LEAD POISONING OF STELLER'S SEA-EAGLE (*HALIAEETUS PELAGICUS*) AND WHITE-TAILED EAGLE (*HALIAEETUS ALBICILLA*) CAUSED BY THE INGESTION OF LEAD BULLETS AND SLUGS, IN HOKKAIDO, JAPAN

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ABSTRACT.—The Steller's Sea-Eagle (*Haliaeetus pelagicus*) and the White-tailed Eagle (*H.albicilla*) are among the largest eagles. The total population of the Steller's Sea-Eagle is estimated at 5,000 to 6,000 individuals, and these eagles winter in large numbers in northern Japan, on the island of Hokkaido. Lead poisoning of Steller's Sea-Eagles in Japan was first confirmed in 1996. By 2007, 129 Steller's and White-tailed Eagles had been diagnosed as lead poisoning fatalities. High lead values up to 89 ppm (wet-weight) from livers of eagles available for testing indicate that they died from lead poisoning. Necropsies and radiographs also revealed pieces of lead from rifle bullets and from shotgun slugs to be present in the digestive tracts of poisoned eagles, providing evidence that a source of lead was spent ammunition from lead-contaminated Sika Deer carcasses. Tradition and law in Japan allow hunters to remove the desirable meat from animals and abandon the rest of the carcass in the field. Deer carcasses have now become a major food source for wintering eagles.

Reacting to the eagle poisoning issue, Hokkaido authorities have regulated the use of lead rifle bullets since 2000. The Ministry of the Environment mandated use of non-toxic rifle bullets or shotgun slugs beginning the winter of 2001. However, these regulations are limited to the island of Hokkaido, and depend largely on cooperation from hunters. A nationwide ban on the use of lead ammunition for all types of hunting and cooperation from citizens would solve the problem of lead poisoning of eagles. *Received 15 July 2008, accepted 17 September 2008.*

SAITO, K. 2009. Lead poisoning of Steller's Sea-Eagle (*Haliaeetus pelagicus*) and White-tailed Eagle (*Haliaeetus albicilla*) caused by the ingestion of lead bullets and slugs, in Hokkaido Japan. *In* R. T. Watson, M. Fuller, M. Pokras, and W. G. Hunt (Eds.). Ingestion of Lead from Spent Ammunition: Implications for Wildlife and Humans. The Peregrine Fund, Boise, Idaho, USA. DOI 10.4080/ilsa.2009.0304

Key words: Hokkaido, hunting, Japan, lead poisoning, Steller's Sea-Eagle, White-tailed Eagle.

HOKKAIDO, THE MOST NORTHERN ISLAND OF JAPAN, provides habitat for four large-sized raptors. The largest species is the Steller's Sea-Eagle (*Haliaeetus pelagicus*), followed by the White-tailed Eagle (*H. albicilla*), Golden Eagle (*Aquila chrysaetos*), and Mountain Hawk Eagle (*Spizaetus nipalensis*). A high quality natural environment that has abundant food resources is necessary to sustain these species. Forests cover 71% of Hokkaido of which 67% is natural forest; those forests constitute about one quarter of the natural forest areas of Japan (Hokkaido forestry statistics in 2005 fiscal year). The natural environment of Hokkaido is comparatively well-conserved on a nationwide scale. However, currently there are human influences affecting the large birds of prey there.

SEA EAGLES

The Steller's Sea-Eagle is one of the largest eagle species in the world, and breeds almost exclusively in the coastal regions of eastern Russia. It has a high contrast white and black body color and a vivid orange beak. The body length is 89 cm (male) to 100 cm (female), wing span 210 cm (male) to 230 cm (female), and mass of 5 to 7.5 kg. The native Ainu people of Hokkaido call the Steller's Sea-Eagle "*Kapacchilikamui,*" which means "God of the Eagles."

The total population of the Steller's Sea-Eagle is estimated at 5,000 to 6,000 individuals in the limited coastal region of the Okhotsk Sea. The breeding area is the northern part of Sakhalin island, the lower Amur, Kamchatka, and the Bering Sea coast in the southern part of Coriyac. When winter comes, the eagles migrate toward south Kamchatka, the Korean peninsula, south Sakhalin, and northern Japan. Steller's Sea-Eagles winter in large numbers together with White-tailed Eagles, in northern Japan, on the Islands of Hokkaido (1,500 to 2,000 individuals) and South Kurile.

Biologists have been investigating Steller's Sea-Eagles at the breeding grounds in the north and have been radio tracking birds since the 1990s (Meyburg and Lobkov 1994, Ueta and McGrady 2000, Utekhina et al. 2000). As a result, the flyway between Japan and Russia, and also movements on the wintering grounds have gradually been clarified. The migration route of the Steller's Sea-Eagle from the breeding area to the wintering area in Hokkaido is via Sakhalin Island or the Kurile Islands. The eagles that migrate by Sakhalin come to Hokkaido through the Soya Cape (northernmost cape of Japan) in October. Afterwards, most of the eagles move along the Okhotsk Sea toward eastern Hokkaido, feeding on salmon that enter rivers. However, a portion of the population moves along the Japan Sea, and reaches the southern part of Hokkaido where it winters. Eagles that survive the winter migrate north toward the breeding ground, beginning in February until May, with the adults leaving first (Ueta and Higuchi 2002).

The Steller's Sea-Eagles select wintering areas depending on the food source. The principal diet of sea eagles, as their scientific name "*Haliaeetus*" expresses, is fish (Ueta et al. 1995, Shiraki 2001) such as salmon and pollack. Eagles also prey on ducks and scavenge stranded marine mammals. In the early 1980s, the pollack fishery was prosperous, and many sea eagles gathered around the Rausu at the Shiretoko Peninsula in Hokkaido. However, the pollack fishery has suffered recently. Around the same time, the population of Sika Deer (*Cervus nippon*) has dramatically increased. As a result, deer carcasses resulting from accidents, starvation, or hunting were easily discovered by eagles in the mountains of Hokkaido. Steller's Sea-Eagles found these deer as a new food source, and now are commonly observed inland.

The Steller's Sea-Eagle is classified as a Vulnerable Species in the IUCN (International Union for Conservation of Nature and Natural Resources) Red List of Threatened Species. The species is on the Natural Monument list (Law for the Protection of Cultural Properties), listed as a national endangered species of wild fauna and flora in Japan (Law for the Conservation of Endangered Species of Wild Fauna and Flora), and is classified as an endangered species in the Japanese Red Data Book.

The White-tailed Eagle has a 190–210 cm wingspan and 3.5–5 kg body mass. Females are significantly larger than males. The adult bird is mostly brown except for the white tail and yellow beak and legs. The species is distributed from Europe through eastern Asia. The population in Siberia migrates to winter in southern areas including Japan. Hokkaido Island is a main wintering spot for the population that migrates from Sakhalin Island and the Kamchatka Peninsula in the Far East of Russia. A small population is resident in northern Japan. The White-tailed Eagle is called by Ainu, "*Onneu,*" which means "Old and Large One."

The White-tailed Eagle mainly preys on fish, sometimes on birds and small mammals, and also scavenges carcasses or garbage left by humans. They gather in flocks at feeding sites such as fisheries, harbors, lagoons, or rivers, and also at roosting sites during the winter season. Now they also feed on Sika Deer carcasses. White-tailed Eagles are designated as a Japanese Endangered Species and also on the Natural Monument of Japan list. Moreover, Steller's Sea-Eagles and White-tailed Eagles are included in The Conventions and Agreements for Protection of Migratory Birds between Japan and the partner countries (United States, Russia, Australia, and China).

LEAD POISONING FROM LEAD AMMUNITION

Lead poisoning in avian species has been reported in Japan previously. However, it was mainly cases of waterfowl, and was caused by the ingestion of fishing weights or lead pellets. Waterfowl swallow small stones or grit with food to assist digestion, but they also ingest lead weights used for fishing and lead pellets used in waterfowl hunting. The lead poisoned or shot waterfowl are a source of secondary poisoning to raptors that prey or scavenge on waterfowl.

However, 92 Steller's Sea-Eagles and 37 White-tailed Eagles have died since the first detection of the lead poisoned Steller's Sea-Eagle in 1996 at Abashiri, Hokkaido (Saito et al. 2000, Kurosawa 2000). In this case, a lead shot from waterfowl hunting was found in the ventriculus of the eagle. The case of eagle lead poisoning caused by lead bullets used in Sika Deer hunting was first confirmed in 1997. Since then, based on the study of preserved eagle samples, we know that the lead poisoning of the eagle was already occurring in 1986.

Twenty-one eagles (18 Steller's and three White-tailed) were confirmed to have been lead poisoned in the winter of 1997–98 and 26 more (16 Steller's and ten White-tailed) in 1998–99 (Figure 1). Afterwards, the number of eagle lead poisonings decreased slightly (ten Steller's and four White-tailed in 1999–2000), but the collection rate of the eagles varies depending on the number of persons who enter the mountain areas, and on the snowfall conditions. In 2003, two cases of lead poisoning in Mountain Hawk Eagle (*Spisaetus nipalensis orientalis*) were discovered (Figure 1). This indicates that lead poisoning caused by spent lead ammunition occurs among several raptor species.

The main cause of death of those cases was the lead rifle bullets and shotgun slugs used in Sika Deer hunting. Until 2003, tradition and law in Japan

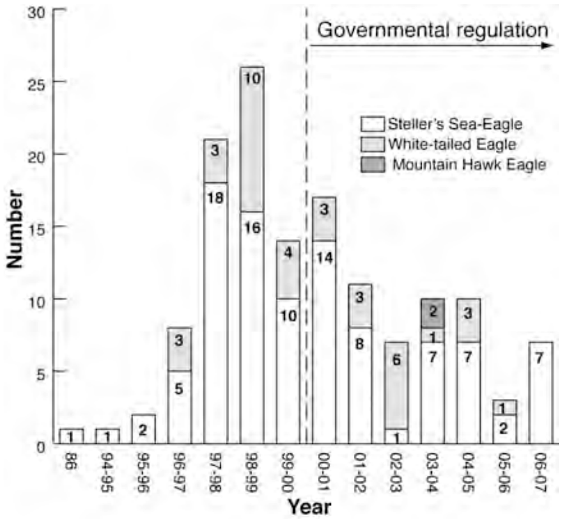

Figure 1. Number of eagles found dead from lead poisoning.

allowed hunters to remove the desirable meat from animals and abandon the rest of the carcass in the field. A number of lead fragments remain in the body of the deer, and these can be ingested by raptors when they scavenge the carcasses. Because of the reduced availability of fish or fish remains, deer carcasses have now become a major food source for these wintering eagle populations. Furthermore, in 1998, Hokkaido government authorities announced a radical deer population control program to reduce the feeding damage caused by Sika Deer. This would cull the herd in eastern Hokkaido from the current 200,000 animals to 30,000 within three years. As a result, the remains of Sika Deer left by hunters increased and Sika Deer that had been wounded and died afterwards also greatly increased.

It is understood that the Steller's and White-tailed eagles are still using the dead Sika Deer as an important winter food source. Soft tissue is exposed where the lead enters the deer, and this area becomes a convenient place for birds to begin eating. According to field observations, adult eagles are dominant at a carcass and force other birds away, and consequently, adult eagles are at high risk of consuming meat that contains a large amount of lead fragments at and near the bullet entry wound.

A large amount of deer meat and hair are frequently observed in the crop or ventriculus of eagles that have been killed by trains, probably when the eagle approached the railway track to eat from the carcass of a deer killed by collision with a train. If deer have been wounded by a lead bullet in the past, it is possible they can be a source of lead poisoning to scavengers at all times of year. Moreover, lead poisoning of eagles also is caused by ingestion of lead shot used for waterfowl hunting. This occurs when raptors prey on or scavenge waterfowl that ingested or were wounded by lead shot. The Steller's Sea-Eagle and White-tailed Eagle and waterfowl together inhabit coastal, lakeside, and riverside habitat in Hokkaido. In this situation, without a strict regulation of lead shot, eagles also are at risk when preying on lead contaminated waterfowl. Lead poisoning in sea eagles is characterized by the high mortality of the adult birds.

Steller's Sea-Eagles normally weigh 6 to 8 kg but individuals killed by lead show severe weight loss. Due to malnutrition, wasting of the pectoral muscles and reduced amounts of visceral fat were conspicuous. Green diarrhea similar to that observed among lead-poisoned waterfowl was observed in each case. Atrophy of livers and distended gallbladders filled with bile were commonly observed. Liver lead values of 2.0 to 89 ppm (wet-weight) demonstrated that these eagles were killed by lead. Necropsies and radiographs have revealed pieces of lead from rifle bullets and from shotgun slugs to be present in the digestive tracts of poisoned eagles.

Even if the amount of ingested lead was not fatal, the toxic substance can have sub-lethal effects (e.g., neurological) that could contribute to other causes of death, such as a being hit by cars. Moreover, the number of lead poisoned eagles collected is just a tip of the iceberg. It is thought that far more eagle carcasses occur in the midwinter in mountains where no one visits. It is suggested that actual casualties by lead poisoning are far more than the number found. Furthermore, the demographic impact of lead is difficult to measure because no one knows how many individuals have died during migration and in their breeding range (Russia). Lead poisoning certainly can be an important factor for the population status of these two sea eagle species (e.g., Ueta and Masterov 2000). It can be said that the population control of Sika Deer that was begun for wildlife management, has produced an unintended threat to the endangered sea eagles.

RESCUE AND TREATMENT OF LEAD POISONED SEA EAGLES

Rescued eagles usually were taken to the nearest zoo until it was learned that the common cause of eagle death was lead poisoning. For lead poisoning cases, prompt treatment becomes an important key to prevent death of the bird. This is because the toxicity of lead is very high, and the influence is remarkable in birds. Dissolution and absorption of lead are rapid in birds of prey because their gastric-acid secretion is high. Because of this, it is thought that the influence of lead is larger than in other types of birds. Lead poisoning generally causes digestive symptoms such as colic, vomiting and asitia. In addition, lead poisoning influences the hematopoietic tissue, appearing as a symptom of clinical importance.

Lead causes a decrease of the amount of hemoglobin in the red blood cell by obstruction of heme synthesis, and this causes critical anemia. Moreover, lead poisoning disrupts normal liver and kidney function and causes adverse effects on the central and the peripheral nervous systems. Therapy is provided by Ca-EDTA (injection and oral) in Japan. The side effects of this treatment of lead poisoning are strong. Therefore, it is necessary to carefully administer the amount based on the density of lead in the individual. Special equipment is required to measure the concentration level of lead, and diagnosing lead poisoning is not easily done in each case.

As a response to the frequent occurrence of raptor lead poisoning, the Japanese Ministry of the Environment together with Hokkaido local agencies decided to centralize the reception of live and dead birds at the Kushiro Shitsugen Wildlife Center, where the veterinary hospital of the Institute for Raptor Biomedicine in Japan exists. The Center utilizes the Lead Care System® (ESA Inc.), which can measure lead concentration quickly with a small blood sample (0.005 ml). The Hokkaido Institute of Public Health contributes to the diagnosis.

The criteria for assessing lead exposure in raptors have been established by using examples from waterfowl:

Hepatic level
- <0.2 ppm: normal range
- 0.2–2 ppm: high exposure
- >2 ppm: lead poisoning

Blood level
- <0.1 ppm: normal range (obstruction of the enzyme level is reported at 0.1 ppm.)
- 0.1–0.6 ppm: high exposure
- >0.6 ppm: lead poisoning

When a high density of lead is confirmed by these tests (e.g., Table 1), both routes of Ca-EDTA administration can be used under a regimen that considers the side effects and subsequent blood lead concentration.

Among the live and dead birds brought to the Wildlife Center, there are some cases that have not been obviously diagnosed as lead poisoning, but irrespective of other causes of accident or sickness, they did show a high lead level in blood. Even among individuals that had a traffic accident (collision with vehicle or train) or electrocution, many show high concentrations of lead in the blood or organs. Now that eagles are accustomed to feeding on carcasses, they are attracted to traffic accident carcasses that occur near the road or railroad and thus are vulnerable to traffic accidents. Finally, documentary research and review of preserved eagle specimens has revealed lead poisoning among cases that had been diagnosed previously as starvation.

A CIVIC GROUP "EAGLE LEAD POISONING NETWORK"

In the spring of 1997, most lead poisoning of large raptors was thought to be caused by the ingestion of lead from rifle bullets. In July 1998, the Hokkaido government formally announced that lead bullet fragments remain in the body of shot Sika Deer. Thereafter, public opinion began to move greatly for prevention. However, lead poisoning victims kept increasing. In winter 1998–1999, 26 Steller's and White-tailed Sea Eagles were found dead by lead poisoning. The total number of eagle carcasses found this winter was 33, and 78% had lead poisoning.

Table 1. Case examples of lead concentration in blood and tissues of lead poisoned raptors.

Species	Date of collection	Blood lead level (ppm)	Hepatic lead level (ppm)	Origin detected by lead isotope ratio analysis*
Steller's Sea-Eagle	2004/1/15	6.5	4.2	Rifle
Steller's Sea-Eagle	2004/1/17		10.4	Rifle
Steller's Sea-Eagle	2004/1/24		14.6	Rifle
Steller's Sea-Eagle	2004/1/31		7.8	
Steller's Sea-Eagle	2004/11/3	4.5 (tibial BM)		Rifle
Steller's Sea-Eagle	2005/3/22		10.0	
Steller's Sea-Eagle	2005/5/5		12.0	
Steller's Sea-Eagle	2007/4/20		11.2	Rifle
White-tailed Eagle	2005/2/12		9.0	Rifle
White-tailed Eagle	2006/4/16		2.0	
White-tailed Eagle	2008/2/4	1.4		Rifle

* 208/206 Pb and 207/206 Pb isotope ratio
Analyzed by Dr. Kazuo Jin, Hokkaido Institute of Public Health

Consequently, in July 1998, veterinarians from eastern Hokkaido took a leading part to establish a civic group, the “Eagle Lead Poisoning Network.” Citizens, including students, teachers, company employees, hunters, and civil servants began participating in the group activities for the prevention of lead poisoning. The group’s network of activity was organized as shown below.

Investigation of Large Raptors in Hokkaido.—The purpose of this field investigation was to study the behavior and ecology of wintering eagles that move inland from the historically used coastal habitats, and to understand the cause-and-effect relationships of lead poisoning. This investigation included the distribution and number of Steller’s and White-tailed Sea Eagles, the occurrence of abandoned deer carcasses, and eagle dependence on the hunting remains. This information will contribute to predicting the extent of lead poisoning, and taking concrete and effective measures to reduce it.

When a debilitated or dead eagle was found during field work, we brought it to the Wildlife Center. In addition, abandoned deer carcasses were buried or transported to Deer Carcass Collection Boxes that were established by the local government. Where the boxes do not exist, deer carcasses were brought to a waste repository.

This investigation provided biological information about sea eagles that inhabit the mountain area and showed that in eastern Hokkaido, a large population of sea eagles winters inland in the mountains, feeding on deer carcasses that result from hunting activities. Also, eagles that winter mainly near the sea coast or lake shore do occasionally feed on hunting remains in addition to aquatic prey.

The inland count of eagles is small in November. An increase occurs from December to January, becoming maximum from February to March, and then greatly decreases in April. However, some young eagles have been found even in early May. This change in the occurrence of sea eagles using the inland landscape seems to reflect the deer hunting season, which usually starts in November and ends in late January or February.

Investigation to Understand Lead Poisoning Occurrence in the Environment.—It is necessary to closely examine the injured or sick individuals and to do post mortem examination to correctly understand the influence of lead poisoning in the population. Therefore, veterinarians and veterinary students use autopsy, x-ray examination, concentration measurements of lead, and they collaborate with the Hokkaido Institute of Public Health to detect the origin of lead using lead isotope ratio analysis. In addition, we have studied the extent of lead poisoning indirectly by measuring lead in fecal samples and by x-ray examination of the pellets collected in the field.

Moreover, with collaboration from the local Hokkaido agency, there is investigation of the bullet material that remains inside the deer carcass. The sample collection is done in the hunting fields of eastern Hokkaido, and when a fresh deer carcass, without evidence of eagle feeding, is found, a 30–50 cm square of soft tissue around the bullet impact area is collected. The samples are closely examined by x-ray, and when the presence of the metallic substance is detected, it is isolated, measured, and described in detail to verify the origin. This investigation continues to demonstrate the presence of the lead contaminated deer carcasses in the wintering habitat of Sea Eagles, even after the governmental ban of lead ammunition in Hokkaido.

Improvement of the Wintering Environment.—Patrol of the hunting ground and removal of abandoned dead Sika Deer is frequently done to prevent raptor lead poisoning. Historically, many remains from hunting were left on the snow. Hunters removed the desirable meat from animals and abandoned the rest of the carcass (skin, bone, intestine, and the damaged parts) in the field. Many edible parts lay under the snow, which melts in early spring. Although our understanding of lead poisoning grows, continued publicity of correct preventive measures is necessary, because deer remains contaminated with lead are still a problem.

Until the appropriate processing of game becomes widely accepted, the members of the Network take the initiative of burying or removing deer remains to reduce as much lead pollution in the environment as possible. It is not straightforward to remove more than 50 cm of snow cover, pickax the hard frozen soil, and dig a sufficient hole to bury a large deer. Despite this difficult situation, volunteers patrol the hunting field to dispose of dead deer. Along forest roads where remains left by hunters are particularly abundant, volunteers load a truck with carcasses and remains and transport them for disposal. In the maximum case, 1 ton of deer carcasses was collected at one forest road, during one day of cleaning activity.

In due course, these activities received publicity, and the government and hunting association started to express concern. The practice of dumping the carcass has gradually changed. Still, some carcasses are clandestinely dropped into the river from the bridge, or placed in culverts that pass under the forest road.

Activity to Promote the Shift to Nontoxic Bullets.—It is well known that lead is a toxic substance, but lead bullets and slugs have been long used for hunting in Japan, though most are made of imported lead. There are alternatives such as a specialized bullet that will not fragment upon impact, the copper bullet (e.g., Barnes X-bullet), and lead-core bullets of special non-fragmentive design (Winchester Fail Safe bullet). These are well known and sold as bullets that do not expose lead after impact with the target. At the time when lead poisoning of eagles became a serious problem in Hokkaido, the X-bullet was almost impossible to obtain in Japan. Therefore, if some hunters wanted to use the copper bullet, it was necessary to make them with an expensive reloading machine. To improve the situation, the Network bought a complete set for reloading and loaned it to the local hunting association.

Education Activity.—The Eagle Lead Poisoning Network used the internet to provide the latest and most accurate information about lead poisoning in raptors and prevention activities. Moreover, multiple publications including an annual report have been sent to the government, hunters, and nature conservation groups. Scientific findings have been published from academic conferences. In addition, a multitude of symposia and forums have shared findings among participants and experts (e.g., Lead Poisoning of Steller's Sea Eagle in Eastern Hokkaido, 1997).

RESPONSE OF GOVERNMENT ADMINISTRATION

Reacting to the eagle poisoning issue, the Hokkaido local government has regulated the use of lead rifle bullets for Sika Deer hunting since 2000. In addition, the government announced that hunters would be required to use non-toxic rifle bullets or shotgun slugs for Sika Deer hunting by winter of 2001. In 2003, the restriction against abandonment of shot game was announced. This regulation was put in force, not only to prevent eagle lead poisoning, but also to avoid attracting the Brown Bear. The regulation of lead rifle bullets and shotgun slugs for all big game hunting, including Brown Bear, started in the winter of 2004. Despite this, lead poisoning of eagles continues. Seven Steller's and three White-tailed Sea Eagles were victims of lead in winter 2004–2005. Moreover, one Steller's and two White-tailed Sea Eagles in winter 2005–06, and seven Steller's Sea-Eagles in winter 2006–07 were poisoned.

The lead bullet and slug restriction is limited to Hokkaido Island. Only the regulation of the use of lead shotgun pellets for waterfowl hunting is present as a legal restriction in certain limited areas elsewhere in Japan. Many hunters come from outside of Hokkaido every year. Under the condition of legality outside Hokkaido, it is difficult to verify that all "foreign" hunters change their bullets to non-toxic ones on Hokkaido Island.

When eagle lead poisoning began to appear as a serious problem, the local authority placed "garbage boxes" in the hunting fields and asked hunters to bring their game remains there as a way to decrease the amount of abandoned deer carcasses. The boxes were full on weekends or after holidays, and carcasses were occasionally stacked in piles on the roof of the garbage box. Despite this, the number of dead deer in the hunting field increased again because Sika Deer population control efforts continued after the hunting season, and the garbage boxes had been removed. Thus, disposal remained problematic. Also, after the regulation against the use of lead ammunition, the local authority discontinued the use of the garbage boxes. Because of this present situation, eagle lead poisoning still exists, and the government should try to ameliorate the situation.

The present restriction is a prohibition of "using" the lead bullets, but it does not limit sales or ownership of lead ammunition. In addition, it is difficult to catch an offender "red-handed." These factors will prolong the threat of lead poisoning. It is unrealistic to do perfect management for the resolution of the problem in the deep mountain areas during the severe winter period. However, if the police come frequently to the hunting field, collect deer tissue samples at bullet entry points, and examine for the presence of lead fragments, they will document the problem, and then the use of lead ammunition will certainly decrease.

A nationwide abolishment of all lead ammunition could solve the problem of raptor lead poisoning. It is extremely important to closely monitor the threats caused by spent lead from ammunition, not only in Hokkaido, but in all of Japan. It is expected that the elimination of this threat will be achieved most quickly by continued cooperation of government administrations, hunters, and other citizens.

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