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REVIEW PAPERS

WATERFOWL HUNTING IN THE CONTEXT OF LEAD CONTAMINATION AND ETHICALLY NON-CONFORMING CONDUCT

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Abstract

Projectiles made of lead alloys are used for waterfowl hunting in Europe. The paper demonstrated that lead pellets, due to their construction and use, contaminate the environment, especially water ecosystems. During one hunting session, tens of thousands of lead balls are introduced to the environment. Moreover, dispersed heavy metal is ingested by birds as gastroliths; as a result, game birds as well as protected birds become intoxicated with lead. During hunting trips, birds are also injured. When entering into the food chain, lead from pellets poses a risk to many living organisms, including predators and scavengers. Injured or intoxicated birds have difficulty joining seasonal migrations.

Meat, especially of wild ducks and geese, is consumed during the hunting season by hunters and their families. Considering the level of lead in the muscles of game birds, venison consumers are also exposed to lead intoxication. In Europe, an increasing number of hunters who use lead pellets has resulted in lead being accumulated in game birds, which is a hazard to the public health.

In view of the above facts and other hazards resulting from hunting, which endanger humans and animals, the authors recommend a total ban on waterfowl hunting.

Keywords: lead, lead intoxication, environment, hunting, waterfowl, public health, venison.

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INTRODUCTION

It has been shown that levels of elements and chemical compounds in tissues of game animals are dangerously high (Felsmann et al. 1999, 2001, Szarek et al. 2001, Babińska et al. 2008, Binkowski et al. 2013). Tissues of animals shot with lead pellets present a particular risk to humans (Mateo et al. 2011). The content of lead in the muscles of game birds is sometimes so high that these birds should not be consumed by humans. Considering the huge number of lead pellets fired during waterfowl hunting, it may be concluded that lead which they contain is the main source of contamination of local biocenoses with this element (Kendall et al. 1996, Felsmann et al. 1999, Henny et al. 2000, Brewer et al. 2003, Mateo et al. 2003, Mateo, Guitard 2003, Svanberg et al. 2006, Mateo et al. 2007, Babińska et al. 2008, Felsmann et al. 2010, Martinez-Haro et al. 2011, Sanderson et al. 2012, Binkowski et al. 2013, Mateo et al. 2014).

Moreover, it is hard to approve of the fact hunting certain duck species is allowed although they can be easily mistaken for protected species. However, the permission to do so is granted by law (*Regulation No 45*). The authors know cases of garganeys being shot when mistakenly taken for young mallards or cases of shooting such characteristic birds as shovelers.

Mallard as a popular game species

Mallard (*Anas platyrhynchos*) represents the most common bird from the *Anas* genus living in Europe (Bauer et al. 2005). In Poland, the species from this genus inhabit water reservoirs rich in nutrients (Książkiewicz 2006). Many birds are increasingly often overwintering in cities and adopting a sedentary mode of life (Książkiewicz 2006). Adult individuals weigh approximately 1 kg (up to 1.5 kg) with a wing span of about 1 m and a similar total length from the beak to the end of rectrices. These birds demonstrate distinct sexual dimorphism. The differences are most evident in plumage (especially during the reproduction season). The mallard, as a representative of Anatini, rarely dives and collects food from the surface of water or by immersing only the head and neck to ingest food from just beneath the surface; it also feeds on land. Due to the prevalence and nesting on areas that are easily accessible to humans, mallards are the most common target for hunters in many countries (Książkiewicz 2006).

Despite the regulations on avian protection, the European Union leaves the issues of hunting for local settling by the member states (*Directive …* 2009). The hunting season for mallards starts at the end of summer (mid-August in Poland) and lasts until the beginning of the following year (until the end of December in Poland) (Regulation No 48). In this time slot, it is difficult to distinguish young mallards by their body silhouette and size from adult individuals of different duck species (for instance, from garganeys and common teals).

Environmental pollution during waterfowl hunting

Pellets which are commonly used for duck hunting contain several hundred lead projectiles (Felsmann et al. 2010). As a result, thousands of new pellets made of very toxic metal are released to local biocenoses during each hunting session. Even if each shot hit the target, it would be irrelevant for environmental pollution as only a few projectiles are needed to shoot a bird. The number of pellets fired during hunting season (August – December) at a location inhabited by birds is too high to be accepted. The dispersion of lead that is introduced to the environment exacerbates the risk to living organisms (Kendall et al. 1996, Bouton, Pevsner 2000, Henny et al. 2000, Hoffman et al. 2000, Mateo et al. 2003, Mateo, Guitard 2003, Degernes 2006, Svanberg et al. 2006, Mateo et al. 2007, Felsmann et al. 2010, Martinez-Haro et al. 2011, Sanderson et al. 2012). The form of projectiles (minute balls) causes very slow release of lead, which occurs in the absence of natural processes that would facilitate its removal from the environment (Kendall et al. 1996). Lead pellets are deposited in bottom sediments of water reservoirs, whereas in soil they are moved slowly into deeper layers by gravity (Henny et al. 2000, Hoffman et al. 2000, Mateo, Guitard 2003, Martinez-Haro et al. 2011). In the aquatic environment, lead has easy access to the food chain (Kendall et al. 1996, Felsmann et al. 1999, Henny et al. 2000, Mateo, Guitard 2003, Degernes 2006, Svanberg et al. 2006, Mateo et al. 2007). In soil, this element stays in pellets for a very long time, leading to its high concentration in hunting areas (Kendall et al. 1996, Felsmann et al. 2010).

Lead pellets ingested as gastroliths are a serious risk to most avian species due to the physical properties of this metal (Kendall et al. 1996, Mateo et al. 2000, Mateo, Guitard 2003, Mateo et al. 2007). Birds do not have sensory capacities to let them distinguish pebbles (small pieces of rock) from lead pellets (Kendall et al. 1996, Mateo et al. 2000). The process of food grinding in the gizzard results in microscopic particles of this metal being removed from the surface of pellets. Lead is absorbed into the body as chemical compounds formed in the distal segments of the digestive tract (Daury et al. 1993, Kendall et al. 1996, Hoffman et al. 2000, Mateo et al. 2007, Binkowski et al. 2013).

The negative impact of lead on living organisms is widely known, especially its adverse effect on functions of the nervous system in higher animals (Hoffman et al. 2000).

The hazards associated with lead in pellets was noted several decades ago in the USA, where shooting of birds with toxic pellets was effectively eliminated (Brewer et al. 2003). In other countries, attempts are being undertaken to eliminate this hazard (Kendall et al. 1996, Mateo et al. 2001, Noer et al. 2007, Martinez-Haro et al. 2011, Mateo et al. 2014). It is worth mentioning that sight, which is a very important sense for many avian species, is impaired when the body is intoxicated with lead, and this can be life-threating to birds (Birrenkott et al. 2004).

The above facts constitute an important argument supporting a ban on waterfowl hunting.

Exposure of game birds to lead intoxication

The described mechanism leading to lead intoxication is intensified in game birds by wounds inflicted during hunts. Lead which penetrates into muscles, internal organs and underneath the skin reacts with compounds in the body fluids and is transported to tissues throughout the body, which results in the disturbed functioning of vital organs (Daury et al. 1993, Falk et al. 2006, Felsmann et al. 2010, Mateo et al. 2014).

Birds are shot when flying and such shots (from the underneath and side), even if not fatal, most often damage the muscles (mainly pectoral muscles) – Figure 1. When pellets are left in the largest muscles, which have

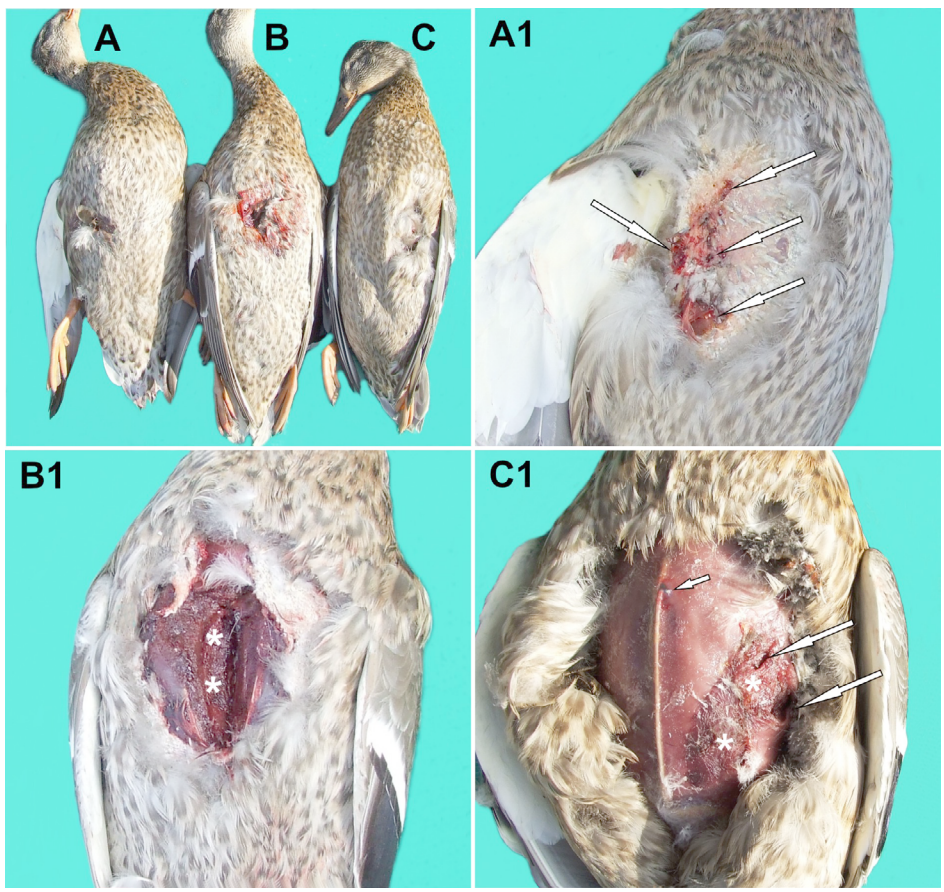

Fig. 1. Gunshot wounds in ducks located in relation to the direction of the shot: A – C; gunshot damage of the skin and the muscles in the same ducks visible after removal of feathers: A1 – C1; inlet wounds (long arrows), muscle damage (asterisks), lead pellet in muscles (short arrow), extensive skin rupture (B1, C1)

a rich blood supply, lead can quickly permeate into all tissues and organs. By injuring the muscles, lead pellets prevent birds from species-specific activity (Mateo et al. 2001, Cory-Slechta 2003 Falk et al. 2006, Madsen, Rigert 2007, Felsmann et al. 2010). The penetration of even a single pellets to body cavities presents a considerable danger (Mateo et al. 2001, 2007, Binkowski, Meissner 2013).

While analysing the above situation, it should be added that birds rapidly change the direction of flight, by moving relatively fast and effectively. Very few hunters can accurately aim and shoot flying birds. It should be emphasized that the recognition of an avian species does not in itself guarantee an accurate shot (Aglioti et al. 1995, Corballis et al. 1999). In the timeframe from a fraction of a second to a few seconds, a hunter has to synchronize the speed of a bird with the velocity of pellets and accurately position the barrel. A fast-moving target is shot at when this motion is taken into account. Aiming straight at a flying bird is the most common mistake and results in a missed (late) shot (Dehaene et al. 1998, Corballis et al. 1999). Firing an accurate shot requires aiming at the bird with a proper and always changing advance, which is difficult to predict as it depends on the direction into which a bird is moving (away from, towards or from the side of a hunter). In the light of these intricate factors, which influence effective shooting, it becomes clear that the skill of hitting a flying bird is rare (Aglioti et al. 1995, Noer et al. 2007).

Precise recognition of avian species often becomes impossible in poor light, especially during morning and evening hunts. Just the silhouette of a duck or a goose seen by a hunter does not allow a quick assessment of either the size of a bird or the distance to it. This results directly from the physiology of perception. An additional difficulty arises from vision deficits and an imperfect ethical conduct among hunters. Moreover, psychologists and neurologists have proven that the perception of an individual is not only a result of the transposition of visual stimuli, but is also modulated by other factors (Aglioti et al. 1995, Dehaene et al. 1998, Corballis et al. 1999, Striedter 2006). These factors include previous experiences of a hunter, their current knowledge as well as the perception of stimuli in specific situations. Emotions associated with hunting and the willingness to shoot and collect a specific game animal are the other factors that impact the way hunters react (Aglioti et al. 1995, Dehaene et al. 1998).

Pellets, as intended by constructors, were designed to hurl many small projectiles which, after leaving a barrel, form a cone with the peak directed towards the opening of the barrel (Szyrkowiec 1988). Considering the type of a barrel opening in shotguns, an accurate shot can be only fired from a distance of 20 to 25 metres. Further than that, the base of the cone is approximately 1 mm in diameter (Szyrkowiec 1988). This property of pellet guns, together with objective difficulties in firing accurate shots, results in the majority of shots being ineffective. However, some pellets may injure birds that are targeted as well as other birds flying in flocks which are not

shot at. In some countries, these properties of shotguns are taken into account, which is reflected in legal regulations on hunting (Noer et al. 2007).

The performed analysis demonstrates that the above way of hunting inflicts injuries in many birds (Daury et al. 1993, Falk et al. 2006, Madsen, Rigert 2007, Felsmann et al. 2010, Mateo et al. 2014). Injured birds have difficulty moving, which prevents or hinders their spring and autumn migration (Kendall et al. 1996, Falk et al. 2006, Madsen, Rigert 2007, Mateo et al. 2007). Even with minor injuries, lead in pellets causes intoxication and the dysfunctions associated with intoxication may be manifested in a time period distant from the inflicted injury (Kendall et al. 1996, Hoffman et al. 2000, Mateo et al. 2001, Falk et al. 2006, Mateo et al. 2007). This relatively common phenomenon justifies the call for cessation of waterfowl hunting.

The described hazards from lead also apply to predators and scavengers which consume injured or dead birds (Kendall et al. 1996, Mateo et al. 2001, 2003, Birrenkott et al. 2004, Babińska et al. 2008).

Exposure of humans to consumption of avian meat contaminated with lead

During a hunting season, consumption of game bird meat is high, especially among hunters' families (Mateo et al. 2001, Ahamed, Siddiqui 2007, Mateo et al. 2011, 2014). The mass of breast muscles constitutes the major part of the total muscle bulk and is the largest portion of birds' meat which is consumed. The method of hunting mallards described herein results in each bird being hit with pellets in the breast muscles (Mateo et al. 2011, 2014) – Figure 1. Consequently, the breast muscles accumulate the highest level of lead (Ahamed, Siddiqui 2007, Mateo et al. 2011, 2014). According to many studies, the level of lead in the internal organs and muscles of mallards is so high that it presents a risk to humans who consume this variety of meat (Binkowski, Meissner 2013, Daury et al. 1993, Mateo et al. 2011, 2014). In accordance with the European food law, permissible lead levels in meat destined for consumption are clearly lower than those detected in mallards (*European Commission Regulation …* 2006, Mateo et al. 2014). Furthermore, lead concentration is the highest near the channel of a shot wound (Mateo et al. 2011). Traditionally, venison consumption does not require excising the elements damaged by pellets from the muscles and it is not practiced to remove pellets themselves (Mateo et al. 2011, 2014).

Consumption of food with a substantial level of lead is unhealthy. This is also an incomprehensible violation of the rules on food and nutrition safety adopted in the European Union. The preamble to the food law contains provisions pertaining to the need to protect human health and life by eliminating dangerous factors from food while adhering to scientific evidence (*European Commission Regulation* 2006, Kasperczyk et al. 2013). Studies on the content of lead in the internal organs and tissues of game birds have been conducted in many countries and their results confirm that everywhere the

levels of elements and chemical compounds are higher than the ones permitted by the food law (Table 1). Despite this, the cited hazards are overlooked, allowing bird hunting together with the consent for game meat consumption.

Table 1

Concentration of Pb in edible tissue of water game birds published by various authors

No.	Age of birds	Concentrations of Pb in birds tissue (mg kg^{-1} wet mass)				Author
		muscle		liver		
		average	maximum level	average	maximum level	
Mallard (*Anas platyrhynchos)*						
1	I			**~ 0.03**	< 2	Binkowski et al. (2013)
	A			**~ 0.03**	< 1	
2	I	0.122	0.283	**0.155**	**0.441**	Szymczyk, Zalewski (2003)
	A	0.154	0.209	**0.417**	0.892	
3	A+I			**~ 0.11**	**~ 0.49**	Florijančić et al. (2009)
4	A+	**~ 0.02**	~ 10.7	**~ 0.3**	~ 53	Mateo et al. (2014)
Tufted duck (*Aythya fuligula*)						
5	I	**0.036**	**0.069**	**0.165**	**0.300**	Szymczyk, Zalewski (2003)
	A	**0.042**	**0.051**	**0.139**	**0.291**	
6	A+I			**0.17**	**0.17**	Mateo et al. (2014)
Common pochard (*Aythya ferina*)						
7	A+I	0.11	0.49	**0.42**	6.9	Mateo et al. (2014)
Garganey (*Spatula querquedula*)						
8	I	0.246	0.285	**0.476**	0.521	Szymczyk, Zalewski (2003)
Common teal (*Anas crecca*)						
9	A+I	**0.05**	15.5	**0.02**	6.1	Mateo et al. (2014)
Coot (*Fulica atra*)						
10	I			**~ 0.3**	< 2.3	Binkowski et al. (2013)
	A			**~ 0.3**	< 7.9	
11	I			**0.0932**	**0.15**	Felsmann et al. (1999)
12	A+I	**0.01**	130	**0.12**	0.66	Mateo et al. (2014)
Canada geese (*Branta canadensis*)						
13	A+I	**0.060**		**0.376**		Tsipoura et al. (2011)

I – immature birds; A – adult birds; **bold text** – level accepted by UE food law (European Commission Regulation 2006).

In addition, the number of shot birds does not have any economical importance and, at the same time, is so high that it creates a risk to public health. In Poland, where the percentage of hunters in the total population is one of the lowest in Europe, there are approximately 120,000 hunters. Considering the fact that a hunter's family is composed of 3 to 5 members, this constitutes about 400,000 -500,000 people, namely 1% of the population, whereas this percentage is much higher in other European countries (Internet 1).

It should be emphasized that lead is not the only xenobiotic detected in game birds' tissues and organs. In individual specimens, the levels of cadmium, mercury, pesticides and chemical substances generated by different branches of the economy are very high (Felsmann et al. 2001, Szarek et al. 2001, Mateo, Guitard 2003, Babińska et al. 2008, Binkowski et al. 2013).

Adhering to the doctrine of human health protection, especially by means of establishing the food law, consumption of game bird meat should be forbidden. This can be achieved in practice only by the ban on hunting for this avian species.

Exposure of game birds to startling in their habitats and reduction of habitat areas

In Poland**,** waterfowl hunting starts around 15th of August. Depending on atmospheric conditions, young individuals hatched in a given year are at different stages of development. In some years, they may be insufficiently developed to fly skilfully (personal observations). Hunts organized in this season result in birds being startled and forced to fly in less safe locations. In some hunting grounds, individuals may be startled several times on the same day. Stress experienced by birds, especially by young individuals, obviously has a negative impact on their health (Colwell et al. 1988, Spraker 1993, Klaassen et al. 2012). Startled birds are forced to spread wing rapidly, to quickly gain height and to fly away from their habitat. Sudden movements performed at the maximum tension of the muscles with the maximum load on the joints and tendons result in damage to these anatomical structures (Colwell et al. 1988, Spraker 1993, Felsmann et al. 2010). Startled birds do not return at once or do not come back to their habitats at all (Evans, Day 2001, Madsen 2001, Bregnballe, Madsen 2004, Bregnballe at al. 2004). In mid-August, the muscular and articular systems as well as tendons in young mallards are not fully developed (Spraker 1993). Injuries, depending on their degree and extension, are present as dysfunctions (Colwell et al. 1988, Spraker 1993). Considering the necessity of undertaking autumn migration (the first one for young birds), it should be emphasized that each injury to the locomotor system presents a direct risk to life during migration (Colwell et al. 1988, Spraker 1993).

In addition, permission for hunting mallards from mid-August does not include other animal species that live in the same or nearby habitats. Hunts startle these animals with consequences that are at least similar to the those which threaten game birds (Colwell et al. 1988, Spraker 1993).

The habitat areas of many animal species are shrinking due to human activities and climatic changes. For waterfowl, it is not only the repossessing of their habitats by humans that matters, but it is also other human activities that lead to transformations of these habitats, for example, land drying (Binkowski, Meissner 2013, Gill et al. 2001, Evans, Day 2001, Davis et al. 2011, Link et al. 2011).

CONCLUSIONS

The current state of knowledge indicates that waterfowl hunting is now an anachronism and an unjustified human activity in Europe:

1. Waterfowl hunts result in a substantial accumulation of lead in the environment, which causes risks to living organisms and the dispersed form of lead pellets exacerbates the risk.

2. The level of lead in the muscles of game birds is often higher than that permitted in food products by the food law. Considering the number of consumers (hunters and their families), consumption of these birds presents a risk to public health;

3. Establishing the protective status only for some waterfowl species does not protect them from being killed or injured during hunts. This fact does not always result from ill will of hunters;

4. The starting point of hunting in mid-August together with the highest intensity of hunts in this month forces birds to fly from their habitat sites. Hunts result in injuries to the locomotor system, especially in young individuals.

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REFERENCES

Aglioti S., DeSouza J.F.X., Goodale M.A. 1995. *Size-contrast illusions deceive the eye but not the hand*. Curr. Biol., 5: 679-685.

Ahamed M., Siddiqui M.K.J. 2007. *Environmental lead toxicity and nutritional factors*. Clin. Nutr., 26: 400-408.

Babińska I., Szarek J., Binkowski Ł.J., Skibniewska K., Wojtacka J., Markiewicz E, Felsmann, M.Z., Zakrzewska M., Gesek M., Dublan K. 2008. *Grey herons (Ardea cinerea* L.*) as a tool for monitoring the environment for metal concentrations in the vicinity of a pesticide tomb in the Iławskie Lake District*. Fresen. Environ. Bull., 17(1): 98-102.

Bauer H-G., Bezzel E., Fiedler W. 2005. *Das Kompendium der Vögel Mitteleuropas*, *Alles über Biologie, Gefährdung und Schutz*. Aula-Verlag. Wiebelsheim. (in German)

Binkowski Ł.J., Meissner W. 2013. *Levels of metals in blood samples from mallards (Anas platyrhynchos) from urban areas in Poland*. Environ. Pollut., 178: 336-342.

Binkowski Ł.J., Sawicka-Kapusta K., Szarek J., Strzyżewska E., Felsmann M.Z. 2013. *Histopathology of liver and kidney of wild living Mallards Anas platyrhynchos and Coots Fulica atra with considerably concentrations of lead and cadmium*. Sci. Total. Environ., 450-451: 326-333.

Birrenkott A.H., Wilde S.B., Hains J.J., Fischer J.R., Murphy T.M., Hope C.P. Parnell P.G. Bowerman W.W. 2004. *Establishing a food-chain link between aquatic plant material and avian vacuolary myelinopathy in mallard (Anas platyrhynchos)*. J. Wildl. Dis., 40(3): 485-492.

Bouton C.M. Pevsner J., 2000. *Effects of lead on gene expression*. Neurotoxicology, 21: 1045-1055.

Bregnballe T., Madsen J., Rasmussen P.A.F. 2004. *Effects of temporal and spatial hunting control in waterbird reserves*. Biol. Conserv., 119: 93-104.

Brewer L., Fairbrather A., Clark J., Amick D. 2003. *Acute toxicity of lead, steel, and an iron-tungsten-nickel shot to mallard dicks (Anas platyrhynchos)*. J. Wild. Dis., 39(3): 638-648.

Colwell M.A., Gratto C.L., Oring L.W., Fivizzani A.J. 1988. *Effects of blood sampling on shorebirds: injuries, return rates, and clutch desertions*. Condor, 90: 942-945.

Corballis P.M., Fendrich R., Shapley R.M., Gazzaniga M.S. 1999. *Illusory contour perception and a modal boundary completion: evidence of a dissociation following callosotomy*. J. Cognitive Neurosci., 11(4): 459-466.

Cory-Slechta D.A., 2003. *Lead-induced impairments in complex cognitive function: offerings from experimental studies*. Child Neuropsychol., 9: 54-75.

Davis B.E., Afton A.D., Cox R.R. Jr. 2011. *Factors affecting winter survival of female Mallards in the Lower Mississippi Alluvial Valley*. Waterbirds, 34(2): 186-194.

Daury R.W., Schwab F.E., Bateman M.C. 1993. *Blood lead concentrations of waterfowl from unhunted and heavily hunted marshes of Nova Scotia and Prince Edward Island, Canada*. J. Wildl. Dis., 29(4): 577-581.

Degernes L., Heilman S., Trogdon M., Jordan M., Davison M., Kraege D., Correa M., Cowen P. 2006. *Epidemiologic investigation of lead poisoning in trumpeter and tundra swans in Washington state, USA, 2000-2002*. J. Wildl. Dis., 42(2): 345-358.

Dehaene S., Naccache L., Le Clec' H.G., Koechlin E., Mueller M., Dehaene-Lambertz G., van de Moortele P-F., Le Bihan D. 1998. *Imaging unconscious semantic priming*. Nature, 395(8): 597-600.

Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds. DOI: 10.3000/17252555.L_2010.020.eng

European Commission. Regulation (EC) No 1881/2006 of 19 December 2006 on eating maximum levels for certain contaminants in foodstuffs. Off. J. Eur. Union, 20.12.2006 L364/5-L364/24; 2006.

Evans D.M., Day K.R. 2001. *Does shooting disturbance affect diving ducks wintering on large shallow lakes? A case study on Lough Neagh, Northern Ireland*. Biol. Conserv., 98: 315-323.

Falk K., Merkel F., Kampp K., Jamieson S.E. 2006. *Embedded lead shot and infliction rates in common eiders Somateria mollissima and king eiders S. spectabilis wintering in southwest Greenland*. Wildl. Biol., 12(3): 257-265. DOI: http://dx.doi.org/10.2981/0909-6396(2006)12[257:ELSAIR]2.0.CO;2

Felsmann M.Z., Skibniewska K., Szarek J., Gesek M. 2010. *Morphological pattern of internal organs in mallard ducks (Anas platyrhynchos* L.*) from an intensive hunting area*. Fresen. Environ. Bull., 19(2a): 322-326.

Felsmann M.Z., Szarek J., Markiewicz K. 1999. *Lead content in young coots (Fulica atra) nesting in the area of Bydgoszcz and Żnin*. Biul. Magnezol., 4(2): 318-321. (in Polish)

Felsmann M.Z., Szarek J., Markiewicz K., Felsmann M., Przeździecka D. 2001. *Cadmium con-*

centration in the liver of young mallards (Anas platyrhynchos) depending on their nesting place. Biul. Magnezol., 6(2): 143-149. (in Polish)

Florijančić T., Opačak A., Bošković I., Jelkić D., Ozimec S., Bogdanović T., Listeš I., Škrivanko M., Puškadija Z. 2009. *Heavy metal concentrations in the liver of two wild duck species: influence of species and gender*. Ital. J. Anim. Sci., 8(3s): 222-224. DOI: 10.4081/ijas.2009.s.3.222

Gill J.A., Norris K., Sutherland W.J. 2001. *Why behavioural responses may not reflect the population consequences of human disturbance*. Biol. Conserv., 97: 265-268.

Henny J.C., Blus L.J., Hoffman D.J. Sileo L., Audet D.J., Snyder M.R. 2000. *Field evaluation of lead effects on Canada geese and Mallards in the Coeur d'Alene River Basin, Idaho*. Arch. Environ. Contam. Toxicol., 39: 97-112.

Hoffman D.J., Heinz G.H.,Sileo L., Audet D.J., Campbell J.K., LeCaptain L.J. 2000. *Developmental toxicity of lead-contaminated sediment to mallard ducklings*. Arch. Environ. Contam. Toxicol., 39: 221-232.

Internet 1. http://www.face.eu

Kasperczyk S., Błaszczyk I., Dobrakowski M., Romuk E., Kapka-Skrzypczak L., Adamek M., Birkner E. 2013. *Exposure to lead affects male biothiols metabolism*. Ann. Agric. Environ. Med., 20(4): 721-725.

Kendall R.J., Lacher T.E. Jr., Bunck C., Daniel B., Driver C., Grue C.E, Leighton F., Stansley W. 1996. *An ecological risk assessment of lead shot exposure in non-waterfowl avian species: upland game birds and raptors*. Environ. Toxicol. Chem., 15(1): 4-20.

Klaassen M., Hoye B.J., Nolet B.A., Buttemer W. 2012. *Ecophysiology of avian migration in the face of current global hazards*. Phil. Trans. R. Soc. B., 367:1719-1732.

Książkiewicz J. 2006. *A mallard duck – Anas platyrhynchos* L.*, means a flat-billed duck*. Wiad. Zoot., 1: 25-30. (in Polish)

Link P.T., Afton A.D., Cox R.R. Jr., Davis B.E. 2011. *Use of habitats by female Mallards wintering in Southwestern Louisiana*. Waterbirds, 34(4): 429-438.

Madsen J. 2001. *Can geese adjust their clocks? Effects of diurnal regulation of goose shooting*. Wildl. Biol., 7: 213-222.

Martinez-Haro M., Taggart M.A., Martín-Doimeadiós R.R.C., Green A.J., Mateo R. 2011. *Identifying sources of Pb exposure in waterbirds and effects on porphyrin metabolism using noninvasive fecal sampling*. Environ. Sci. Technol., 45: 6153-6159. DOI: org/10.1021/es2009242

Mateo R., Taggart M.A, Meharg A.A. 2003. *Lead and arsenic in bones of birds of prey from Spain*. Environ. Pollut., 126: 107-114.

Mateo R., Guitard R., Green J. 2000. *Determinants of lead shot, rice, and grit ingestion in dicks and coots*. J. Wildl. Manag., 64(4): 939-947.

Mateo R., Baos A.R., Vidal D., Camarero P.R., Martinez-Haro M. et al. 2011. *Bioaccessibility of Pb from ammunition in game meat is affected by cooking*. Treatment. PLoS ONE 6(1): e15892. DOI: 10.1371/journal.pone.0015892

Mateo R., Vallverdú-Coll N., López-Antia A., Taggart M.A, Martínez-Haro M., Guitard R., Ortiz-Santaliestra M.E. 2014. *Reducing Pb poisoning in birds and Pb exposure in game meat consumers: The dual benefit of effective Pb shot regulation*. Environ. Int., 63: 163-168.

Mateo R., Green J., Jeske C.W., Urios V., Gerique C. 2001. *Lead poisoning in the globally threatened marbled teal and white-headed duck in Spain*. Environ. Toxicol. Chem., 20(12): 2860-2868.

Mateo R., Green J., Lefranc H., Baos R, Figuerola J. 2007. *Lead poisoning in wild birds from southern Spain: A comparative study of wetland areas and species affected, and trends over time*. Ecotox. Environ. Safe., 66: 119-126.

Mateo R., Guitard R., 2003. *Heavy metals in livers of waterbirds from Spain*. Arch. Environ. Contam. Toxicol., 44: 398-404.

MADSEN J., RIGERT F. 2007. *Do embedded shotgun pellets have a chronic effect on body condition of pink-footed geese?* J. Wildl. Manag., 71(5): 1427-1430. DOI: dx.doi.org/10.2193/2006-108

NOER H., MADSEN J., HARTMANN P. 2007. *Reducing wounding of game by shotgun hunting: effects of a Danish action plan on pink-footed geese*. J. Appl. Ecol., 44: 653-662. DOI: 10.1111/j.1365-2664.2007.01293.x

Regulation No 45 item 433. Ministry of the Environment Regulation defining the list of species of wild game. Journal of Law 2005. (in Polish)

Regulation No 48 item 459. Ministry of the Environment Regulation on determining the hunting seasons for game animals. Journal of Law 2005. (in Polish)

SANDERSON S., NAIDU R., BOLAN N., MCLURE S. 2012. *Effect of soil type on distribution and bioaccessibility of metal contaminants in shooting range soils*. Sci. Total. Environ., 438: 452-462.

SPRAKER T.R. 1993. S*tress and capture myopathy in artiodactylids*. In: *Zoo and wild animal medicine: Current therapy*. FOWLER M.E. (eds)., W.B. Saunders Company, III ed. 481-488.

STRIEDTER G.F. 2006. *Précis of principles of brain evolution*. Behav. Brain. Sci., 29: 1-36.

SVANBERG F., MATEO R., HILLSTRÖM L., GREEN A.J., TAGGART M., RAAB A., MEHARG A.A. 2006. *Lead isotopes and lead shot ingestion in the globally threatened marbled teal (Marmaronetta angustirostris) and white-headed duck (Oxyura leucocephala)*. Sci. Total Environ., 370: 416-424.

SZAREK J., FELSMANN M.Z., MARKIEWICZ K., MARKIEWICZ E., FELSMANN M. 2001. *Cadmium levels in young coots originating from industrial and agricultural regions of North-Middle Poland*. Pol. J. Environ. Stud., 10(6): 489-491.

SZYMCZYK K., ZALEWSKI K. 2003. *Copper, zinc, lead and cadmium content in liver and muscles of mallards (Anas platyrhychnos) and other hunting fowl species in Warmia and Mazury in 1999-2000*. Pol. J. Environ. Stud., 12(3): 381-386.

SZYRKOWIEC A. 1988. *Hunting firearm*. Wyd. MON, Warszawa, Polska. (in Polish)

TSIPOURA N., BURGER J., NEWHOUSE M., JEITNER C., GOCHFELD M., MIZRAHI D. 2011. *Lead, mercury, cadmium, chromium, and arsenic levels in eggs, feathers, and tissues of Canada geese of the New Jersey Meadowlands*. Environ. Res., 111: 775-784.