Lasers as Nonlethal Avian Repellents

Bradley F. Blackwell; Glen E. Bernhardt; Richard A. Dolbeer

The Journal of Wildlife Management, Vol. 66, No. 1. (Jan., 2002), pp. 250-258.

Stable URL:
http://links.jstor.org/sici?sici=0022-541X%28200201%2966%3A1%3C250%3ALANAR%3E2.0.CO%3B2-R

The Journal of Wildlife Management is currently published by Alliance Communications Group.

Your use of the JSTOR archive indicates your acceptance of JSTOR's Terms and Conditions of Use, available at http://www.jstor.org/about/terms.html. JSTOR's Terms and Conditions of Use provides, in part, that unless you have obtained prior permission, you may not download an entire issue of a journal or multiple copies of articles, and you may use content in the JSTOR archive only for your personal, non-commercial use.

Please contact the publisher regarding any further use of this work. Publisher contact information may be obtained at http://www.jstor.org/journals/acg.html.

Each copy of any part of a JSTOR transmission must contain the same copyright notice that appears on the screen or printed page of such transmission.

The JSTOR Archive is a trusted digital repository providing for long-term preservation and access to leading academic journals and scholarly literature from around the world. The Archive is supported by libraries, scholarly societies, publishers, and foundations. It is an initiative of JSTOR, a not-for-profit organization with a mission to help the scholarly community take advantage of advances in technology. For more information regarding JSTOR, please contact support@jstor.org.

http://www.jstor.org
Thu Sep 27 17:14:23 2007

LASERS AS NONLETHAL AVIAN REPELLENTS

BRADLEY F. BLACKWELL,[1] U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services, National Wildlife Research Center, Ohio Field Station, 6100 Columbus Avenue, Sandusky, OH 44870, USA
GLEN E. BERNHARDT, U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services, National Wildlife Research Center, Ohio Field Station, 6100 Columbus Avenue, Sandusky, OH 44870, USA
RICHARD A. DOLBEER, U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services, National Wildlife Research Center, Ohio Field Station, 6100 Columbus Avenue, Sandusky, OH 44870, USA

Abstract: Lasers have been demonstrated to be potentially effective avian repellents; however, studies combining adequate controls and replication that test such applications of lasers in wildlife management have not been reported. We conducted 2-choice cage tests to quantify the effectiveness of a 10-mW, continuous-wave, 633-nm laser as a visual repellent (treating a perch) against brown-headed cowbirds (*Molothrus ater*) and European starlings (*Sturnus vulgaris*), and a 68-mW, continuous-wave, 650-nm laser in dispersing (i.e., targeting birds with the laser) starlings and rock doves (*Columba livia*) from perches and Canada geese (*Branta canadensis*) and mallards (*Anas platyrhynchos*) from grass plots. All experiments were conducted under low ambient light (≤ 3 lx) conditions. In 3 experiments with stationary and moving laser beams treating a randomly selected perch, brown-headed cowbirds were not repelled. Similarly, a moving beam did not repel European starlings from treated perches or cause them to disperse when targeted. Rock doves exhibited avoidance behavior only during the first 5 min of 6 80-min dispersal periods. Notably, 6 groups of geese (4 birds/group) exhibited marked avoidance of the beam during 20-min periods ($n = 23$), with a mean 96% of birds dispersed from laser-treated plots. Six groups of mallards (6 birds/group) also were dispersed ($\bar{x} = 57\%$) from treated plots during 20-min periods ($n = 12$), but habituated to the beam after approximately 20 min. We contend that lasers will prove useful as avian repellents, but further controlled studies are needed to evaluate species-specific responses relative to laser power, beam type, wavelength, light conditions, and captive versus field scenarios.

JOURNAL OF WILDLIFE MANAGEMENT 66(1):250–258

Key words: *Anas platyrhynchos*, avian repellent, *Branta canadensis*, brown-headed cowbird, Canada goose, *Columba livia*, diode laser, European starling, He–Ne laser, mallard, *Molothrus ater*, rock dove, *Sturnus vulgaris*.

As issues of safety, health, and property damage associated with wildlife populations have increased over the last 3 decades (Blokpoel 1976, Conover and Chasko 1985, Dolbeer 1998), management options have been progressively restricted toward use of nonlethal methods (Dolbeer 1998, Smith et al. 1999, Blackwell et al. 2000). Unfortunately, few nonlethal technologies (e.g., auditory, chemical, physical, or visual) presently exist, and those available often are limited in effectiveness by circumstance (Mason and Clark 1992, Clark 1998, Dolbeer 1998). For example, in a review of issues affecting discovery, formulation, and delivery of chemical bird repellents, Clark (1998) found only 18 nonlethal product labels comprising 5 active ingredients registered by the U.S. Environmental Protection Agency. Thus, a need exists for the identification of methodologies that can broaden the base of effective avian repellents and the circumstances governing their application.

One such methodology, using lasers to alter bird behavior, was introduced nearly 30 years ago (Lustick 1973), but has received little attention. (The term "laser" is an acronym for Light Amplification by Stimulated Emission of Radiation.) During his research on the avian repellent effects of lasers, Lustick (1973) relied on concentrated laser beams (454–514 nm, ≥ 500 mW) that produced radiant energy exceeding maximal permissible exposure levels for animals and humans (Occupational Safety & Health Administration [OSHA] 1991, American National Standards Institute [ANSI] 1993). However, recent technological advances have made available lasers that pose little risk of eye damage and have been used to disperse birds.

Specifically, anecdotal observations have been made of gulls (Laridae) moving away from laser beams (4 types of lasers, including a Class-III B [see laser classification below], 5–10 mW, He–Ne laser; Briot 1996). Also, double-crested cormorants (*Phalacrocorax auritus*), a species that should be highly sensitive to electromagnetic wavelengths found in the blue–green aquatic environment (i.e., little visible light beyond 575 nm; see Bowmaker 1987), have been dispersed from night roosts in response to a Class-III B, 5-mW, He–Ne, 633-nm laser (Desman™ Laser model FL R 005)

---

[1] E-mail: bradley.f.Blackwell@aphis.usda.gov

and a hand-held, Class-II, battery-powered, 68-mW, 650-nm, diode laser (Laser Dissuader™; SEA Technology, Albuquerque, New Mexico, USA; Glahn et al. 2001).

Although different in several aspects of design, the lasers noted above are similar in power and therefore classification. Laser classification is determined by the amount of radiant power within a 7-mm aperture at a distance of 20 cm (Code of Federal Regulations 21, Subchapter J; OSHA 1991). The Class-II category comprises visible lasers that emit a radiant power ≤1 mW (low-power continuous wave; OSHA 1991). The Class-III B category of lasers includes moderate-power lasers (between 5 and 500 mW, continuous wave) that generally are not capable of producing hazardous diffuse reflection except for conditions of intentional staring done at distances close to the diffuser (OSHA 1991). Thus, the relative safety of the laser operator and anyone exposed to laser radiation can be inferred from the classification of the device in use.

However, despite reported use of lasers in avian dispersal and the relative safety of Class-II and -III B devices, the efficacy of laser technology as an avian dispersal tool has been evaluated in a replicated format only for the dispersal of double-crested cormorants from night roosts (Glahn et al. 2001). Investigations of laser efficacy involving multiple species in combination with adequate controls and replication have not been conducted. Our objective was to quantify avoidance behavior by birds exposed to an AC-powered, Class-III B, He–Ne laser and the battery-powered, Class-II, hand-held, Laser Dissuader™ in cage tests.

METHODS

Test Species

We selected brown-headed cowbirds, European starlings, rock doves, Canada geese, and mallards as models for our experiments based on statistics of bird strikes to aircraft (i.e., groups of birds most frequently struck) and species availability. Cleary and Dolbeer (1999) noted that 78% of the 22,935 bird strikes to aircraft reported to the U.S. Federal Aviation Administration (1990–1998) comprised gulls and terns (Laridae), raptors, blackbirds (Icteridae), European starlings, waterfowl (Anatidae), and doves (Columbidae).

We captured adult male brown-headed cowbirds (hereafter referred to as cowbirds) from June through August 1999 and European starlings (mixed sexes; hereafter referred to as starlings) during October 1999 in decoy traps in northern Ohio, USA. Rock doves (also of mixed sexes; hereafter referred to as doves) were captured in walk-in funnel traps during November 1999. We held passerines in 2.4- × 2.4- × 1.8-m cages in an outdoor aviary in Erie County (see structure of aviary in Woronecki et al. 1988). Doves were held in 2.4- × 2.4- × 1.8-m outdoor cages fitted with perches, shelters, and windbreaks. We fed millet and grit to cowbirds, Master Mix Gamebird Food and apples to starlings, and Brown's Premium Alimento Paba Palomas pigeon feed and grit to doves.

We captured Canada geese (hereafter referred to as geese) of undetermined sex during molt in northern Ohio on 20 June 1999 and transported the birds to a 0.4-ha fenced holding area in Erie County, Ohio, that contained grass and shade and included about 20 m^2 of an adjacent 2-ha pond. We cut the primary feathers from 1 wing before releasing the geese into the holding area. To prevent the escape of geese during the experiment, we pulled the primary feathers from 1 wing on 31 August. Whole-kernel corn and poultry pellets were provided as food supplements.

We obtained male mallards ($n = 36$) from Ridgway's Hatchery and Farm, LaRue, Ohio, USA (where they were held in a 0.4-ha area). On 2 March 2000, we transported them to the 0.4-ha fenced holding area in Erie County. Mallards were held in 4 2.4- × 2.4- × 1.8-m cages within the fenced 0.4-ha area. We cut the primary feathers from 1 wing before releasing the ducks into the cages. Whole-kernel corn and duck grower pellets were fed to the mallards; water and food were provided ad libitum to all birds.

Lasers Evaluated

We selected the AC-powered, Class-III B, High-performance Uniphase, 10-mW, He–Ne, 633-nm laser (use of trade names does not imply endorsement by the U.S. Department of Agriculture) because its power, wavelength, and optics are similar to the Desman™ laser (a product marketed for bird dispersal and tested by Glahn et al. 2001; see above), and because of its 6-fold difference in price (US$1,200 vs. US$7,500). We selected the Class-II 68-mW, 650-nm Laser Dissuader™ (optical configuration allows Class-II rating) for testing because its use is approved by the U.S. Air Force as a physical security device. The safety of the Laser Dissuader™ is based on the human blink reflex (0.25 sec), which prevents concentration of the beam on the retina (Dennis et al. 1999). Also, the laser is similar in wavelength to the Desman™, and BFB secured use of a Laser Dissuader™ for concurrent testing by Glahn et al. (2001).

Because only 1 laser (of each configuration) was available, concurrent tests (within and between species) were not possible. We assume, however, that time was not a factor in the behavior of the birds recorded during our experiments. Further, the Laser Dissuader™ was not available during our experiments with cowbirds. In addition, the repellent effect of lasers used against birds has been observed only during situations of low ambient light (as perceived by humans), or high contrast between the laser beam and ambient conditions (Briot 1996, Glahn et al. 2001). We therefore conducted all experiments under low-light (high laser-contrast) conditions so as to maximize avian perception of the beam and thus behaviors indicating beam perception (e.g., avoidance).

Experiment 1: Cowbird Response to a Stationary 0.81-mm Laser Beam

Our objective in this experiment, using cowbirds as a model, was to determine whether birds would avoid a perch treated with a 0.81-mm laser beam (not directed at the birds). In this experiment, we used the AC-powered Class-III B, High-performance Uniphase 10-mW, He–Ne, 633-nm laser for continuous illumination over the length of a randomly selected perch within a sheltered flight cage (2.4 × 2.4 × 1.8 m) isolated from disturbance. We positioned 2 perches (0.64-cm diameter × 2.4-m length) 0.7 m from the closest cage side parallel to a perch, 1.0 m apart, and 0.3 m from the top of the cage. Water and food pans (each 0.25-m diameter) were placed in the center of the cage. We positioned the laser directly behind the cage side that was perpendicular to the pre-selected perch, and shielded it from the birds, with the exception of an aperture for the beam to enter the cage. The stationary continuous beam, positioned 6–9 cm above the perch, was 0.81 mm in diameter at the laser head, 1.00 mm upon entering the cage, and 4.00 mm on exit. We placed a wooden box painted flat black (the catch box) at the end of the perch opposite to the laser to receive the beam exiting the cage, thereby preventing reflection of the beam back to the cage area. The single continuous beam was always present unless blocked by a bird. Because we were testing the efficacy of visual repellence of a stationary laser beam, a blocked beam did not bias the experiment.

We used the amount of feces accumulated under a perch during the night as an index of perch choice. We randomly assigned 5 experimentally naive cowbirds to each of 10 groups. For each test, we placed a group into the flight cage at approximately 1630 hr to acclimate to the cage. At approximately 2130 hr, we pre-weighed 2.0- × 0.5-m sheets of paper and placed them below each perch. These papers were used to collect feces produced by the birds resting on the perches. This activity also served to redistribute birds prior to the start of the test. Next, we activated the laser 0.5 hr after sunset. This procedure maximized visibility of the beam to the birds. Preliminary observations indicated no response to the laser under daylight (low laser-contrast) conditions. After activating the laser, we turned the laboratory lights off and left the birds until 1 hr before sunrise. We then placed the papers in a heated drying room for at least 30 min, and next reweighed them to obtain the dry fecal mass. We incorporated the procedures outlined above for the remaining groups during each of 9 nights of testing (3–18 Jun 1999).

Experiment 2: Cowbird Response to a Stationary 2.00-cm Laser Beam

Our objective for this experiment was to repeat the procedures used in Experiment 1, again using cowbirds as a model, and determine whether the index of perch preference was influenced by the larger beam diameter. Here, we mounted an Edmund Scientific Compact Zoom Beam Expander to the above laser and conducted tests at the 20× increment (i.e., increasing beam diameter and decreasing divergence, yielding a highly collimated beam). The stationary continuous beam was 2.00 cm in diameter at the laser head, upon both entering and exiting the cage. We conducted the experiment during 10 nights from 12 July through 3 August 1999.

Experiment 3: Cowbird and Starling Response to a Moving 0.81-mm Laser Beam

Our objective in this experiment was to determine whether cowbirds and starlings would avoid a perch treated with a 0.81-mm laser beam moving in a consistent pattern over the perch. For cowbirds, we repeated the procedures used in Experiment 1, with the exception of the laser treatment and sample size (6 groups comprising 5 experimentally naive birds each). We housed an electric motor, fitted with a hexagonal axle and 6 first-surface mirrors rotating at 10 rpm, in the catch box (see above) to reflect the main beam. We reflected the main laser beam in 0.5-m sweeps, 1 sweep per sec across, and 1 to 20 cm above the perch. The spot from the reflected beam was visible on the solid backing that shielded the laser from view. Again, a single, continuous beam was always present unless blocked by a bird (which subsequently prevented reflection of the beam). We conducted the cowbird phase of Experiment 3 during 6 nights, 23–31 August 1999.

We also exposed starlings to the moving 633-nm beam, but during 6 20-min periods per group with an observer present. As with cowbirds, we held each test group in a sheltered flight cage (2.4 × 2.4 × 1.8 m) isolated from disturbance and minimum intrusion of outside light. We positioned 2 perches (0.05-m diameter × 1.75-m length) 1.6 m high on opposite sides of the cage, 0.6 m from the closest parallel side of the cage, and 1.2 m apart. We positioned the laser 3.6 m from the cage and placed a 0.25-m diameter pan of water in the center of the cage. We observed the experiment from behind a blind in the same location as the laser.

We randomly assigned experimentally naive starlings to 3 groups, each comprising 6 birds. We placed each test group in the cage at least 1 hr prior to testing, but did not control for outside light (via the laboratory windows) until beginning a test. We conducted tests from 1000 to 1500 hr under controlled light conditions ranging from 1 to 3 lx. We measured the ambient light using an INS DX-100 Digital Lux meter.

To begin a test, an observer approached the cage to frighten the birds, thereby redistributing them between the perches, producing an effect similar to the placement of paper below perches in the cowbird experiments above. We then activated the laser beam over a randomly selected perch, and moving in the pattern noted above. At the end of a 20-sec interval ($n = 60$), we recorded use of the treatment versus control perch (i.e., the number of birds on each perch). Birds on the cage sides or floor were not counted. At the close of the 20-min period, we allowed a 5-min interval before beginning the next and identical 20-min period ($n = 6$). We conducted the starling phase of Experiment 3 between 0830 and 1430 hr on 6 days, 17–30 November 1999.

We calculated a 95% confidence interval around the mean use of the control perch separately and by species for each of the 3 experiments.

Experiment 4: Starling and Dove Response to Laser Harassment

Our objective for this experiment was to simulate operational laser dispersal of birds from a night roost, using starlings and doves as models. We conducted this experiment under the same design and lab conditions as in Experiment 3, with the exception of the laser used and perch position. We randomly treated selected perches by using the hand-held, Class-II, battery-powered, 68-mW, 650-nm, diode laser (Laser Dissuader™; SEA Technology, Albuquerque, New Mexico, USA), focused to a 7.6-cm spot at 6.7 m. We positioned the perches with the most distant end from the observer 1.2 m from the closest parallel side of the cage, and the end closest to an observer approximately 0.6 m from the side of the cage. The subsequent angle of the perches to the left and right of the observer aided counts of the perching birds. We positioned the observer and a laser operator behind a blind 6.7 m from the cage.

The treatment procedure involved moving the laser beam from outside the cage, across and approximately parallel to a randomly selected perch, thereby treating 1 perch. In the same fashion or by directly aiming the beam at the bird, we re-exposed starlings that did not move ahead of the beam (i.e., toward the control side and perpendicular to the approaching beam). We deactivated the laser upon successful movement of the 6 starlings to the control side and did not reactivate the laser until the pre-selected interval for switching treatment sides (or when birds approached the treatment perch from the control side). We directed the beam over a randomly selected perch for 3 consecutive 20-min periods at 20-sec intervals ($n = 60$ intervals). During the fourth 20-min period, we alternated the treatment side every 20 sec. Our purpose for the fourth period was to create a situation under which birds (if responding) might habituate to the beam. We again calculated a 95% confidence interval around the mean use of the control perch. We conducted the starling phase of Experiment 4 between 1000 and 1600 hr on 1, 2, and 8 December 1999.

For doves, we incorporated the same test design and conditions as in the starling phase (above), with the exception of sample size (6 groups, each comprising 4 birds) and number of replications. For 1 20-min period, we treated a randomly selected perch at 20-sec intervals ($n = 60$ intervals). During a second 20-min period, we alternated the treatment side every 20 sec. We conducted the dove phase of Experiment 4 between 1000 to 1430 hr on 5 days, 15–23 December 1999.

Experiment 5: Goose and Mallard Response to Laser Harassment

Our objective for this experiment was again to simulate operational laser dispersal of birds from a night roost, but using geese and mallards as models. We tested the hand-held 650-nm laser against 6 groups of geese (4 birds/group) in separate 80-min periods (conducted after sunset) on 6 nights from 8 September through 8 October 1999. We placed 4 geese in a 3.6- × 8.5- × 2.4-m outside test cage at least 1 hr before a test. The test cage was sided with 0.025-m nylon mesh and set upon a uniformly mowed grass surface. We placed a single 0.5-m diameter pan of water in the center of the cage and in line with marking flags on the outside, which divided the cage area lengthwise into 2 3.6- × 4.2-m plots.

We positioned a recorder and laser operator 35 m from the side of the test cage. We used a diffuse flashlight beam to provide sufficient light to observe the movement of the geese at night (the diffuse beam did not produce an avoidance response by the geese). To treat a plot, we followed the same procedures as in the starling phase of Experiment 4, with the exception that the laser beam was focused to a 0.15-m spot at 35 m. We exposed the first group of geese, however, to only 3 20-min periods. In addition, we also conducted 3 daylight tests with 3 groups of geese previously exposed to the 80-min nighttime tests. We calculated a 95% confidence interval around the mean use of the control plot.

We also tested the hand-held 650-nm Laser against 6 groups of mallards (6 birds/group), using the same test design as with the geese (above), with the exceptions of cage acclimation time (at least 30 min before a test) and periods of testing. We conducted 1 20-min period in which a randomly selected side of the cage was treated by the laser at 20-sec intervals ($n = 60$ intervals), followed by a second 20-min period in which the treatment side was alternated every 20 sec. We conducted tests with mallards on 6 nights, 4–10 March 2000. Again, we calculated a 95% confidence interval around the mean use of the control plot.

Subsequent to the above experiments, we conducted field trials under operational conditions (without controls or replication), and observations from those trials are discussed relative to findings from the controlled experiments.

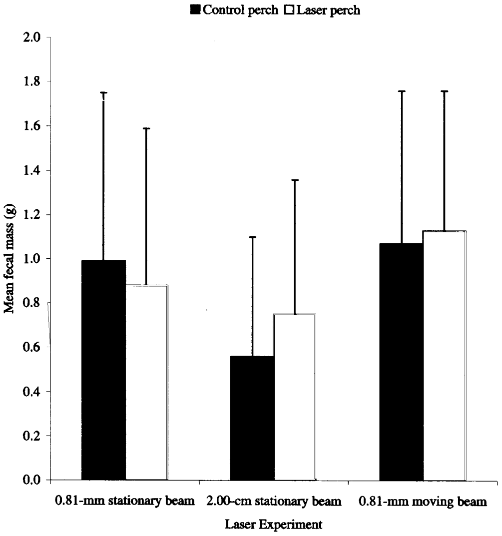

Fig. 1. Mean total fecal mass per test group collected under control and treatment perches in each of 3 2-choice experiments with male brown-headed cowbirds in which a randomly selected perch inside a 2.4- × 2.4- × 1.8-m cage was treated by an AC-powered, Class-III B, High-performance Uniphase, 10-mW, He–Ne, 633-nm laser. The 3 experiments were conducted over 26 nights from 3 June through 31 August 1999 in Erie County, Ohio, USA, and included a 0.81-mm stationary beam (10 groups, 5 birds/group), 2.00-cm stationary beam (10 groups, 5 birds/group), and a 0.81-mm beam (6 groups, 5 birds/group) reflected over the perch at 1-sec intervals. Lines above the bars indicate 1 SD (i.e., variance about the mean total fecal mass per test group).

RESULTS

In each of the 3 cowbird experiments, birds were not repelled from perches treated with the 633-nm laser. Mean fecal mass under control and treatment perches did not differ in each of the 3 experiments (Experiment 1: 95% CI about the $\bar{x}$ fecal mass (g) under the control perch: $0.5 < 1.0 < 1.5$; $\bar{x}$ [SE] fecal mass under the treatment perch = 0.9 [0.7] g; Experiment 2: $0.2 < 0.6 < 0.9$ g; 0.8 [0.6] g; Experiment 3: $0.2 < 0.6 < 0.9$ g; 1.1 [0.6] g; Fig. 1). Likewise, the 3 groups of starlings in Experiment 3 did not avoid the moving 633-nm beam over 18 20-min periods. Instead, the starlings may have been attracted to the light source (95% CI about the $\bar{x}$ number of birds on the control perch: $0.8 < 1.3 < 1.8$; $\bar{x}$ [SE] number of birds on the treatment perch = 2.3 [0.8]).

Similar to our findings for the 633-nm laser in Experiment 3, the 3 groups of starlings in Experiment 4 showed no avoidance of the 650-nm beam over 12 20-min periods (95% CI about the number birds on the control perch per 20-sec interval: $1.4 < 1.8 < 2.2$; $\bar{x}$ [SE] number of birds on the treatment perch per 20-sec interval = 2.2 [0.4]). Also in Experiment 4, the 6 groups of doves initially avoided the beam (during the first 5 min), but habituated over the remaining minutes of the first period and exhibited no avoid-

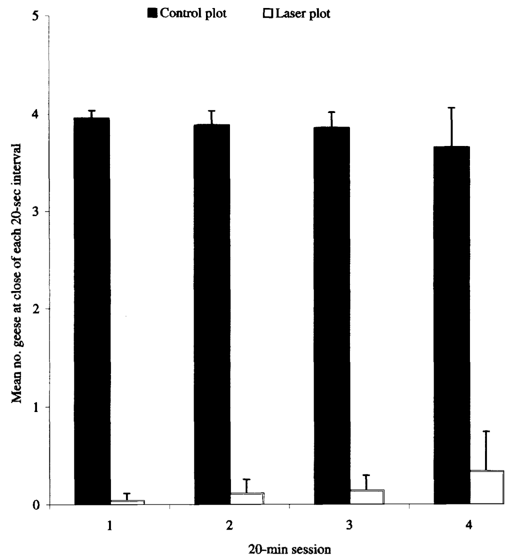

Fig. 2. Mean number of Canada geese observed in control and treatment plots during each of 4 20-min periods in which 1 side of the 3.6- × 8.5- × 2.4-m cage (i.e., the treatment plot) was treated with a hand-held, Class-II, battery-powered, 68-mW, 650-nm, diode laser (Laser Dissuader™; SEA Technology, Albuquerque, New Mexico, USA) at 20-sec intervals. The test was conducted over 6 nights from 8 September through 8 October 1999 in Erie County, Ohio, USA. Lines above the bars indicate 1 SE.

ance of the beam during the second 20-min period (n = 12 20-min periods; $\bar{x}$ [SE] number of birds per 20-sec interval: control perch = 2 [0.1], treatment perch = 2 [0.1]).

In contrast to the behavior of starlings and doves, the 6 groups of geese tested in Experiment 5 (4 birds/group) exhibited marked avoidance of the 650-nm laser beam in each 20-min period (n = 23; Fig. 2). On average, 96% of geese had moved from the treatment plot to the control plot at the end of a 20-sec interval (95% CI about the $\bar{x}$ number birds on the control plot per 20-sec interval: $3.6 < 3.8 < 4.0$; $\bar{x}$ [SE] number birds on the treatment plot per 20-sec interval = 0.2 [0.2]). Further, though we noted some increase in use of the treated plot by the end of the fourth 20-min period for a group (Fig. 2), on average 91% of geese had moved to the control plot. Also, the 3 groups of geese exposed to a 20-min test period during daylight hours exhibited behavior indicative that they could discern the beam or beam spot, but were not repelled (control plot: 1.9 [0.1] birds; treatment plot: 2.1 [0.1] birds).

In addition, over 2 20-min periods, the 6 groups of mallards tested in Experiment 5 each exhibited avoidance of the 650-nm beam (95% CI about the $\bar{x}$ number birds on the control plot per 20-sec interval: $3.3 < 3.4 < 3.6$; $\bar{x}$ [SE] number birds on the treatment plot per 20-sec interval = 2.6 [0.2]). However, in contrast to the geese, the behavior of the mallards was not consistent over the 2 periods (Fig. 3); during the second 20-min period, no difference was observed in use of control and treated plots ($2.8 < 3.1 < 3.3$ birds; 2.9 [0.4] birds).

DISCUSSION

In 3 2-choice experiments with cowbirds that were presented with a perch treated by a 633-nm laser, no difference was observed in perch use. Similarly, starlings were not repelled from a perch treated with a 633-nm moving beam, nor were starlings dispersed from perches by the beam from the hand-held 650-nm laser. This lack of effective repellence of cowbirds and starlings by these long-wavelength lasers should not, however, be construed as evidence of a general ineffectiveness of laser technology in repelling or dispersing birds. The results of our experiments should rather be viewed relative to the fact that wildlife control methods are often species- and context-specific.

For example, doves exhibited initial avoidance of the 650-nm beam but habituated after approximately 5 min. In addition, over 6 40-min periods, mallards exhibited avoidance of the 650-nm beam used to treat a randomly selected grass plot. Yet, during the last 20-min test period, the ducks habituated to the beam. In contrast, geese exhibited marked avoidance of the 650-nm beam, with no indication of habituation. Also, Glahn et al. (2001) report equal effectiveness of the Desman™ and Dissuader™ lasers as dispersal tools used against double-crested cormorants at night roosts, but no reaction to the Desman™ laser during tests with captive cormorants (the Dissuader™ Laser was not used on captive birds).

Notably, the Desman™ laser produces only a 30-mm beam diameter at the laser head (relative to approximately 76 mm for the Dissuader™), thus yielding a beam spot possibly too small to elicit an avoidance response by cormorants over short distances (e.g., ≤35 m). However, the context issue of a captive versus field scenario must be considered (see below). We note also that starlings and gulls (*Larus* sp.) were essentially unresponsive to the high-intensity argon laser (454–514 nm, ≥500 mW) used by Lustick (1973), while mallards were much more sensitive, results similar to our findings with lower-power, longer-wavelength lasers.

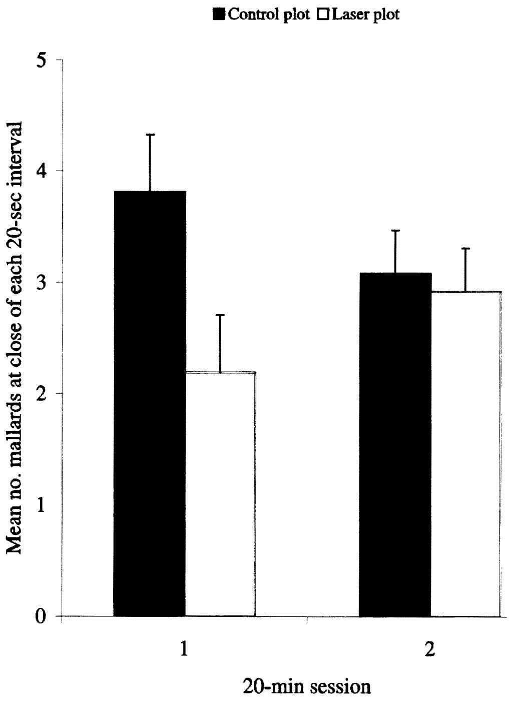

Fig. 3. Mean number of mallards observed in control and treatment plots during each of 2 20-min periods in which 1 side of the 3.6- × 8.5- × 2.4-m cage (i.e., the treatment plot) was treated with a hand-held, Class-II, battery-powered, 68-mW, 650-nm, diode laser (Laser Dissuader™; SEA Technology, Albuquerque, New Mexico, USA) at 20-sec intervals. The test was conducted over 6 nights from 4 through 10 March 2000 in Erie County, Ohio, USA. Lines above the bars indicate 1 SE.

Lustick (1973) speculated that differences observed in avian species response to laser treatment might be due to maximum sensitivity to different ranges of the light spectrum relative to behavioral ecology (e.g., diurnal vs. crepuscular or nocturnal species). Moreover, the range of the spectrum used by a bird might vary relative to specific behaviors, such as mate selection, foraging, or navigation (e.g., some species might orient by the ultraviolet radiation of the sun; Bowmaker 1987, Bennett et al. 1994, Hart et al. 1998). Electrophysiological studies of the avian retina suggest that birds in general can distinguish colors ranging from the ultraviolet (350 nm) to the red (750 nm; Bowmaker 1987, see also Bennett et al. 1994), spanning the visual range of humans (400–700 nm). Also, birds have a complex system of cone cells in their retinas that contain oil droplets in addition to visual pigments. These oil droplets filter light entering the eye and may serve to alter hues that birds perceive and affect brightness and saturation (Bennett et al. 1994).

In addition, light conditions under which a bird perceives and responds to a laser also may vary among species and wavelengths (possibly negating the need in some situations for high contrast between beam and ambient light). In this study, however, geese, and to a lesser extent mallards, reacted in what might be best described as a neophobic avoidance response to the approaching beam or beam spot contrasted against a dark background. Further, avoidance behavior might be more pronounced and consistent when birds are exposed to a laser in a natural setting where escape is possible (see Glahn et al. 2001). For example, subsequent to this research, a variety of species have been dispersed from night roosts during informal field trials involving the 650-nm laser (Appendix 1).

Although our controlled experiments provided a choice of treated versus untreated areas, all birds were repeatedly exposed to a treatment that caused no mortality and, given the complexities of the avian eye (see above), likely little discomfort (see also Glahn et al. [2001] relative to findings of no ocular damage to cormorants after direct exposure to the Class-III B Desman™ Laser at distances as small as 1 m). Thus, our findings for doves and mallards exposed to the 650-nm laser while in captivity may not represent behaviors of these species in natural settings. However, these data provide necessary information relative to potential habituation to the 650-nm laser.

MANAGEMENT IMPLICATIONS

We recommend that further controlled studies are needed to evaluate species-specific responses relative to laser power, beam type, wavelength, light conditions, and captive versus field scenarios. Also, we suggest that understanding the range of wavelengths of which a species might be aware is an important aid in designing future experiments. For example, Avery et al. (1999) suggest that near-ultraviolet wavelengths may serve as visual deterrents in diurnal bird species such as the red-winged blackbird (*Agelaius phoeniceus*).

We note, however, that wavelength sensitivity does not connote repellence. Long-wavelength sensitivity has been demonstrated in the European starling (peak absorption within certain retinal cone pigments, λ_{max}, of 563 nm; Hart et al. 1998), rock dove (up to 615 nm; Bowmaker 1987), and mallard (λ_{max} = 570 nm; Jane and Bowmaker 1988), species exhibiting no beam avoidance or a limited response during this study. Although such data are not readily available for all species, spectral sensitivity may be inferred to some degree from spectrophotometric work with congeners, or species of similar ecology (see Bennett et al. 1994, Hart et al. 1998).

Importantly, because of the response of avian species exposed to the long-wavelength lasers evaluated to date (this study and Glahn et al. 2001), as well as our anecdotal field observations of the response of Canada geese, wading birds (Ardeidae), and American crows (*Corvus brachyrhynchos*) to the 650-nm laser, we contend that laser technology will prove to be a valuable nonlethal component of integrated bird management plans for airports, agriculture, aquaculture, and other property types. Further, although our experiments did not involve comparisons of diffuse light and lasers, the potential advantages of laser technology over those of diffuse light include greater directivity and accuracy over distance due to a lower degree of beam divergence (factors particularly important in dispersing birds from bodies of water). Finally, in some instances (e.g., dispersal of Canada geese and double-crested cormorants), lasers may limit the need for chemical repellents and explosive dispersal devices (Glahn et al. 2001).

ACKNOWLEDGMENTS

J. D. Cepek, E. J. Poggiali, T. W. Seamans, R. J. White, and S. W. Young provided field assistance. Dr. R. R. Speers, Bowling Green State University, provided technical guidance with selection of lasers. Col. J. J. Short, U.S. Air Force Research Laboratory, worked closely with the authors and SEA Technology, Inc. on potential applications for laser technology as an avian repellent. We thank SEA Technology, Inc. for providing the Laser Dissuader, and the Ohio Division of Wildlife for providing Canada geese. Sponsorship and funds for this research were provided by the Federal Aviation Administration (FAA). Opinions expressed in these studies do not necessarily reflect current FAA policy decisions governing the control of wildlife on or near airports. M. L. Avery, E. J. Cramer, J. F. Glahn, J. Heisterberg, and M. E. Tobin provided reviews of earlier drafts of this manuscript.

LITERATURE CITED

[ANSI] AMERICAN NATIONAL STANDARDS INSTITUTE. 1993. American national standard for the safe use of lasers. ANSI Z136.1. Laser Institute of America, New York, USA.

AVERY, M. L., J. S. HUMPHREY, D. G. DECKER, AND A. P. MCGRANE. 1999. Seed color avoidance by captive red-winged blackbirds and boat-tailed grackles. Journal of Wildlife Management 63:1003–1008.

BENNETT, A. T. D., I. C. CUTHILL, AND K. J. NORRIS. 1994. Sexual selection and the mismeasure of color. American Naturalist 144:848–860.

BLACKWELL, B. F., T. W. SEAMANS, D. A. HELON, AND R. A. DOLBEER. 2000. Early loss of herring gull clutches after egg-oiling. Wildlife Society Bulletin 28:70–75.

BLOKPOEL, H. 1976. Bird hazards to aircraft: problems and prevention of bird/aircraft collisions. Clarke, Irwin, Ottawa, Ontario, Canada.

BOWMAKER, J. K. 1987. Avian color vision and the environment. Proceedings of the International Ornithological Congress 19:1284–1294.

BRIOT, J. L. 1996. Latest French experiments with lasers to frighten birds. Proceedings of the International Bird Strike Committee 23:345.

CLARK, L. 1998. Review of bird repellents. Proceedings of the Vertebrate Pest Conference 18:330–337.

CLEARY, E. C., AND R. A. DOLBEER. 1999. Wildlife hazard management at airports. Federal Aviation Administration, Office of Airport Safety and Standards, Airport Safety and Compliance Branch, Washington, D.C., USA.

CONOVER, M. R., AND G. G. CHASKO. 1985. Nuisance Canada goose problems in the eastern United States. Wildlife Society Bulletin 13:228–233.

DENNIS, J. T., J. T. HARRISON, W. E. WALLACE, R. J. THOMAS, AND S. R. CORA. 1999. Visual effects assessment of the Dissuader laser illuminator. United States Air Force Research Laboratory Report AFRL-HE-BR-TR-1999-0179.

DOLBEER, R. A. 1998. Population dynamics: the foundation of wildlife damage management for the 21st Century. Proceedings of the Vertebrate Pest Conference 18:2–11.

GLAHN, J. F., G. ELLIS, P. FIORNELLI, AND B. DORR. 2001. Evaluation of moderate- and low- power lasers for dispersing double-crested cormorants from their night roosts. Proceedings of the Eastern Wildlife Damage Management Conference 9:34–45.

HART, N. S., J. C. PARTRIDGE, AND I. C. CUTHILL. 1998. Visual pigments, oil droplets and cone photoreceptor distribution in the European starling (*Sturnus vulgaris*). Journal of Experimental Biology 201:1433–1446.

JANE, S. D., AND J. K. BOWMAKER. 1988. Tetrachromatic colour vision in the duck (*Anas platyrhynchos* L.): microspectrophotometry of visual pigments and oil droplets. Journal of Comparative Physiology 161A:225–235.

LUSTICK, S. 1973. The effect of intense light on bird behavior and physiology. Bird Control Seminar—Proceedings 6:171–186.

MASON, J. R., AND L. CLARK. 1992. Nonlethal repellents: the development of cost-effective, practical solutions to agricultural and industrial problems. Proceedings of the Vertebrate Pest Conference 15:115–129.

[OSHA] OCCUPATIONAL SAFETY & HEALTH ADMINISTRATION. 1991. Guidelines for laser safety and hazard assessment. Directives PUB 8-1.7. U.S. Occupational Safety & Health Administration, Washington, D.C., USA.

SMITH, A. E., S. R. CRAVEN, AND P. D. CURTIS. 1999. Managing Canada geese in urban environments. Jack

Berryman Institute Publication 16, and Cornell University Cooperative Extension, Ithaca, New York, USA.

WORONECKI, P. P., R. A. DOLBEER, AND D. L. OTIS. 1988. Evaluating corn varieties for resistance to damage by blackbirds and starlings. Pages 27–38 *in* S. A. Shumake and R. W. Bullard, editors. Vertebrate pest control and management materials: 5th volume. American Society for Testing and Materials Special Technical Publication 974, Philadelphia, Pennsylvania, USA.

Received 24 October 2000.
Accepted 9 October 2001.
Associate Editor: Clark.

Appendix 1. Species dispersed by the beam from a hand-held, Class-II, battery-powered, 68-mW, 650-nm, diode laser (Laser Dissuader™; SEA Technology, Albuquerque, New Mexico, USA) during informal (i.e., no controls or replication) field trials in 2000 and 2001.

Species	Month	Location and context	Time of day	Approx. no.
American crow (*Corvus brachyrhynchos*)	Feb	Ohio: staging area and roost trees	Dusk–night	10,000
Black-bellied whistling duck (*Dendrocygna autumnalis*)	Apr	Louisiana: flooded rice field	Dusk–night	200
Blue-winged teal (*Anas discors*)	Apr	Louisiana: flooded rice field	Dusk–night	20
Canada goose (*Branta canadensis*)	Mar	Ohio: 2-ha pond	Night	200
Common raven (*Corvus corax*)[a]	Mar	Wyoming: gas refinery	Dusk–night	400
Fulvous whistling-duck (*Dendrocygna bicolor*)	Apr	Louisiana: flooded rice field	Dusk–night	100
Great blue heron (*Ardea herodeas*)[b]	Jun	Oregon: fish hatchery	Dusk–night	30
Mallard (*Anas platyrhynchos*)	Apr	Louisiana: flooded rice field	Dusk–night	20
White-faced ibis (*Plegadis chihi*)	Apr	Louisiana: flooded rice field	Dusk–night	6,000
Vultures (*Cathartes aura* and *Coragyps atratus*)[c,d]	Jul–Aug	Florida: roost trees	Dusk–night	150

[a] L. Clark (U.S. Department of Agriculture, National Wildlife Research Center, Fort Collins, Colorado), unpublished data.

[b] Use of a diffuse light against great blue herons foraging in raceways resulted in birds dispersing to trees on the hatchery grounds where further harassment with diffuse light was ineffective; use of the 650-nm laser resulted in birds leaving the hatchery grounds.

[c] M. L. Avery (U.S. Department of Agriculture, National Wildlife Research Center, Florida Field Station), unpublished data.

[d] Vultures also dispersed in response to diffuse light, but were easily targeted at distance by use of the 650-nm laser.