Human Health and Ecological Risk Assessment

for the Use of Wildlife Damage Management Methods

by APHIS-Wildlife Services

Chapter XXXIII

THE USE OF LASERS IN WILDLIFE DAMAGE MANAGEMENT

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EXECUTIVE SUMMARY

Select classes of lasers provide effective, non-lethal and environmentally sound tools used in integrated, wildlife damage management to mitigate the impacts of animals causing damage, especially avian species. With proper training, WS employees are effective and efficient at using lasers to focus their efforts on specific target animals and can use these methods at low risk to human safety and to the environment. WS annually averaged 1,898 work tasks associated with the use of Class 2-3b lasers (see laser Table 1, below) from FY16-20. Of these work tasks, 99% were to disperse or herd birds, primarily Canada geese (39%), European starlings (17%), American crows (13%), and rock doves (8%). Projects involving the use of these devices (hereafter, “lasers”) were conducted primarily to protect health and human safety and agricultural resources.

The Animal and Plant Health Inspection Service (APHIS) evaluated the potential human health and environmental risks from WS’ proposed use of lasers and determined that the risks to human health and the environment are negligible. Risks to workers are low based on WS personnel being trained in the proper use of lasers in accordance with WS Directive 2.470. Risks to the general population are negligible because site selection and timing of activities minimize exposure to the public, and the fact that WS personnel will typically be present at the site during laser operations. Lasers are used to disperse or direct the movement of animals and are not methods that would contaminate water or result in the bioaccumulation of chemicals or other hazardous materials. Environmental hazards associated with lasers generally are limited to the unintentional injury of target and nontarget species. Training WS staff in the use of lasers for animal dispersal reduces the risks of injury to target and nontarget species. Risks are negligible for nontarget fish and wildlife based on how WS uses lasers. WS personnel have been effective in using lasers and no personnel have been injured nor have accidents or incidents involving aircraft or other property occurred because of the use of lasers. No nontarget species have been documented to be harmed by WS use of lasers. Thus, WS concludes that the use of lasers is of low risk to WS personnel, the public, nontarget species, and the environment.

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GLOSSARY OF TERMS AND ABBREVIATIONS

Attenuation The decrease in the power or energy of a laser as it passes through an absorbing or scattering medium (e.g., atmosphere).

Beam A collection of light and photonic rays characterized by direction, diameter (or dimensions), and divergence (or convergence).

Beam Size/Diameter One of the elements used to describe a given laser beam; generally expressed in millimeters. Due to divergence, the beam diameter may not correlate to the actual spot size seen on the ground.

Blink Reflex Also called the corneal reflex, is the involuntary reflex of the eyelids (or blinking) caused by stimulation of the cornea (such as by touching or by a foreign body), or in this case a bright light. The reflex is rapid; generally taken as less than 0.1 second.

Diffuse Reflection Change in the spatial distribution of a beam of radiation when it is reflected in many directions by a surface or by a medium.

Divergence The increase in the diameter of the laser beam with distance from the exit aperture.

Intrabeam Viewing All viewing conditions whereby the eye is exposed to the direct or specularly reflected laser beam, in contrast, for example, to viewing of diffuse reflections.

Laser **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation; a device that produces radiant energy predominantly by stimulated emission.

Laser Safety Officer (LSO) Individual appointed by WS National Wildlife Research Center Project Leader or WS State Director who is familiar with laser technology, safety, and training. Roles include selection of appropriate lasers, acquisition, and training.

Maximum Permissible Exposure (MPE) the level of laser radiation to which a person may be exposed without hazardous effects or adverse biological change in the eye or skin.

Nominal Hazard Zone (NHZ) A three-dimensional volume of airspace where the level of direct, reflected, or scattered radiation during normal operation exceeds the applicable MPE.

Nominal Ocular Hazard Distance (NOHD) The distance along the axis of the laser beam beyond which the appropriate MPE is not exceeded (i.e., an indication of the “safe viewing distance”).

1 INTRODUCTION

A type of nonchemical wildlife damage method not covered in previous risk assessments is the use of lasers in wildlife damage management (WDM). Lasers are used by the USDA, Animal and Plant Health Inspection Service (APHIS), Wildlife Services (WS) Program to deter or repel animals that cause damage to agricultural and natural resources, and property (e.g., machinery/equipment, non-residential buildings) and to disperse birds from areas where they might be exposed to hazardous conditions (i.e., oil/chemical spills) or pose a hazard to human health and safety (e.g., airports, urban roosts). Lasers are also used to direct the movement of birds from a distance to increase capture efficacy (e.g., geese roundups). Most lasers used by WS in WDM are handheld, but automated systems to disperse birds over large areas, such as crop fields are available. Some typical target species of lasers include vultures, crows, gulls, geese, starlings, and blackbirds.

WS selects lasers for use in bird dispersal based on the following attributes: class/power of laser, color/wavelength (color as perceived by humans), ability to operate in various light and distance conditions, structure/shape, effectiveness for species targeted, company reputability, source, and cost (USDA Wildlife Services 2020). The laser should also have the required labeling and safety mechanisms per the WS Directive[1] (2.470). The types of lasers used include handheld, pointer, or rifle-stock mounted lasers of Class 2, 3R, and 3B[2]. These laser classes include devices of four colors/wavelengths: blue (450-495 nm), green (495-570 nm), green (620-750 nm), and red (620-750 nm). In terms of numbers of individuals, crows (48%) and European starlings (40%) were the primary species dispersed by WS from FY16-FY20. Mammals were also involved in dispersal projects, with only 1% of the total number dispersed.

This human health and ecological risk assessment provides a qualitative evaluation of the potential risks and hazards to human health, wildlife, and the environment due to using lasers to disperse wildlife in targeted areas or to assist in the capture of wildlife in targeted areas. The methods used in this risk assessment follow standard regulatory guidance and methodologies and generally conform to other Federal agencies such as the US Environmental Protection Agency (USEPA) (National Research Council 1983, USEPA 2022).

2 LASERS

2.1 Description

A laser (Light Amplification by Stimulated Emission of Radiation) device produces radiant energy predominantly by stimulated emission (ANSI Z136.1 2022). A basic type of laser consists of a sealed tube containing a pair of mirrors and a laser medium that is excited by some form of energy to produce visible light or invisible ultraviolet (to most humans, but variable across wildlife species) or infrared radiation. Ambient light is made up of different wavelengths or colors (as perceived by humans), where wavelengths are characterized by photons in wave form, but differing in energy and distance between wave peaks. In a laser beam, the wavelength-specific light is coherent or collimated, meaning that the beam is moving as parallel rays, and therefore will spread minimally as it travels. The physics associated with the laser beam allow a sharp focus over distance (FDA 2023, Lawrence Livermore National Laboratory 2024).

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[1]WS Directives referenced in this document are found @ https://www.aphis.usda.gov/wildlife-services/directives
[2] Class 4 lasers may also have been used during FY16-20 but are no longer in use.

Laser classification indicates the beam hazard level to humans during normal operation (i.e., the capability of the laser to cause eye injury). The hazard level of a laser or laser system is represented by a number or numbered capital letter. The laser classifications are Class 1, 1M, 2, 2M, 3R, 3B, and 4 (ANSI Z136.1 2022) (Table 1).

Table 1. Laser classification, power, and product examples.

Class	Laser Power	Product Examples
1, 1M	<0.39 milliwatts	Laser printer, CD player, DVD player
2, 2M	<0.99 milliwatts	Bar code scanner
3R	Between 1 and 4.99 milliwatts	Laser pointer
3B	Between 5 and 499.9 milliwatts	Laser light show projector, industrial or research laser
4	>500 milliwatts	Laser light show projector, industrial or research laser, medical device laser for eye surgery or skin treatment

2.1.1 Intrabeam Viewing

Intrabeam viewing is the exposure of the eye to the laser beam through either direct viewing or specular reflections. Specular reflections occur relative to certain surfaces, such as mirrors, water, certain construction materials (e.g., polished metals), and coated materials intended to reflect light. The surface can redirect the beam, leaving the properties of the laser beam intact. Whereas in diffuse reflections the beam is scattered. The scattering causes the intensity or energy per unit area of the beam to be decreased and the potential, incident irradiance on the eye to be lower (Lynga and Urban 2017). The blink reflex (natural aversion of the eye to bright light can also limit intrabeam exposure to a safe level for lasers of Class 2 or lower.

2.1.2 Maximum Permissible Exposure

The Maximum Permissible Exposure (MPE) is defined as the level of laser radiation to which a person might be exposed without hazardous effects or adverse biological change in the eye or skin (ANSI Z136.1 2022) The MPE is primarily a function of laser wavelength and duration of exposure, and will also vary based on laser type (pulsed vs. continuous wave). Generally, the eye-safe exposure limits are lower than skin exposure limits. Once the MPE has been determined for a laser, it can be used along with the output parameters, such as power and divergence or beam spread, to determine eye and skin hazard distances.

In the ANSI standard, the eye hazard distance is referred to as the nominal ocular hazard distance (NOHD). The NOHD is defined as the distance along the axis of the unobstructed laser beam to the human eye where exposure is not expected to exceed the appropriate MPE (ANSI Z136.1 2022).

2.1.3 Attenuation and Laser Scattering Effects

Attenuation of a laser beam is the decrease in the power or energy of a laser as it passes through an absorbing or scattering medium. Attenuation is dependent on the laser wavelength and atmospheric quantities, such as visibility, aerosol density, and smoke (ANSI Z136.6 2015). The laser beam is often broadened and defocused and might be deflected from its initial broadcast direction (USAF 2006).

In general, a laser beam is attenuated as it travels through the atmosphere. The attenuation and alteration depend upon the wavelength of the laser, power output, and general atmospheric conditions. Laser light can be scattered forward and backward during attenuation, with relatively little of the light scattered laterally (USAF 2006).

Three types of atmospheric scattering occur:

a. Rayleigh Scattering is the cause behind human perception of a blue sky. Shorter wavelengths (e.g., within the blue region of the spectrum) are scattered around 10 times more by oxygen and nitrogen molecules than the longer red wavelengths or other colors visible to the human eye.
b. Nonselective scattering results from the impact of light with large particles such as fog, clouds, rain, or snow.
c. Mie scattering is caused by the presence of aerosol particles and small water droplets.

The scattering effects of the laser beam can be managed from a health and safety perspective by designating NHZs for each beam generated. The NHZ for a laser system is the area in which the laser beam that can be pointed in any direction with no obstruction closer than the applicable NOHD. The NHZ is represented as a three-dimensional sphere with a radius equal to the NOHD. At any point inside the sphere, exposures would be above the applicable MPE. During wildlife dispersal, the NHZ would be represented by a hemisphere or dome extending out into free space above the treatment area to an altitude equal to the applicable NOHD. As such, the laser operator should not point the beam upwards, absent an impenetrable barrier. The ground would serve as the impermeable floor of the dome. Atmospheric attenuation has little effect on NOHDs shorter than 1093 yds (1000 m) or on upwardly directed beams (ANSI Z136.6 2015).

2.2 Types of lasers used in Wildlife Damage Management

Lasers for use in wildlife damage management and/or capture assistance generally fall into one of two types; hand-held/portable (Figure 1) and fixed/automated (Figure 2). The advantage of handheld lasers is in their design; they can be used at any appropriate location and relocated as easily as the operator needs. These devices are relatively small. Disadvantages include the need for an operator, and if a large number of wildlife are to be dispersed, the need for multiple devices.

Fixed or automated lasers designed for use in wildlife damage management are bulky, box-like devices. They have a base or plate to allow them to be secured to a surface and can move through several axes. Fixed or automated lasers do not require personnel on-site to operate them, which can be an advantage and disadvantage. Extreme caution must be used in placing these devices and in developing procedures for activating and deactivating them.

Figure 1. Example of a hand-held/portable laser for bird dispersal. The Agrilaser Handheld 500 is a Class 3B, 532 nm green laser.

Figure 2. Example of a fixed/automated laser for bird dispersal. The Avix automated laser bird repelling system is a Class IIIB, 532 nm laser.

2.3 Product Use

Lasers can be used as an alternative to or in combination with other types of nonchemical deterrents, such as pyrotechnics, shotguns, and propane cannons for dispersing birds from areas where they might be damaging resources and/or property, might be exposed to hazardous conditions (i.e., oil/chemical spills, airports) or might pose a hazard to human health and safety (e.g., airports). Different from other types of nonchemical deterrents, lasers may also be used to direct the movement of birds from a distance to increase capture efficacy. Due to the lower power levels, directionality, accuracy of distance, and silence of laser devices, they are often a safe and effective species-specific alternative to other traditional dispersal tools.

Research on the use of lasers in wildlife management began in the 1970s (Lustick 1972;1973). Initially tested with European starlings, mallards, and gulls, Lustick (1972) found that all three species showed group avoidance response to a concentrated laser beam (454-514 nm, ≥500mW) that produced radiant energy exceeding MPE levels for animals and humans (ANSI Z136.1 2022). In these experiments, bird reactions were due to beam energy, not visual detection and response to a novel, perceived threat. Research on many avian species and situations has now been conducted with lasers that pose less risk of eye damage to animals or humans (Table 2). Few research studies have shown the successful use of lasers for deterring mammals.

Relatively low-power, mid- to long-wavelength lasers provide an effective means of dispersing some bird species under low-light conditions. The visual deterrent effect of a laser is associated with some degree of detection, possibly novelty of the stimulus, as well as dynamics of the beam when the device is moved by the applicator. The best results are typically achieved during low-light conditions (i.e., sunset through dawn) and targeting structures or trees close to roosting birds, reflecting the beam on foliage or other surfaces (APHIS WS 2003). Response by birds could be a startle reaction to the moving beam or beam spot presented on the structures, as well as escape. Research, however, has shown that the effectiveness of low-powered lasers varies depending on the bird species, the context of the application, and contrast of the beam to ambient conditions (APHIS WS 2002). Class 3B and 4 lasers are sometimes used under relatively high ambient light conditions due to the higher power laser providing greater beam contrast than with Class 3R or lower-class lasers (but, see Section 4, below)

Table 2. Studies of laser use with wildlife identifying the species, use type, and laser color.

Species	Use	Laser Color	Reference
Vultures	Roost Dispersal	Red	(Avery et al. 2006)
American Crows	Roost Dispersal	Red	(Gorenzel et al. 2002)
American Crows	Roost Dispersal	Red	(Chipman et al. 2008)
Rooks	Roost Dispersal	Green	(Matsyura 2018)
Red-winged Blackbirds	Roost Dispersal (Cattails)	Red, green	(Homan et al. 2010)
Red-winged Blackbirds	Crop protection (Sweet corn)	Green	(Brown and Brown 2017;2021)
Brown-headed Cowbird	Dispersal	Red	(Blackwell et al. 2002)
European Starling	Dispersal	Red	(Blackwell et al. 2002)
European Starling	Crop Protection (Sweet corn)	Green	(Brown and Brown 2017;2021)
European Starling	Crop Protection (Sweet corn)	Green	(Manz et al. 2024)
Rock Pigeon	Roost Dispersal	Red	(Blackwell et al. 2002)
Rock Pigeon	Roost Dispersal	Green	(Matsyura 2018)
Gull Sp.[1]	Dispersal (water storage sites)	Green	(Baxter 2007)
Ring-billed Gull	Dispersal	Red, green	(Lecker et al. 2015)
Canada Goose	Dispersal	Red	(Blackwell et al. 2002)
Canada Goose	Dispersal (Park)	Unknown	(Curtis et al. 2016)
Canada Goose	Dispersal (Urban)	Red	(Sherman and Barras 2004)
Canada Goose	Dispersal	Red	(Werner and Clark 2006)
Barnacle Goose, Brant Goose	Crop Protection (grassland)	Green	(Clausen et al. 2019)
Herons, egrets, bitterns	Dispersal (contaminated fresh water)	Red	(Gorenzel et al. 2010)
Gray Heron	Roost Dispersal	Green	(Shirai et al. 2020)
American White Pelicans, Double-crested Cormorants	Dispersal (contaminated fresh water)	Red	(Gorenzel et al. 2010)
Mallard	Dispersal	Red	(Blackwell et al. 2002)
Ducks[2]	Dispersal (contaminated fresh water)	Red	(Gorenzel et al. 2010)[4]
Ducks[3]	Dispersal (water bodies)	Violet, green	(Cassidy 2015)
Double-crested Cormorants	Roost Dispersal	Red	(Glahn et al. 2000)
Herring Gull, Great Black-backed Gull	Dispersal	Green	(Alfarwi 2020)
Mixed Species	Dispersal (Poultry farm)	Green	(Elbers and Gonzales 2021)
White-tailed Deer	Dispersal	Red, Blue, Green	(VerCauteren et al. 2003, VerCauteren et al. 2006)

[1]Black headed gull, common gull, lesser black-backed gull, herring gull, great black-backed gull
[2]Dabbling duck (mallard, gadwall, cinnamon teal) Diving Ducks (Canvasback, ring-necked duck, lesser scaup, common goldeneye, bufflehead, hooded merganser, common merganser, ruddy duck)
[3]Dabbling duck (mallard, Canada goose, American wigeon, blue-winged teal, American coot, Northern Shoveler); Diving duck (Lesser scaup, red-necked grebe, common goldeneye); waders (Greater yellowlegs).
[4]Not effective on gulls, rails/coots, grebes, plovers, and sandpipers

2.4 Laser Safety Controls

Engineered controls, administrative controls, and personal protective equipment, either alone or in combination, may be used to control laser hazards. Engineering controls are built-in safety features dependent on the laser classification. These can include protective housings, remote interlocks, dead-man switches, master switches, and spectrum filters. Administrative controls aid in managing the risk associated with laser use and can be implemented where lasers are used. These types of controls include appointing a Laser Safety Officer (LSO), safe working procedures, training, record keeping, correct device labeling, and eye and skin examinations.

Laser dispersal of wildlife is limited to authorized and properly trained personnel only, which reduces the possibility of inadvertent human and wildlife optical exposure to laser radiation. The treatment area is searched to identify other people in the vicinity (e.g., co-workers, bystanders) and check for vehicles or potential aircraft (if on an airfield) before any outdoor laser activities take place. In addition, the treatment area is checked for reflective surfaces which might include signs, reflectors, windows, water, polished materials, etc.

Safety measures employed by WS during avian laser use include the following:

a. Use of precautionary measures (e.g. optical density glasses), if appropriate.
b. Usage of laser safety system such as an interlock or key switch and trigger or dead-man switch.
c. Limiting laser exposure to self and others.
d. Avoid bounce back by never pointing a laser at a window or a reflective object.
e. Understanding the dangers of pointing lasers toward human/wildlife eyes or in the direction of aircraft (i.e., always pointing the laser at a structure and/or toward the ground and never pointing the beam at the eyes of a bird).
f. Never aim the laser at people, aircraft, or vehicles. The beam should always have a point of termination.
g. Knowing the intended target and what is beyond that target.
h. Never powering on a laser until ready to use it.
i. When using automated systems ensure beams terminate at the perimeter of the application area.

2.5 Laws, Regulations, Policies for the Safe Use of Lasers

WS follows all applicable laws, regulations, policies, and directives for the safe use of lasers. WS personnel must report all accidents and incidents to their supervisors and others as required. Laser use involves inherent risks, which are minimized by following training and safety guidelines. WS employees must complete training established by WS before handling and using lasers for official WS WDM activities. Safe use of lasers also requires appropriate storage, inspections, and security (WS directive 2.470) and these guidelines inherently reduce risks to WS personnel and the public.

A manufacturer may designate lasers or laser systems to a specific class in accordance with the Federal Laser Product Performance Standard (FLPPS), which consists of 21 CFR 1040 Performance Standards for Light-emitting Products, 21 CFR 1040.1 Laser Products, and 21 CFR 1040.11 Specific Purpose Laser Products, or International Electrotechnical Commission (IEC) 60825-1, the International Standard for the Safety of Laser Products. WS restricts use of lasers to Class 3 or lower.

WS storage and security requirements as outlined in WS directive 2.470 include:

a. Following manufacturer's guidelines on storage instructions,

b. Storing lasers in a locked and secured box, locked building/room, or in a locked box in a vehicle when not in use.
c. Long-term storage (a week or longer) in a dry, cool place to prevent damage or corrosion. Batteries removed during long-term storage (over 2 weeks).
d. During transport, lasers secured in a manner that prevents accidental activation.

2.5.1 Applicable Regulations and Policies:

While the Occupational Safety and Health Administration (OSHA) is the regulatory authority to develop and enforce federal laws in accordance with the Occupational Safety and Health Act of OSHA of 1970, OSHA does not have a comprehensive laser standard to regulate the use of lasers. OSHA has an alliance with the Laser Institute of America (LIA, www.LIA.org) to provide workers and employers with laser-related information, guidance, and resources (including in-person and online training) to promote workplace safety and health awareness and responsibilities for the use of lasers. The American National Standards Institute (ANSI) Z136 series of laser safety standards is published by the LIA.

ANSI Z136.1 “American National Standard for Safe Use of Lasers”, and ANSI Z136.6 “Safe Use of Lasers Outdoors”

U.S. Department of Transportation Federal Aviation Administration Air Traffic Organization Policy Order JO 7400.2P (Effective April 20, 2023)

This order specifies procedures for use by all personnel in the joint administration of the airspace program.

U.S. Department of Transportation Federal Aviation Administration Advisory Circular (AC) 70-1B Outdoor Laser Operations (Effective February 14, 2022 and updated May 05, 2022)

This AC provides information to assist proponents planning to conduct outdoor laser operations that might affect aircraft operations in the United States National Airspace System.

Air Force Instruction 48-139 of the Laser and Optical Radiation Protection Program (April 22, 2020)

This document incorporates guidance and criteria for the safe use of lasers and laser systems as defined in the American National Standards Institute (ANSI) Z136.1 (2022).

2.6 WS Use Pattern of Lasers

WS annually averaged 1,898 work tasks[3] associated with the use of lasers from FY16-20. Of these work tasks, 99% were to disperse or herd birds, primarily Canada geese (39%), European starlings (17%), American crows (13%), and rock doves (8%) (Table 3). Additionally, a small number of work tasks were associated with training events and demonstrations for cooperators. Thirty-eight states reported using lasers to aid in wildlife damage management activities from FY16-20 (Table 4).

[3] A Work Task is defined as a visit to a property, or a portion of it, where a WS employee conducts field work. However, duration is not considered, therefore a Work Task could be 10 minutes to 10 hours in duration. A work tasks is similar to and could be considered an “event”.

Table 3. The annual average number of target animals hazed with lasers by WS in WDM activities by species from FY16-20 throughout the United States.

Species	Annual average number of work tasks	Annual average number dispersed
American Coot	1.2	182
American Crow	248.2	330,844
American Kestrel	0.4	0.4
American White Pelican	4	72
Anhinga	0.4	1
Bald Eagle	11	119
Barn Swallow	2	44
Black Vulture	33.2	989
Black-crowned Night Heron	1.2	4
Black-necked Stilt	0.2	0.4
Blue-winged Teal	0.6	13
Boat-tailed Grackles	0.2	.
Brant	2.2	190
Bufflehead	1	6
Canada Goose	744	54,208
Cattle Egret	10	186
Cliff Swallow	0.2	15
Common Grackle	4	12
Common Raven	15.2	375
Cooper's Hawk	0.8	0.6
Coyote	0.2	0.2
Domestic Duck	0.8	39
Domestic Goose	0.4	0.2
Double-crested Cormorant	7.8	342
Eurasian Collared Dove	31.8	1,333
European Starling	318	277,114
Fish Crow	1.4	.
Gadwall	1.4	5
Glaucous-winged Gull	15.2	944
Gray Wolf	0.2	.
Great Black-backed Gull	0.2	1
Great Blue Heron	4.6	18
Great Egret	8.2	96
Greater White-fronted Goose	1	970
Great-tailed Grackle	0.2	20
Herring Gull	2.8	257
Hooded Merganser	0.2	1

House Finch	0.4	0.2
House Sparrow*	48.4	4,338
Killdeer	0.2	3
Laughing Gull	1	66
Mallard	73.4	2,171
Mixed Blackbirds	0.4	600
Mourning Dove	83.2	2,558
Mute Swan*	0.6	0.6
Neotropic (Oliveaceous) Cormorant	4.6	185
Northern Harrier	0.2	0.2
Northern Shoveler	1	104
Osprey	0.2	0.2
Pied-billed Grebe	0.2	0.2
Redhead	0.4	4.2
Red-shouldered Hawk	1	1
Red-tailed Hawk	0.2	0.2
Red-winged blackbirds	0.2	5
Ring-billed Gull	5.8	1,101
Ring-necked Duck	1.4	45
Ring-necked Pheasant	0.2	0.2
Rock Dove*	156.6	11,554
Ruddy Duck	1.4	370
Savannah Sparrow	0.2	20
Short-billed Gull	0.2	30
Short-eared Owl	0.2	0.6
Snow Goose	0.2	80
Snowy Egret	0.4	2
Snowy Owl	0.2	0.2
Turkey Vulture	37.4	587
White Ibis	0.2	12
Wild Turkey	1.2	4
Wood Duck	2.6	11
Woodchuck	0.2	0.4
TOTAL	**1,898**	**692,256**

*Introduced species

Table 4. The annual average number of work tasks and target animals hazed with lasers in each state by WS in WDM activities from FY16-20.

State	**Annual average number of work tasks**	**Annual average number dispersed**
Alaska	38	1,459
Arizona	13	512
Arkansas	82	1,037

California	4	861
Colorado	2	4,470
Florida	15	156
Georgia	0.4	0
Idaho	5	81
Illinois	559	143,236
Indiana	0.8	10,140
Iowa	334	348,281
Kansas	46	20,377
Kentucky	1	1,926
Louisiana	2	33
Maine	0.4	41
Maryland	5	38
Michigan	0.2	0
Mississippi	0.2	0
Missouri	108	90,209
Nebraska	4	239
New Jersey	304	21,236
New Mexico	0.6	0
New York	14	5,928
North Carolina	15	1,029
Ohio	17	2,575
Oklahoma	4	3,374
Oregon	3	138
Pennsylvania	140	24,457
South Carolina	4	34
Tennessee	40	1,518
Texas	24	870
Utah	1	4
Vermont	0.4	10
Virginia	17	335
Washington	18	3,457
West Virginia	75	4,184
Wisconsin	0.8	170
Wyoming	2	0
Total	**1,903**	**692,415**

WS uses lasers alone and in combination with other nonchemical deterrents (described in USDA WS (2024) Use of Nonchemical Deterrents in Wildlife Management) to disperse wildlife for the protection of health and human safety, natural resources, property, and agricultural resources. Lasers are also used to help direct or corral individuals from a distance when conducting goose roundups to aid in capture success.

3 HAZARDS

Lasers can produce intense beams of collimated radiation in the optical/visible, UV, and infrared spectrums. While lasers vary greatly in power output, wavelength and purpose, the hazard potential can be significant due to the concentrated energy density. Depending on the wavelength, energy, and pulse duration, lasers cause different effects on biological tissues (Thach 1999). Laser radiation can be extremely hazardous to the eyes and the skin, and cases of serious injury, including loss of sight, have been documented. Additionally, the extreme distances at which laser emissions can be visible pose a significant threat to aviation through the possibility of startling, dazzling, or distracting pilots.

The hazard posed by a given laser cannot be determined by simply checking the output power, wavelength, or beam size. For example, a 5 mW device with a 3 mm beam at 600nm can be more hazardous than a 30 mW device with a 30 mm beam at 600nm, given other variable parameters (AAWHG 2014).

Several aspects of the application of a laser or laser system influence the total laser hazard evaluation.

a) The personnel who may use or be exposed to laser radiation,

b) The capability of the laser or laser system to injure personnel or interfere with task performance,

c) The environment in which the laser is used, including access to the beam path. (ANSI Z136.1 2022).

Hazards associated with the operation of a laser include environmental hazards such as fire hazards and wildlife exposure, operator hazards such as skin exposure and ocular hazards, airfield/public hazards such as potential ocular hazards to the public or airport employees, and overflying aircraft hazards, such as exposing pilots.

3.1 Human Health Exposure and Risk Characterization

The primary safety and occupational health hazards associated with laser activities are biological changes to the eyes and skin. Indirect non-beam safety and occupational health hazards include collateral radiation, electrical shock, fire, and mechanical hazards.

3.1.1 Ocular hazard

Eyes are the most susceptible to damage from lasers. Different parts of the eyes are susceptible to different wavelengths (Table 5; Figure 3). Damage can be in the form of retinal burns, retinal hemorrhage, corneal damage, or global rupture. Visible radiation is focused on the retina. Due to focusing mechanisms in the eye, the intensity of light focused onto the retina from the lens can increase by many orders of magnitude (Lynga and Urban 2017). The blink reflex in humans, caused by stimulation of the cornea is rapid (approximately <0.1 sec) and can afford sufficient eye protections for Class 2 and lower lasers. Appropriate controls are essential to prevent eye damage. Other ocular hazards associated with laser exposures could include distraction, glare (or dazzle), flash-blindness (can persist from several seconds to several minutes), after images (can persist from several minutes up to many days), scotomas (can be a temporary or permanent ocular defect, or other psychological effects. These other ocular hazards are of particular concern to overflying aircraft pilots. Disruption by laser glare of visually guided tasks might be significant and could seriously affect aircrew performance (D'Andrea et al. 1992).

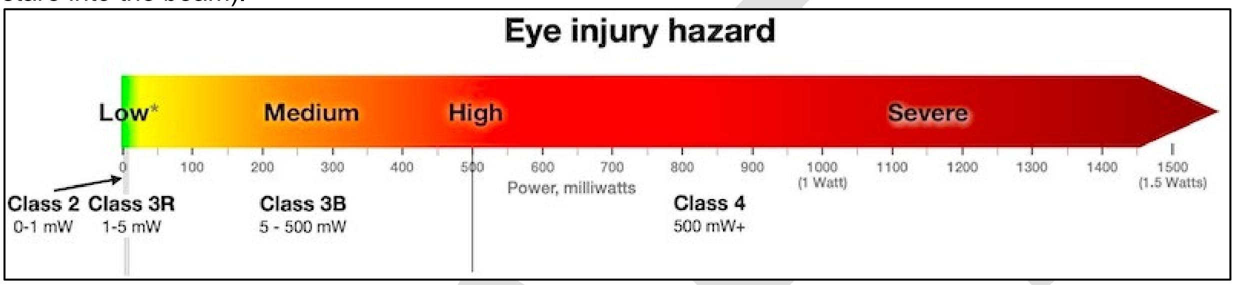
Table 5. Parts of the eye most susceptible to laser injury.

Eye Anatomy	Wavelengths	Potential Damage
Retina	Visible (400-780 nm) Near Infrared (780-1400 nm)	Painless injury, vision loss, retinal burn, loss of acuity, blind spot

Cornea	UVC (200-280 nm)/UVB (280-315 nm) Mid-infrared (1400-3000 nm) Far Infrared (3000-1,000,000nm)	Painful injury, photokeratitis, superficial and/or deep corneal burn, opacification/scarring
Lens	UVA (315-400 nm) Near Infrared (780-1400 nm) Mid-infrared (1400-3000 nm)	Acute exposure: lenticular burn; chronic exposure: cataracts

Reference (LIA 2009, Huang et al. 2018, Daggett et al. 2020)

Figure 3. Eye injury hazard descriptions visualized below are valid for exposures relatively close to the laser. Because the beam spreads, less light will enter the pupil at greater distances. The hazard decreases the farther a person is from the laser and the shorter the exposure time (e.g., do not deliberately look or stare into the beam).



3.1.2 Skin Hazard

Skin is less at risk from damage caused by lasers, but depending on their power density, lasers can cause skin damage due to the radiation being focused onto a small spot. Exposure to lasers still needs to be managed appropriately to minimize potential skin burns. The skin can tolerate higher levels of radiation than the eye, and also, there is no focusing mechanism in the wavelength region 400-1400 nm. Absorption properties of the skin are wavelength dependent. UV radiation is absorbed in the outermost layer of the skin. A maximum is reached at 800 nm where the penetration depth is around 1 cm. As the wavelength increases, the penetration depth decreases again. The sensitivity of the skin can be increased by photo-sensitizing agents, for example, medication and certain chemicals. Thermal injury to the skin is similar to injury caused by contact with hot surfaces. A reddening of the skin, blisters, and charring can result from the exposure. A study on the effect of different laser doses (12,500- 17,200 mw/cm^2) on the skin of albino rats by Abuarra et al. (2012) indicated that tissue damage caused by a CO_2 laser at a distance of 10 cm caused increasing tissue damage as the radiation dose increased. For wavelengths with a large penetration depth, a large volume of tissue is affected and can result in necrosis (Lynga and Urban 2017).

3.1.3 Aircraft Hazard

According to the FAA, pilots reported an annual average of 6,560 laser incidents within U.S. airspace between 2016 and 2020. FAA data from 2016-2020 indicate that laser events took place even at altitudes below 10 feet, while over 50% occurred between 1,000 and 7,000 feet. Pilots flying above 40,000 feet also reported an annual average of 13 incidents. Between 2016 and 2020, there was an annual average of 28.6 incidents with a reported injury. The most common color of laser reported is green in 89% of the incidents between 2016 and 2020 (FAA 2024).

Research has shown that laser irradiance below levels that produce damage or flash-blinding effects can create glare, also known as veiling luminance and disability glare, affecting a pilot's visual search performance. Glare effects are short-term, lasting only as long as the light source is present. Glare results from a combination of factors, including light scattering inside the eye, forward light scattering by the atmosphere, aircraft windscreen, glasses, or prescription contacts (D'Andrea et al. 1992).

3.2 Environmental Hazards

3.2.1 Fire hazard

There are two types of fire hazards from lasers, especially high-powered lasers. Laser emission from a high-power (Class 4) laser can readily ignite sensitive materials in their path. Laser emission from lower-class lasers, especially when concentrated over very small areas, can cause explosions in combustible liquids and gases or in high concentrations of airborne dust. Laser equipment can also present a fire hazard due to the flammable components, plastic parts, lithium batteries, etc. contained within it, which can overheat or catch fire in the event of a fault within the equipment.

3.2.2 Hazards to Wildlife

The anatomy of avian eyes differs from mammalian eyes, but they share features common to all vertebrates (Waldvogel 1990). Like mammalian eyes, avian eyes are also potentially susceptible to damage from laser light. A study conducted by Glahn et al. (2000) exposing double-crested cormorants to Class 3B lasers at distances of 1-33 meters showed no retinal degeneration or necrosis at any distance. A laboratory study of controlled experiments examining the effects on house sparrow behavior relative to laser exposures at 7 different power levels (up to and including 270 mW, i.e., a Class 3B setting) at 1-meter distance found that direct laser exposure in birds can alter visual exploratory behavior in the context of foraging and influence foraging effort and food consumption rates (Blumenthal 2020). Further experiments with house sparrows and European starlings have shown that exposure at 1-meter distance to a Class-4 laser at exposure times up to 1 second caused corneal edema, cataracts, retinal atrophy, displacement of the photoreceptor nuclei, and degeneration of the scleral cartilage (Harris 2021).

4 RISKS

4.1 Human Health and Safety Risks

Risks to WS employees and the public from using lasers could occur. During WDM laser dispersal activities, there is a potential for direct laser-beam hazards to the eyes and skin as well as non-beam hazards. WS minimizes risks to human health and safety by implementing training, safety, storage, and security practices highlighted in WS Directive 2.470 and as discussed in Section 2. In addition to training, WS has designated laser safety officers (LSOs) who will be responsible for selection and acquisition of appropriate lasers per the WS Directive and managing laser training. This includes purchasing devices that display the appropriate manufacturer’s label warnings of potential exposures to radiation and are procured from companies that provide evidence of adherence to FDA guidelines for laser manufacturing and use.

WS used lasers in over 9,490 work tasks in FY16-20 with no incidents and has not had any accidents with lasers since WS-use of lasers for wildlife damage management began. To avoid most, if not all, laser accidents, WS employees undergo initial training with a recertification requirement every 3 years. Adhering to the training requirements and WS directive, including always pointing the laser in a safe direction, never powering on a laser until ready to use it, and knowing your target and what is beyond. In addition to these basic rules, WS employees consider many additional safety measures when using lasers. Those measures include knowing the locations of coworkers and bystanders, knowing how to operate the device safely, and ensuring the device is safe to operate. Other measures that WS employees abide by include storing devices, so they are not accessible to unauthorized persons.

4.1.1 Ocular Risks

Personal protective equipment (PPE) for the use of lasers can include eye protection such as optical density glasses in some fields. However, using this type of PPE might not be appropriate in all circumstances. For example, laser operations from watercraft at night (e.g., dispersing cormorant roost) or operations at night in structures with steps, landings, or elevated walkways (e.g., dispersing blackbird roosts). A recent review of retinal injury indicated that high-power lasers, defined as a power output greater than 5mW (class 3B and higher), were associated with 85.1% of reported cases of injury. While, low-power lasers, defined as a power output less than 5mW (Class 3R or lower), were less commonly implicated (14.9% of reported cases) (Bhavsar et al. 2021). WS personnel will only be using lasers of Class 1-3, which could include Class 3B lasers. Class 3B lasers are inherently dangerous for direct viewing, but are unlikely to start fires, cause skin damage, or pose diffuse reflection hazards (ANSI Z136.1 2022). No eye injuries have been reported from WS laser use. Adherence to training protocols helps to reduce the occurrence of eye injuries for WS employees and the public.

4.1.2 Skin Risks

The occurrence of skin injury from handheld laser use is rare. A recent study by Qutob et al. (2021) indicated that less than 1% of laser users in Canada reported any discomfort or injury due to laser use. The study also indicated that among users of and those exposed to the light from handheld laser devices, 27.0% indicated that they, or someone else, had intentionally directed the laser beam toward their eyes or skin (Qutob et al. 2021). WS personnel are trained not to aim lasers at themselves or others, further reducing the risk of skin injuries.

4.1.3 Aircraft Risks

Lasers can be an effective tool for dispersing loafing birds in airport environments. As described in Section 3.1.3, aircraft pilots are susceptible to flash-blinding and injury from laser-exposure incidents . Laser exposure in flight from a ground base is recognized as a distraction or disruption to critical phases of flight (Dietrich 2017). Laser exposures, as described in Section 3.1.3 however, were not in the context of wildlife management by WS. Use of lasers on airports will be in collaboration with the FAA and Airport Manager, subject to constraints of surfaces that will block or “catch” the beam and conducted to reduce chances of human exposure. WS shall not use lasers on or near airfields unless airport management and/or the FAA provide WS with written permission to do so (WS Directive 2.470). WS personnel working within 5 miles of a runway are also mindful of beam termination points. Upon permission to use lasers on or near airfields, laser use will be exercised with extreme caution.

4.2 Environmental Risks

4.2.1 Fire Risks

Fire risks from WS use of lasers for wildlife damage management are extremely minimal. The risk of fire from laser use increases with an increase in the power of the laser, especially those above

5mW. Under some unique situations, it is possible that Class 3 lasers can initiate fires. Class 4 lasers have a greater potential hazard to initiate fires, but WS does not use Class 4 lasers. By knowing the environment and conditions where lower-class lasers are used, WS avoids the potential for igniting combustible liquids or gases with laser use. WS will store lasers in dry and cool places when not in use to prevent damage or corrosion and avoid the potential for overheating or causing a fire due to a fault in the equipment. WS employee vehicles can be equipped with fire extinguishers if they are transporting lasers.

4.2.2 Risks to Wildlife

WS use of lasers in wildlife damage management would be selective for the target species since the target is identified prior to application. WS use of lasers does not usually affect nontarget species, except in the case of misidentification of target species. Environmental risks are greatest for those nontarget animals similar in appearance to target animals, especially when they are present in mixed flocks of birds. The risk of misidentifying animals is minimized through the training of WS personnel in species identification, resulting in the use of lasers being highly selective. The use of lasers in proximity to nontarget species is not likely to occur at a high frequency or at a high magnitude. WS employees are trained to use lasers to avoid aiming the laser beam directly at birds and instead at vegetation or surfaces near birds. In addition, the beam is not typically fixed in a single position but moves horizontally to avoid sustained contact with individuals. Research has shown effects on bird eyes when Class 4 lasers are aimed directly in the dilated eyes of birds at a distance of 1 meter (Harris 2021). However, WS only uses lasers of Class 1-3, reducing the risk of injury to target and nontarget animals. Thus, risk or injury to target and nontarget animals is minimal.

It should be noted that the presence of humans in particular areas could have risk factors for nontarget species. However, WS personnel have not reported any occurrences in which they were responsible for disrupting nontarget animals unintentionally. Additionally, operations in the field typically do not cause disturbances in areas over a long period of time.

5 UNCERTAINTIES AND CUMULATIVE EFFECTS

Uncertainty in this risk assessment is minimal as WS has numerous years of experience using lasers in wildlife damage management. The knowledge gained from this experience has helped reduce risks associated with lasers, especially regarding human health and safety. No recorded incidents of laser injury have occurred. The use of lasers has also shaped policies and standard operating procedures to minimize risks associated with the use of those methods.

Cumulative impacts could occur to target and nontarget animals. However, cumulative impacts are addressed in National Environmental Policy Act documents[4] and found not to be significant to any native population. Additionally, the "Introduction to WS Methods Risk Assessments," Chapter 1 gives all species taken by WS from FY11 to FY15 and shows no significant impacts from a population standpoint. From a human health perspective, using lasers in WDM will not have any known cumulative impacts.

6 SUMMARY

Lasers are an effective non-lethal and environmentally sound tool used in integrated wildlife damage management to mitigate the impacts of animals causing damage, especially avian

[4] More detailed analysis of these programs can be found at (https://www.aphis.usda.gov/wildlife-services/nepa). These documents analyze different species categories, programs, and methods used in wildlife damage management.

species, but the effectiveness of lasers varies among species. Different bird species' visual acuity affects how they will respond to dispersal attempts. In addition, the time of day and type of laser that is used might affect results. With proper training, WS employees are effective and efficient at using lasers to focus their efforts on specific target animals and can use these methods with very low risks to human safety and to the environment. WS personnel have been very effective in using lasers and no personnel have been injured or accidents or incidents have occurred due to the use of lasers. No nontarget species have been harmed. Thus, it is concluded that the use of lasers is of low risk to WS personnel, the public, nontarget species, and the environment.

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