the situation surrounding wildlife conservation is complicated. Understanding wildlife needs and how people and wildlife interact in the ecosystem will be essential. The advancement of wildlife monitoring techniques, such as non-invasive genetic sampling, camera trapping, and traditional transect surveys, offers an effective method for gathering accurate information about wildlife. When evaluating wildlife habitat, landscape ecology methods offer a broad perspective. Species distribution models (SDM) can use landscape data, information about human influence, and species ecology

information to predict critical conservation regions. Well-designed questionnaire surveys can identify people's wildlife interactions.

Range expansion for wildlife occurs due to human activity and climate change. There is a need for knowledge and an updated management approach. Since 2019, the water deer *(Hydropotes inermis)*, a small size (15 kg) deer species, has been recognized as a new expanded species in northeast China and the far east of Russia. With several different deer species, high diversity of wildlife exists in the expanded region, including the Amur tiger and Amur leopard. The newly expanded water deer have a high reproductive rate, may serve as a potential prey animal for big cats influencing other species, and may even interact with local people.

In this dissertation research, I used camera trapping, species distribution models, and questionnaire surveys to assess the northward movement of water deer in northeast China, focusing on the Tumen transboundary region between northeast China, the Russian Far East, and North Korea.

My research had three main goals:1) to confirm the species expansion, 2) to assess the habitat, and 3) to assess people's attitudes. I also tried to draw the implications for the big cat conservation from the results. In order to accomplish the goals, I collaborate with regional partners in the research area, such as the local forestry department, Yanbian University, Beijing Normal University, Wildlife Conservation Society, and others, to gather ecological data, conduct household surveys, and analyze landscape data. The research results may provide management guidance for the newly expanded deer species and contribute to the conservation of endangered big cats.

In chapter 1, I employed camera traps, ecological studies, and genetic techniques to identify the expanding deer species and collected information on their range. The range of water deer has extended northward by at least 500 km from its previous distribution limit, and this population shares a tight evolutionary relationship with Korean water deer.

In chapter 2, I identified the appropriate environment and figured out potential expansion pathways for the water deer. MaxEnt model was used to access the habitat. Because environmental factors can be evaluated through their contribution to the model, I discovered that the suitable water deer habitat on the east coasts of the Korean Peninsula (Hamyong-namdo patch) and west coast of the Korean Peninsula (Pytongan-namdo patch) and the newly expanded region along the border between China, North Korea, and the Russian Far East (Hunchun patch). Elevation, wetland region, the availability of water sources, and farmland habitat were significant factors that helped water deer choose their home in the new area. Three main connection routes were estimated among habitat patches. The east route was from Hamyong namdo cross Ryangando and Hamyong bukdo to Hunchun; the middle route was from Pyongan namdo cross Chagang do to Baishan, Atu, Helong, Longjing to Hunchun; The west route was from Pyongan namdo to Chagang do, Baishan, Antu, Dunhua, Wangqing to Hunchun. The predicted habitat connections may serve as the water deer dispersal routes in the past, and further dispersal trends may be predicted through the modeling results. Predators, such as tigers and leopards, may also use the similar routes for their future dispersal.

In Chapter 3, I also investigated residents' attitudes toward wildlife using a questionnaire survey, which may have ramifications for the new extension of water deer management. I discovered that people's attitudes regarding wildlife are influenced by their age, gender, education, and contact with wildlife. Residents usually had neutral sentiments toward large animals, but they had very negative opinions against wild boar, especially if they had suffered losses from crop raiding. It will be crucial to be alert of any potential conflict in the new expansion territory of the water deer, given that the species may induce severe crop raiding in the area in the future. All of these details will be crucial and useful for managing and conserving the newly expanded water deer population. This study illustrates how a scientific working process brings together wildlife, habitat, and the local community when gaining access to and conserving newly expanded species in new ranges. This study results may have important implications to tiger and leopard

conservation, both positive and negative. First positive implication is that the northward expansion of water deer into the newly established big cat range in northeast region of China may have positive effects on big cat populations by increasing prey animal diversity in their habitat. Secondly, we forecasted the potential corridors for water deer, which can be used in the future for big cats as a potential habitat or dispersal routes because of the potential existence of new prey species in the connection areas; Finally, the data on the local people's attitudes towards wildlife can help building strategic plans for future tiger and leopard conservation education and prey management. However, the results may have negative implications for big cat population; for example, potential introduction of novel diseases or pathogens of ungulates to the expanded region, creation of potential disturbance or competition in the wildlife community of the expanded region, bringing about a new type of wildlife-human conflict in the region etc.

Keyword: Amur tiger, Amur leopard, water deer, new habitat, conservation, human-wildlife interaction

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General Backgrounds

While large carnivores play an important ecological role (Eeden et al., 2018), their populations have declined globally due to human activities (Ripple et al., 2014; Uduman et al., 2021). The leading causes of biodiversity loss and the population declines of wildlife species are the growth of the human population and the growth of the economy. It is becoming more and more challenging to maintain a wild area free from human influence. In areas where people and wildlife co-exist, it is critical to comprehend how wild animals interact with their surroundings and the local people. Tigers (*Panthera tigris*) and leopards (*Panthera pardus*) are one of the most significant large carnivores, also called big cats. The population and habitat decrease dramatically with the rapid human population explosion and development in the big cat's habitat.

In northeast China and southwest Primorye, an isolated Amur tiger (*Panthera tigris altaica*) population and the last population of Amur leopard (*Panthera pardus orientalis*) remained. This transboundary mountain ecosystem allows wildlife movement. On the Chinese side, Changbai mountain in northeast China has an estimated 25,000 km^2 of potentially suitable tiger habitat.

Water deer (*Hydropotes inermis*) appeared in this big cat’s habitat since the year of 2019, which can be critical prey species for big cats. However, there is minimal knowledge of this new range of them. This deer species can increase the prey diversity for big cats, and their habitat can also be used for predators, but they may also bring negative impacts on the local ecology, such as increased conflicts between wildlife and local people, and impact on other species and so on. It is necessary to investigate this deer's status in the new habitat for an updated conservation plan for big cats in the region.

Research on wildlife conservation typically only considers one aspect of ecology, genetics, or sociology. The habitat of wildlife must be taken into account for successful management and mitigation of adverse effects. Wildlife species, including large carnivore and other middle-sized or smaller herbivores, complete the food chain network in northeast China. The entire food chain benefits the environment in a significant way. Complex factors may cause a species to change or enlarge its habitat. According to reports, water deer have recently appeared in the region near the Chinese and Russian borders. It is critical to comprehend this newly discovered deer species and how it interacts with its surroundings and other species because systematic research has yet to be conducted. Confirming the status of the species is the goal of our research. To comprehend this new range's species distribution, habitat use, and management options, we applied methods from wildlife ecology, landscape ecology, molecular ecology, and social study.

Amur tiger (*Panthera tigris altaica*)

One of the most significant living carnivores is the tiger (*Panthera tigris*) (Karanth & Chellam, 2009). Tigers were once extensively dispersed throughout Asia (Goodrich et al., 2015a), but they currently only live in 6% of their historical range (Walston et al., 2010), and by 2014, there were only about 3500 wild tigers left in the world (Goodrich et al., 2015a).

By pledging to double the number of wild tigers by 2022, all 13 countries with extant tiger range formed the Global Tiger Recovery Program in 2010. The number of tigers has increased throughout this time in some range nations, such as Nepal (Dhungana et al., 2017), India (Mehrabi & Naidoo, 2022), and northeast China (Wang et al., 2015), but has decreased in others, such as Malaysia (Ten et al., 2021). The slaughter of tigers for the trade in their body parts or because of confrontation with humans, as well as unintentional deaths like road fatalities, have all been cited as anthropogenic theats to tigers (Kumar, 2021; Ten et al., 2021).

Although the tiger has been eradicated from most of China, there is a small but expanding Amur tiger (*Panthera tigris altaica*) population in provinces of Jilin and Heilongjiang (Qi et al., 2021). In the 1970s, 150 was found in northeast China, and in 1998, it was thought that there were only 7-9 tigers in Jilin province and another 5-7 in Heilongjiang (Zhang et al., 2005). However, the number of tigers has steadily increased over the past 20 years: between 2012 and 2014, 26 individuals were identified (Wang et al., 2015), and between 2013 and 2018 there were 55 tigers found in northeast China in four different landscapes (Figure 1) (Qi et al., 2021).

Several protected areas have been established to help with this recovery to preserve adequate habitats that could support future tiger populations. For instance, the Jilin Hunchun Northeast Tiger Nature Reserve was established in Hunchun, Jilin province, in 2001, and the Northeast China Tiger and Leopard National Park, covering an area of 14,600 km^2, was established by the Chinese government in

2017 to assist the recovery of both the Amur tiger and Amur leopard populations (*Panthera pardus orientalis*).

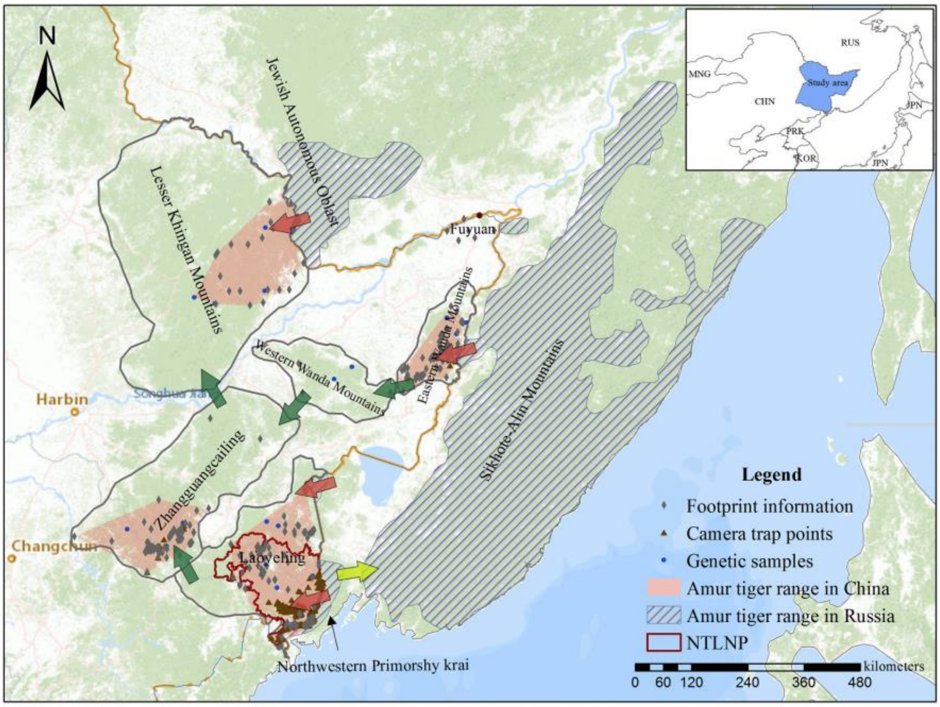

Figure 1. Amur tiger appearance in northeast China during 2013-2018 (Qi et al., 2021).

Amur tiger conservation in northeast China still has many obstacles to overcome.

Source of prey. The low density of large ungulates, mainly big-size prey like wild boar and sika deer, will restrict the carrying capacity for tigers, ultimately causing the terrain to be unable to support a sustainable tiger population.

Habitat patches' poor connectivity. The tiger's ability to move between its existing and potential habitat patches will be influenced by human activities, mainly farming and grazing in areas not effectively preserved as a tiger habitat.

Amur leopard (*Panthera pardus orientalis*)

The leopard, *Panthera pardus*, used to be one of the most wildly ranging carnivores. The Far Eastern, or Amur leopard, *Panthera pardus orientialis*, is the northernmost of all leopard subspecies and was initially distributed throughout northeast China and Korean Peninsula. Due to habitat loss and hunting, the distribution and numbers of Amur leopards decreased; 38-46 Amur leopards were estimated in the year 1973 (according to Abramov and Pikunov survey), mainly distributed Russian-Chinese border. In 1985 (according to Pikunov and Korkishko survey), the population in southwestern Primorye remained the same as in 1973, which was 25-30 animals, but Sikhot-Alin and the western section of Pogranichny Raion leopards disappeared. On the other side of China's border, Jilin province held around 15 leopards in the 1990s. Leopards are extinct in South Korea, but some may still appear in the border region with China and Russia in North Korea. During the last 20 years of conservation on the region's wildlife and habitat, in 2014-2015, an estimate suggests that about 84 leopards inhabit Jilin and the southwestern Primorye landscape (Vitkalova et al., 2018). In the landscape, leopard inhabits mountainous, forested regions with enough roe deer, sika deer, badger, hare, and raccoon dog. The movement of leopards was related to long-distance migrations of roe deer, a key prey species for Amur leopards. Adult leopard requires one adult to ungulate every 12-15 days by radio tracking analysis; the low density of ungulates limits the leopard population from increasing (Mequelle et al., 1996).

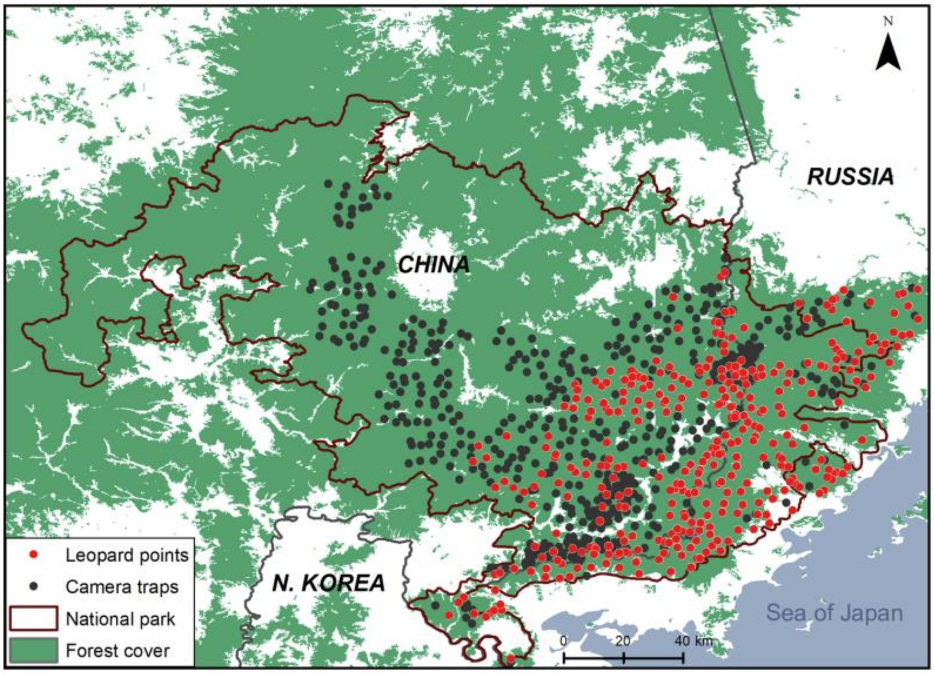

Figure 2. Amur leopard appearance in northeast China during 2014-2015 (D. Wang, Accatino, Smith, & Wang, 2022).

It is critical to comprehend the main elements affecting the leopard population. Here are some of the main threats; others may also include direct hunting, the loss of genetic diversity, possible diseases, etc.

Prey animal. Prey animal density is one aspect of prey animal density crucial for leopard survival. Since the establishment of the Northeast Tiger and Leopard National Park in China in 2016 and the Land of Leopard National Park in Russia in 2012, more stringent law enforcement measures have been implemented. Before that, though, ungulate hunting was a significant issue in China and Russia.

Habitat loss due to logging, fires, or development. Farming, logging, or planned construction projects will reduce or deteriorate the amur leopard's habitat because humans and leopards use the same area.

Conflicts with the local community. Neither China nor Russia has received a single report of an Amur leopard attacking a human. Indirect threats occurred more frequently than direct conflicts. People hunting ungulates will reduce their prey base, and habitat destruction will impact leopards.

The conservation of Amur tiger and amur leopard

One of the critical areas for extensive cat conservation is our research area. The area is home to the last remaining Amur leopard population (about 100 individuals) and a solitary tiger population (about 40 individuals). The small number of populations presents a significant challenge for the valuable big cat's recovery. Jilin Province is in northeast China, bordering North Korea to the south, Heilongjiang to the north, and Primorsky Krai of Russia's Far East to the east. The downstream Tumen area is the primary research area. In the Sikhote-Alin protected area region of Russia, a large population of 450–500 still exist. One small population is separated from this large population and lives in the Tumen River region downstream. Southwest Primorsky Krai in the Russian Far East, Hunchun and Wangqing in Yanbian in Jilin Province, and some border regions in the DPRK are all included in this region. In this region, about 40-50 tigers still exist. The downstream Tumen River has Northeast Asia's highest biodiversity. Internationally, many species have significant conservation value. There are other species like Asian black bears (*Ursus thibetanus*), brown bears (*Ursus arctos*), and ungulates, are excluded red deer (*Cervus elaphus*), roe deer (*Capreolus pygargus*), sika deer (*Cervus nippon*), musk deer (*Moschus moschiferus*), longTailed Goral (*Naemorhedus caudatus*), and wild boar (*Sus scrofa*). The Amur tiger is the national animal of China, Russia, and the DPRK and is listed as a level 1 protected species in each of the three nations. This big cat population was drastically reduced due to extensive human activity. Tiger habitat was negatively affected for a century

by human activity, including population growth, war, hunting, and logging, which led to a sharp decline in the tiger population. The former distribution nearly covered northeast Asia, but only about 500 individuals remain in the area between China, Russia, and the DPRK.
Since the creation of protected areas in China and Russia, ungulate populations have increased, increasing the amount of prey available for the tiger population. This has led to the hope for a small-scale population recovery.
Due to their position at the top of the food chain, the Amur tiger, the ecosystem as a whole must be preserved. The three most crucial needs were met easily: food (prey), water, and a place to shelter. However, the reality is that there are conflicts between humans and tigers due to human population growth, resource needs, and development in the human domain area. Having enough prey is important. Wild boar, sika deer, and roe deer are the main prey items for Amur tigers in the study area.

The Amur leopard once inhabited the entirety of northeast China, the Korean peninsula, and the far east of Russia, but they are currently in danger of going extinct. With fewer than 100 individuals left in the world and the last population located in the Tumen River basin, they are more endangered than Amur tigers. This species is listed as a level 1 protected animal in three nations. Roe deer is the main prey for them in the area. The population of leopards is seriously threatened by its low reproductive rate and severe inbreeding issue. The conservation of the leopard population will benefit from increased prey density.

Based on the threats Amur tigers and leopard are challenging, protect their prey, protect important habitat for tiger and leopard, increase amur tiger and leopard population size, and promote the conservation policy are the most important main parts for the conservation of them (Figure 3). Our research focuses on two parts of these objectives. Identify the baseline information on the potential prey-water deer and the local community attitude towards big cats and their prey. This will increase the knowledge of prey and reduce the human influence on prey and big cats.

In the real world, wildlife threats typically come from human activity and naturally occurring causes. Therefore, traditional biology knowledge is required, such as understanding animal behavior and breeding, but large-scale ecology and social knowledge are also crucial when solving conservation problems.

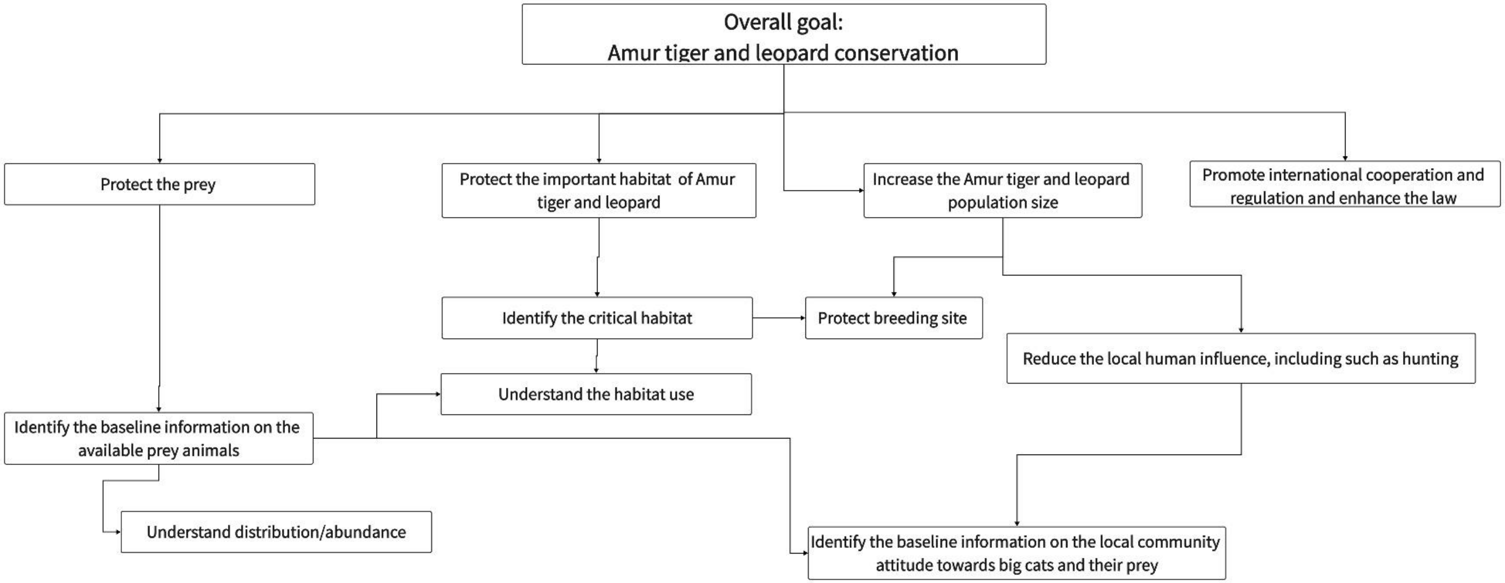

Figure 3. The framework of objectives for achieving the goal of Amur tiger and leopard conservation.

Water deer (*Hydropotes inermis*)

In 2021, water deer teeth were discovered in a tiger's scat in Russia (unpublished information provided by a local ranger), and on the last day of the year, a camera trap in the Tumen River on the Chinese side of the river caught a leopard preying on a water deer.

Water deer and roe deer belong to the tribe *Capreolini* of the subfamily *Capreolinae* of the deer family *Cervidae* (Cooke, 2019; Gilbert et al., 2006b). Water deer is native to China and the Korean peninsula (Whitehead, 1993; H. g. Won, 1968). Geographical distribution allows for the identification of two subspecies: the Chinese water deer (*H. i. inermis* Swinhoe, 1870) and the Korean water deer (*H. i. argyropus* Heude, 1884) (Harris & Duckworth, 2015). They are the only deer species without antlers and have canine tusks that are used in combat during rut season (Gilbert et al., 2006b). Water deer have historically been found south of 42 degrees latitude in China. Later, the Jiangsu Province coastal region was used to describe the distribution range (Ohtaishi & Gao, 1990; Sheng et al., 1999; Zhang et al., 2006). The range in the 1990s was between latitudes 110 and the Chinese coast and latitudes 24 and 34 degrees north (Cooke, 2019). In the 1990s, there were approximately 10,000 water deer in China. By 2011, there were only fewer than 5,000 (Fautley, 2013; Sheng, 1992). But some captive breeding and release projects were started in Shanghai, which will eventually benefit the wild population (Chen et al., 2016). [*]

Sixteen deer were relocated from Moonchen in Kangwon Province to South Hamgyong Province in 1958 as part of the historical distribution of water deer

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[*] The deer population in China fell precipitously as a result of habitat destruction and human activity disturbance, and water deer in Shanghai disappeared completely at the beginning of the 20th century. The Shanghai region started the deer reintroduction project in 2006 to protect the deer and the urban diversity of Shanghai (Chen et al., 2016).

along the Taebak and Nangrim mountains in Korea (Won & Smith, 1999; Won, 1968). The 1990s a significant decline in population size happened due to hunting and habitat destruction (Won & Smith, 1999). However, according to recently published data, the number of water deer is rising throughout the Korean Peninsula, particularly in South Korea. Despite being thought to have little economic value, as their population grew, they were considered a pest in agriculture. In South Korea, there are a lot of reported cases of roadkill (Jo et al., 2018). The estimation of the population size in South Korea is 500, 000 – 700, 000 (Cooke, 2019).

Previous research found that water deer ranged in weight from 11 kg to 16.3 kg depending on the region. Age, whether an animal is dead or alive, and other factors may affect an individual's weight in the wild, but the average female weighs more than males (Cooke 2019). Average shoulder height in England is 47 cm to 52cm (male) and 49cm to 50cm (female) whereas 56 cm (male) and 54 cm (female) in China (Cooke, 2019). Water deer are smaller than the closely related roe deer species. Average shoulder height for roe deer is 65–70 cm, and weights range from 18–30 kg (Cooke, 2019).

Water deer can live in a variety of habitats, including rice paddies, river valleys, coastal habitats, forest wetlands, meadows, and river valleys (Jo et al., 2018; Kim & Lee, 2010). According to Dubost et al. (2011) and Schilling & Rössner (2017), this species, which is distinguished by an unusually high reproductive output and early sexual maturation, is well adapted to the ecological opportunities and risks in a changing environment (Dubost et al., 2011; Schilling & Rössner, 2017). It is the only deer species still in existence without antlers, which is thought to be the result of a secondary loss within the Cervidae family (Gilbert et al., 2006a).

The main threats to water deer include habitat destruction and fragmentation, human activity, particularly hunting, and road deaths. Ten thousand water deer hunt cases were reportedly reported yearly (Sheng, 1992). The primary motivation for hunting is the belief that traditional Chinese medicine can be used as medicine. According to the medical text Compendium of Materia Medica (本草纲目), milk from water deer cubs' stomachs, known as Zhangbao (獐宝), is beneficial for children's indigestion (Figure 4). Previously, deer were killed for their milk, but today, many farms obtain it surgically. However, hunting remains a significant threat to deer in the wild. We can comprehend how hunting in the past affected the wild water deer population.

(A) (B) (C)

Figure 4. 'Zhangbao', the milk from the stomach of water deer cub (Photos from a water deer farm in Hangzhou, Zhejiang China). A is the 'Zhangbao' package will be sold in the market. B is the milk powder; C is solid milk.

IUCN and the Red List of China's Vertebrates listed water deer as vulnerable species under Category II of the Chinese State Key Protected Wildlife in China (Jiang, 2021; Smith & Xie, 2009). They are frequently viewed as wildlife pests in South Korea due to their abundance and crop damage (Kim, 2016).

In the past 70 years, no records of water deer have existed in Northeast China. There is no historical evidence of water deer in Russia. In Southwest Primorsky Krai, a camera trap captured the first image of a water deer of Russia in 2019. In addition, hunters killed a deer that scientists later determined to be a water deer based on morphology after being initially believed to be a musk deer (Belyaev & Jo, 2020). This information led to the official announcement of the water deer as a new species on the Russian mammal list (Darman & Sedash, 2020). It is difficult to confirm the claims made in some documents that water deer were once widely distributed in eastern China and the Korean peninsula, reaching as far north as China's Liaoning Province (Smith & Xie, 2009); more studies revealed that northeast China was not included in the water deer's farthest northern distribution (Cooke, 2019; Zhang, 1997) (Figure 5). For example, the Chinese Academy of Sciences' Institute of Zoology's mammal research team conducted five years of fieldwork from 1953 to 1957; they did not record any data on water deer in Northeast China (CAS, 1958).

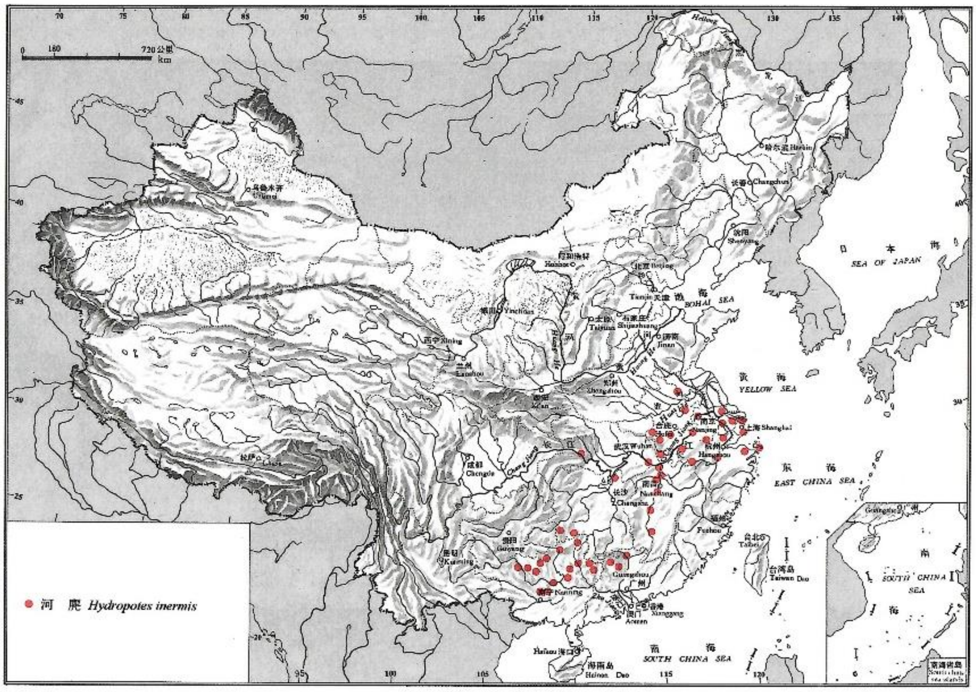


Figure 5. The geographical distribution of the Chinese water deer *Hydropotes inermis* in China (Zhang, 1997).

Purpose of the research

The new habitat for water deer is the important Amur tiger and leopard range region (Figure 6). The water deer range expansion is expected to be a very important factor in the future for the conservation and restoration of big cat populations and biodiversity in northeast Asia. Thus, it is importance to have information on the historical and status of water deer and future prediction of water deer interactions with their environment and other species in the northeast Asia.

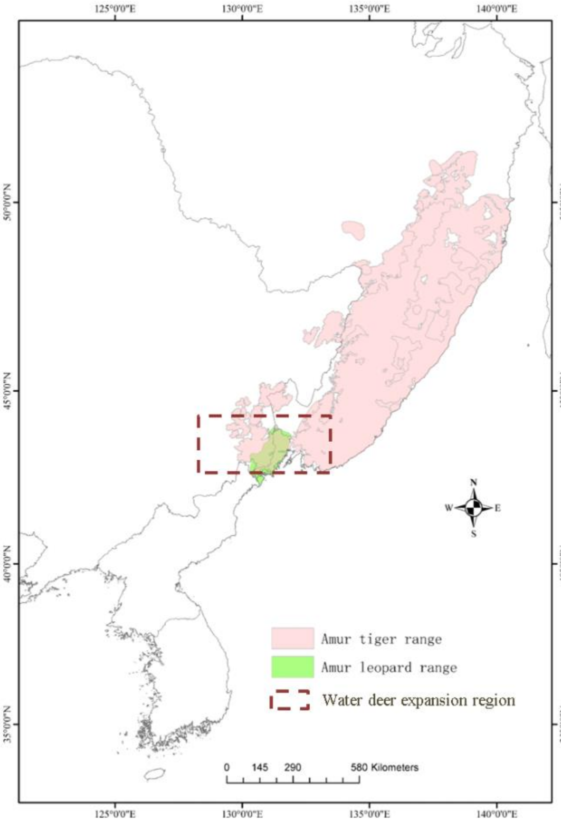


Figure 6. Map of the extant range of the Amur tiger and leopard in the study area. Amur tiger range was drawn based on IUCN, 2015 (Goodrich et al., 2015b); Amur leopard was processed according to Feng. *et al*., 2017 (Feng et al., 2017), and base layers were created through ArcMap 10.3 (ESRI, Redlands, USA).

Big cats have the potential to use water deer as important prey (Figure 7). The low prey animal density was one of the main threats to the survival of these two big cats. Tigers and leopards primarily prey on wild boar, sika deer, red deer, and roe deer; the size of the prey makes a difference in preference.

Figure 7. Water deer was hunted by an Amur leopard in Tumen in 2021 downstream Tumen River (Camara trapping data was from Beijing Normal University monitoring center).

According to historical sources, water deer were not present in Northeast China or Russia. Now, water deer reports have been systematically verified. Where are they distributed, how they expand, where they probably expand to, and will they cause conflicts with the local community? There must be an answer to each of these queries. This population in Northeast China was expanded from its original distribution. However, it can also have adverse effects on the ecosystem. Non-native deer can compete with other ungulates in their area and negatively influence agricultural and forest natural vegetation. (Putman & Moore, 1998; Relva et al., 2009).

My dissertation," New habitat for water deer (*Hydropotes inermis*) in Northeast China and local community's attitudes towards wildlife in the region, and its implications for the conservation of Amur tigers (*Panthera tigris altaica*) and Amur leopards (*Panthera pardus orientalis*) "focuses on the water deer population is northward migration in this region, and this new expansion species will be necessary for tiger and leopard conservation in the region. I hope to provide answers regarding the water deer's unique distribution, distribution traits, and new range region human-wildlife interaction. Additional scientific information regarding conservation and management can be updated with this knowledge. I created a study flow with three main parts: confirm the species range, forecast the habitat, and gauge the local community's attitude (Figure 8). Our study area is located in the Northeast Chinese province of Jilin, which shares a border with North Korea and the Russian Far East. In the area of Hunchun (Yanbian, Jilin) and Primorsky (Russian far east), ecological data collection and camera trap sampling were carried out. The questionnaire survey was conducted in the Yanbian Jilin region.

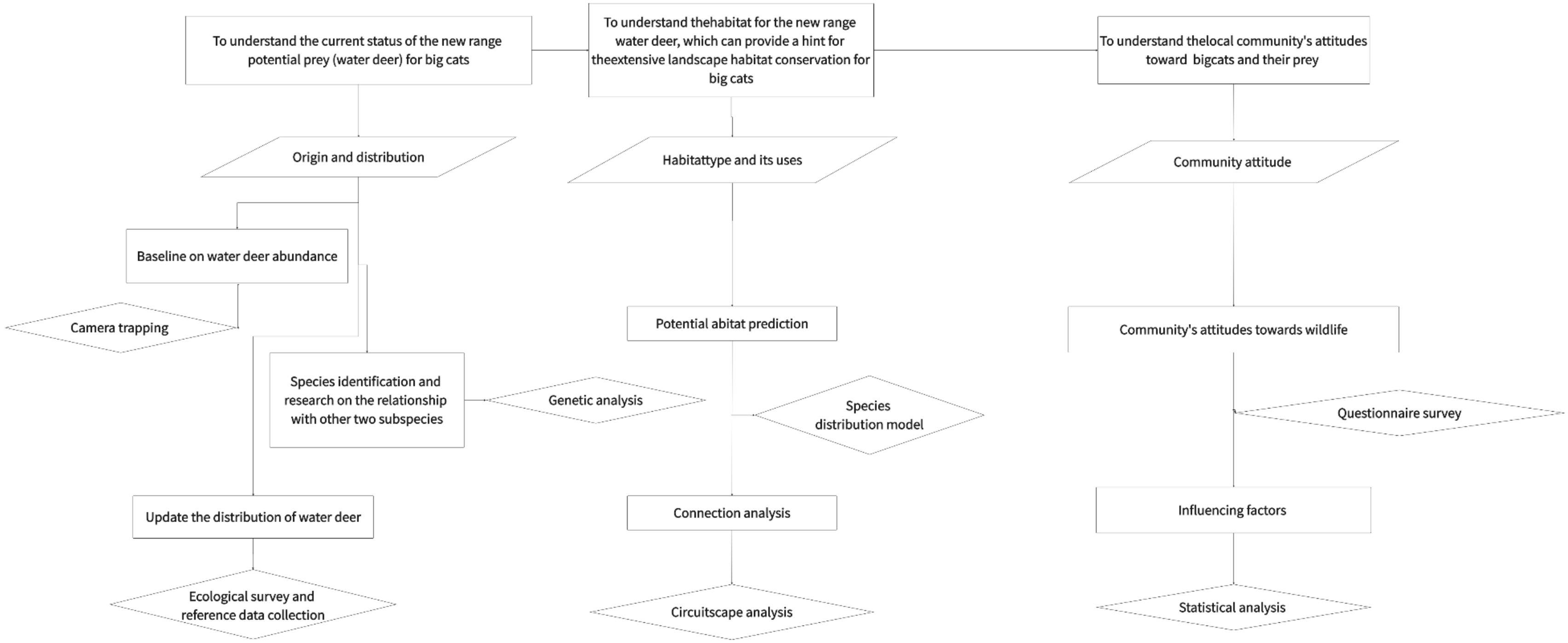


Figure 8. Research flow chart.

Following are the objectives and methodology of the research

I. Using camera traps and genetic sampling to understand the current status of expanding prey. If the newly discovered deer species is a water deer, what are their distribution patterns and densities like? Why this question is significant because it helps us understand the challenges facing conservation efforts and their efficacy. Camera traps, ecological surveys, and genetic techniques were all used to find the answer to this question.

II. Estimating new expanding prey habitats and connections, which provide landscape conservation solutions for big cats. It will always be vital to identify the core region and suggest special treatment for conservation plan makers to prevent the construction or other types of human interference in the wildlife-appearing land, especially in the human-intensive country.

III. How can wildlife be long-term conserved? The top-down approach to conservation is crucial for determining the direction of the movement, but local communities also impact the strategy's long-term success or execution. To successfully solve the conservation issues that contribute to tiger and leopard conservation in a sustainable way, it is crucial to comprehend the attitudes of the local people toward wildlife. A questionnaire survey was employed in the research region to ascertain the opinions of the existing communities and how various causes might influence those attitudes. The results will help with conservation management.

CHAPTER I.
Northward expansion of water deer (*Hydropotes inermis*) the potential prey for big cats: origin and distribution

Introduction

The IUCN Red List rates the water deer (*Hydropotes inermis* Swinhoe, 1870), one of the most primitive members of Cervidae, as "Vulnerable" (Harris & Duckworth, 2015). This species used to be widely distributed in eastern China and the Korean peninsula, extending as far north as Liaoning Province in China (Jo et al., 2018; Ohtaishi & Gao, 1990; Smith & Xie, 2009). Water deer may thrive in a variety of habitats. They can also be found in agricultural areas, particularly paddy farms, but primarily in wetlands, meadows, river valleys, and coastal environments (Jo et al., 2018; Kim et al., 2010). Habitat loss, degradation, and illegal hunting are the primary threat to species in the wild. Traditionally, two water deer subspecies are recognized with disjunct geographic distribution: Korean water deer (*H. i. argyropus* Heude, 1884) and Chinese water deer (*H. i. inermis* Swinhoe, 1870) (Harris & Duckworth, 2015). Korean water deer is widely distributed in South Korea and, to some extent, in North Korea. Chinese water deer have fragmented distributions in Southeast China extending up to Jiangsu Province in the north (Ohtaishi & Gao, 1990; Sheng et al., 1999; Zhang et al., 2006). Recently, water deer were discovered in the Jilin Province of China (Li et al., 2019; Wang et al., 2020). This was the first record of water deer in Northeast China in the past seventy years. In 2019, a camera trap took the first photograph of water deer in Southwest Primorsky Krai (Russia), adjacent to Jilin Province. Historically, there existed no record of water deer in Russia. In 2014, a hunter harvested a deer with a canine but no antler from Mikhailovsky, Primorsky Krai. Later in 2019, a scientific examination confirmed that the hunted animal was water deer (Belyaev & Jo, 2020). Based on this evidence, the water deer was officially announced as a new species on the Russian mammal list (Darman & Sedash, 2020). The water deer has now expanded its range based on recent evidence. Species conservation in an expanded range predominantly depends on the understanding of ecology (habitat use, activity, movement pattern, etc.) and genetics (origin and affinity with other populations). In this study, we applied ecological surveys, camera traps, and genetics to understand water deer distribution in the expanded range.

Material and methods

Research area

A camera trapping survey was conducted for this study in Hunchun and Jian in the Jilin Province and Southwest Primorsky Krai in the Russian Far East, which is situated in the transboundary zone of the Yalv River and Tumen River downstream. The Yalv River divides China and North Korea. The Tumen River separates China and North Korea, while a 15-kilometer piece of land farther downriver separates Russia and North Korea.
The region is a temperate coniferous broadleaved mixed forest with a mild climate and high biodiversity, and it is home to numerous significant flagship species or subspecies of Northeast Asia, such as the red-crowned crane (*Grus japonensis*), white-naped crane (*Antigone vipio*), white-tailed eagle (*Haliaeetus albicilla*), chum salmon (*Oncorhynchus keta*), Amur tiger (*Panthera tigris altaica*) and Amur leopard (*P. pardus orientalis*) (Wang et al., 2020). Data was gathered from July 2019 to July 2021.

Camera trapping and ecological survey

Camera-trap locations were chosen after considering water deer's biology, habitat preferences, and activity patterns (Jo et al., 2018; Kim et al., 2010).
We conducted a questionnaire survey with the local community to record information about the species occurrence and hunting and roadkill data from China and Russia. In China, 12 cameras were set during January-April 2020 in Jingxin wetland south of Hunchun. Fifty-seven cameras were used in the Mijiang stream region, a tributary of the Tumen River, between 2019 and 2020; Four cameras were used in Jian, China. Five camera traps were set in southwest Primorsky, Russia: the Karasik wetland area on the left bank of the Tumen River valley (July–November 2019) and the Tesnaya River wetland close to Peter the Great Bay

(February-March 2020).

Total 78 cameras were set during July 2019 and June 2020, totaling 33,375 working days. To get a general understanding of the pertinent population situation, the Relative Abundance Index (RAI) is computed in the sampling sites (Carbone et al., 2001).

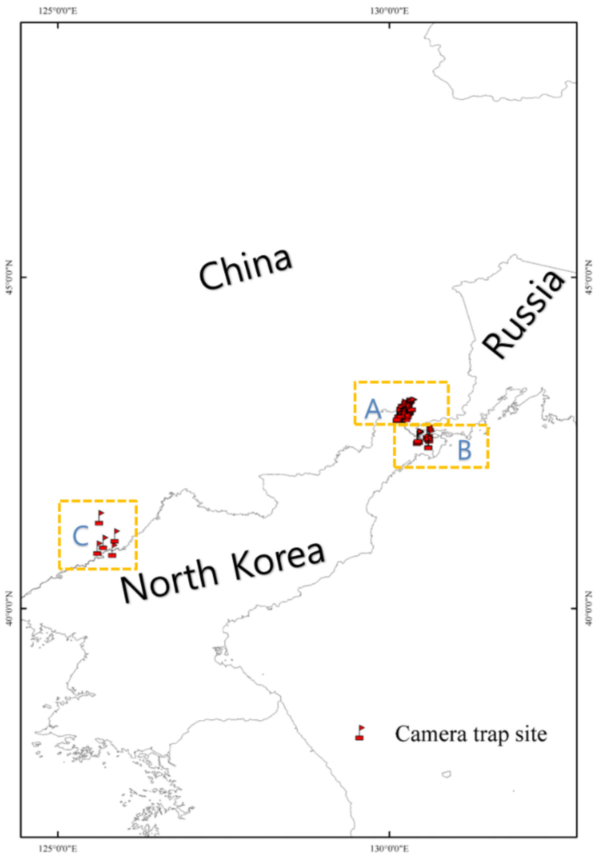


Figure 9. Map of our camera-trapping study area. Site A is Mijiang, Hunchun, China; Site B is downstream Tumen River region, Jingxin, Hunchun, China and southwest Khasansky of Russian Far East; and Site C is Jian, Jilin, China

Camera traps (LTL 6210M, Shenzhen, China) were fixed to trees at the height of 40 to 80 cm, and they were set to record continuously for 24 hours a day with a 1-minute break between each series of 15-second recordings. Medium sensitivity was chosen. For each species, we include the number of detections. The memory card and battery were changed every three months.

In the further analysis of camera trap data, we first removed videos that had no information (mainly due to foliage, light, and wind), and then we identified other recordings of wildlife and human activity videos. One identical detection was deemed to be one separate detection when it occurred within 30 minutes. Relevant abundance and distribution were calculated using the detection, video date, and species description dataset.

Water deer can be distinguished from roe deer by their tails and teeth (male water deer have long canine teeth, which roe deer do not have), and they can also be distinguished from musk deer by their tails and fur color (water deer have short tails and a light brown fur color in comparison to musk deer). Morphological characteristics were used for water deer identification (Figure 10).

Only one report of a species at a trap site was made every 0.5 hours to reduce inflated counts brought on by multiple detections of the same occurrence.

We opportunistically gathered information about the presence of water deer throughout the field study, including hoofprints, urine, and scat, based on recognizing individuals and pinpointing their GPS coordinates. Field indicators were safely identified to species based on at least two specialists' opinions.

A B

Figure 10. Water deer (B) and roe deer (A) photo from camera trapping.

In addition, records of occurrences were acquired through published technical reports, roadkill, hunts, and evidence from the literature (Belyaev & Jo, 2020; Darman & Sedash, 2020; Darman et al., 2019; Li et al., 2019; Wang et al., 2020). This data was retrieved to provide readers with a better idea of the new and growing water deer range.

Mitochondrial DNA for species identification and ancestry detection

We conducted mitochondrial DNA research to understand better water deer' phylogeny and genetic ancestry in northeast China and Russia. Five tissue samples (two from China and three from Russia) from roadkill or hunting (Figure 11, Table 1). The national park administrations from China and Russia provided the samples, and the appropriate authorities obtained the required authorization for genetic analysis.

Figure 11. Road killed water deer found in 2019 in Jingxin Hunchun, China.

Using the Qiagen Blood and Tissue DNA extraction kit following the advised procedure and safety measures, DNA was extracted. We amplified the mitochondrial cytochrome *b* gene's incomplete segment (Irwin et al., 1991) and the D-loop (Kim et al., 2014). Genius Prime was used for sequence quality check, editing, and alignment. The species identity of each of the analyzed samples was reconfirmed using NCBI blast.

Two stages were taken to confirm the phylogenetic position of the water deer samples: first, among other deer species (Pitra et al., 2004) using the cytochrome *b* gene, and second, within the subspecies of the water deer using D-loop sequences (Kim et al., 2014; Li et al., 2020; Putman et al., 2020).

Table 1. Water deer sample information for genetic analysis.

Sample ID	Area	Location	Sample type	Date	Notes
JL01	Bolidong, Hunchun, Jilin Province, China	E 130.44102, N 42.55645	Tissue	2019-7	Roadkill
JL02	Baliancheng, Hunchun, Jilin Province, China	E 130.26988, N 42.87993	Tissue	2019-5	Roadkill
RFE01	Khasansky district of Primorsky Krai, Russia	E 130.47771, N 42.33729	Tissue	2019-12-11	Hunted as roe deer
RFE02	Khasansky district of Primorsky Krai, Russia	E 130.43504, N 42.34924	Tissue	2019-12-25	Hunted as roe deer
RFE03	Khasansky district of Primorsky Krai,Russia	E 130.65602, N 42.41273	Tissue	2020-2-15	Confiscated from poaching

For each phylogenetic tree reconstruction, the jModelTest v2.1.7 (Darriba, Taboada, Doallo, & Posada, 2012; Guindon & Gascuel, 2003) supplied the best-fit substitution model. For the cytochrome *b* and D-loop sequences, separate phylogenetic trees were created. The maximum likelihood phylogenetic tree with 1,000 bootstraps was created using the MEGA software (Tamura et al., 2011). Using MrBayes v 3.2.7, the Bayesian Inference (BI) tree was created (Ronquist et al., 2012). During phylogenetic analysis, sika deer (*Cervus nippon*) and Siberian roe deer (*Capreolus pygargus*) were utilized as outgroups (GenBank accession numbers Z70317; JF893528). In order to display the relationships between populations, we also created the median-joining network (MJN) of water deer haplotypes (D-loop sequence) using the program Network v 10 (Bandelt, Forster, & Röhl, 1999).

Result

Water deer distribution and relevant abundance

In the new expansion area during the period 2019 to 2021, we recorded 19 mammal species over 33,375 trap days at 78 camera stations (Table 2). We detected 19 mammals in the research area, including water deer, roe deer (*Capreolus capreolus*), wild boar (*Sus scrofa*), sika deer (*Cervus nippon*), amur leopard *(Panthera pardus orientalis*), amur tiger (*Panthera tigris altaica*), Asian black bear (*Ursus thibetanus*), brown bear (*Ursus arctos*), red fox (*Vulpes vulpes*), raccoon dog (*Nyctereutes procyonoides*), Siberian weasel (*Mustela sibirica*), Eurasian otter (*Lutra lutra*), Siberian chipmunk (*Tamias sibiricus*), Eurasian red squirrel (*Sciurus vulgaris*), amur hedgehog (*Erinaceus amurensis*), yellow-throated marten (*Martes flavigula*), leopard cat (*Prionailurus bengalensis euptilurua*), Manchurian hare (*Lepus mandshuricus*) and Asian badger (*Meles leucurus*). Total detections varied across the study sites, ranging from one detection of a brown bear (*Ursus arctos*) and Eurasian otter (*Lutra lutra*), respectively, to 4,085 detections of roe deer.

(A)

(B)

(C)

(D)

Figure 12. Water deer photos. Photographs of water deer captured by camera traps in the expansion areas in China and Russia. (A) A male in forest wetlands: 01/14/2020; (B) a female with fawns in the deciduous forests: 12/12/2020; (C) a male in rice paddies: 11/19/2021; and (D) a male in seasonal swamps: 10/24/2019.

We strictly followed the morphology identification characteristics to differentiate water deer from other species. A total of 144 independent detections of water deer were captured (Figure 12). Water deer with fawns were also detected in the wild, and the deer occurred in diversified habitats, including forest wetlands, swamps, and croplands.

Table 2. A list of each species camera-trapped in different study regions, including the number of independent detections, number of camera-traps, and working days.

Camera/Species	Tesnaya	Karasik	Jingxin	Mijiang	Jian	Total
Number of camera-traps	3	2	12	57	4	78
Working days	294	90	945	31045	1001	33375
Water deer (*Hydropotes inermis*)	**3**	**3**	**9**	**68**	**61**	144
Roe deer (*Capreolus capreolus*)	141	22	162	3753	7	4085
Wild boar (*Sus scrofa*)	190	-	284	1536	15	2025
Sika deer (*Cervus nippon*)	42	-	1	176	-	219
Amur leopard (*Panthera pardus orientalis*)	1	1	-	21	-	23

Table 2. (Continued).

Species	Tesnaya	Karasik	Jingxin	Mijiang	Jian	Total
Amur tiger (*Panthera tigris altaica*)	1	-	-	1	-	2
Asian black bear (*Ursus thibetanus*)	-	-	-	7	-	7
Brown bear (*Ursus arctos*)	1	-	-	-	-	1
Red fox (*Vulpes vulpes*)	-	-	12	850	-	862
Raccoon dog (*Nyctereutes procyonoides*)	-	-	17	1909	2	1928
Siberian weasel (*Mustela sibirica*)	-	-	3	116	11	130
Eurasian otter (*Lutra Lutra*)	-	-	-	1	-	1

Table 2. (Continued)

Species	Tesnaya	Karasik	Jingxin	Mijiang	Jian	Total
Siberian chipmunk (*Tamias sibiricus*)	-	-	-	10	-	10
Eurasian red squirrel (*Sciurus vulgaris*)	-	-	-	21	20	41
Amur hedgehog (*Erinaceus amurensis*)	-	-	-	61	-	61
Yellow-throated marten (*Martes flavigula*)	-	-	-	88	2	90
Leopard cat (*Prionailurus bengalensis euptilurua*)	-	-	6	86	2	94
Manchurian hare (*Lepus mandshuricus*)	-	-	-	276	45	321
Asian badger (*Meles leucurus*)	-	-	-	1187	11	1198

In addition to our camera-trapping data, 95 other ecology data occurrence records were obtained in the new expansion area from 2017 to 2021, including 37 from the photographic evidence, 53 from the field survey, two from the roadkill, and three from hunted individuals. We used the overall records to update the range of water deer, and this species has recently expanded beyond its known geographical distribution (Figure 14).

Wild boar

Leopard cat

Yellow-throated marten

Siberian weasel

Figure 13. Other wildlife species captured by camera trap.

Wildlife RAI was calculated, representing the relevant abundance in different sites. From the value, we can see water deer RAI from high to low were Jian (6.1), Karasik (3.3), Jingxin (1.3), Tesnaya (1.0), and Mijiang (0.5) (Table 3). Jian had the highest value of water deer RAI. Compared to the Tumen River region, there is a high possibility that water deer had the dispersal history from the Yalv river much earlier. The national boundary is still a hotspot for wildlife dispersal because Mijiang, a place inside the border, has a lower water deer RAI value than other areas nearby.

Table 3. Relative abundance index (RAI) of wildlife in research sample plots in the boundary region (events per 100 trap/days).

Species	Tesnaya	Karasik	Mijiang	Jingxin	Jian
Water deer	**1.02**	**3.33**	**1.3**	**0.50**	**6.10**
Roe deer	47.95	24.40	23.00	9.23	0.70
Wild boar	64.62	0	43.00	12.47	1.50
Sika deer	14.28	0	0.18	0	0
Far eastern leopard	0.34	1.11	0	0	0
Amur tiger	0.34	0	0	0	0
Brown bear	0.34	0	0	0	0
Stray dog	0	15.55	1.29	2.24	0
fox	-	-	1.84	0.50	0
Raccoon dog	-	-	2.76	0.50	0.20
Weasel	-	-	0.55	0	1.10

The water deer detection and capture from camera trapping were consistent in the study area during the monitoring time. The water deer with cubs were also detected. Camera trapping data include 58 appearance records of water deer in the study area. Sixteen records were from the boundary area between China and Russia, while others are from the Mijiang, west of Hunchun, China. The average RAI of water deer was 2.45, much lower than the other species like roe deer (21.06) or wild boar (24.32) in the study area. During the study period, three large-size predator species were also recorded: the Amur tiger, Amur leopard, and brown bear (*Ursus arctos*).

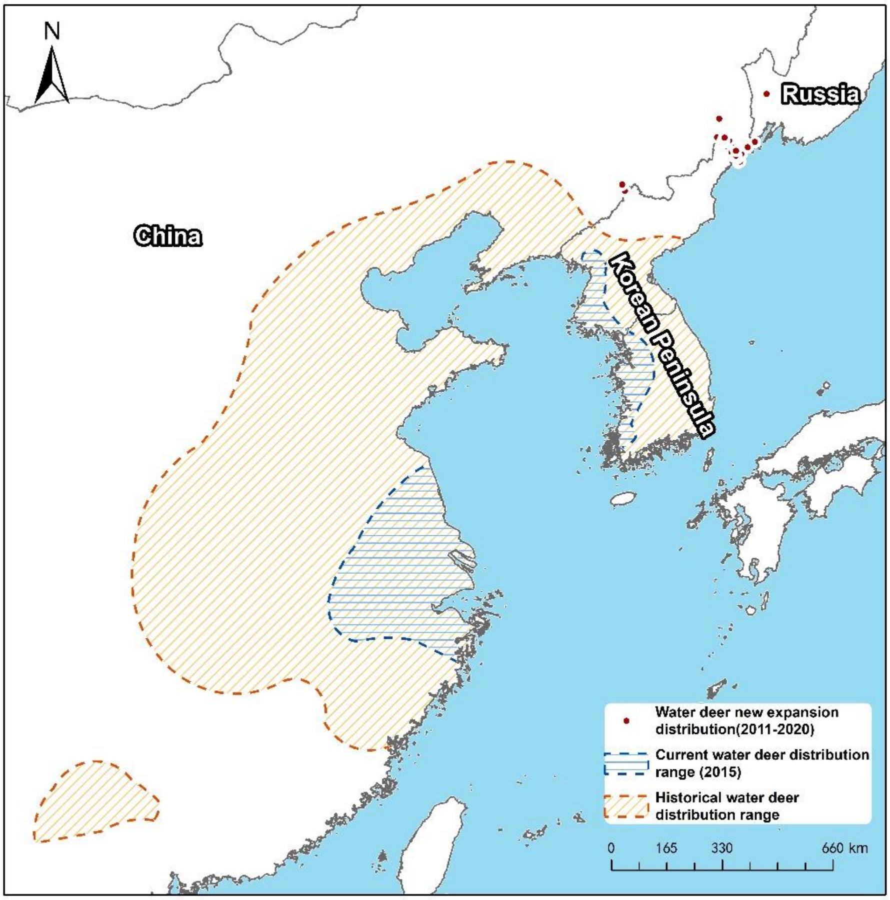


Figure 14. Distribution of *Hydropotes inermis* in Northeast Asia（Based on Ann Marie Schilling and Gertrud E. Rossner, 2017; Won,1968).

Species identification and ancestry detection

For the examined samples, consensus sequences of 822 bp for the D-loop and 1140 bp for cytochrome *b* were obtained. According to NCBI blast, the examined samples appear to be water deer. Additionally, phylogenetic research using the cytochrome *b* gene sequences of 49 deer species verifies the species' identity (Figure 15).

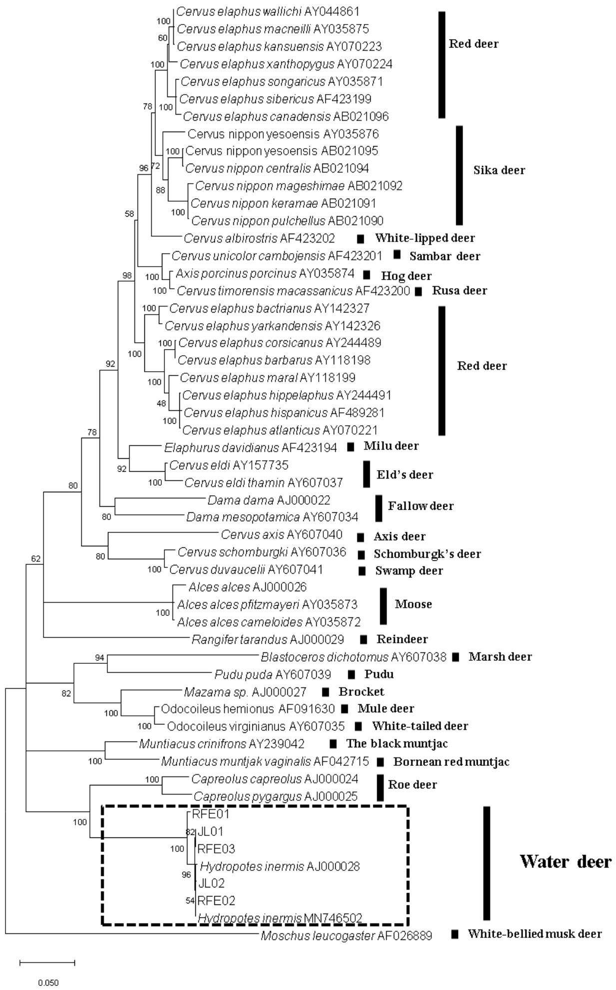


Figure 15. Maximum likelihood tree using cytochrome *b* sequences from deer species (Li et al., 2022).

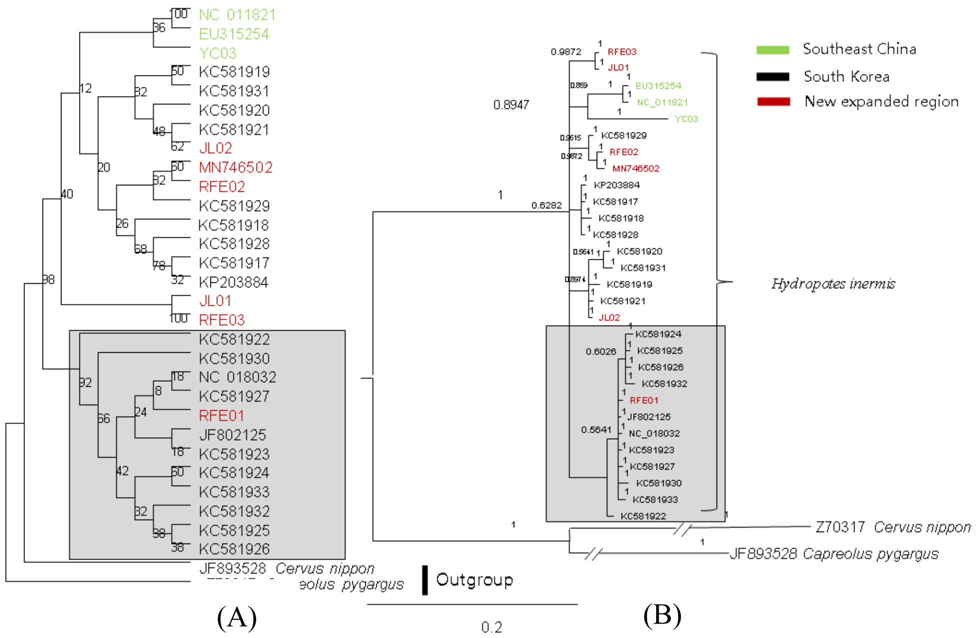


Figure 16. Maximum likelihood and Bayesian inference trees based on control region data from water deer and two outgroups (A: Maximum likelihood tree; B: Bayesian inference tree) (Li et al., 2022).

For each reconstruction of a phylogenetic tree, the jModelTest v2.1.7 (Darriba et al., 2012; Guindon & Gascuel, 2003) supplied the best fit substitution model. For the cytochrome *b* and D-loop sequences, separate phylogenetic trees were created. The maximum likelihood phylogenetic tree with 1,000 bootstraps was created using the MEGA software (Tamura et al., 2011).

Using MrBayes v 3.2.7, the Bayesian Inference (BI) tree was created (Ronquist et al., 2012). During phylogenetic analysis, sika deer (*Cervus nippon*) and siberian roe deer (*Capreolus pygargus*) were utilized as outgroups (GenBank accession numbers Z70317; JF893528).

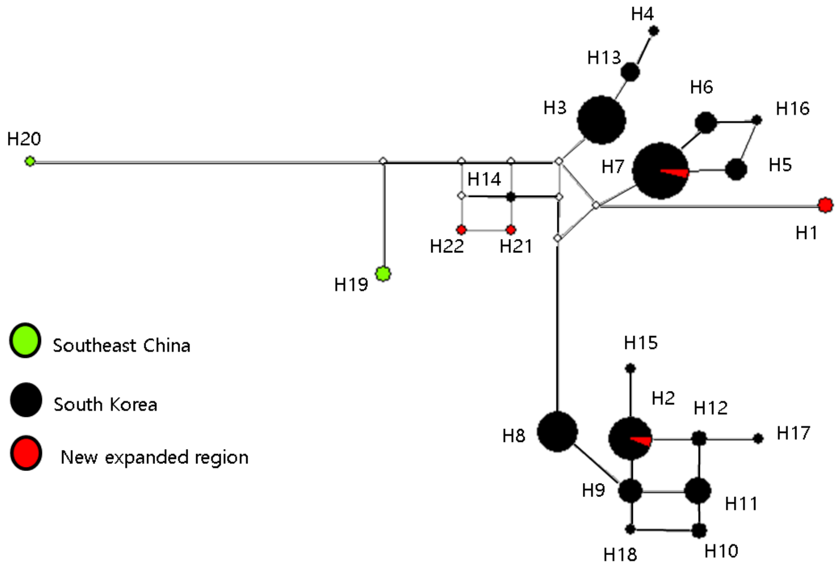


Figure 17. Median-joining network (MJN) analysis with control region haplotypes of water deer (Li et al., 2022).

Water deer mitochondrial D-loop sequences were used to generate ML and BI phylogenetic trees, and it was discovered that there was no distinct clustering of subspecies sequences (Figure 16). The phylogenetic tree indicates that there are two major subgroups (Figure 16).

Sequences of water deer from southeast China grouped together, but not those from South Korea, Northeast China, or the Russian Far East. The distribution of samples from the newly expanded region was found in both subgroups (Figure 16). In five water deer samples, two haplotypes were novel (sample JL1 and RFE03).

Remaining three haplotypes were previously described for South Korean water deer by previous study (B. J. Kim et al., 2014).

The tested samples and other water deer sequences represented a total of 22 haplotypes (H1 to H22; Figure 17). Haplotype 21 (H21, South Korean water deer haplotype) was reported in two sample samples, one each from northeast China (JL02) and Russia Far East (RFE01) (Figure 17).

Discussion

Distribution and relevant abundance

After 50 years without this species' information in the historical area along the Yalu River in the Chinese provinces of Liaoning and Jilin, water deer have now made a comeback. In the Jilin Baishan Musk Deer National Nature Reserve, water deer were photographed 21 times between December 2017 and March 2018. (Li et al., 2019).

We found old photo (2018) of water deer that was captured by camera-trap in Mijiang area which is west of Hunchun area 5 km north from North Korea boundary. In May 23, 2019, the water deer was wounded by traffic incident when it tried to cross road near Tumen River west of Hunchun, moving from the North Korea border (Darman et al., 2019).

In November 2017, a deer individual previously not seen was taken by the camera traps in Southeast Heilongjiang Province (Dongjingcheng Forestry Bureau, 44.1327 N, 128.3789 E), which is significantly northward of the known sightings of this ungulate in China, about 300 km from the Baishan Reserve in Jilin Province. In Russia, water deer was officially recorded in 2019 just near the border with Hunchun (Darman et al., 2019).

Known northernmost record from a hunted individual occurred in the Mikhailovskiy district of the Primorsky Krai in 2014 (44.1135 N, 131.8284 E), and water deer invaded from downstream of the Tumen River to the north of the Primorsky Krai (approximately 1,000 km^2) (Belyaev & Jo, 2020; Darman & Sedash, 2020). However, it was revealed through conversations with locals and border guards that odd deer, which they called "marsh musk deer," had been spotted in the area of the Tumen River since 2015.

Local rangers found numerous snow footprints of water deer and roe deer crossing the Tumen River at its mouth from North Korea to Russia in January 2020. The new water deer range in Primorskiy province has enlarged by 170 km in just 5 years (Darman & Sedash, 2020). Additionally, a report of the killing of a water deer was made close to Khanka Lake (Belyaev & Jo, 2020). With Hunchun and Wanqing valley in Jilin province, China, and Khasansky district and Razdolnaya (Suifun) River in Primorskiy province, Russia, respectively, occupying adequate habitats, it is apparent that water deer has been expanding northward from its historical range in the past ten years.

Our findings imply that water deer populations may be expanding significantly outside of their present range while also rebounding inside their historical range. With the new territory with high quality protected areas, the population will increase. Russia forbids the hunting of water deer, and Khasansky Provincial Nature Park (96 km^2) and the southern cluster of the Land of the Leopard National Park strongly preserve the species' habitats (150 km^2). Water deer live in the recently constructed Northeast Tiger Leopard National Park of China (14600 km^2) with the rigorous conservation policies. They are recognized as State Second-Class Protected Animals in China.

The peculiarity of the water deer is that it has primitive adaptations that are typically connected to warm climates (Geist, 1998). But this species may survive in cold-temperate seasonal climates that include forest and snow. According to The National Atlas of Korea II (http://www.ngii.go.kr), the average annual temperature in Northeast Asia has increased by 0.2–0.8°C over the past 10 years (2010–2019) compared to the region's long-term average annual temperature (1981–2010). A warmer temperature might cause water deer to spread out to higher latitudes and altitudes because they prefer lowlands (Schilling & Rössner, 2017). To discover how climate change is aiding this species' northward migration and to identify potential corridors, more investigation is necessary.

We advise conducting thorough field investigations, gathering ecological data and camera trapping, to determine the water deer's range restrictions, population size, and preferred habitat. We also advise conducting long-term monitoring to determine their persistence and dispersal rates.

Water deer identification and origin detection

Using the most recent evidence, we used this study to depict the northward migration of water deer. Since the majority of Northeast China and the Russian Far East do not have water deer as an endemic species (Kim et al., 2015; Whitehead, 1993; Zhang, 1997); our research offers new information on the geographic distribution of the species and may indicate that its range has really expanded. Our research will be used to guide conservation efforts for this endangered species. Since 2010, intermittent sightings of water deer have been reported by local forestry workers and border guards in Northeast China and along the transboundary zone between China and Russia. The general people may also mistake this ungulate for a roe deer or a musk deer due to its morphological similarities.

Four theories appear to be viable explanations for the origin and method of introduction of the recently established water deer population in the transboundary area between Russia and China (Hunchun, China and Southwestern Primorskiy, Russia). First, it's likely that the animals were only accidentally moved by humans from existing wild or captive populations that originated in the Yangtze Basin and surrounding areas, or from North or South Korea. The population might also organically spread from the Baishan area in Northeastern China along the Tumen River range to the transboundary zone. The third possibility is that it could increase from the mainland of China. Finally, they might grow organically from the North Korean population that already lives along the East Sea coast.

Because there are no official records of water deer transfer activities throughout the past few decades in China, the first hypothesis about manmade migration of the population seems dubious. There do not appear to be any clear motivations for those unregulated actions of live wild animal translocation, even if we cannot completely rule out the possibility of undetected or unlawful translocation of animals by unrecognized individuals. There were several times water deer population translocation from west to east. The translocated population might have been used as a source population for the newly expanded range if it survived and migrated to the north. When local rangers found numerous water deer tracks in the snow across the Tumen River at its mouth from North Korea to Russia in January 2020, they were able to confirm this water deer movement (according to a questionnaire survey). Additionally, a water deer was apparently hurt in a car accident at the Tumen River in May 2019 in Russia, close to the North Korean border (Darman et al., 2019).

Genetic analysis results demonstrating that the water deer population in the China/Russia border region does not contain the original Chinese population haplotype or closely related haplotypes support the rejection of the translocation of individuals from the Yangtze Basin and surrounding area, but the small sample size (n=3) of the South Chinese population is a limiting factor for proper interpretation. It appears exceedingly implausible that South or North Korea would move animals illegally across the border without the border security apparatus noticing. Because very little data was collected from other places of water deer, it is difficult to confirm the possibility of route one, and further research is required in other areas for this species. The second hypothesis is that the population is expanding from the interior of China.

Because the China/Russia transboundary territory is located downstream of the Tumen River and the Baishan area is connected to the transboundary region via the Yalu and Tumen rivers, the third hypothesis has some merit. Water deer favor river basin areas as habitat and dispersal corridors, therefore the river may act as one of these (Kim et al., 2010; Zhang et al., 2006). Additionally, water deer are reputed to be proficient swimmers (Kim, 2016). The proposed corridor along the Yalu and Tumen rivers would need to cross a high elevation area, which is an unsuitable habitat or route for water deer. This is just one of the many problems with the theory. Another is the absence of any records or anecdotal incidents of water deer sightings or existence in the planned corridor area over the past many decades. The last theory appears to be the most likely because it is backed up by numerous circumstantial evidence.

The historical and current distribution of water deer in North Korea is poorly known. However, an official document from North Korean indicates that there had been anthropogenic translocation event of live water deer from western part of North Korea to eastern part in end of 1950s and end of 1960s (Won, 1968). The newly created population in the transboundary zone between China and Russia may have been directly descended from the translocated population had it survived and spread to the North. Additionally, the findings of the current study's genetic research show that the transboundary population is made up of a variety of lineages and haplotype groups, and that its makeup is remarkably similar to that of the population of water deer in South Korea (Kim et al., 2010). We can presume that the genetic makeup of the North Korean water deer population is similar to the South Korean population because there was no physical or ecological barrier separating North and South Korea prior to the Korean War. According to which the newly established population in the transboundary region is of North Korean origin, is supported by the similarity of the genetic composition of the transboundary population and the South Korean population, which indicates that the two populations are related.

In order to have a proper management, first, since this newly expanded population is unique, it should be managed as one distinct population between Russia and China; second, attempts to reintroduce water deer from South Korea or the south of China should be avoided in order to manage this population; third, more survey is required, and more genetic analysis, sampling from South China and North Korea will help to have a better understanding of this population.

However, there are still some limits to our research, and it is challenging to discern between the two subspecies of water deer based on their distinct clades (Kim et al., 2014). We use the D-loop gene, which has been recognized as the polymorphic region of the mitochondrial gene in the case of water deer, but when used for tracing phylogenetic trees low statistical support may happen due to the size limitation (Larizza et al., 2002). These results may have been influenced by two factors: first, sampling limitation, for more South Korean subspecies samples than the other subspecies in the south of China population; and second, low resolution of genetic data. Subspecies are being improperly or insignificantly separated as a result of such resolution. More unbiased and equitable sampling is required in all potential populations of water deer in China and North Korea for greater resolution, and in addition to mtDNA, it may also be necessary to use some nuclear markers. Previous research showed common morphological traits between two water deer subspecies in South Korea and South China using craniodental measurement (Kim et al., 2015). The morphological differences between the skull of water deer in the new region and those of the other two subspecies are worth to be analyzed in the future.

In order to have a proper management, based on the current knowledge, first, since this newly expanded population is unique, it should be managed as one distinct population between Russia and China; second, attempts to reintroduce water deer from South Korea or the south of China should be avoided in order to manage this population; third, more survey is required, and more genetic analysis, sampling from South China and North Korea will help to have a better understanding of this population.

Mutual impact on the population with big cats

Water deer can be one of the most critical new prey species for the big cats in the downstream Tumen River region in the future. Based on 40 years of research in the Serengeti ecosystem in East Africa, two critical factors determine the predators choose the prey, diversity of prey species and body size. The higher diverse prey species will be preferred, and small ungulates will be exposed to more predators with more predation opportunities. Predators have close impact on the prey species (Sinclair, Mduma, & Brashares, 2003). The growth of water deer will benefit the transboundary ecology and could provide more prey for predators (such endangered tigers and leopards), particularly in the Land of Leopard National Park in Russia and China's Northeast Tiger and Leopard National Park. We saw that the three deer had widespread sympathies across a big area.

Big cats in the new territory can control the water deer population. Carnivores will control their prey species population examined by the different forms of research. Through the control experiment, by controlling the predator mountain line (*Felis concolor*) population, it was examined their prey species elk (*Cervus canadensis*) population, which was highly related. In the south of Yellowstone ecosystem, the extinction of large carnivore grizzly bear (*Ursus arctos*) and wolves (*Canis lupus*) caused a remarkably increasing in the prey species moose (*Alces alces*), the consequences were the degradation of the vegetation (Berger et al., 2001). Other research also includes predators like Lynx or even small snakes, which also play an essential role in controlling their prey species (Campbell et al., 2012; Heurich et al., 2012). Because of this interaction, one solution for managing herbivores is introducing the predator. In high lands of Scotland, the red deer (*Cervus elaphus*) was once reaching the carrying capacity; using the structured Markov predator-prey model, the wolves (*Canis lupus*) will positively influence the reducing the deer population (Nilsen et al., 2007). Water deer, as the potential prey for big cats, will be influenced by the population, but how the real interaction may happen needs further monitoring and research.

Northeast Jilin and southwestern Primorskiy are far beyond the historical range of water deer. It coexists with roe deer in suitable habitats in river valleys and marshes. While water deer are a new species in this area and have the potential to improve the environment as well as serve as possible prey for predators like leopards and tigers, it is also important to monitor their impact on other ungulate species. To ascertain if the rising population is a recent undetected expanding population in

China or spread from the Korean Peninsula, future research should also include a thorough ecological and genetic assessment utilizing high-throughput sequencing and a species distribution model. Long-term monitoring is necessary to determine the detrimental effects of water deer, how the animal interacts with the endemic species in its family-the roe deer and sika deer-and how it impacts local vegetation.

Conclusion

Camera traps and genetic methods provided proof that water deer were moving further north. We present the argument that this species most likely originated in North Korea by arguing about the habitat connections and haplotype resemblances. We advise treating this population of water deer as unique and delaying any attempts at translocation or individual reintroduction from China or the Korean peninsula until a comprehensive examination of the population's ancestry has been conducted.

Collaboration between researchers and managing organizations from all of the countries where water deer are found is essential for a thorough assessment of the population status and a landscape conservation strategy because the northward expansion of this deer may be unavoidable. Additionally, in order to ease the evidence-based management and conservation of these populations in a landscape dominated by humans, we suggest changing the water deer's distribution range on the IUCN Red List.

The new range of water deer population can provide an important prey source for big cats, and big cats will also influence their population; the interaction between predator and prey needs further monitoring.

CHAPTER Ⅱ.

Prediction of water deer habitat and potential habitat patches connection

Introduction

For big cats to have a healthy population there must be enough habitat and connectivity between habitat patches. In Northeast China, five important habitat patches have been identified since 2010 as potential tiger habitat patches (Li et al., 2010), At the moment, tigers are known to inhabit the northern patches (1 Hunchun wangqing, 3 South Zhangguangcailing, 4 Muling), but there is no information on patch 2 Changbai. The water deer's recent extension into the same area as Hunchun wangqing, together with its prospective habitat, will be crucial for the distribution of tigers. Due to the importance of prey animals for big cats. Research on the habitat of expansion of the water deer population in the new habitat, we may also be able to learn some suggestions for preserving the corridor that serves as a big cat's habitat.

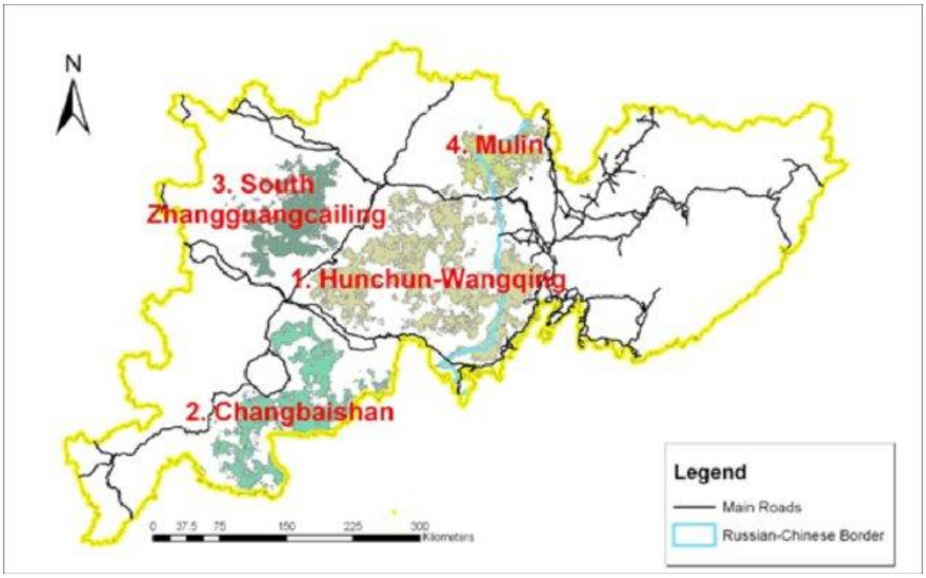


Figure 18. Potential habitat for Amur tiger in Northeast China (Li et al., 2010).

It is essential to comprehend how organisms interact with their surroundings. It is possible to predict where water deer will find a suitable habitat and whether they will be able to disperse by observing how they interact with their surroundings and the condition of their environment in their new range region.

Due to human activity, climate change, and population growth of the focal species, species may leave their original distribution range (Márquez et al., 2011; Moreira et al., 2015). Monitoring is essential because a species' habitat preferences are more obvious when it first moves to a new location than they are once it has been there for a while.

According to Schilling and Rössner (2017), the Chinese water deer population is declining and lives in a fragmented habitat (Schilling & Rössner, 2017). The Korean Peninsula is where the Korean water deer is primarily distributed (Jo et al., 2018). Water deer are known to be a common species in South Korea, where they may be found in most environments, such as marshes, grasslands, and woods (Jo et al., 2018). The North Korean government has provided support for the protection of water deer in the wild since they are classified as species with economic value (Won, 1968).

Historically, water deer populations were found in western North Korea. Since 1968, this species has moved three times to the east of North Korea (Won, 1968). Protected places in eastern North Korea, such as Cheonbul Mountain Animal Reserve in South Hamgyeong Province and Daegak Mountain Animal Reserve in North Hwanghae Province, reported the presence of water deer in 2005. (MNA, 2005). In North Korea, there are no precise occurrence statistics or population descriptions for water deer. However, it may be inferred from the information at hand that water deer are present in suitable habitats in both western and eastern North Korea (Harris & Duckworth, 2015; MNA, 2005). But as of 2019, there have been numerous reports of water deer in the region between China, Russia, and North Korea, places where there haven't previously been any official records of this species (Darman et al., 2019). There are still a lot of natural places with very little human impact in the recently settled regions, in the lower Tumen River basin in China, and in the Russian Far East. (Qi et al., 2021). In national parks in the region where China and Russia meet, big cats like tigers and leopards may prey on water deer because they are herbivores and contribute to ecosystem services (Belyaev & Jo, 2020; Darman & Sedash, 2020; Darman et al., 2019). The possible expansion trend and dispersal routes can be determined by studying how the habitat is used (Rodríguez et al., 2013; Srivastava, 2019; Stevens et al., 2013). Management and conservation of local wildlife and ecosystems depend on an understanding of this species' habitat (Morrison & Mathewson, 2015). The wetlands, swamps, lowlands, grasslands, and agricultural areas are preferred by water deer (Sheng et al., 1999). New water deer sightings are being reported along the Yalu and Tumen rivers, which may be because there are vast stretches of ideal habitat along the riverbanks. The rapid population growth of this deer species (Jung et al., 2016) may make it an important mid-sized mammal species in newly settled areas, have an impact on river and wetland ecosystems, and change the distribution of other wildlife.

Understanding the changes in habitat conditions brought on by new population expansions and forecasting their distribution as well as potential dispersal routes are urgently needed. By taking into account the species and their environmental characteristics, species distribution models and landscape analyses can aid in the provision of the knowledge. We can determine the crucial habitats for the species using the results of the species distribution model and comprehend key variables that are crucial for management strategies. As was done for amphibians, species distribution models can aid in deciding North Korea's top conservation priority (Borzee et al., 2021).

A species' habitat utilization can be evaluated using species distribution modeling (SDM), which is also known as environmental, bioclimatic, species niche, or habitat suitability modeling (Franklin, 2009). The findings may provide crucial information for managing the species by revealing factors that may have an impact on it (Hilts et al., 2019). SDM can be used to estimate the effects of changes in land use and to predict species dispersal under scenarios of climate change (Manish & Pandit, 2019). Although land use prediction data and climate change data are frequently employed separately, several unanticipated biases may be present due to incomplete information on species population size or land cover connectivity (Pearman et al., 2020; Saito et al., 2014). A popular machine learning technique for SDMs is maximum entropy (MaxEnt), which was created expressly for presence-only data to address the issues with small, inadequately samples (Elith et al., 2006). The fundamental concept is to treat the unknown information indiscriminately while fully accounting for the known information when estimating the distribution of unknown probability (Xing & Hao, 2011). Predicting the amount of habitat appropriateness also makes it possible to calculate the differences in habitat and resources between protected and unprotected areas (Evcin et al., 2019). Circuit theory, a recently established method that can measure mobility across a landscape, has numerous applications in the disciplines of movement, population genetics, landscape ecology, and fire behavior (Dickson et al., 2019). Based on random walk and graph theories, this approach (Shah & McRae, 2008) is used to analyze graphs, is typically described as a network of nodes connected by resistors.

Our hypothesis is that the water deer's suitable habitat in and around the current expanding area aids in the species' northward migration. Understanding the elements that aid water deer in expanding their range is the goal of our research. In order to direct management plans for monitoring and research in the newly occupied areas, it is critical to comprehend the habitat preferences of the species and predict their range. We predicted the characteristics of the water deer habitat using a MaxEnt model, and we used the circuit technique to examine the network of conservation areas in the Tumen transboundary area. The findings offer a comprehensive understanding of the prospective habitat and potential water deer dispersal routes, which may be applied to more extensive wildlife monitoring and conservation measures.

Material and methods

Data processing

We forecast the appropriateness of a water deer habitat using the Maxent model. We conducted a field study, a literature review, camera traps, and questionnaire surveys of the local populace and the forestry department to collect data on appearance. From 2019 to 2021, camera traps were set up in a water deer-prone area. In order to gather information, we also conducted a field survey where we recorded track and sighs including rest, eating, and other activity-related data. We also recorded the information type and GPS position for recordings of roadkill, hunting, published literature records (Belyaev & Jo, 2020; Li et al., 2019; Li et al., 2020) and records from the public Global Biodiversity Information Facility (GBIF) database (GBIF, 2021), we recorded the information type and GPS location. The new expansion area (34.70317°N-49.008799°N, 117.65389°E-139.26630°E) that includes the southern provinces of Liaoning, Jilin, and Heilongjiang in China, the Primorye region in Russia, the entirety of North Korea, and the northern half of South Korea was the subject of our investigation.

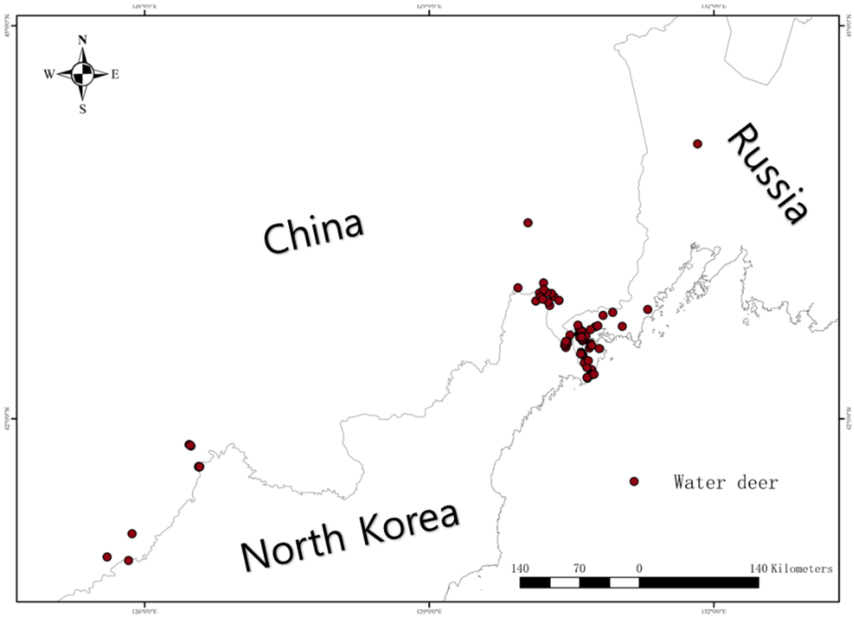


Figure 19. Water deer distribution data used for modeling. Based on SRTM elevation data, a base layer was produced in ArcMap 10.3. (desktop.arcgis.com; ESRI, Redlands, USA). Locations of occurrences were based on the author's data and published data sources (Belyaev & Jo, 2020; Darman et al., 2019; Li et al., 2019) as well as GBIF database (DOI: 10.15468/39omei)

We also processed other prey species records for the modeling—three main prey animals for tiger and leopard in northeast China. The roe deer data was collected using a transect survey in 2015~2016 in Huangnihe and Changbaishan mountains in northeast China, totaling 38 occurrence points. Wild boar information was collected in 2015~2016 in Hunchun, Longjiang, and Russia; a total of 312 points were collected using camera trapping monitoring and a transect survey. A total of 209 occurrences of sika deer information was collected during a field ecology survey in 2015 in Russia and the 2016~2017 transect survey in Hunchun and Changbai mountains.

Model parameter setting and justification

In order to avoid overfitting, we eliminated datapoints that were 500 meters apart when building the habitat model (Aiello et al., 2015). This restriction is based on the about 1 km^2 home range of water deer (Kim & Lee, 2011).

Regarding the ecology of water deer in southeast China and South Korea, seven important environmental characteristics (Table 4) were picked for habitat modeling, including altitude, slope, aspect, distance to built-up areas, distance to water source, distance to agriculture, and distance to roads (Jung et al., 2016; Song & Kim, 2012; Zhang et al., 2006). The selection of environmental factors included both naturally occurring and human-influenced components and took into account the ecological requirements of water deer. Altitude, slope, aspect, and the need for water are all examples of topographical characteristics that are naturally occurring. Human activities might change how wildlife uses its habitat. We considered the distance to roads, the distance to crops, and the distance to populated areas as factors that were influenced by humans. Three topographic variables—altitude, slope, and aspect—were extracted from the SRTM 90-meter resolution World DEM database (Jarvis et al., 2008). The same environmental variables are used for other species for comparison purposes.

Table 4. Environmental variable for species distribution model.

Variable name	Data process	Data source
Landcover	30 m resolution	GLCLU (https://glad.umd.edu/dataset/global-land-cover-land-use-v1)
Altitude (DEM) Slope Aspect	ArcGIS special analysis extracted	SRTM (https://srtm.csi.cgiar.org/)
Distance to cropland Distance to built-up	ArcGIS distance mapping	GLCLU (https://glad.umd.edu/dataset/global-land-cover-land-use-v1)
Distance to water	ArcGIS distance mapping	OpenStreetMap (https://www.openstreetmap.org/)

Aspect was divided into five groups, with values ranging from 0-360°: level (1-0.0001°), north (315-360°), east (45-135°), south (135-225°), and west (225-315°). Altitude and slope variables were continuous data. 19 different types of land cover (Table 5), including desert, semi-arid, dense short vegetation, open tree cover, dense tree cover, tree cover gain, tree cover loss, salt pan, wetland sparse vegetation, wetland dense short vegetation, wetland open tree cover, dense cover, wetland tree cover gain, wetland tree cover loss, ice, water, cropland, built-up area, and ocean, were processed from global land cover (Hansen et al., 2021).
The ArcGIS Euclidean distance tools in ArcGIS 10.3 (ESRI, Redland, CA, USA) was used to calculate distances between developed areas, crops, and water sources, utilizing data from land cover and the open street map database as sources (Hansen et al., 2021; OpenStreetMap, 2015).

Table 5. Land use legend used as environmental variable (Hansen et al., 2021).

Value	Strata	Value	Strata
1	True desert	11	Wetland open tree cover
2	Semi-arid	12	Wetland dense tree cover
3	Dense short vegetation	13	Wetland tree cover gain
4	Open tree cover	14	Wetland tree cover loss, not fire
5	Dense tree cover	15	Ice
6	Tree cover gain	16	Water
7	Tree cover loss, not fire	17	Cropland
8	Salt pan	18	Built-up
9	Wetland sparse vegetation	19	Ocean
10	Wetland dense short vegetation	20	No data

We initially checked the correlation status to prevent model overfitting, which may be brought on by correlation among environmental variables. Using the ArcGIS points tool, 500 random points were created (Figure 20), and values were added to these points from all variables.

Using IBM SPSS software version 26.0, we performed a Spearman's correlation test (George & Mallery, 2019). To estimate habitat suitability, seven uncorrelated environmental factors were used (threshold = 0.7). The factors so chosen were aspect, slope, elevation, landcover, distance to water, distance to agriculture, distance to built-up area. We chose a 500 m resolution for the studies (Kim & Lee, 2011), and used the 2000 Korean Central Belt 2010 projection scheme, taking into account the water deer's home region.

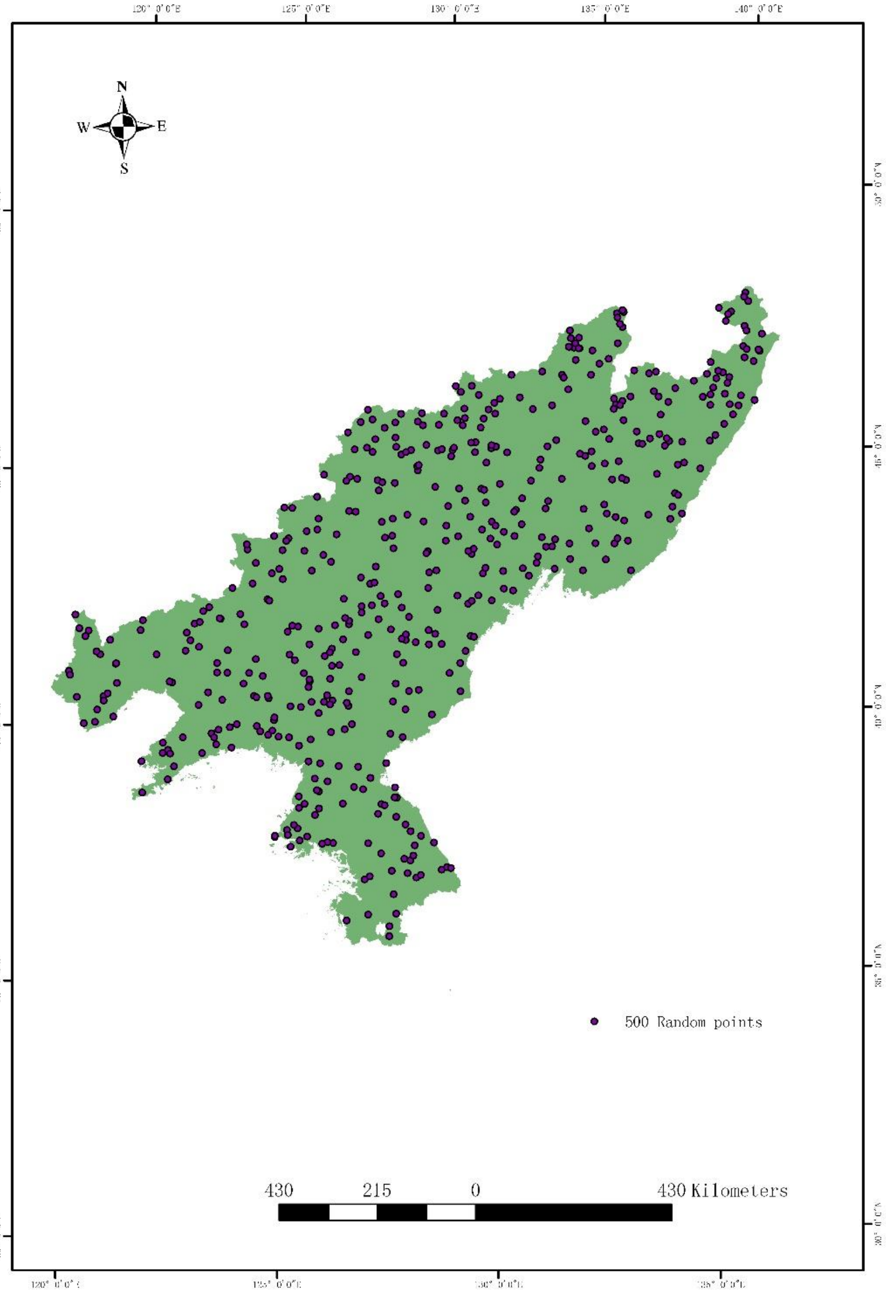


Figure 20. Random points to process environment variable value correlation test.

In this study, we built the model to estimate habitat suitability using MaxEnt 3.4.1 software (Phillips et al., 2017). We entered occurrence points and the seven uncorrelated environmental factors into the program, set the output format to Logistic, and used the data from the occurrence of 25% of the species as test data. Performance of MaxEnt is directly correlated with feature selection and the regularization multiplier value (Zhu & Qiao, 2016).

We used 10,000 backdrop points to build the model. In order to evaluate the influence of environmental variables, a Jackknife analysis was utilized. A threshold-independent area under the curve (AUC) of the receiver operating characteristic curve was used to assess the model's performance (ROC). Using ArcGIS 10.3, the Jenks approach was used to assess habitat suitability level (ESRI, Redland, CA, USA).

Habitat connectivity assessment

Using the Appling landscape connectivity analysis approach, habitat connectivity was examined to forecast appropriate habitat links. According to Ohm's law, when voltage V and resistance R are put across a resistor, current I flows through it, with the voltage V and resistance R determining how strong the current is (McRAE, et al., 2008). Complex landscapes can be viewed as the conductance in the application of circuit theory to landscape ecology, while species randomly moving in various directions can be viewed as the random walker.

Low resistance values are assigned to ecological features that are helpful (positive) for the migration of the focus species, such as preferred land cover types, whereas high resistance values are assigned to ecological features that are detrimental. One of the Maxent results is an ascii file containing a prediction of the likelihood that a water deer will use its habitat, with a value ranging from 0 to 1. A higher number denotes a greater likelihood. We process raster files using the ArcGIS ascii to raster tool, and then use the special analysis tool of ArcGIS to enlarge the value by a factor of 100, and then subtract 101 from that value to process a new raster surface that can be used as a resistance map with a range of 1 to 101 (Liu et al., 2018). The resistance raster file's final transformation resulted in an ascii file.

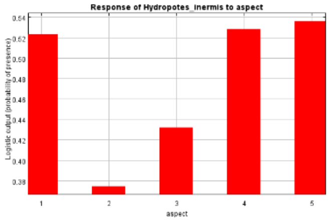
For areas with high-quality habitat, as determined by the results of MaxEnt, connectivity was examined. As nodes and the target locations for the analysis on connection, high quality habitat patch regions were chosen. The patches received specified values, such as 1, 2, and 3, among others. The layer was saved as an ASCII file with the background values set to 0.

In order to calculate the resistance between the nodes for the background, we had to define resistance surfaces. The resistance surface and node map were converted to ASCII data and submitted to the Circuitscape ArcGIS toolkit to determine the connection map (Brad et al., 2013). The surface resistance can also be determined from the MaxEnt modeling results (Feng et al., 2021). In the parameter environment, connect value was set as eight neighbors, others were set as default.

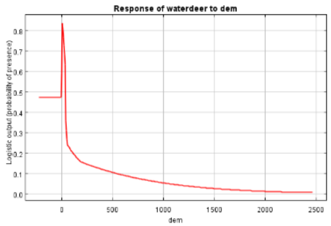
Results

Environmental variables influencing water deer and comparation with other preys

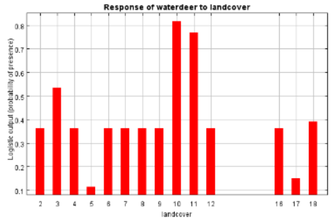
In the modeling result for water deer, seven independent variables, elevation is the most critical factor for the habitat modeling (contributing 56.9% to the model), followed by distance to cropland (16%), landcover (11%), and distance to water (10.2%). The contribution of other variables, via., slope (2%), aspect (0.9%), and distance to built-up areas (2.6), make up only 5.5% of the model. In the habitat model of roe deer, distance to cropland contributed the most to the model (45%), followed by elevation (17.5%) and landcover (16.1%); In the habitat model of sika deer, distance to cropland contributed the most to the model (58.6%), followed by elevation (13.5%) and distance to water (8%); In the habitat model of wild boar, distance to cropland contributed the most to the model (44.1%), followed by landcover (27.5%), and slope (9.9%). The curves that follow each show a separate Maxent model built using only that variable. These charts show how the selected variable and dependencies brought about by correlations between the selected variable and other variables affect expected appropriateness.



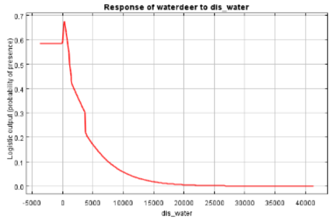
Aspect



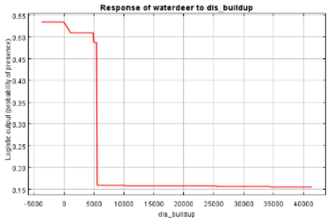
DEM



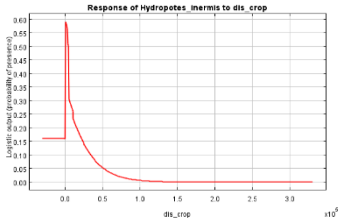
Land cover



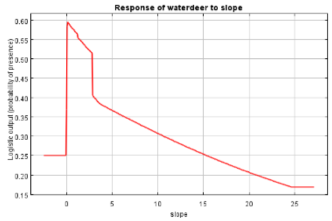
Distance to water



Distance to build up



Distance to cropland



Slope

Figure 21-1. Response curves of water deer to environmental variables used for model prediction. The X-axis represents each environmental variable, and the Y-axis represents the change in the probability of water deer with the environmental variables. (Training data AUC=0.931)

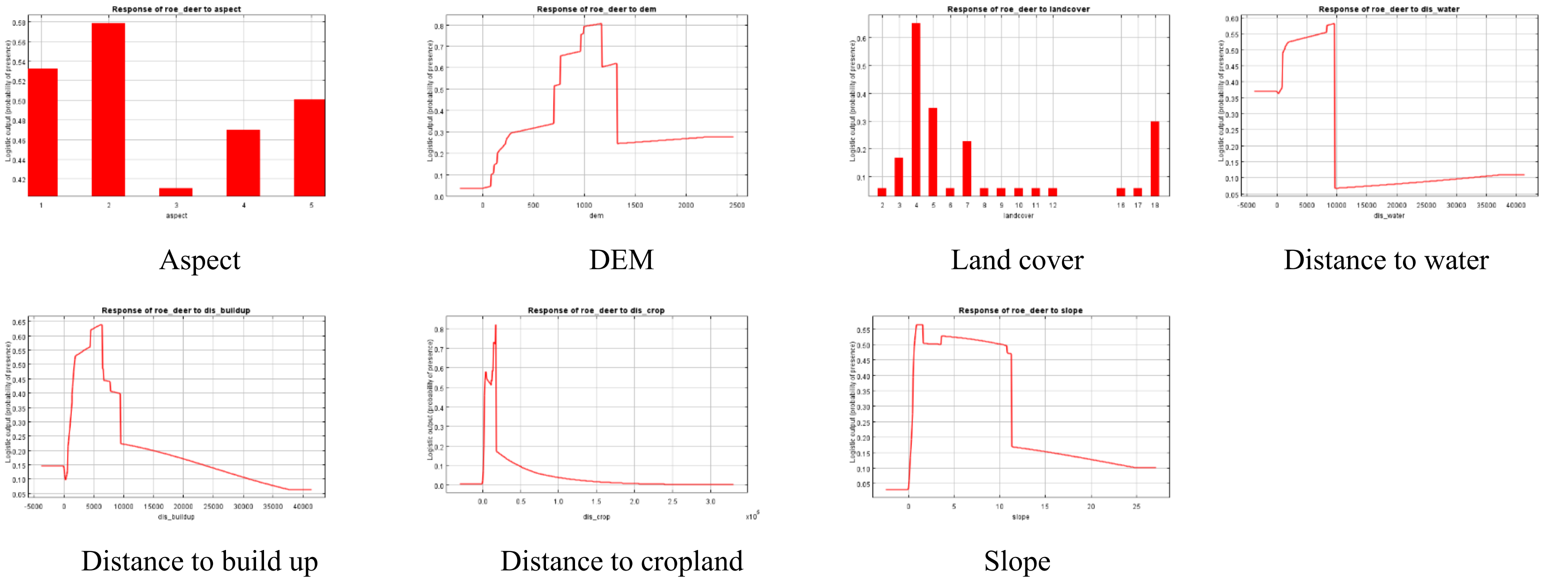


Figure 21-2. Response curves of roe deer to environmental variables used for model prediction. The X-axis represents each environmental variable, and the Y-axis represents the change in the probability of water deer with the environmental variables. (Training data AUC=0.943)

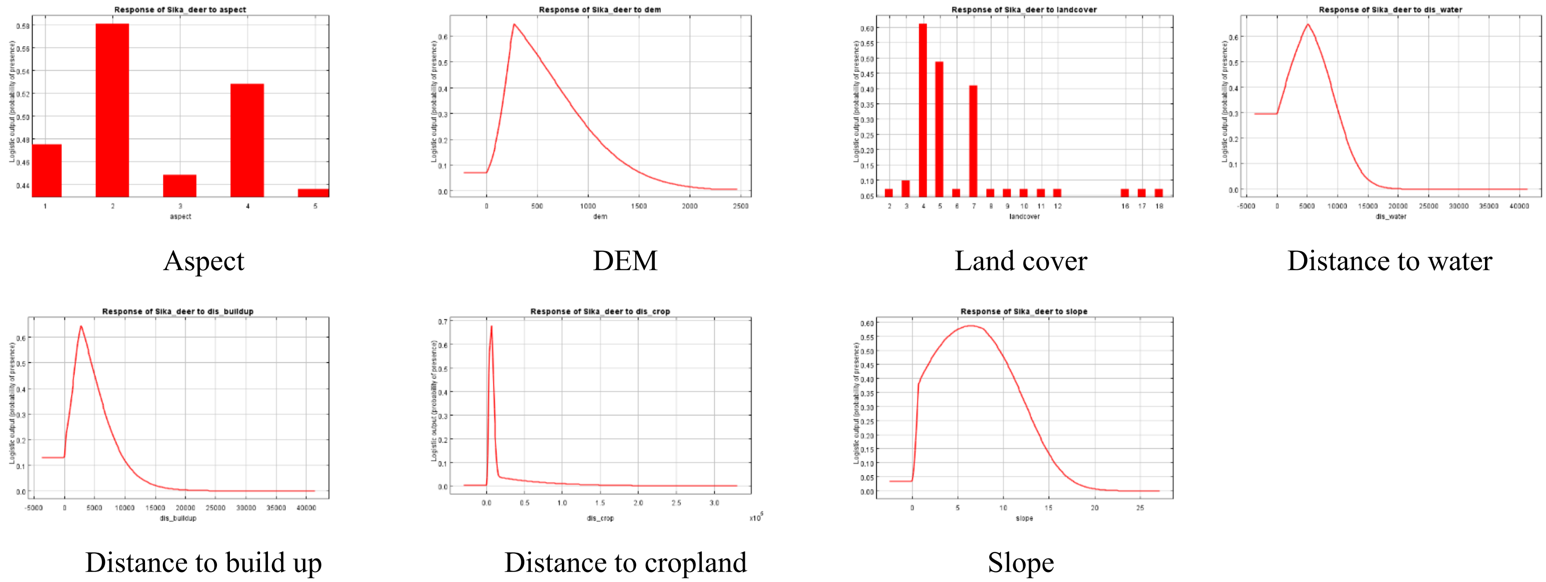


Figure 21-3. Response curves of sika deer to environmental variables used for model prediction. The X-axis represents each environmental variable, and the Y-axis represents the change in the probability of water deer with the environmental variables. (Training data AUC=0.960)

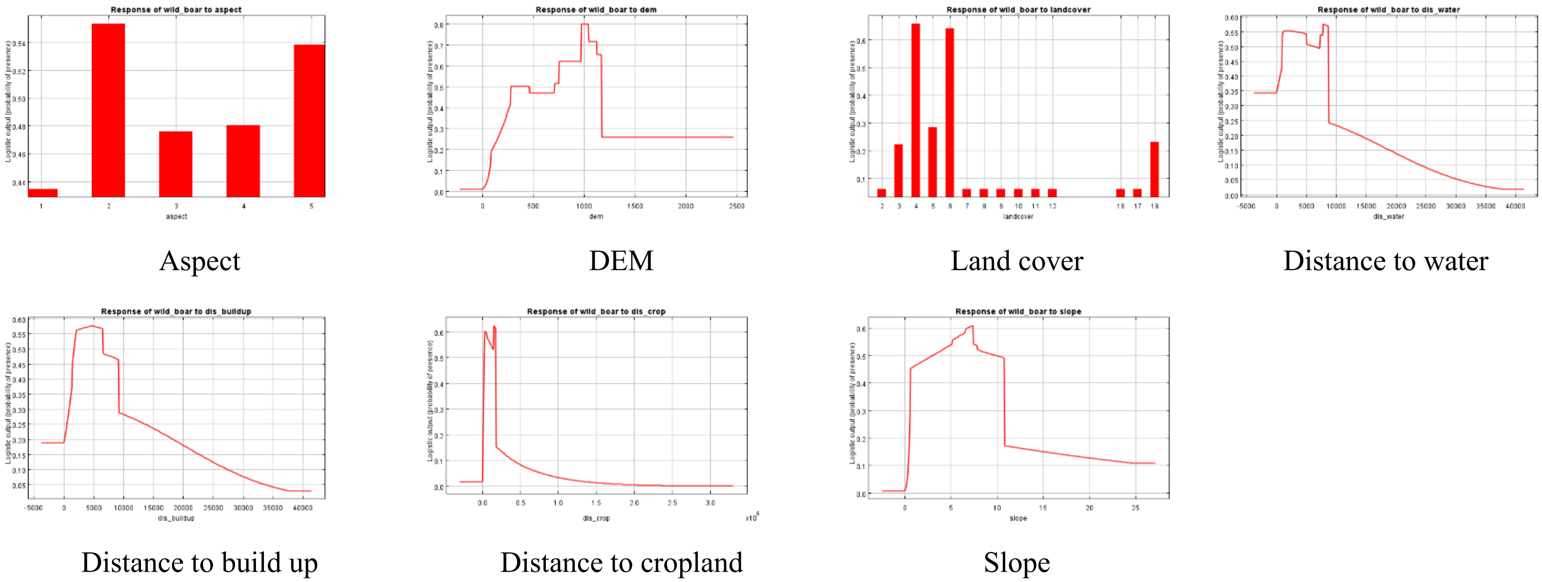


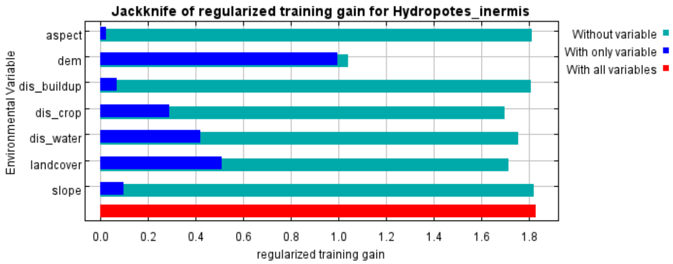
Figure 21.4. Response curves of wild boar to environmental variables used for model prediction. The X-axis represents each environmental variable, and the Y-axis represents the change in the probability of water deer with the environmental variables. (Training data AUC=0.923)

Using response curves revealed the trend of the effect of the environmental variables in the model on the potential distribution of each species. Water deer prefer areas with dense short vegetation and wetland with open/dense tree cover; and prefer low elevation (<50 m), close to cropland (<10,000 m), and close to the water source (<1,000 m). Roe deer preferred the distance to cropland from 10,000 m to 20,000m, an open tree cover area, and flat slopes (<10 degrees). Sika deer preferred the area close to cropland (<10,000 m), low land (elevation between 250 m to 550 m), and distance to build up between 2,000 m to 5,000m. For wild boar, they preferred open tree cover region, the region with a distance to cropland less than 20,000 m, and flat slopes (4~11 degrees) (Table 6).

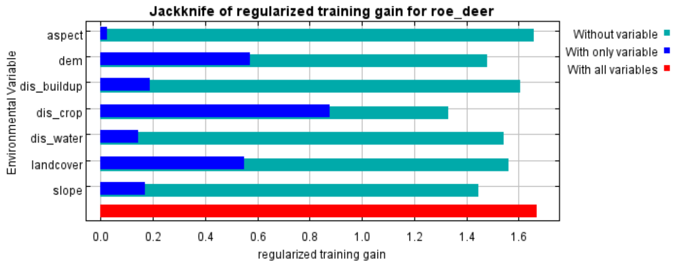
Table 6. Environmental variables selection for prey species

Environmental variable	Roe deer	Sika deer	Wild boar	Water deer
Distance to build up	2000~7000	2000~5000	1500~7000	<5000
Distance to cropland	10,000~20,000	<10000	<20000	<10000
Aspect	2,1	2,4	2,5	1,4,5
Landcover	4	4	4,6	3,11,12
Distance to water	1,000~10,000	2500~8000	1000~8000	<1000
Slope	1~10	3~10	4~11	<4
DEM	700~1700	250~550	700~1100	<50

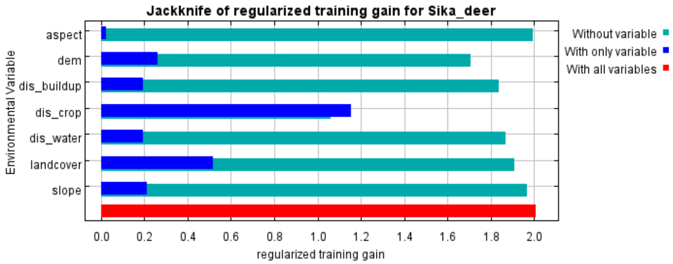
The jackknife test results are of varying values. DEM has the most helpful information because it exhibits the most significant gain. DEM appears to contain the most information not contained in the other variables since it is the environmental variable that reduces the benefit the most when it is excluded. The Maxent model's internal jackknife test of the factor importance showed DEM made the most significant contribution to the distribution model for water deer and wild boar; Distance to cropland made the most significant contribution to the model of roe deer and sika deer (Figure 22).



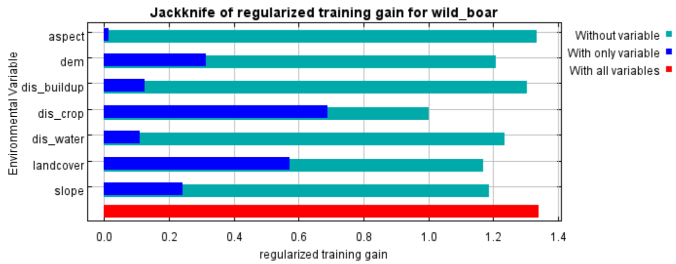
Water deer



Roe deer



Sika deer



Wild boar

Figure 22. Environmental variable Jackknife of regularized training for prey species

Species distribution model predicted suitable habitat for water deer

Our Maxent model had an AUC value over 0.9, indicating that our model could accurately simulate the relationship between the geographical distribution of water deer and the factors analyzed.

The habitat best for the species was primarily found in three regions. One included the western coast of the Korean Peninsula and the southern Liaoning region in northeast China. The second was found along the east coast of the Korean Peninsula, up to the Russian Far East's northern edge. The third followed the Ussuri River for 740 kilometers to the north. It comprised the lower Tumen valley area where water deer had recently spread.

The Northeast Tiger and Leopard National Park in China and the nearby Land of Leopard National Park in Russia both contain portions of high-quality habitat, although some of the best habitats are located downstream of the Tumen River and are not covered by any protected areas.

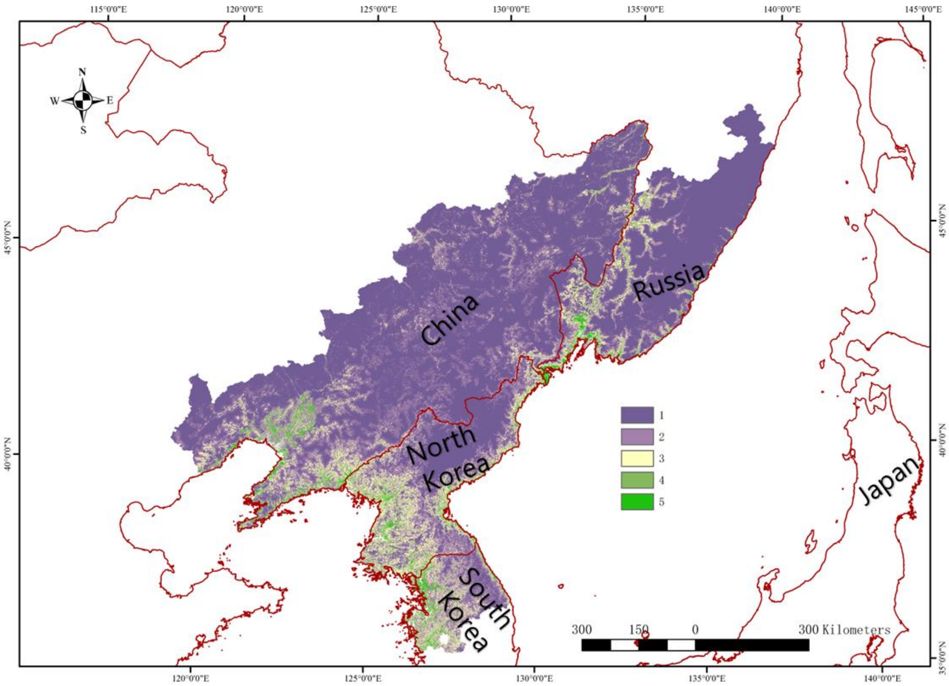


Figure 23. Maximum Entropy model of habitat suitability for water deer (AUC=0.921). Value from 1 to 5 represent the suitability level from low to high. Maxent predict the specific habitat map for the water deer.

Habitat connectivity for water deer

From the Maxent result, three targeting habitat patches can be focused on. They were the newly expanding Tumen River region (Hunchun), East North Korea region (Hamyong-namdo), and West North Korea region (Pytongan-namdo). The newly occupied areas in the lower Tumen region were defined as the target region of Hunchun. The predicted high-value habitat in the west and east coasts of the Korean Peninsula, for which there are also records of water deer (Harris & Duckworth, 2015; MNA, 2005), were defined as regions Hamyong-namdo and Pytongan-namdo respectively (Harris & Duckworth, 2015; MNA, 2005). From the result of network analysis, the focal pair of **the blue area represents the Hunchun**

new water expansion area, the dark green area represents the high-quality habitat in North Korea's Hangyong namdo province, and the light green area represents the high-quality habitat in Pyongan namdo province.

Region Hunchun comprised the areas newly occupied by water deer, located in the lower Tumen River basin. Pyongan-namdo patch was in the western part of North Korea, including North Pyongan province, the western part of South Pyongan province, the Pyongyang region, and the western parts of North and South Hwanghae provinces. Hamyong-namdo patch included the southern part of South Hamgyong province and the northern area of Kangwon province in eastern North Korea. Our results show robust connectivity between regions Pyongan-namdo and Hamyong-namdo but only weak connectivity between these two regions and region Hunchun.

From the result, three possible routes can be seen (Figure 24). East route (red) from Hamgyong namdo crosses Ryangangdo and Hamyong bukdo to Hunchun; middle route (black) from Pyongan namdo crosses Chagang do to Baishan, Antu, Helong Longjing to Hunchun; west route (green) from Pyongan namdo to Chagnag do, Bashan, Antu Dunhua, Wangqing and to Hunchun.

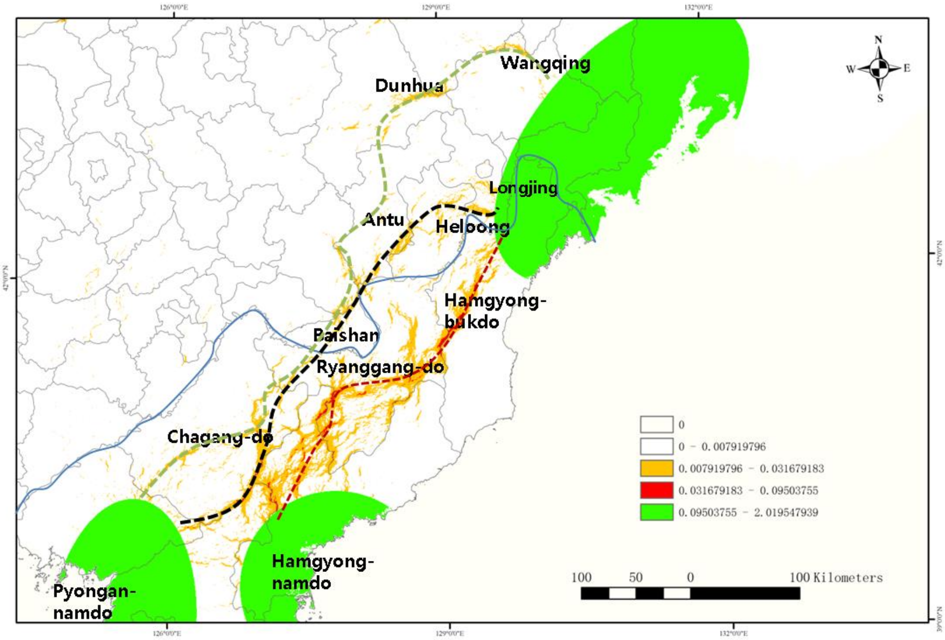


Figure 24. Possible dispersal analysis of water deer. Three main routes between the suitable habitat patches for the regions were calculated.

Discussion

Important environmental factor for water deer

An appropriate habitat evaluation can give insight into the patterns of water deer expansion into the transboundary area between northeast China, North Korea, and the Russian Far East. In order to locate suitable habitats over a greater area, encompassing sections of the Korean Peninsula, northeast China, and the Russian Far East, our study employed current knowledge on this expansion together with landscape variables.

Our research made predictions about a suitable environment on the east and west coastlines of the Korean Peninsula, which were in line with the data in the records already in existence. We looked at the impact of landscape elements to identify suitable habitats, which may help to explain why the range of water deer is expanding. According to our findings, the suitable habitat continues northward into the Russian Far East, where there is less anthropogenic pressure and good access to water supplies and forests. Compared to other deer species, water deer have a high reproduction rate. A female deer can give birth to an average of three to four calves yearly, with a record-high of seven offspring. After one year, the calves are sexually mature (Kim, 2016). Populations in the areas of expansion are likely to multiply due to their high reproductive potential, and they will likely continue to expand their territory northward.

According to our model, low height, closeness to agriculture and water, and the existence of wetlands were significant environmental factors. As body size and morpho-physiological traits are direct determinants of a deer's diet composition, this may be related to the physiology and diet of water deer as well as competition with other deer species like roe deer (Storms et al., 2008). If a new species of deer is introduced, the environment will be affected, and there may be competition with the current deer (Dolman & Waber, 2008; Richard et al., 2010).

Given that GPS tracking data from water deer research in South Korea showed that forests, wetlands, agricultural, and water regions were the most often used land covers, our findings in the context of land use variable result from the habitat model coincide with the understanding of the species (Park & Lee, 2013). Additionally, there was a strong correlation between the desire for broadleaved woods and slopes between 20 and 25 degrees (Kim et al., 2010). Landscape elements of equal importance in South Korea and the recently invaded territory include wetlands, water, and agricultural areas, while variations may occur due to diverse topographical conditions in various locations. To predict the habitat of water deer in South Korea, MaxEnt is indicated to be a very accurate machine learning method (Song & Kim, 2012). MaxEnt did well in our investigation for predicting habitat and influencing factors.

Habitat connection

A high probability of water deer spread from North Korean populations to the recently occupied zone was calculated for three potential pathways based on a landscape connectivity analysis, and at the same time, no barriers could be seen separating the two viable North Korean sites.

The recently colonized area in the lower Tumen region was close to significant protected areas, including the Land of the Leopard National Park in Russia, the Khasansky Provincial Nature Park, and the Northeast China Tiger and Leopard National Park.

Protected sites in North Korea, like the Suryong Mountain Animal Reserve in Tosan County of North Hwanghae Province, which can link the two suitable habitat patches region Hamyong namdo and region Pyongan namdo, may also be crucial for the distribution of animals. Protected places include Daeheung Animal Reserve, Donggye Animal Reserve, and Gwanmobong Nature Reserve Forest Area can be found along the anticipated Eastern route in the provinces of Ryanggang and North Hamyeong. Some protected areas for fish or birds, like

Kuumya Migratory Bird Reserve in South Hamgyong Province and Rason Migratory Bird Reserve in North Hamgeong Province, which links the wetlands in the lower Tumen River with the wetlands in China and Russia, may also help provide suitable water resources and wetland habitat for water deer dispersal. Water deer dispersal through the middle and western pathways may cross central and northern North Korea into China and proceed along the border to the recently captured region. The Geumseok and Ogasan nature reserves in North Korea may provide as a habitat for water deer migrating north across the Yalu River, which serves as the boundary between China and North Korea. From there, dispersing water deer can travel across the northern Changbai mountain region to the Tiger and Leopard National Park, where they can then travel to the recently settled area. They can also travel to the forests in China in the Jilin Baishan Musk Deer National Nature Reserve. The lack of animal movement data, which could help us understand dispersal routes and habitat linkages, limits the anticipated route estimate.

The expansion of water deer showed that the ecological corridor exists in the northeast Asian landscape. The routes can be used for water deer dispersal prediction and also can be used by predators in the future. The habitat characteristics with low elevation and wetland and the region close to cropland provide new habitats for big cats. Extensive cat conservation may benefit from understanding the water deer dispersal method. The connectivity between habitat patches is essential for the viability of the Amur tiger population's protection, and the Changbai mountain region was expected to be an essential potential habitat for its recovery (Hebblewhite et al., 2012). There is evidence that Amur tigers and leopards are already hunting these new prey species in the recently settled area. Unpublished camera trap images of a leopard hunting water deer in China and a tiger scat with water deer teeth in Russia are two examples of the proof that is now available. According to an ecological study on tigers, the most crucial needs of a wild tiger are prey, water, and protected spaces for hunting (Schaller, 1967). Since food availability is the most fundamental and crucial factor for predators, new prey locations may help big cats return to the ecosystem. The expansion of the water deer population and our assessments of the connections between habitats reveals connectivity between locations for wildlife in the region despite the numerous barriers caused by national security concerns between the nations of Northeast Asia. Future surveys could significantly impact how well the connected landscape is preserved.

Possible effect for big cats and other species

Water deer may provide one crucial prey source for big cats, especially for Amur leopards in the newly expanded region; the suitable habitat of water deer may also be used for big cat species. From our habitat modeling, our result shows water deer have different habitat preferences with current prey species; in the short time, the diversity of prey is increasing in the region can be assumed. Various empirical research provides evidence on predator-prey interaction patterns—the influence on both sides and the different effects on the ecology (Lima, 1998). As a generalist predator, a tiger or leopard's feeding strategy is based on many prey species, which means water deer may not strongly influence the big cats' abundance. However, predators will occur in the prey habitat, big cats can also use the suitable habitat of water deer, and connection areas (which can be used as a corridor). Previous research showed that tigers or leopards have highly frequently used habitat types but are not strict with specific habitat types (Barber-Meyer et al., 2012; Hebblewhite et al., 2014). Such as leopards, different subspecies, elevation from the low land of the desert to high elevation in the Himalayan mountains, from wetland to grassland, and the high density of prey provide the main contribution to the big cats' habitat choice (Fattebert et al., 2013). Avoiding human disturbance, prey distribution, and competition with other predators significantly influence tiger and leopard habitat use strategy (Dunford et al., 2022). Tigers' density is closely related to prey density (Qi et al., 2020). The increasing prey density is a critical aspect of big cats' conservation. Different prey sizes will meet the priority needs of a predator of different body sizes (Qi et al., 2020). Amur tigers' main preys are red deer and sika deer in Russia, but wild boars in China provide essential prey. Amur leopards' main prey is roe deer; this reduces the competition between the two big cat animals in the same region (Yang et al., 2018). Because water deer are similar in size to roe deer, we believe they may influence leopard prey availability. Compared to other prey species, wetlands and grassland are essential habitats for them; these regions are now not frequently used by big cats, and the other habitat may be used actively because of this newly expanded deer. Habitat heterogeneity affect predators kill rates and the density of prey and predators (Gorini et al., 2012). New water deer may provide an opportunity for exam the predator-prey interactions in the perspective on the habitat choice and how the habitat change influence the species behavior.

Herbivores also affect vegetation. The excessive number of herbivores can destroy the forest shrub layer, which will also limit the herbivore population (Rooney et al., 2004). If the population of water deer is increasing too much over the capacity, it can cause vegetation consequences and also influence other herbivore populations, which will influence big cats.

In addition, the interactions of water deer in the newly established habitat may serve as a natural experiment on how big cats interact with the environment in which water deer dominate as an herbivore mammal. This gives insight into how we should manage a big cat species restored in an ecosystem where water deer is a dominant species as prey for the big cat species.

The success of landscape conservation can be hampered by several problems, including a lack of surveys, illegal hunting, ambiguous reserve boundaries, a lack of local knowledge, and inadequate stakeholder cooperation. In addition, numerous water deer deaths have been attributed to roadkill (Kim et al., 2021); as a result, roadkill prevention efforts are also required. According to the information that is currently known on water deer in South Korea, these animals eat crops, rice, and other agricultural goods. Special precautions must be taken in areas with high-quality habitats to prevent conflicts between water deer and the local population (Kim, 2016). It is necessary to address other immediate dangers, such as unlawful hunting, by educating the community and implementing projects that lessen interactions between wildlife and people. Knowledge sharing between various stakeholders within and between nations will not only help to improve the management of one species but will also be advantageous to the ecosystem and the entire landscape. Our study examined the landscape connectivity in the transboundary area and the habitat appropriateness in the new range zone. The findings of our study may be crucial for future investigations into the foraging habits of water deer and their interactions with other species.

Conclusion

Our study predicted optimal habitats and three potential dispersal routes for water deer by analyzing data from recently settled areas in the transboundary area between China, Russia, and North Korea; I also analyzed other prey species using the same variables. Water deer has a different preference for local prey, and more extensive potential habitat is available for the new deer specie in the region. The water deer in the new habitat provides a new choice of prey for big cats, increasing the prey diversity for big cats. With this knowledge, we can give a basic overview of how this species uses its environment and show there is connectivity for wildlife in the larger landscape. This connectivity can help protect the entire landscape, but different conservation strategies are needed, such as conflict mitigation in the new region.

CHAPTER III.
Local people attitude towards big cats and their prey

Introduction

In order to create effective conservation and management plans, it is crucial to comprehend human-wildlife interaction. Since locals interact with wildlife, how they feel about large carnivores is crucial to their preservation in environments occupied by humans. Locals are not familiar with the new extended water deer but studying how they interact with other local wildlife will be crucial for the future of a new expanding species. Understanding the attitude status is essential. Typically, information on a number of different aspects will be needed during interviews, such as: 1) conflicts between the local community and protected areas; 2) conflicts between the community and wildlife; 3) participant conditions in conservation programs; and 4) socio-demographic factors like age, education level, wealth, gender, and religion, among others. (Bhatia et al., 2019; Kideghesho et al., 2006). The influencing elements, as it will be crucial to determine management strategies based on a variety of factors. According to prior study on wildlife in other areas, a few key elements have a different impact on how the population views wildlife (Table 7) (Bhatia et al., 2019; Hayman et al., 2014; Khan et al., 2020; Kideghesho et al., 2006; Mogomotsi et al., 2020; Tessem et al., 2010).

Table 7. Factors may influence the people attitude towards wildlife (Bhatia et al., 2019; Hayman et al., 2014; Khan et al., 2020; Kideghesho et al., 2006; Mogomotsi et al., 2020; Tessema et al., 2010).

Positive influence	Negative influence	Have relevant
Benefits from protected areas, Fewer conflicts with wildlife	Reduction in value of livestock	Conflict level
Good relations from protected area staff	Payment of compensation for damages to crops	Participant conservation programs
High education levels	Higher nuisance belief scores	Income
Older people (age matter)	High risk belief scores	Education
Larger family	Presence of livestock (or pets), Foot and mouth disease	Gender
Diversified income source	Residence adjacent to fresh water	Religion

Livestock grazing in tiger habitat provides a significant percentage of local populations' income, raising the possibility of human-tiger conflict (Pettigrew et al., 2012). Understanding the needs of the community and the factors that affect attitudes toward tigers and their prey species can assist identify direct and indirect risks to tigers and recommend remedies that will have the support of local communities (Ravenelle & Nyhus, 2017).

Given that 70% of the designated Chinese Tiger and Leopard National Park is located in Yanbian Korean Autonomous Prefecture, a semi-autonomous region of China that shares land borders with the Democratic People's Republic of Korea (North Korea) and Russia, and makes up the majority of the Amur tiger's current distribution in China, it may be especially crucial to gain a better understanding of the perspectives and concerns of local communities in our study area (Song, 2020). The Korean Chinese ethnic minority, which has its own traditions, customs, and identity, makes up 37% of Yanbian's two million citizens. Han Chinese and other ethnic minority groups make up the remaining 43% (NBS, 2019). The region's GDP per capita ($5,000 USD) was less than half the national average in 2019 (NBS, 2019), making locals possibly more susceptible to economic losses, such as those brought on by conflicts between people and wildlife.

The wild boar is one of the main preys when compared to other animals since there is a strong correlation between predator body size and the prey animal body size. Similar meal comparisons are made with the wild boar, one of the principal species of prey, in different locations (Hayward et al., 2012; Reddy et al., 2004; Sugimoto et al., 2016). Conflicts between humans and their prey species, in addition to tigers/leopard, may have a harmful indirect effect on carnivores. One of the key factors in the success of conservation is understanding the interactions between the local population and the prey species.

In this chapter, we assessed local residents' attitudes toward the wildlife in Yanbian Korean Autonomous Prefecture, Jilin Province, northeast China, including the Amur tiger Amur leopard, bears and their prey species, namely sika deer, roe deer and wild boar. We predicted that the local population would view these species differently and that views toward these target species would vary in the community depending on a variety of criteria, including demographics, income level, educational background, and prior experience with depredation.

In order to understand attitude structures, we first employed factor analysis and cluster analysis. Then, we used regression modeling to see how the pertinent elements affected people's attitudes. Effective conservation can management plans can be processed by taking these important variables into consideration.

Material and methods

Study area

The region of China where we conduct our research, Yanbian Korean Autonomous Prefecture, is bordered by both North Korea and Russia (Figure 25). 70 percent of Northeast China's 14,000 km^2 Tiger and Leopard National Park (NTLNP) is located in Yanbian Korean Autonomous Prefecture (L. Yang et al., 2016).

Arable farming and animal grazing, which take place in and around NTLNP, are the main economic activities in our research area. Cattle are grazed in the nearby mountains from May to October, and from November to April, they are fed with fodder near villages

In early spring (April to May) of 2017, we utilized stratified random sampling to choose 27 villages in the study region to survey. Total 139 household interviews were conducted.

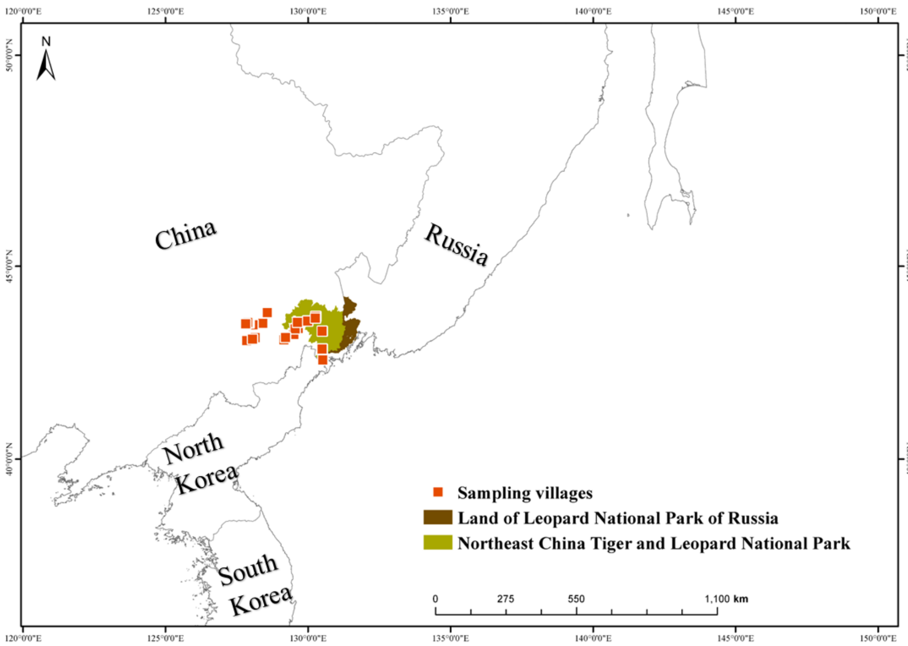


Figure 25. Questionnaire sampling villages in the study area. Red squares indicate study villages. Two protected areas are shaded: the dark grey region refers to the Land of Leopard National Park (Russia), and the light green region refers to Northeast China and Leopard National Park (China).

Questionnaire Survey

We employed a structured interview questionnaire (Appendix 5), which was given in Chinese during face-to-face interviews (Du, 2018).

Before beginning the interview, verbal consent to participate was obtained from each participant in accordance with Seoul National University Institutional Review Board No. 1608/001-011 procedures. Each household was only allowed to have one adult participant for the interviews. Every participant was older than 18 years old. There were 48 questions total in each survey, plus a few sub questions. Based on our knowledge of the local populations and general wildlife issues in northeast China gained over more than 10 years of combined work there and with reference to the published literature, survey questions were developed (Pettigrew et al., 2012; Soh et al., 2014). The questionnaire asked about the respondents' basic demographic and socioeconomic characteristics (Hayman et al., 2014; Kideghesho et al., 2006), their understanding of wildlife and its conservation (Khan et al., 2020; F. Liu et al., 2011; Mogomotsi et al., 2020), their attitudes toward local wildlife (Kideghesho et al., 2006), and their perspectives on human-wildlife conflict (such as livestock predation, crop damage, or harm to humans) (Mogomotsi et al., 2020) as well as their wildlife consumption experience and attitudes.

To understand the wildlife consumption status, we asked the residents experience on wildlife consumption and tested statements about attitude towards consuming wildlife (Table 8).

Table 8. Observations on the consumption of wildlife. For each statement, a score from 1 to 5 indicating strong positive agree, agree, neutral, disagree, and strongly disagree will be requested.

No.	Observation
1	We are allowed to eat the wild animals that are sold in markets.
2	Eating wild animals will be beneficial during the new year's celebrations.
3	Wild animals are natural, which are good for health.
4	It is hard to eat because there are less and fewer wild animals now.
5	Although I don't consume wild animals, I don't mind if others do.
6	I avoid eating wild animals since I'm not sure if they contain parasites.
7	People who reside in cities may request wild animals from their rural relatives.
8	Domesticated boars are not as tasty as wild ones.

Basic information and attitude analysis

To analyze the demographic questions, we employed descriptive statistics. Then, to assess people's attitudes regarding wildlife and its conservation, we used an exploratory factor analysis (EFA), which allowed us to look into possible correlations between responses (An & Sean, 2013). Twelve questions dealing with attitudes were chosen for the EFA.

To see if the dataset could be used for EFA analysis, we first performed a Bartlett's Test of Sphericity and a Kaiser-Meyer-Olkin (KMO) test for sample adequacy (Ferguson & Cox, 1993; Gallegos & Ritter, 2005). KMO, whose values range from 0 to 1, can be used to determine whether the sample size is enough. The dataset is unsuitable for doing the factor analysis if the value is less than 0.6. The KMO test produced a result of 0.72, indicating that our dataset may be analyzed using an EFA (Shrestha, 2021). All variables could be uploaded, and data reduction was chosen using the analytical tool in IBM SPSS Statistics (Version 26). We chose the first solution for statistics in a descriptive environment for the factor analysis, together with KMO and Bartlett's Test of Sphericity for the correlation matrix. We used the varimax method and rotated the display solution in the rotation option. The suppress absolute values parameter in the settings was set to 0.45. The default settings for other options were kept.

We used the Hierarchical clustering approach to establish the number of groups for each component after getting the factors through the EFA and to examine the demographic distribution of the samples among the groupings. The Euclidean distance measure and the single solution number of clusters were set to 3 in an SPSS hierarchical cluster analysis, while all other parameters were left in the default backdrop.

Analysis of factors influencing attitude

We investigated which variables might affect the attitude factor indexes using multiple linear regression (Espinosa & Jacobson, 2012). Each attitude factor index was represented by the sum of the variables for each factor. Age, gender, education, annual income level, primary source of income, personal experience of livestock depredation caused by wildlife, other agricultural loss to wildlife (e.g., loss of arable crop), the number of cattle owned by the family, and whether a family were long-term residents or migrated to the region from another place were all chosen as potential influencing factors of attitudes toward wildlife and wildlife conservation (typically, another region of China). To look into potential relationships between variables and local communities' attitudes toward wildlife, we conducted a multiple linear regression. IBM SPSS Statistics was used for all pertinent analyses (Version 26).

Results

Respondent demographics

The majority of households in our sample (38.76%) in our study area had an annual income of between US$2,000 and US$6,000. According to official figures, the Yanbian had an average GDP per capital of $5,000 in 2019, which is less than half of China's average GDP per capital ($10, 276) (NBS, 2019). The primary sources of income in our research area came from raising corn and beans, grazing cattle, and doing part-time jobs (Table 9).

Table 9. Annual income and economy activities in the survey area. The lower income households (including annual income between $1,000~ $ 2,500 and less than $ 1,000) reported main income were from child or government support in our research samples

Annual income level (Percentage from total. n=139)	**Income level**	**Economy activities**			
		Farming (corn/bean)	Grazing cattle	Fungi harvest	Part-time job
High-income (14.6%)	>$12,000	89.47%	26.31%	-	-
Middle-upper income (18.6%)	$5,000~$12,000	83.3%	41.47%	41.47%	-
Middle-income (38.76%)	$2,000~$6,000	89.8%	22.45%	-	28.58%
Middle-lower income (20.16%)	$1,000~$2,500	-	-	-	-
Low income (7.75%)	<$1,000	-	-	-	-

While households with lower income levels relied more on arable farming, those with higher income levels tended to rely more heavily on fungus farming and cow grazing. In our sample, respondents between the ages of 50 and 60 made up the majority (32.3%) of the respondents. the most widely used education (Table 10).

Table 10. Demography information.

Variable	**Description**	**Count**	**Effective percent (%)**
Gender	Female	59	44.7
	Male	73	55.3
Age	<20	1	8
	20-30	10	7.7
	30-40	12	9.2
	40-50	30	23.1
	50-60	42	32.3
	>60	35	26.9
Education	No education	8	6.2
	Dropped out from elementary school	5	3.9
	Graduate from primary school	30	23.3
	Graduate from middle school	62	48.1
	Graduate from vocational high school	2	1.6
	Graduate from high school	14	10.9
	Graduate from Junior college	5	3.9
	undergraduate	2	1.6
	Postgraduate	1	0.8

The level of education up to middle school was greater in our research region than in the entire province of Jilin and the national average for China, however the levels of education up to high school were lower than the national average for

China or Jilin (Ning, 2021) (Table 11).

When presented with images of the target species one at a time, over 90% of respondents knew and could identify tigers, leopards, and bears, but only half of the respondents could distinguish among different deer species. Five out of the 131 respondents reported the experience of physical injuries caused by wildlife, of which two cases involved wild boar and three cases involved bears. No participant had experienced physical injury from big cats. 10% of the families surveyed had experienced loss of cattle or poultry caused by carnivores.

Table 11. Education status in China and Jilin. The 2020 Chinese government research of education in China (Ning, 2021).

Region	**Primary school education**	**Middle school education**	**High school education**	**Higher level above high school**
China	24.77%	34.51%	15.01%	15.47%
Jilin province	22.32%	38.23%	17.08%	16.74%

Eight cases of livestock predation involved leopard cats (*Prionailurus bengalensis*), a small felid which typically predated poultry; one case involved predation by a bear (*Ursus spp*.); and there were three cases of cattle predation by tigers. Cattle owners received compensation from the government for livestock depredation caused by carnivores whereas other crops damaged by wildlife were not well compensated for in our study samples. 74% of families surveyed reported that they had lost an agriculture product due to wildlife within the last five years. Corn and beans made up a large proportion of the products lost to wildlife. In 24% of cases, losses were estimated to be more than half of the anticipated harvest. Among the 87 households that reported agricultural losses, the species involved were: wild boar (84 cases), Siberian roe deer (*Capreolus* *pygargus*) (5 cases), bears (4 cases), badger (*Meles meles*) (2 cases), and pheasant (*Phasianus colchicus*) (2 cases).

48% of families reported that they had corns destroyed and 40% of them reported that they had losses of both corn and beans caused by wildlife. Losses of other crops like ginseng and pumpkins were also reported.

Wildlife consumption

Wild boar (35.1%), roe deer (61.8%), and pheasant (15.3%) were the top three most-consumed species. 49.6% of the respondents indicated they had no prior experience eating wildlife. It may be awkward to inquire about eating wildlife because the majority of wild animals are recognized as protected species under Chinese law.

We put this to the test by asking, "Do you believe that wild boar is more delectable than domestic boar?" 'Of the respondents, 41.2% did not express attitudes regarding the inquiry, while 56.5% did so with opinions that were either less tasty (37.4%) or more delectable (19.1%) than domestic ones.

Compared to the question about ingesting animals (where 35.1% of respondents indicated they have consumed wild boar), the result of 41.2% indicates that people had no experience eating wild boar. We can see that the result may be underestimated compared to the actual circumstance.

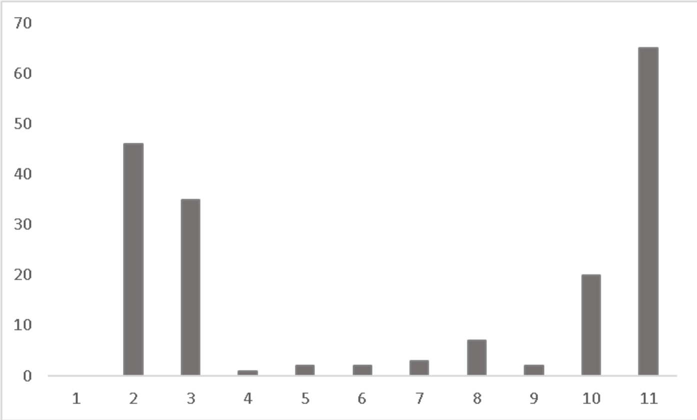


Figure 26. Experience of respondents who had consumed wild animals (n=131). 1 denotes wild tigers or leopards, 2 wild boar, 3 roe deer, 4 sika deer, 5 red deer, 6 flock of geese, 7 unnamed animals, 8 hare, 9 frogs, 10 pheasants, and 11 denotes no prior experience with consuming wild animals.

Eight questions about wildlife consumption were delivered to local people. Neutral perspective with average response towards questions were question 1 'We are allowed to eat the wild animals that are sold in markets' is 3.2 (SD=1.4), and question 8 'Domesticated boars are not as tasty as wild ones.' Which is 3.3 (SD=1.4); People did not agree with ideas about question 2' Eating wild animals will be beneficial during the new year's celebrations.' With the average grade of 3.5(SD=1.2), median value is 4 and question 7 'People who reside in cities may request wild animals from their rural relatives.' With average value of 3.5 (SD=1.2); They relevant agree with ideas about question 3 'Wild animals are natural, which are good for health.' (average=2.5, SD=1.4), question 4 'It is hard to eat because there are less and fewer wild animals now.' (average=2.2, SD=1.3), question 5 'Although I don't consume wild animals, I don't mind if others do.' (average=2, SD=1.2) and question 6 'I avoid eating wild animals since I'm not sure if they contain parasites.’ (average=2.6, SD=1.3).

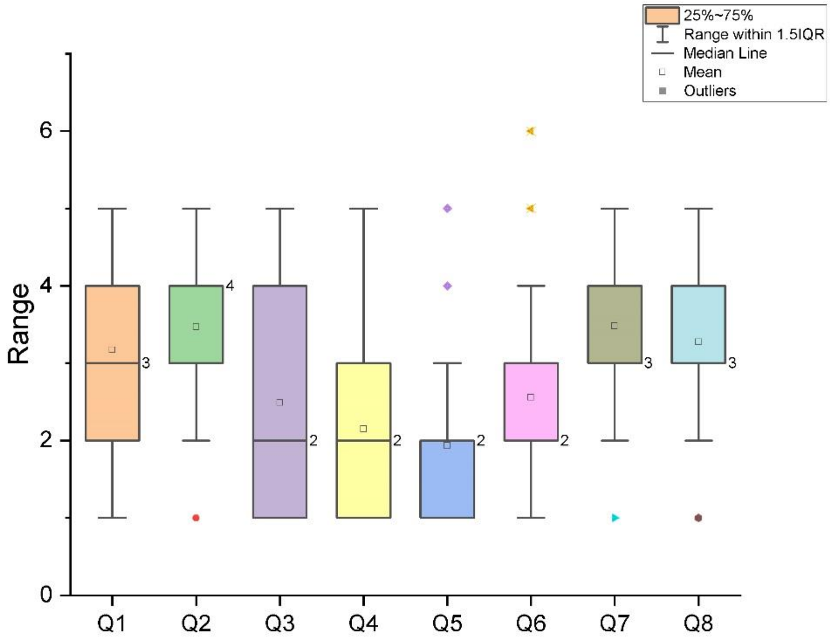


Figure 27. Response towards questions related to wildlife consumption.

Answer range from 1 (strongly agree) to 5 (strongly disagree); Q1 is ‘We are allowed to eat the wild animals that are sold in markets.’; Q2 is ‘Eating wild animals will be beneficial during the new year's celebrations.’; Q3 is ‘Wild animals are natural, which are good for health.’; Q4 is ‘It is hard to eat because there are less and fewer wild animals now.’; Q5 is ‘Although I don't consume wild animals, I don't mind if others do.’; Q6 is ‘I avoid eating wild animals since I'm not sure if they contain parasites.’; Q7 is ‘People who reside in cities may request wild animals from their rural relatives.’; Q8 is ‘Domesticated boars are not as tasty as wild ones.’

Attitudes towards wildlife

12 survey items were used to gauge respondents' attitudes about animals. Table 12 reports information on five factors. All factors together provide 72% of the total. All of the load coefficients are higher than 0.45, indicating strong correlations between all of the elements and the potential for using common factors to successfully explain the variables.

Six target species were mentioned in survey questions 2.7.1–2.7.6 under the heading "preference to one specific species," with a scale of 1–5 for each level, ranging from "strongly dislike" to "like very much." This was done to assess the direct response from interview scores. As a result of our findings, component 1 is defined as attitudes toward large carnivores because the loadings for "preference to tiger," "preference to bear," and "preference to leopard" were, respectively, 0.895, 0.859, and 0.858.

We can sum up the second factor as preference to ungulates because preference to red deer, sika deer and roe deer each had loadings of 0.916, 0.872, and 0.795, respectively. This indicated that these three variables have a strong correlation with factor 2; preference to red deer, sika deer, and roe deer are the order of importance. agreement that since there are not many tigers, hunting should be prohibited. and support for the notion that "fauna, like sika deer or roe deer, do not adversely affect our existence hence we should not hunt them" had loading values in factor 3 of 0.799 and 0.710, which can be interpreted as desires for lessening hunting to support in wildlife conservation.

The statements "The wild boar population is too large; we should lay some snares in the mountain to hunt them," "Do you watch programs linked to wildlife?" and "Preference to wild boar" are evaluated according to three factors, which are loaded at 0.746, 0.519, and 0.467 respectively. The primary attitude toward wild boar, or the statement "the wild boar population is too large, and we should lower the population," gave the greatest coefficient value to component 4, making it the most significant variable in that factor.

With only one variable and a loading value of 0.872, the final component, which measured agreement with the claim that "we have lived here for a long time and have the right to exploit natural resources," could be summed up as the dominating attitude toward resource use. With a combined contribution of 72.34%, the five variables may account for 72.36% of all the attitude difficulties we investigated. Factor 1 has the highest contribution value of 21.357, while factor 5 has the lowest contribution value of 9.165 (Table 12).

The households that were surveyed had generally neutral attitudes toward all of the large carnivores, such as Amur tigers, Amur leopards, and bears (90% of respondents were close to "neutral"), but they had very negative attitudes toward wild boar (96% of respondents were between "dislike" and "strong dislike,"). They exhibited mainly indifferent to modestly favorable sentiments toward deer species, such as roe deer, sika deer, and red deer (between neutral and like)

Table 12. Factor loading values based on Exploratory Factor Analysis (N=139).

Variable	**Factor1**	**Factor 2**	**Factor 3**	**Factor 4**	**Factor 5**	**Contribution**
B2. Attitudes towards tigers	0.895	-	-	-	-	21.357
B8. Attitudes towards bears	0.859	-	-	-	-	-
B3. Attitudes towards leopards	0.858	-	-	-	-	-
B6. Attitudes towards red deer	-	0.916	-	-	-	21.264
B5. Attitudes towards sika deer	-	0.872	-	-	-	-
B7. Attitudes towards roe deer	-	0.795	-	-	-	-
B9. Agreement to the statement 'the tiger population is small, so we should ban hunting'	-	-	0.799	-	-	10.558
B12. Agreement to the statement 'wildlife such as sika deer or roe deer do not negatively influence our life so we should not hunt them'	-	-	0.710	-	-	-
B11. Agreement to the statement 'the wild boar population is too big; we should set some snares in the mountain to hunt some'	-	-	-	0.746	-	9.992
B1. Do you often watch wildlife documentaries?	-	-	-	0.519	-	-
B4. Preference towards wild boar	-	-	-	0.467	-0.552	-
B10. Agreement to the statement 'We have lived here for a long time and have the right to use natural resources'	-	-	-	-	0.872	9.165

Note: Extraction method principal component analysis; Rotation method: Kaiser normalized maximum variance method; Rotation converges after 7 interactions; KMO=0.721, Bartlett's Test of Sphericity=0； Total contribution of the factors is 72%, and all the loading coefficients are higher than 0.45, which means that there is a close correlation among each factor, and the common factors can be used to explain the variables effectively. By reading the loading values, 5 main attitude categories were classified as Factor 1, which could be described as the attitude towards carnivores; Factor 2 could be described as the preference towards herbivores; Factor 3 could be described as attitude towards reducing hunting to benefit wildlife conservation; Factor 4 could be described as the attitude towards wild boars; Factor 5 could be described as the attitude towards nature resourc

Tiger, leopard perceptions

To identify the respondents' attitude categories, cluster analysis was utilized. Among the results, three groups performed the best. Age, gender, and ethnicity were listed as factors to understand the various groupings. There were 13 individuals in group three, 40 people in group two, and 70 participants in group one (Table 13).

On a Likert scale, attitudes were rated from 1 to 5, with 1 being 'strong dislike', 2 'dislike', 3 'no feeling', 4 'like', and 5 'very strong like'. We evaluated people's attitudes toward large animals like tigers, bears, and leopards.

Group 2 had the highest mean value (4.15 for the tiger, 4.1 for the bear, and 3.49 for the leopard), indicating that this group gave these species the most priority. The lowest mean ratings for Group 3 were for the tiger (1.08), bear (1), and leopard (1), demonstrating a profound aversion to large carnivores.

Group 1 had the highest percentage of sample instances and a score between "like" and "no feeling" (2.66 for tiger, 2.7 for bear, 2.53 for leopard). More respondents in groups 1 and 2 liked predators, whereas more respondents in group 3 disliked them.

Table 13. Demography information in different groups of attitudes towards large carnivores. In the variables, age value from 1(18-20), 2(20-30),3(30-40),4(40-50),5(50-60),6(above 60); gender value 1(male), 2(female); ethnicity value 1(Chinese), 2(Korean Chinese), 3(Manchu), 4(Hui), 5(others).

Variables	Description	Group1	Group 2	Group 3	Total
Age	Mean value	4.59	4.66	4.46	4.60
	Case No.	69	41	13	123
	Proportion of total	56.1%	33.3%	10.6%	100.0%
Gender	Mean value	1.66	1.49	1.50	1.59
	Case No.	70	41	12	123
	Proportion of total	56.9%	33.3%	9.8%	100.0%
Ethnicity	Mean value	1.09	1.07	1.62	1.14
	Case No.	69	41	13	123
	Proportion of total	56.1%	33.3%	10.6%	100.0%
Attitudes towards tigers	Mean value	2.66	4.15	1.08	2.98
	Case No.	70	41	13	124
	Proportion of total	56.5%	33.1%	10.5%	100.0%
Attitudes towards bears	Mean value	2.70	4.10	1.00	2.98
	Case No.	70	41	13	124
	Proportion of total	56.5%	33.1%	10.5%	100.0%
Attitudes towards leopards	Mean value	2.53	3.49	1.00	2.69
	Case No.	70	41	13	124
	Proportion of total	56.5%	33.1%	10.5%	100.0%

A cluster analysis was used to group the variables with attitude, gender, ethnicity, and age. It is possible to gather closed persons who have similar attitudes and comprehend their demographic data. The gathered Groups 1 and 2 participants were older than group 3 participants. Group 3 had more women than groups 1 and 2, combined. Groups 1 and 2 had more respondents who were Han Chinese, whereas group 3 had more respondents who belonged to ethnic minority groups. Those who were older and Han-Chinese respondents had a higher propensity to express views that suggested a better tolerance for huge carnivores, according to the clustering analysis's findings.

Perceptions of prey species

Compared to deer species, wild boar encounters with people were more frequently reported. The mean response to the questions about whether people like sika deer, red deer, or roe deer was 3.83, 3.69, and 3.41, respectively (Table 14). This result showed that people had very positive sentiments about each deer species. 5.7% of respondents fell into group 2, which represented the attitudes of all deer species, and got a poor score. For sika deer (3.36) and red deer (3.45), those in groups 1 and 3 received high ratings, but roe deer received relatively low results (1.64).

Table 14. Demography information in different groups of attitudes towards deer species. In the variables, age value from 1(18-20), 2(20-30), 3(30-40), 4(40-50), 5(50-60), 6(above 60); gender value 1(male), 2(female); ethnicity value 1(Chinese), 2(Korean Chinese), 3(Manchu), 4(Hui), 5(others).

Variables	Description	Group1	Group 2	Group 3	Total
Age	Mean value	4.71	4.29	3.91	4.61
	Case No.	104	7	11	122
	Proportion of total	85.2%	5.7%	9.0%	100.0%
Gender	Mean value	1.58	1.43	1.73	1.58
	Case No.	104	7	11	122
	Proportion of total	85.2%	5.7%	9.0%	100.0%
Ethnicity	Mean value	1.09	1.86	1.18	1.14
	Case No.	104	7	11	122
	Proportion of total	85.2%	5.7%	9.0%	100.0%
Attitudes towards sika deer	Mean value	4.00	1.57	3.64	3.83
	Case No.	105	7	11	123
	Proportion of total	85.4%	5.7%	8.9%	100.0%
Attitudes towards red deer	Mean value	3.86	1.57	3.45	3.69
	Case No.	105	7	11	123
	Proportion of total	85.4%	5.7%	8.9%	100.0%
Attitudes towards roe deer	Mean value	3.72	1.57	1.64	3.41
	Case No.	105	7	11	123
	Proportion of total	85.4%	5.7%	8.9%	100.0%

Women were more likely than men to have favorable views about deer, and Han Chinese respondents were more favorable toward deer species than were respondents from other ethnic groups. The groups' attitudes toward deer were unaffected by age. In contrast, the average preference rating for wild boar was 1.75, falling between severely disapproving and disliking (Table 15). Only 4.1% of respondents said they "like" this species. 44.3% of respondents agreed that there should be measures taken to reduce the wild boar population, such as the use of snares. Male respondents and older respondents were more likely to show more tolerant attitudes toward wild boar.

Table 15. Demography information in different groups of attitudes towards wild boars. In the variables, age value from 1(18-20), 2(20-30), 3(30-40), 4(40-50), 5(50-60), 6(above 60); gender value 1(male), 2(female); ethnicity value 1(Chinese), 2(Korean Chinese), 3(Manchu), 4(Hui), 5(others).

Variables	Description	Group1	Group 2	Group 3	Total
Age	Mean value	4.47	4.80	4.71	4.61
	Case No.	53	5	63	121
	Proportion of total	43.8%	4.1%	52.1%	100.0%
Gender	Mean value	1.69	1.80	1.48	1.59
	Case No.	54	5	62	121
	Proportion of total	44.6%	4.1%	51.2%	100.0%
Ethnicity	Mean value	1.15	1	1.14	1.14
	Case No.	53	5	63	121
	Proportion of total	43.8%	4.1%	52.1%	100.0%
Do you often see the programs related to wildlife	Mean value	0.5	0.4	0.51	0.50
	Case No.	54	5	63	122
	Proportion of total	44.3%	4.1%	51.6%	100.0%
Attitudes towards wild boar	Mean value	1.85	4	1.48	1.75
	Case No.	54	5	63	122
	Proportion of total	44.3%	4.1%	51.6%	100.0%
There is consensus that the wild boar population is too large, and that some hunting should be done in the mountains.	Mean value	4.07	1.60	1.43	2.61
	Case No.	54	5	63	122
	Proportion of total	44.3%	4.1%	51.6%	100.0%

Factors influencing attitudes

In the linear multiple regression models, we tested the effects of nine response variables on the five attitude components. We discovered a negative correlation between yearly income level and positive sentiments ('like', 'like very much') toward large carnivores (coefficient=-0.217; p0.05) (Table 16).

Table 16. Factors influencing how people feel about large carnivores

Variables	***Std Beta coefficient***	***Sig.***
Age(A1)	0.185	0.069
Gender(A2) *	-	-
Education level(A5)	0.180	0.064
Annual income level(A8)	**-0.217**	**0.030**
Main source of income (A10)	-	-
Whether any livestock have been lost to wildlife (A14) **	-	-
Whether any crops have been lost to wildlife (A15) **	-	-
Number of cattle owned (A16)	-	-
Whether migrated to the region from another place (A17) ***	**0.192**	**0.035**
F-statistic	3.598	
Sig.	0.008	
Adjusted R^2	0.079	
Std. Error of the Estimate	2.846	

In general, participants who had moved to Yanbian from outside the research area showed less tolerance for large carnivores (coefficient=0.192; p0.05) and various deer species (coefficient=0.220; p0.05).

Families with more income sources were more likely to express negative attitudes towards conservation (coefficient=-0.223; p<0.05) (Table 17).

Table 17. Factors influencing how people feel about conservation

Variables	*Std. Beta coefficient*	*Sig.*
Age(A1)	0.064	0.507
Gender(A2) *		
Education level(A5)	0.097	0.317
Annual income level(A8)		
Main source of income (A10)	**-0.223**	**0.014**
Whether any livestock have been lost to wildlife (A14) **	-0.126	0.163
Whether any crops have been lost to wildlife (A15) **	-	-
Number of cattle owned (A16)	-	-
Whether migrated to the region from another place (A17) ***	-	-
F-statistic	2.595	
Sig.	0.040	
Adjusted R^2	0.050	
Std. Error of the Estimate	1.165	

Additionally, those participants who had suffered crop losses displayed a lower liking for wild boars and a higher level of willingness for the management of the wild boar population (coefficient=-0.299; p0.01) (Table 18).

Respondents with higher incomes (coefficient=0.231; p0.05) and those who had witnessed wildlife preying on cattle (coefficient=0.181; p0.05) were more likely to have more ardent opinions in support of unrestricted use of nature resources (Table 19). Variables associated with attitudes towards conservation

Table 18. Variables associated with attitudes towards wild boar

Variables	*Std. Beta coefficient*	*Sig.*
Age(A1)		
Gender(A2) *		
Education level(A5)	-0.127	0.184
Annual income level(A8)	0.108	0.273
Main source of income (A10)	-0.129	0.164
Whether any livestock have been lost to wildlife (A14) **	0.053	0.552
Whether any crops have been lost to wildlife (A15) **	**-0.299**	**0.002**
Number of cattle owned (A16)	-	-
Whether migrated to the region from another place (A17) ***	0.046	0.618
F-statistic	2.374	
Sig.	0.034	
Adjusted R^2	0.064	
Std. Error of the Estimate	1.929	

In our study, communities with higher income levels were more likely to have unfavorable attitudes toward carnivores, because grazing livestock was one of their main sources of revenue. Families who had livestock damage reported being more ready to use natural resources freely, which might lead to grazing in protected areas.

Table 19. Variables associated with attitudes towards free use of nature resources

Variables	*Std. Beta coefficient*	*Sig.*
Age(A1)	-0.114	0.246
Gender(A2) *	0.066	0.459
Education level(A5)		
Annual income level(A8)	**0.231**	**0.022**
Main source of income (A10)	-0.049	0.586
Whether any livestock have been lost to wildlife (A14) **	**0.181**	**0.044**
Whether any crops have been lost to wildlife (A15) **	-	-
Number of cattle owned (A16)	-	-
Whether migrated to the region from another place (A17) ***	-	-
F-statistic	3.051	
Sig.	0.013	
Adjusted R^2	0.079	
Std. Error of the Estimate	1.064	

Given that wild boars are one of the most important prey animals for Amur tigers, the significantly negative attitude towards them is concerning for tiger conservation. This could have long-term negative effects on tiger conservation. We believe that the region's extensive agricultural damage by wild boars, which has led to a strong negative attitude against them, is to blame. In light of this, minimizing crop damage caused by wild boars may help locals' attitudes toward wildlife in general and wild boars in particular.

Table 20. Variables associated with attitudes towards deer species

Variables	***Std. Beta coefficient***	***Sig.***
Age(A1)	0.123	0.230
Gender(A2) *	0.107	0.239
Education level(A5)	-0.066	0.508
Annual income level(A8)	-0.127	0.208
Main source of income (A10)	-	-
Whether any livestock have been lost to wildlife (A14) **	-	-
Whether any crops have been lost to wildlife (A15) **	-	-
Number of cattle owned (A16)	-	-
Whether migrated to the region from another place (A17) ***	**0.2203**	**0.029**
F-statistic	2.326	
Sig.	0.047	
Adjusted R^2	0.052	
Std. Error of the Estimate	2.598	

Younger respondents and ethnic minority groups showed higher percentage of negative opinions. Compared to long-term inhabitants, respondents who had just moved from other parts of China displayed less tolerance for the target fauna. Higher-income families indicated a larger readiness to use natural resources unrestrictedly and had more negative opinions about large carnivores.

Families with a history of cattle depredation had a greater inclination to use natural resources unrestrictedly, while those whose crops had been harmed by animals were more prone to harbor negative views about wild boar. Surprisingly, a family's likelihood of supporting wildlife conservation decreased with the number of sources of income they possessed. Families with more sources of income were more likely to rely on various natural resources, which could be the reason of this.

Discussion

Due of their potential threat to human life and property, large carnivores are sometimes viewed adversely by the people with which they coexist (Frank et al., 2015; Johansson et al., 2016). This may be encouraged by the finding in our results that no cases of human casualties were reported, whereas livestock loss to large carnivores appears to currently be relatively uncommon and where the loss of livestock to tigers does occur, farmers receive compensation from the government-led compensation program. However, even if the likelihood is currently quite remote, as the tiger population in the area grows in the future, there could be increased risks to human life or property, as shown in some instances in India (Singh et al., 2015).

For long-term conservation strategies for large carnivores to be effective, in addition to programs aimed at efficient carnivore-human conflict prevention and mitigation programs, detailed plans to improve the local community's attitudes towards large carnivores need to be formulated and included in the strategies. As demonstrated by the jaguar (*Panthera onca*) conservation in the Brazilian Amazon, creating and executing school-based conservation education programs aimed at children and students may be a useful tactic to change their parents' attitudes toward large carnivores (Marchini & Macdonald, 2020). In order to prevent disputes, it's crucial to control and restrict human activity close to the national park (Dhanwatey et al., 2013).

The findings that the local community has a generally neutral attitude toward large carnivores and negative attitudes toward wild boars may be used in large carnivore conservation education programs. For instance, conservation education programs may include the fact that conserving large carnivores may reduce crop damage by reducing wild boar population density (Thinley et al., 2018). The negative perception of wild boars in the neighborhood may gradually change if wild boar crop damage is reduced.

Support from locals is crucial for the long-term preservation of wildlife (Bennett & Dearden, 2014). When a new protected area is created, conservation measures like hunting restrictions, access restrictions, or other restrictions on resource use are frequently implemented. This could lead to the local community developing negative attitudes toward the regulations as well as the species that are primarily targeted for protection (Infield & Namara, 2009).

The success of local conservation projects will undoubtedly depend on targeted conservation messages. Our findings showed that ethnic minorities had fewer favorable opinions toward large carnivore species, while wealthy families and those who had relocated from other parts of China were more likely to have these attitudes. We initially believed that their unique culture might have some positive influence on their attitude toward wildlife because of their unique lifestyle, but an opposite result was found, which may be due to their similar lifestyle with other ethnic groups in this region for a significant amount of time existing old culture or stories, particularly those related to tigers (Lim, 2017).

In order to determine how conservation projects may best target local citizens, we gathered information about participants' leisure activities during interviews. The most common response was "watching TV," with the most popular channels being Jilin province channels and channels 1, 2, and 4 of CCTV (Chinese Central Television). These, in our opinion, would be good venues for environmental education programming that supports the goals of wildlife conservation. High-income households and migrants from other parts of China might require a customized engagement strategy, such as the introduction of an economic plan for wildlife-friendly items as a substitute source of income (Roe et al., 2015).

Despite the fact that our findings and those of other studies suggest that livestock theft may lead to a change in people's attitudes toward large carnivores (Karanth et al., 2017; Miller et al., 2016; Mishra, 2002; Wang & Macdonald, 2006), it's possible that the current compensation measures are insufficient to reduce human-wildlife conflict. Communities in tiger habitat continue to graze cattle the traditional way, which entails permitting cattle to graze freely in the mountains throughout the summer and giving them salt only infrequently. Since cattle were fed inside throughout the winter and early spring while grazing in the woodlands from May to October, there was a larger risk of carnivore predation of livestock in the summer. Prior to the creation of the Jilin Hunchun Amur tiger nature reserve, traditional cattle grazing methods already existed. A crucial conservation strategy that has been applied in a variety of situations around the world is financial compensation for losses brought on by human-wildlife conflict (Nyhus, 2016; Ravenelle & Nyhus, 2017). In accordance with the policy known as the "important protected terrestrial wildlife property damage compensation regulation," the province of Jilin began making up damages brought on by wildlife in 2006 (Jilin, 2005). Until 2021, nine provinces, including Jilin, developed uniform compensation procedures based on China's laws protecting animals. The policies' primary goal was to compensate animal losses rather than to lessen friction between humans and wildlife (Pettigrew et al., 2012). Livestock must occasionally be kept in a predator-proof enclosure, as is the situation in southern Kenya (Maclennan et al., 2009), and in Greece, if the same incident occurred repeatedly, appropriate preventive measures would need to be taken (Fourli, 1999).

Following the adoption of the compensation program, the financial damage to livestock owners from cattle depredation by large animals was minimal. Regions with high biodiversity are frequently found in underdeveloped economic areas (Adams et al., 2004; Fisher & Christopher, 2007). These circumstances can result in negative views toward animals and their conservation as a result of economic losses brought on by wildlife (Dickman, Macdonald, & Macdonald, 2011; Pettigrew et al., 2012).

In Jilin, such compensation totaled $1.29 million (USD) by 2009; 8.96% of those cases featured tigers, while others involved bears or migratory birds (Pettigrew et al., 2012). While the first tiger-focused nature reserve in China (Jilin Hunchun Northeast Tiger Nature Reserve), which was founded in 2001, prohibits livestock from grazing within the protected area and continues to provide compensation even if livestock is predated inside the nature reserve's boundaries, 180 cattle and 3 horses were predated by tigers in 2017, according to Hunchun Forestry Department statistics, and only 5 owners did not receive compensation since the tiger depredation proof was ambiguous. The large proportion of received compensation can unintentionally promote livestock grazing in areas designated as tiger habitat protection. Due to the transmission of illnesses or nutritional competition with other herbivores, grazing in the forest may also have a serious threats to other wildlife species (Clifford et al., 2009; Gortázar, Ferroglio, Höfle, Frölich, & Vicente, 2007; Schieltz & Rubenstein, 2016). Cooperation with livestock owners will be crucial when deciding how to lessen the practice of grazing animals in forest areas. Given that there are increased risks involved with cattle grazing in protected forest areas and that this may be an instance where compensation has unanticipated negative repercussions (Erwin & Daniel, 2005). To urge local residents to refrain from grazing in key tiger and other large carnivore habitat, we advise gradually eliminating the payout of compensation when depredation occurs inside protected areas.

Our findings revealed that 95% of respondents had unfavorable opinions towards wild boar. Corn was the primary agricultural product lost, and it was also found in Spain (Herrero et al., 2006). Because wild boars are an essential prey species for Amur tigers and because they contribute significantly to the biomass of the environment, wild boar conservation in our study region is crucial for tiger conservation (Kerley et al., 2015). Amici et al. (2011) noted the likelihood of a high density of wild boar damage in areas close to forests and rivers (Amici et al., 2011), like in our study area, as examples of agricultural landscape elements that have been connected to wild boar damage (Jin et al., 2021).

Our survey also revealed that fewer than half of the families polled were using methods to stop wild boars from damaging farmland (47 in 140). The most common method was using firecrackers or other loud objects to frighten away wild boar (20 instances in 47 responses), and half of the respondents believed that this method worked. The neighborhood's other actions included constructing plastic barriers and starting fires. We point out that it would be incredibly unlikely to completely eradicate crop raiding caused by wild boar, but it would be possible to lessen the damage caused by wild boar using conflict resolution techniques like building electric fences (Honda et al., 2011; Vidrih & Trdan, 2008), though doing so would increase local electricity consumption, or traditional management techniques that have been demonstrated to be effective in practice in India, like smearing domestic animals with poison (Rao et al., 2015), and burning dried pig dung, which decreased crop damage in earlier trials by 35% to 50% (Rao et al., 2015). In places with high wild boar populations, other interventions, including offering alternative agriculture planting plans, could be helpful (Herrero et al., 2006).

The effectiveness of using conservation initiatives that could benefit communities as a way to increase public support for wildlife protection has been explored (Roe et al., 2015). The program includes members of the local community (including those who have suffered crop losses due to herbivores like wild boar or other herbivores, or other losses from carnivores), conservation organizations, researchers, and local authorities, all of whom will unavoidably aid in reducing conflicts and fostering a positive attitude toward wildlife. Roe deer are probably also very significant, aside from wild boar. Local communities expressed less preference for roe deer compared to other deer species in the clustering result of attitudes towards deer species. Crops in agricultural lands were confirmed to be one of the most significant food sources for European roe deer (*Capreolus capreolus*), and more recently, Asian (Siberian) roe deer (*Capreolus pygargus*), as well (Choi et al., 2020). When compared to other deer species, roe deer utilize small forests and agricultural regions more frequently (Putman, 1986). As with wild boar, crop damage may have an impact on how the community feels about roe deer. Farmers may seek direct or indirect retribution against ungulate species as a result of conflicts between tiger prey species and human groups, which could have a long-term harmful impact on tiger conservation (Ramakrishnan et al., 1999).

Although this study sheds crucial information on how locals feel about threatened large carnivores and the species that provide as their prey in an understudied region, it has some significant flaws. Although Yanbian is a region of national significance for the conservation of tigers in China, different parts of the territory had variable densities of tigers and other large animals. We used random sampling, but we were unable to gather enough data to conclusively assess the opinions of the communities living in the region's areas with relatively greater and lower tiger numbers. Incorporating village differences and using a random effect model would provide additional observations to the linear regression analysis, however due to insufficient sampling in various locations, only fixed effects were employed to select one group as the explanation. Another drawback is that although our findings suggested that migrant families might be less tolerant of the target wildlife, we did not collect information on the length of time that families had lived in the area or where in China they had migrated from, which might have shed lighter on our findings (for example, whether their perceptions changed over time). The implementation of policies, particularly those that pertain to conservation efforts, may also have an impact on community sentiments.

Conclusion

Our study demonstrates that while local communities in Yanbian Korean Autonomous Prefecture, northeast China, a region of national significance for the conservation of the tiger, generally hold relatively neutral attitudes toward large carnivores, they demonstrated strongly negative attitudes toward wild boar, probably as a result of crop raiding. To ensure that widespread societal support for large carnivore conservation and the conditions necessary for its success (like a sustainable ungulate population), it may be necessary to develop more targeted and nuanced conservation education programs, tailored for high income families, residents who are recent migrants from other regions of China, and ethnic minority groups. When it comes to successfully promoting favorable views toward big cats and big cat conservation in rural communities, especially where there are high levels of poverty and subsistence farming, monetary support in the form of compensation is unquestionably a useful instrument. It would be advantageous to have a detailed compensation plan where no compensation is provided for the loss of livestock within the core protected areas in order to reduce livestock grazing in protected areas that are intended to serve as tiger habitat and to lower the potential risk of human-tiger conflict. However, we suggest that the current compensation system can be improved. Additionally, different groups could require various forms of help. Financial compensation may be warranted, as well as the testing and deployment of methods to decrease crop-raiding by wildlife, when the livelihoods of households have been directly harmed by wildlife, such as the loss of agricultural products to ungulates, an important species of tiger prey.

Appendix

Appendix 1. Water deer occurrence information used for the MaxEnt modelling

Date	Date type	Description	Area	Longitude	Latitude	Source
2019-5-23 0:00	Roadkill	Carcass	China-hunchun	130.26985	42.879933	China-monitoring
2019-7-9 0:00	Roadkill	Carcass	China-hunchun	130.44103	42.556456	China-monitoring
2020-1-3 0:00	Monitoring	Footprint,Urine	China-hunchun	130.04065	43.513537	China-monitoring
2020-1-8 0:00	Monitoring	Footprint,Urine	China-hunchun	130.57775	42.659826	China-monitoring
2020-1-8 0:00	Monitoring	Footprint,Urine	China-hunchun	130.58338	42.654924	China-monitoring
2020-1-8 0:00	Monitoring	Footprint,Urine	China-hunchun	130.58737	42.652447	China-monitoring
2020-1-11 0:00	Monitoring	Footprint,Urine	China-hunchun	130.58896	42.640048	China-monitoring
2020-2-15	Confiscated from poaching			13065602	42.41273	Khasansky district of Primorskiy,Russia

Appendix 1. (Continued)

Date	Date type	Description	Area	Longitude	Latitude	Source
2020-1-11 0:00	Monitoring	Footprint,Urine	China-hunchun	130.60797	42.617634	China-monitoring
2020-1-11 0:00	Monitoring	Footprint,Urine	China-hunchun	130.61627	42.607738	China-monitoring
2020-1-11 0:00	Monitoring	Body observation	China-hunchun	130.58937	42.631676	China-monitoring
2020-1-11 0:00	Monitoring	Footprint,Urine	China-hunchun	130.58704	42.632282	China-monitoring
2020-1-12 0:00	Monitoring	Footprint,Urine	China-hunchun	130.45703	42.603261	China-monitoring
2020-1-12 0:00	Monitoring	Footprint,Urine	China-hunchun	130.456	42.584387	China-monitoring
2020-1-12 0:00	Monitoring	Footprint,Urine	China-hunchun	130.42735	42.571211	China-monitoring
2020-1-12 0:00	Monitoring	Footprint,Urine	China-hunchun	130.43967	42.602919	China-monitoring
2020-1-16 0:00	Monitoring	Body observation	China-hunchun	129.93552	43.015839	China-monitoring
2020	Camera trapping	Photo	Mijiang (MJ)	130.14075	42.93641	China-monitoring
2020	Camera trapping	Photo	MJ	130.28911	42.97291	China-monitoring
2020	Camera trapping	Photo	MJ	130.20691	43.02796	China-monitoring
2020	Camera trapping	Photo	MJ	130.18655	42.97186	China-monitoring
2020-1-19 0:00	Monitoring	Body observation	China-hunchun	130.31632	42.94753	China-monitoring
2020-2-11 0:00	Monitoring	Body observation	China-hunchun	130.45464	42.593276	China-monitoring

Appendix 1. (Continued)

Date	Date type	Description	Area	Longitude	Latitude	Source
2020-04-02; 04:06	Camera trapping	Photo	Longshan-2	130.58334	42.65495	China-monitoring
2020-01-14; 14:24	Camera trapping	Photo	Longshan-5	130.60791	42.61762	China-monitoring
2020-01-30; 16:15	Camera trapping	Photo	Longshan-7	130.58699	42.63227	China-monitoring
2020-02-10; 11:36	Camera trapping	Photo	Longshan-7	130.58699	42.63227	China-monitoring
2020-02-13; 07:18	Camera trapping	Photo	Longshan-7	130.58699	42.63227	China-monitoring
2020-03-09; 10:38	Camera trapping	Photo	Longshan-7	130.58699	42.63227	China-monitoring
2020-03-16; 23:53	Camera trapping	Photo	Longshan-7	130.58699	42.63227	China-monitoring
2020-02-13; 11:51	Camera trapping	Photo	Tumenriver-1	130.45703	42.60326	China-monitoring
2020-03-17; 07:32	Camera trapping	Photo	Tumenriver-5	130.43974	42.60297	China-monitoring
2020	Camera trapping		MJ	130.18221	42.98083	
2020	Camera trapping		MJ	130.1245	42.91389	
2020	Camera trapping		MJ	130.12885	42.9267	
2017	Reference		China (Baishan)	126.47111	41.797222	Baishan (Li, 2019)
2018	Reference		China (Baishan)	126.48833	41.786944	Baishan (Li, 2019)
2018	Reference		China (Baishan)	126.46889	41.798611	Baishan (Li, 2019)
2018	Reference		China (Baishan)	126.57361	41.621389	Baishan (Li, 2019)
2018	Reference		China (Baishan)	126.57917	41.623611	Baishan (Li, 2019)
2018	Reference		China (Baishan)	126.48222	41.791667	Baishan (Li, 2019)

Appendix 1. (Continued)

Date	Date type	Area	Longitude	Latitude	Source
	Monitoring	Russia	130.63582	42.43372	Russia monitoring
	Monitoring	Russia	130.63203	42.63052	Russia monitoring
	Monitoring	Russia	130.58044	42.70203	Russia monitoring
	Monitoring	Russia	130.69897	42.34077	Russia monitoring
	Monitoring	Russia	130.7149	42.34165	Russia monitoring
	Monitoring	Russia	130.65116	42.64627	Russia monitoring
	Monitoring	Russia	130.70111	42.58667	Russia monitoring
	Monitoring	Russia	130.60562	42.67994	Russia monitoring
	Monitoring	Russia	130.60838	42.64196	Russia monitoring
	Monitoring	Russia	130.77656	42.72316	Russia monitoring
	Monitoring	Russia	130.70002	42.69388	Russia monitoring
	Monitoring	Russia	130.56824	42.72826	Russia monitoring
	Monitoring	Russia	130.66573	42.31804	Russia monitoring
	Monitoring	Russia	130.66373	42.32211	Russia monitoring
	Monitoring	Russia	130.66235	42.40067	Russia monitoring
	Monitoring	Russia	130.68763	42.55082	Russia monitoring
	Monitoring	Russia	130.7017	42.56922	Russia monitoring
	Monitoring	Russia	130.69975	42.57195	Russia monitoring
	Monitoring	Russia	130.73781	42.3481	Russia monitoring
	Monitoring	Russia	130.67722	42.4525	Russia monitoring
	Monitoring	Russia	131.03647	42.71889	Russia monitoring

Appendix 1. (Continued)

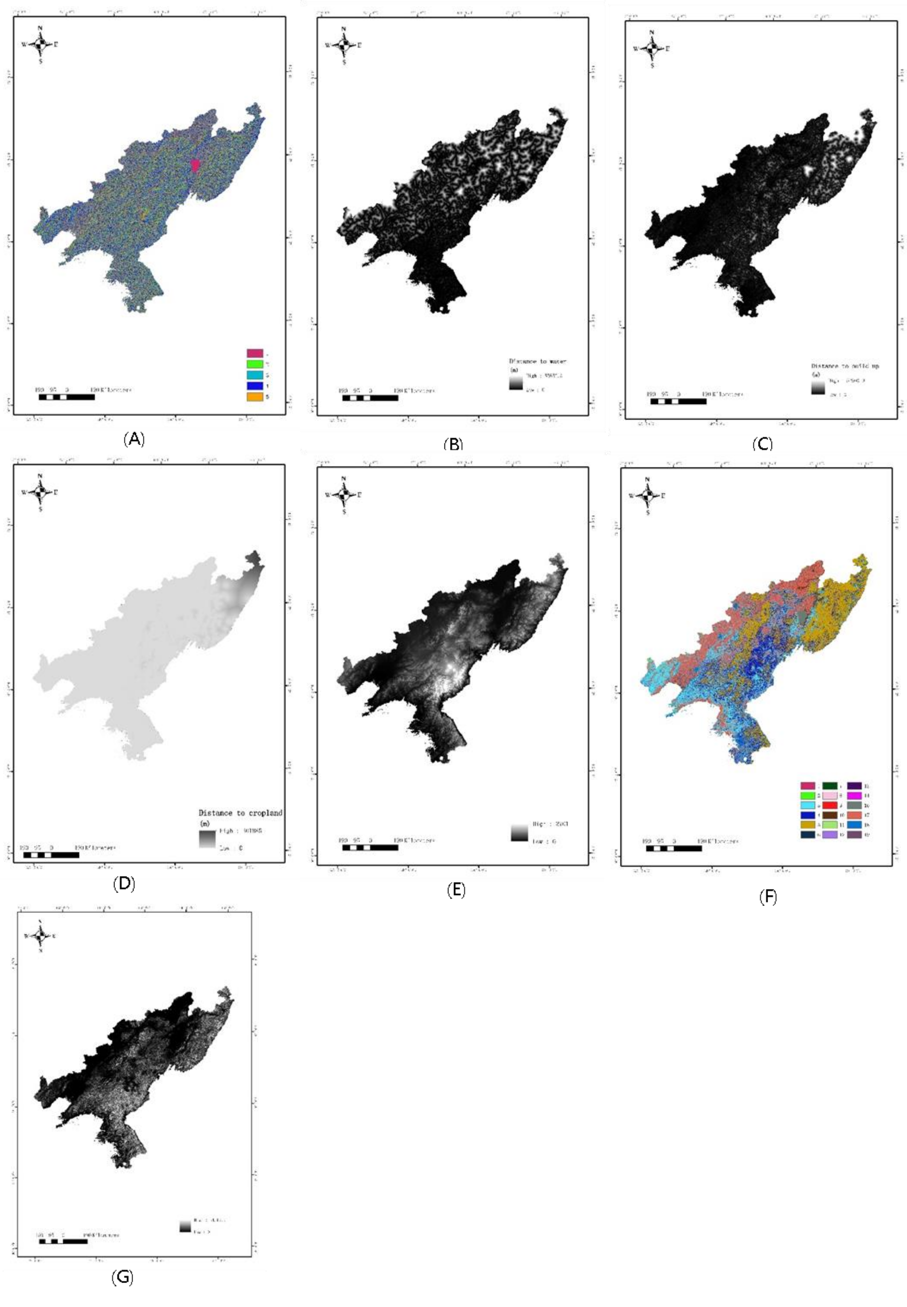
Date	Date type	Area	Longitude	Latitude	Source
	Monitoring	Russia	130.60253	42.51696	Russia monitoring
	Monitoring	Russia	130.60498	42.51165	Russia monitoring
	Monitoring	Russia	130.61074	42.50276	Russia monitoring
	Monitoring	Russia	130.61138	42.49987	Russia monitoring
	Monitoring	Russia	130.7153	42.57071	Russia monitoring
	Monitoring	Russia	130.79283	42.54652	Russia monitoring
	Camera trapping	Russia-Plot1	130.60562	42.67994	Russia monitoring
	Camera trapping	Russia-Plot1	130.60838	42.64196	Russia monitoring
	Camera trapping	Russia- Sample plot 2	130.60115	42.51112	Water deer on photo—traps in Land of Leopard nation park
	Camera trapping	Russia Sample plot 2	130.59747	42.50564	Water deer on photo—traps in Land of Leopard nation park
	Monitoring	Russia- Leopard net	130.60626	42.63669	Water deer on photo—traps in Land of Leopard nation park
2019	Monitoring	Russia- Leopard net	130.93498	42.826	Water deer on photo—traps in Land of Leopard nation park
2019-12-11	Hunted as roe deer		130.47771	42.33729	Khasansky district of Primorskiy, Russia
2019-12-25	Hunted as roe deer		130.43504	42.34924	Khasansky district of Primorskiy, Russia

Appendix 1. (Continued)

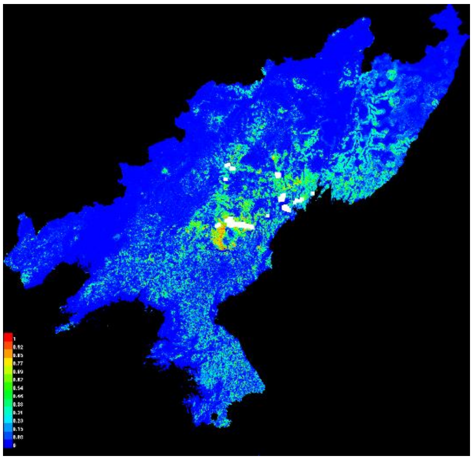
Date	Date type	Area	Longitude	Latitude	Source
	Monitoring	Russia	130.71092	42.38357	Russia monitoring
	Monitoring	Russia	130.62113	42.49879	Russia monitoring
	Monitoring	Russia	130.7048	42.34822	Russia monitoring
	Monitoring	Russia	130.83307	42.80312	Russia monitoring
	Monitoring	Russia	131.30331	42.84975	Russia monitoring
	Monitoring	Russia	130.61216	42.68181	Russia monitoring
	Monitoring	Russia	130.65521	42.4318	Russia monitoring
	Monitoring	Russia	130.75025	42.71531	Russia monitoring
	Monitoring	Russia	130.71656	42.3491	Russia monitoring
2019	Reference		130.2532	42.908	Russia (paper)
2019	Reference		130.4833	42.651	Russia(paper)
2019	Reference		131.8284	44.113497	

Appendix 2. Environmental variables mapping.

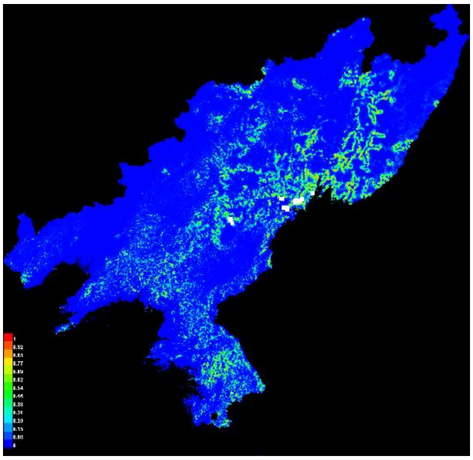
(A): Aspect; (B): Distance to water;(C) Distance to build up; (D) Distance to crop; (E) Elevation; (F) Landcover; (G) Slope



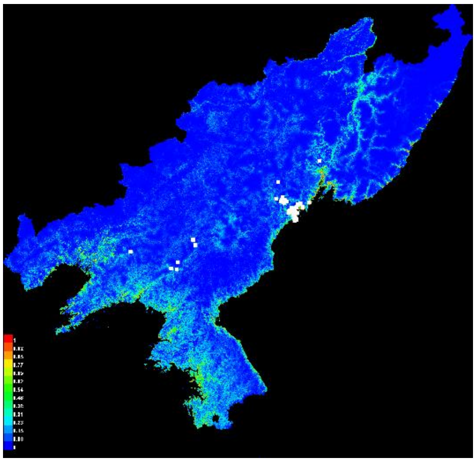
Appendix 3. Maxent result. The potential habitat predicted by model for each prey species.



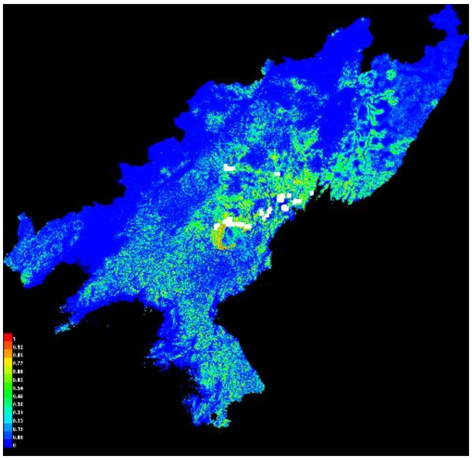
Roe deer



Sika deer



Water deer



Wild boar

Appendix 4. Note for circuitscape analysis result

Solving focal pair 1 of 3
Graph has 3013066 nodes, 2 focal nodes and 205 components.
Solved focal pair 1 of 3
Solving focal pair 2 of 3
Graph has 2978212 nodes, 2 focal nodes and 204 components.
Solved focal pair 2 of 3
Solving focal pair 3 of 3
Graph has 3050213 nodes, 2 focal nodes and 213 components.
Solved focal pair 3 of 3

Pairwise resistances (-1 indicates disconnected node pair):		
Node1	Node2	Resistance
1	2	0.834145721658
1	3	1.57605833435
2	3	0.69795672224

Appendix 5. Questionnaire sheet

Researcher:________________

Contact (telephone/WeChat/QQ):____

Research date:____________________________

Region:1. Yanji 2. Tumen 3. Dunhua 4. Hunchun 5. Longjing 6. Helong 7. Wangqing 8. Antu 9. Shulan 10. Wuchang 11. Ningan 12. Dongning 13 Other Religions:

1.Basic Information

Region name

(e.g.:Name of village committee; Name of forestry farm)

1.1. Age

1.2. 1. 18-20 2. 20-30 3. 30-40 4. 40-50 5. 50-60 6. >60

1.2. Gender

1. Male 2. Female

1.3. Household population:____

1.4. Ethnic group

1. Chinese 2. Korean Chinese 3. Manchu 4. Hui 5. Other

1.5. Religious belief

1. Christion 2. Buddhism 3. Shamanism 4. Other: 5. None

1.6. Education level

1. None 2. Under primary school 3. Primary school 4. Middle school 5. Technical secondary school 6. High school 7. College 8. University 9 Graduate school

1.7. Where were you born?

1. Another place. Why move here?

2. Local

1.8. Are there more or fewer local residents than before?

1. More. What is the reason do you think?______________________
2. Fewer. What is the reason do you think?_______________________
3. No change

1.9. Will your children live here in the future?

1. Yes 2. No 3. Not sure 4. No children

1.10Education of your children?

1. None 2. Under primary school 3. Primary school 4. Middle school
5. Vocational High School 6. High school 7. College 8. University
9. Graduate school

1.11. Your vies on rural children receiving higher education?

1. Strongly support. It is very important, and I will try everything to support children for school.
2. Support and will afford their education within the ability
3. Neither support nor oppose
4. Against. Going to college may not lead to a good job. It's useless.
5. Strongly against. I will not allow children go to school and will persuade others to do so.

1.12. What do you think is the main development industry in your area?

1. Agriculture 2. Forest 3. Tourism 4. Industry (like factory) 5. Estate 6. Other

1.13. What's your family's annually income?

1. Less than 5000
2. 5000~15.000
3. 15.000~30.000
4. 35.000~80.000
5. 80.000~10.000
6. More than 10.000

1.14. Are you satisfied with your life?

1. Very satisfied 2. Normal 3. No

If no, what is the reason?

1. Low Income
2. Medication
3. Transportation
4. Human relationship
5. Hygiene issue
6. Education
7. Other_______________

※※**<u>1.15. What are your family's main activities?</u>**

Category	content	(if yes√, and write the scale)	Annually profits(unit:10.000)	Category	content	(if yes√, and write the scale)	Annually profits(unit:10.000)
1.Farming(☐ close to forest;☐ inside forest; ☐ far away from forest)	Bean	☐( )		7. Grazing	Cattle	☐( )	
	Corn	☐( )			Sheep	☐( )	
					Dog	☐( )	
2.Rice	Rice	☐( )		8.Forestry economy products	NTFP	☐	
3.Economic products	Ginseng	☐( )			Firewood	☐	
	Medicine	☐( )			Frog	☐	
4.Shop		☐		9.Parttime job		☐	
5.Forest occupation compensation		☐( )		10 Fungus farming		☐( )	
6.Land occupation compensation		☐( )		11. Workers			
Other2)				Other3)			

1.16. What do you think is the main source of income for the family:

1. Farming
2. Grazing
3. Payment jobs
4. Shop
5. Forestry economy
6. Other______________________

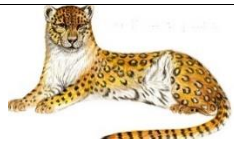
1.17. What is your entertainment when you are free:

1. TV
2. Travel
3. Internet entertainment
4. Exercise
5. Reading
6. Movie

Other_________

____

2. Attitudes towards wildlife and conservation

2.1.1	
2.1.2	
2.1.3	
2.1.4	
2.1.5	
2.1.6	

2.2. What kind of wild animals are there in the local area(you have seen and heard of them, multiply choices/)

1. Tiger 2. Leopard 3. Lynx 4. Sika deer 5. Wild boar 6. Roe deer 7.Bear 8. Red deer 9. Fox 10. Badger 11. Wolf 12. Other 13. Not clear

2.3. Do you usually watch TV programs like *Animal Wor*ld and *Exploring Nature*?

1. Not really 2. Once or twice a year 3. Over 3 times a year

2.4. When did you first hear "wildlife conservation"?

1. 20 years before 2. 10 years before 3. Less than 10 years 4. Less than 5 years 5. Didn't heard about it

2.5. Where do you get those information normally?

1. Government 2. TV 3. Video 4. Community 5. Book and magazine 6. Known people 7. University students 8. Internet

2.6. Is there any change after the wildlife conservation?

1. No

2. Yes in what ways? ____

3. Have loss

2.7. Please select your preference or hate level to the wildlife

	Strongly negative	Negative	Neutral	Positive	Strongly positive
Tiger	1	2	3	4	5
Leopard	1	2	3	4	5
Wild boar	1	2	3	4	5
Sika deer	1	2	3	4	5
Red deer	1	2	3	4	5
Roe deer	1	2	3	4	5
Bear	1	2	3	4	5

2.8. Please circle the number that best fits your attitude

1. Strongly disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly agree

2.8.1. There are not too many tigers, so we need to protect them.........1 2 3 4 5

2.8.2. 'We live here for long time, so we cannot use resources freedom' such statement is wrong …....... ...1 2 3 4 5

2.8.3. 'There are too many wild boars kill some will be fine' such statement is wrong. 1 2 3 4 5

2.8.4. Animals like deer are not harming us so we agree the idea to conserve them ……...1 2 3 4 5

2.8.5. If outsiders come to our place to hunt, we are not agreeing….... ...1 2 3 4 5

2.8.6. Leopard conservation is good for us……….......... ...1 2 3 4 5

2.8.7. Tigers will not harm livestock........ ...1 2 3 4 5

2.8.8. Tigers do not eat human beings………....... ...1 2 3 4 5

2.8.9. If we encounter wildlife related problems, we can easily contact the staff of wildlife protection agencies........ ...1 2 3 4 5

2.9. If the wildlife harm our farmland, can we set snares to prevent?

1. Yes 2. No 3. Don't know 4. Have not done it before

2.10. What changes do you think have taken place in the frequency of livestock being preyed on by wild animals in recent years?

1. Increase 2. Decrease 3. No change 4. Not clear

2.11. Do you think there has been any change in the frequency of crops being harmed by wild animals in recent years?

1. Increase 2. Decrease 3. No change 4. Not clear

3. Human-wildlife conflict

3.1. Do you or your family have the experience of being attacked by wildlife?

1. Yes 2. No

3.1.1. If yes what wildlife?

1. Tiger or leopard 2. Bear 3. Wild boar 4. Deer 5. Other_________

3.1.2. Injury status

1. Dead 2. Serious damaged 3. Not serious injured 4. Scared 5. Other___________

3.1.3 Time______________

3.1.4. Did you get the compensation

1. Yes (If yes, do you satisfied?:1. Yes 2. No) 2. No

Questions will talk with the family who has livestock. If they do not have any please jump to next question

3.2. Was an livestock attacked by wildlife in your family?

1. Yes 2. No

3.2.1. If yes, by what kind of wildlife?

1. Tiger or leopard 2. Bear 3. Wild boar 4. Deer 5. Other_________

3.2.2. Livestock that got hurt.

1. Cattle 2. Sheep 3. Horse 4. Dog 5. Chicken 6. Other

3.2.3. Injury status

1. dead 2. Serious damaged 3. Not serious injured 4. Scared 5. Other__

3.2.4. Time ____________

3.2.5. Did you get the compensation

1. Yes (If yes, do you satisfied? : 1.Yes 2. No) 2. No ___

3.2.6. Frequent seasons:

1. Spring 2. Summer 3. Autumn 4. Winter

3.3. Did you hire someone look after your livestock?

1. Yes 2. No

- If not, how often do you go to check them?______________________________

3.4. Do you have any plan to prevent the loss on livestock?

1. Yes 2. No

If yes, what is it? Is that effective_________________________________

1. Very effective 2. Not so much 3. No

The following questions 3.5-3.6 are for families with farmland. If there is no farmland, skip to next topic.

3.5. Have any wild animals ever damaged your crops?

1. Yes 2. No

3.5.1. If yes what wildlife?

1. Tiger or leopard 2. Bear 3. Wild boar 4. Deer 5. Other_________

3.5.2. Type of crops:

1. Bean 2. Corn 3. Horney 4. Others

3.5.3. Amount of loss:

1). Less than the total product 1/5 2). Around 1/3 3). More than half

3.5.4. Time____________

3.5.5. Did you get the compensation

1. Yes (If yes, do you satisfy? : 1. Yes 2. No) 2. No ___

3.5.6. The most frequent time:

1. Spring 2. Summer 3. Autumn 4. Winter

3.6. Did you do anything to prevent the loss?

1. Yes 2. No

If yes

3.6.1. What is it?___________________________

3.6.2. Is it effective?

1. Very much 2. Kind of 3. Not effective

Thank you so much for your support!

General Discussion

The Amur tiger and leopard are critically endangered animals that risk going extinct. Northeast China is crucial for the survival of the Amur tiger and leopard because it is their only significant habitat. Prey animal resources, habitat and habitat connections, and social support are the key risks to these species' conservation. In the important big cat's habitat, a new deer species, water deer started to use the land as habitat. As one potential prey for the big cats, the baseline information for this ungulate is important for the tiger and leopard conservation. We confirm their distribution and abundance relative to other preys; we also forecast their habitat, which can provide information on the conservation of the entire landscape; and finally, we examined local community attitudes toward big cats and their prey species in order to develop targeted conservation issues.

We verified the northward expension of the water deer, which could be prey for tigers and leopards. Native to China and the Korean peninsula, the water deer *Hydropotes inermis*, this species' distribution, though, seems to be extending quickly. The status, phylogeny, and genetic heritage of the recently discovered population were evaluated in this study using camera traps and molecular technology. In accordance with our findings, water deer have continued to move north, moving at least 500 kilometers beyond their previous distribution boundary. The geographic distribution of this species in Northeast China and the Russian Far East was updated, and we included that information. according to survey results over the past

There has never been a record of this species in either of these areas according to historical survey data collected before the 1990s; thus, this could be a true range expansion rather than merely an extension of the known range. The growing population shared a close phylogenetic connection with Korean water deer, according to a genomic study using mitochondrial DNA. Discussed are the probable migration path and the root causes of the species' distribution range growth. We advise the IUCN Red List to update the water deer's range in order to support the efficient management and conservation of this endangered species, particularly in new areas.

Through habitat research, we predicted the water deer's prospective corridor, which can also provide a proposal for the preservation of the tiger/leopard huge landscape. The range of the water deer has grown since 2017 and now includes northeast China and the Russian Far East. to facilitate the development of a more comprehensive understanding of habitat usage and to offer recommendations for creating a conservation strategy. Between 2017 and 2021, we gathered data on incidence in northeast China and the Russian Far East. We employed Circuitscape to identify potential water deer dispersal pathways and MaxEnt to forecast the habitat appropriateness for the species. For the purpose of predicting the habitat appropriateness, we used seven environmental variables: height, slope, aspect, distance to built-up areas, distance to water sources, distance to agriculture, and distance to roadways. The border region of the Yalu and Tumen River estuaries between China, North Korea, and the Russian Far East, as well as the east and west sections of the Korean Peninsula, provide water deer with high-quality habitat. Three primary patches of appropriate habitat were detected, two in east and west North Korea and one downstream of the Tumen River bordering the Chinese, Russian, and North Korean borders. The factors that helped to accurately simulate the ideal habitats were elevation, proximity to farmland and water supplies, and the presence of wetlands. We also use the same condition analysis for the other important tiger and leopard prey animals, including wild boar, sika deer, and roe deer habitat use. The result shows that elevation contributes the most to the model by water deer and wild boar; the difference is that water deer prefer lower elevation compared to wild boar. We can see limited competition between water deer and other species from the species distribution model, so the potential population growth is high.

Using the circuit theory, three potential dispersal pathways were identified. Water deer might spread throughout a number of protected areas in North Korea, China, and Russia. We can better comprehend the ecological network in northeast Asia thanks to research on water deer dispersal, which will help preserve biodiversity and the region's entire terrain. The need for ongoing monitoring both inside and outside of the protected areas arises from the numerous threats that are now present. It's crucial to conduct out local community awareness campaigns and share information with relevant parties. The habitat connections serve as an illustration of the requirement for such a network, which would also be used by big cat animals in the future.

For large carnivores to survive in human-dominated ecosystems, community attitudes toward them are crucial. We assess local perceptions and attitudes toward the Amur tiger, Amur leopard, bears, as well as their prey species, including sika deer,

roe deer, and wild boar, in Yanbian Korean Autonomous.
After conducting a survey of 139 households, we discovered that community members' perceptions of large carnivores and their prey species were influenced by their main economic pursuits, their prior encounters with wildlife, their household income level, and whether or not they had moved to Yanbian from somewhere else in China or by their place of residence's long-term history of habitation.
We found that the communities we studied had generally positive attitudes toward large carnivores, but extremely negative sentiments were observed toward wild boar, especially where respondents had lost agricultural products to wild boar crop raiding. We advise conservationists in northeast China to use this discovery to promote interest in large carnivore recovery and preservation by focusing messaging on the significance of the tiger as a significant wild boar predator in the ecosystem. Additionally, our results imply that government-provided compensation for livestock lost to large carnivore predation-particularly by tigers-may be lowering cow owners' antipathy toward large carnivores. We also point out that although compensation for livestock losses helps to reduce conflict between people and wildlife, there may be unintended implications of the current compensation program, such as the failure to stop cattle from grazing in protected areas.

Perspective from enhanced potential prey, habitat connections, and local community awareness were all used to give conservation solutions. The ongoing research on big cat diet changes (particularly novel prey components), interactions with other prey animals, habitat utilization, and monitoring for water deer will all be crucial for further conservation. Maintaining and increasing the prey population, expanding the habitat, and raising local community knowledge will all be crucial factors in maintaining a healthy big cat population. Even though our research offers some suggestions in this regard, further research will be required to assess the habitats and conditions of all prey species as well as explore potential community engagement strategies

Our research shows that water deer have already expanded their habitat to the tiger and leopard landscape, become the new habitat for water deer. The suitable high-level habitat along the river system can be focused on for the future monitoring of water deer; the monitoring contents need to include population abundance and interaction with predators and other herbivores, as well as disease monitoring. From the community attitude survey, the main tiger prey wild boar raises the most negative feeling from the people, we discussed possible mitigation strategies on that and discussed about the compensation updates needs as well as people who rely more on natural resources need to be educated with specific strategies. Our findings can contribute to the understand the baseline knowledge of the potential prey, water deer for Amur tiger and leopard, and the baseline attitudes from local community towards wildlife. The information can be used to increase tiger, leopard, and their prey population increasing strategy.

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국문 초록

중국 동북지역에서 새로 확산된 고라니 (*Hydropotes inermis*)의 잠재적 서식지와 지역주민들의 야생동물 인식에 관한 연구 및 아무르호랑이(*Panthera tigris altaica*)와 아무르표범 (*Panthera pardus orientalis*) 보전에 갖는 의미

먹이동물의 분포와 지역 주민들의 야생동물에 대한 인식과 태도는 대형 고양이과 동물 보존에 있어서 중요한 측면 중 하나이다. 자연 경관에 대한 인간의 지배적 영향력이 급속히 확장됨에 따라 아시아에 서식하고 있는 호랑이와 표범 개체군이 소실되거나 또는 개체군 고립과 파편화를 초래하였다. 그럼에도 불구하고 중국 동북지역과 극동러시아 남서부 해안지역 일부에는 아직 아무르호랑이(*Panthera tigris altaica*)와 아무르표범(*Panthera pardus orientalis*)의 서식지가 보전되어 있다. 이곳에 살고 있는 아무르표범은 현재 야생에서 생존하는 마지막 개체군이며 아무르호랑이는 중국 동북지역의 메타 개체군이 된다. 이 지역에는 최근 사슴과 동물종인 고라니(*Hydropotes inermis*)가 자연적인 서식지 확산에 의해 새로 서식하게 되였으며, 이들은 미래 큰고양이과동물(호랑이와 표범)의 잠재적 먹이가 될 가능성이 크다. 그러므로 고라니 개체군 확산에 대한 기초 정보와 지역주민들의 야생동물 인식에 관한 정보는 대형고양이과동물의 보전에 있어 매우 중요하다. 본 연구는 적외선 카메라 기법, 유전자 분석 기법, 종 분포 모델 및 설문조사 방식을 통해 이러한 정보를 얻을 목적으로 진행되었다.

야생동물과 서식지의 보호는 인간의 복지와 생존을 위해서도 중요하다. 그러나 인구 증가는 자원수요 증가와 맞물려 인간과 야생동물이 공존하는 방법에 대한 중요한 도전적 문제를 제기한다. 야생동물에 대한

조사 및 보호에 관한 대부분의 연구는 개개의 특정 분야에 세분화되어 있다. 여러 분야를 아우르는 통합적 연구방식이 쉽지는 않지만 야생동물의 보전에 있어 매우 중요하다. 야생동물과 그 생태환경과의 상호작용, 그리고 경관이 야생동물에게 서식지를 제공하는 방법은 모두 야생동물 보전의 중요한 측면이다. 야생동물 서식지에 사는 주민들이 야생동물에 대해 갖는 태도 및 보전에 대한 인식은 미래의 보전 활동이 성공할 수 있는지 여부와 장기적인 지속 가능성에 있어 중요한 역할을 한다. 보전에 관한 대부분의 연구는 야생동물의 특정 측면에 초점을 맞추고 있지만 야생동물이 직면한 문제는 다양하고 복잡하기 때문에 문제를 종합적으로 고려하는 것은 중요한 의미를 지닌다. 종 생태학, 경관생태학, 사회학적 이론은 모두 보전생물학의 중요한 뒷받침이 되었다.

비침습적 유전자 시료 수집과 분석, 적외선 카메라 및 전통적인 생태 조사와 같은 야생동물 모니터링 기술의 발전은 야생동물에 대한 정확한 정보 수집을 위한 기본 수단을 제공한다. 야생동물 서식지를 평가할 때 경관생태학 분야는 효과적인 평가도구를 제공하고 있으며, 종분포모델(Species distribution model)은 경관척도의 데이터를 이용하여 인간활동의 영향, 환경배경 정보 및 종 생태정보를 결합하여 중점보호지역을 예측할 수 있게 한다. 또한 생태 네트워크 연결 방법을 이용하여 주요 서식지 패치 간의 연결을 계산하고 경관 규모 서식지 정보를 얻을 수 있다. 설문조사 기법은 인간과 야생동물의 충돌 및 주민 인식 상태를 이해하는 데 중요한 정보를 제공할 수 있다.

2019 년에 고라니가 현재 아무르호랑이 및 아무르표범이 분포하는 두만강 하류 지역으로 확산된 것으로 보고되었다. 고라니는 번식률이 높아 미래 대형고양이과 동물의 먹이가 될 가능성이 높지만, 동시에 다른 생물에 일정한 영향을 미치며 지역주민과 충돌할 가능성도 있다.
본 논문 연구에서는 주로 적외선 카메라, 종 분포모델 및 설문조사 기법을 사용하여 중국 동북지역 고라니(대형고양이과동물의 잠재적 먹이)의 북쪽 확산 너비를 평가했으며 연구의 중점 지역은 중국 동북부과 극동러시아의 북한 접경지역이다.

본 연구의 주요 목표는 종의 확장을 확인하고 서식지를 평가하며 야생동물에 대한 지역주민의 태도를 평가하는 것이다. 연구 목표를 달성하기 위해 지역 임업부서, 연변대학, 북경사범대학, 국제야생생물보호학회 및 기타 관련 분야의 지역 파트너와 협력하여 생태 데이터를 수집하고 가구 조사를 수행하고 경관 데이터를 분석했다. 적외선 카메라, 생태학적 데이터 수집, 유전자 시료 수집과 분석을 통해 종을 보다 정확하게 식별하고 분포 범위를 업데이트했으며, 고라니의 분포가 이전에 기록된 범위에서 최소 500km 북쪽으로 확산되었으며, 남한 고라니의 유전적 특성과 더 밀접한 관련이 있음을 확인했다.
연구 결과는 새로운 서식지역으로 확산된 고라니 보호 및 관리에 대한 기본 정보를 제공하고 대형고양이과동물의 보전에 도움을 줄 것으로 기대된다 (제 1 장).

적절한 환경 변수를 결정한 후 MaxEnt 모델을 사용하여 서식지를 분석하면 환경 변수를 평가하고 최종적으로 특정 종에 적합한 서식지를 예측할 수 있다. 한반도 서해안에서 중국 랴오닝성까지, 동해안에서 러시아 우수리강까지 뻗어 있는 고라니 서식에 적합한 넓은 지역을 발견했으며 서식지 연결 분석을 통해 고품질 서식지 플라크를 연결할 수 있는 생태회랑을 도출하였다(제 2 장).

야생동물에 대한 현지 주민의 태도도 설문조사를 통해 확인했는데, 이는 향후 고라니 확산에도 영향을 미칠 것으로 보인다. 야생동물에 대한 지역주민들의 태도가 연령, 성별, 교육 및 야생동물과의 상호작용과 같은 요인과 관련이 있음을 발견했다. 우리의 조사 결과에 따르면 지역주민들은 일반적으로 대형 육식동물에 대해서는 중립적이지만 멧돼지에 대해 부정적 인식을 갖고 있다. 특히 농작물 피해를 입은 경험이 있는 가족은 멧돼지에 대한 불만이 매우 높다. 경제적 수입 수준과 수입원도 야생동물에 대한 지역사회의 태도에 영향을 미치며, 이러한 정보는 호랑이, 표범 및 그 먹이동물의 보호 및 관리전략 수립에 있어 중요한 정보가 될 수 있다(제 3 장).

본 연구는 아무르호랑이와 표범의 기존 서식지에 새로 확산된 유제류에 초점을 맞추어 서식지 평가와 예측을 통해 잠재적 서식지 패치 및 생태회랑 정보를 얻을 수 있었다. 호랑이와 표범에게 직접적인 생존요소는 먹이동물이기 때문에, 이 잠재적 먹이동물의 분포상황, 서식지와 생태회랑에 대해 이해하는 것은 그 포식자의 보전과 관리에도 중요한 정보를 제공한다. 호랑이와 표범의 잠재적 먹이동물의 서식지와 회랑은 그 포식자에게도 중요한 서식지 및 회랑 역할을 할 수 있기 때문에 미래 호랑이와 표범 보호구역 설계에 있어 이러한 정보를 고려할 필요가 있다. 마지막으로 지역사회를 대상으로 하는 설문조사를 통해 야생동물에 대한 현지인들의 태도와 야생동물과의 상호작용에 관한 정보를 얻을 수 있었다. 이는 야생동물 보호에 대한 주민들의 지원을 확보하고 살아있는 동물에 대한 간섭을 줄이는 방법에 대한 중요한 정보 자원이 될 것이다. 본 연구는 야생동물 생태학, 경관생태학 및 사회학적 연구방법을 통합한 연구 사례로 미래의 다른 종 보호에 일정한 시범 역할을 할 수 있을 것이다.

주요어: 아무르호랑이, 아무르표범, 고라니 서식지, 분포, 주민의식
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