Bird Control Seminars Proceedings

Wildlife Damage Management, Internet Center for

October 1973

THE EFFECT OF INTENSE LIGHT ON BIRD BEHAVIOR AND PHYSIOLOGY

Sheldon Lustick
Ohio State University

Lustick, Sheldon, "THE EFFECT OF INTENSE LIGHT ON BIRD BEHAVIOR AND PHYSIOLOGY" (1973). *Bird Control Seminars Proceedings*. 119.
https://digitalcommons.unl.edu/icwdmbirdcontrol/119

THE EFFECT OF INTENSE LIGHT ON BIRD BEHAVIOR AND PHYSIOLOGY

Sheldon Lustick
Zoology Department
Ohio State University, Columbus, Ohio 43210

It has been known for centuries that light (photoperiod) is possibly the major environmental stimuli affecting bird behavior and physiology. The length of the light period stimulates the breeding cycle, migration, fat deposition, and molt in most species of birds. Therefore, it is only natural that one would think of using light as a means of bird control. In fact, light has already been used as a bird control; flood-light traps have been used to trap blackbirds (Meanley 1971); Meanley states that 2000-W search lights have been used to alleviate depredation by ducks in rice fields.

Pulsing light is already used on aircraft, aircraft hangers and high towers as a means of detourinq birds (Schaefer, 1968).

With some positive results already obtained with light as a bird control, the next step is to see if a better light source (the laser) might not have a greater effect. The laser is basically an intense and coherent light with extreme directivity and, thus, might have greater influence on a bird's behavioral and physiological responses.

Practical lasers which cover a wide range of the spectrum are now available, any one of which could be tried in bird control experiments. Before selecting a laser it is necessary to understand something about bird vision. All the available evidence tends to support the belief that the visual acuity of birds is of the same order as that of man, but that the rate of assimilation of detail in the visual field is much higher in birds (Pumphrey, 1961). Also a bird with a single glance lasting perhaps a second takes in a picture which a man could accumulate only by laboriously scanning the whole field piece by piece with the most accurate portions of the retina. The fact that the visual information is taken in by birds at a high rate and simultaneously over a greater part of the visual field has been substantiated by studies of bird navigation (Matthews, 1955), for the only theory of navigation consistent with the evidence implies that birds can assess not only the elevation of the sun but also its rate of change of elevation and its azimuth with high accuracy.

Anyone who has ever watched birds doubts that their reception of color is as good as that of man. The studies of Watson (1915), Lashley (1916), and Hamilton and Coleman (1933) have shown that the curve relating the least perceptible change of wavelength to wavelength has exactly the same form for the pigeon as for man, suggesting that the fundamental mechanisms for discriminating pure colors is the same for both. There is no satisfactory evidence that birds make use of extra-spectral frequencies at either end of the visible spectrum. Matthews and Matthews (1939) showed that the dioptric system is quite opaque to infrared light.

Spectrophotometric analysis of visual pigment extracts prepared from various species of bird retinas have led to some valuable information. Crescitelli (1958a,b) found the great horned owl, screech owl, gull, and pelican to possess pigments with maximum absorption at wavelengths of 502, 503, 501, and 502nm, respectively. Bridges (1962), found the maximum absorption at 502 nm for the duck. Recently, Sillman (1969) extracted, analyzed, and characterized the visual pigments of 20 species of birds, representing 8 orders and 11 families. He found that each species examined yielded at least one visual pigment. In every case the major pigment (and the only pigment in 14 species) exhibited a maximum absorption within the spectral range of 500 to 506 nm. In five species of *passerines*, a second photopigment was detected which ranged in maximum absorbance from 480 to 490 nm, and which constituted from 5 to 10 percent of the total pigment content. It is highly probable that the major pigment isolated in these studies were scotopic or rhodopsin. In fact, in the work cited so far there has been evidence for the presence of any cone pigments. Three species of birds have been reported to possess other pigments in addition to the rhodopsin (Wald, 1937; Wald, 1958; Crescitelli, 1964). This pigment (iodopsin) has a maximum absorbance ranging from 544 nm in the pigeon to 562 nm in the chicken and turkey. The important factor coming out of these studies is that the dominant photopigment displays a marked constancy in the spectral location of 500-506 nm. This being the spectral wavelength that birds are most sensitive to suggests that one would want to use a laser which includes this range. The argon laser emits light over a spectral range of from 454 to 514 nm and, thus would seem to be that to which birds are most sensitive (Figure 1). It should be pointed out that because few cone pigments have been found does not eliminate the possibility of their presence and it is possible that other wavelengths might be as effective or more effective in bird control.

Methods

1. First all birds were tested with a low intensity strobe light (general radio) pulsing at various rates (100 to 1000 per minute) to determine the pulse rates that the birds were most sensitive to.

2. Next we tested the effect of both pulsing and continuous laser light of varying wavelengths on three bird species (starlings, gulls, ducks).

3. We monitored activity, avoidance response, time to avoidance and heart rate in those birds we could put a transmitter on without disturbing them.

4. We varied the intensity of the laser by either increasing the output of the laser or expanding or concentrating the laser beam with a telescope.

For more detailed methods see United States Air Force Technical Report AFML-TR-73-126.

Results and Discussion

STARLINGS. It is only natural that the starling, being a diurnal bird, will be more active during the daylight hours. This explains somewhat why there was an increase in activity with an increasing pulse rate (Figure 2) under simulated night conditions - the shorter the dark period the greater the activity. Of greater interest is that there was significantly greater activity under simulated daytime conditions plus pulsing light than under simulated daylight

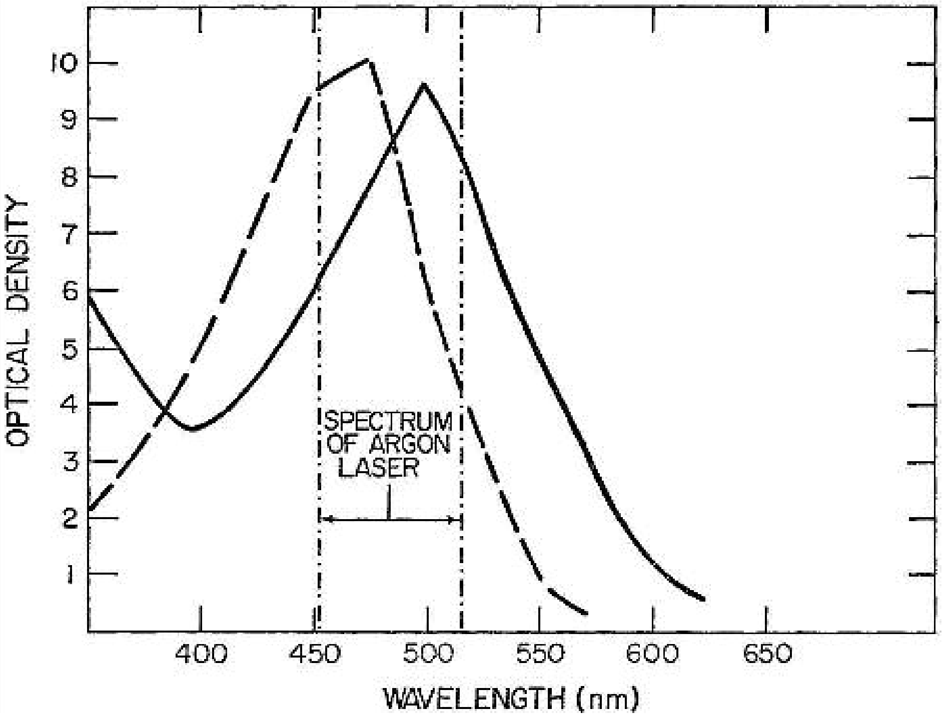


Figure 1 Absorbance spectra of oil droplets (--) and visual pigment extract (-), adapted from Sillman (I969)

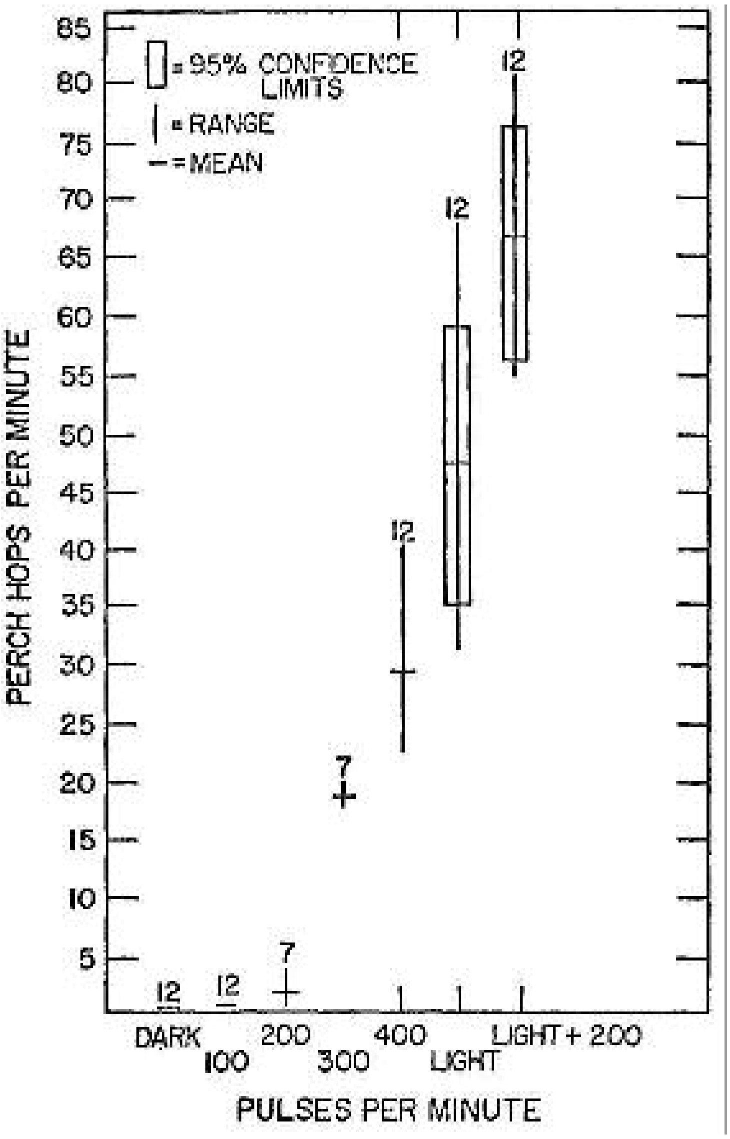


Figure 2. Response of starlings to low intensity light
N = 7-12

alone. This indicates that pulsing light is annoying to the starling causing an increase in activity. That the starlings habituate to pulsing light was shown by the decrease in activity when exposed again to pulsing laser light; overall response was much less under daylight conditions plus the pulsing laser (Table 1). Also the activity decreased during the test period (Table 2), again indicating habituation.

The response of the starling to high-intensity laser light of different wavelengths (488 and 514 nm) was similar. One would expect this response since the peak sensitivity of the bird was between 500-506 nm (Figure 1); thus, the starlings were equally sensitive to 488 and 514 nm. The remainder of the experiments were carried out using the all-wavelength mirror (454-514 nm).

As far as a bird strike with a flying airplane is concerned, it is more than likely that the initial response is important. This initial avoidance response would cause the bird to avoid the oncoming plane if the light source could be seen far enough in advance, thus giving the bird time to avoid a high-speed plane. In the case of the starling, pulsing light is much better than continuous light as a control, mainly because a continuous light source at night could act as an attractant for starlings (Meanley, 1971), where pulsing light is annoying. Remembering that the intense (1-3 W) expanded 4 inch laser beam gave results similar to the low-intensity strobe light, what then is the advantage of the laser? Of course the answer to this question is effective distance. The laser beam, having less divergence, has a greater range which, in turn, gives the bird more time to avoid the plane.

The only laser beam that the starlings did not habituate to in the laboratory was the concentrated beam of at least 0.5-W intensity (irritating). This light range would deny starlings territory. Birds exposed to the beam a few times no longer returned to the area and the birds could be moved at will. Of course this is a highly focused light beam and must be accurately aimed since it can cause eye damage to man. The feasibility of using the concentrated laser beam as a bird control is discussed later.

One can only speculate as to why the starlings and gulls (diurnal birds in general) are not sensitive to extremely intense laser light (expanded beam) capable of doing considerable damage to the mammalian eye. The birds should be extremely sensitive to the argon laser light since their rhodopsin has its peak sensitivity (Figure 1) between 502-506 nm and the laser has its greatest power in this range also. Why then no headshaking or avoidance when exposed to continuous laser light (expanded beam)?

It is known that some birds “sun orient” (Kramer, 1961), i.e. they look directly at the sun in order to get some idea of the azimuth. It is also known that birds fly at very high altitudes (23,000 ft.) where solar radiation is extremely intense. One need only look from an airplane window into the sun when flyibng it at 23,000 feet to determine just how intense it is. Yet these birds fly with their eyes open and possibly, looking right at the sun. Two hypotheses can be set forth to explain the ability of birds to withstand intense light. The first deals with the pecten, a pigmented conical, highly vascularized body. It arises near the attachment of the optic nerve and juts out in the vitreous humor toward the lens. It is an elaborate structure of thin folds richly supplied with small blood vessels (not capillaries). According to Walls (1942),

Table 1. Activity (perch hops/min) responses of starlings to various laser light ranges over a 20-30-minute test period.

Continuous Laser	Total Darkness	Laser 100/min Pulse Rate Dark Room	Laser 200/min + Light	Laser 200/min Dark Room	Cont. Room Light
1.33 (33/2)	0.00	3.0	4.2 (76/1.5)	0.184	13.7
3.6 (101/8)	0.62	5.8 (34/3)	1.0 (24/0.5)	1.5 (47/4)	13.4 (147/7)
1.0 (17/4)	0.33	0.66	2.5 (53/4)	1.2 (16/2)	53
0.89	0.0050	0.2 (4/1)	7.1 (34/0.5)	1.1	41
	0.33	0.1	12.4	2.3 (66/3)	52
	0.35		37.0	3.5 (78/9)	21
	0.00		25.0	2.6 (83/19)	6.6 (74/1.5)
	1.00		45.0	6.7	29
	0.188				
	0.90				
	0.00				
$\bar{X}$ - 1.7	$\bar{X}$ = 0.37 + .33	$\bar{X}$ = 1.8 ± 2.4	$\bar{X}$ - 16.7 ± 16	$\bar{X}$ = 2.37 ± 2	$\bar{X}$ = 25.8 + 18
	$\bar{X}$ = 0.133*	$\bar{X}$ = 0.514*	$\bar{X}$ = 66.0*	$\bar{X}$ = 1.5*	$\bar{X}$ = 47.2*

5.8 (34/3) = 5.8 perch hops per minute over the entire test period, 34 perch hops in the first 3 minutes

* mean value from previous test (before habituation)

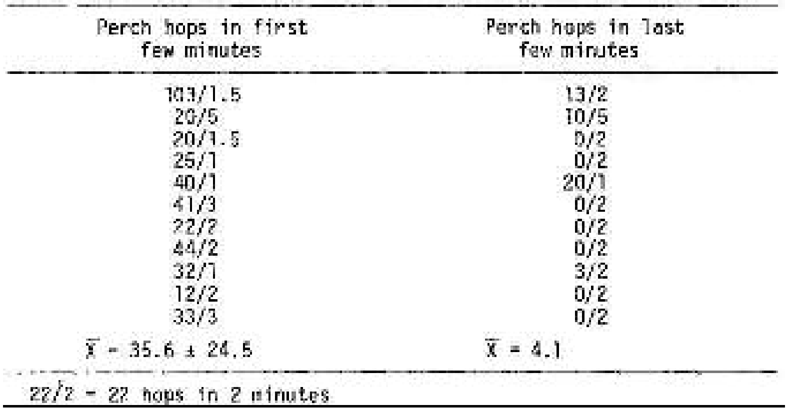
over 30 theories have been proposed to explain the function of the pecten, one of which is light absorption. The position of the pecten is such that it shades the fovea, thus decreasing the effect of intense liqht. Another feature of the pecten, its vascularity, would also explain how the heat of the laser beam is dispersed without burning the retina; for example, 4 watts for 30 seconds is equal to 120 joules or 28.5 calories. When concentrated by the lens of the eye this would be a tremendous heat load for the retina if it were not for some means of dispersing it.

The second hypothesis deals with the colored oil droplets found in the eyes of birds and reptiles. It is usually thought that these oil droplets enhance color vision by acting as filters. When one compares the absorption spectrum of the rhodopsin with the absorption spectrum of the oil droplets (Figure 1) he will see that they overlap somewhat, especially between the wavelenghts of 450 and 510 nm where birds have their greatest sensitivity (Winner, 1959). As Sillman points out, the biological significance of the oil droplets still remains to be determined. Both reptiles and birds that are exposed to intense solar radiation (reptiles in deserts, birds at high altitudes) possess oil color vision; Ducker and Tiemann (1972) have shown that oil droplets in reptiles have little to do with color vision. It is possible that these colored oil droplets act as filters for the intense light. The mechanism by which they could accomplish this is unknown, and further research into bird vision is necessary to determine if either the pecten or oil droplets are responsible for the diurnal birds ability to look at intense light without any gross effects.

MALLARD DUCKS. As with the starlings, the mallards habituated to low-intensity pulsing light extremely fast, there being no significant difference in heart rate after four minutes in any of the low-intensity light regimes. Although there was little response to low-intensity light, the mallards were much more sensitive to high-intensity laser light than the starlings. This is understandable if one knows something about the behavior of the mallard duck. According to Winner (1959) the mallard duck moves to and from its feeding grounds during periods of very low light intensity (less than 0.1 ft-c). Also like many other waterfowl they are known to migrate at night. This would indicate that they have relatively good night vision. Indeed, they could see the investigator in a dimly illuminated room where the starlings could not see the investigator at all. In fact, the starlings would not move and could be picked up by hand in a dark room. The nocturnal feeding behavior of the mallard has already allowed rice farmers to use light as a control (illuminate rice fields and ducks do not feed). As Sillman (1969) pointed out, nocturnal birds have a greater amount of rhodopsin (rod pigment) and, thus, would be expected to have greater sensitivity to light especially over the wavelengths emitted by the argon laser, since it is here that bird rhodopsin has its peak sensitivity.

To bring about an avoidance response in the mallard of at least 50 percent, the intensity of laser light hitting the bird had to be at least 0.01-0.025 W/cm^2 (Table 3). Using the present laser system, the beam could only be expanded six inches and still give high enough intensities. Not only is it important that the bird avoid the laser beam but the time it takes the bird to avoid the light beam is equally important (Table 4). In this study, for a response to be considered as avoidance response it had to occur within 60 seconds. As the flight speed of aircraft increases, response time will become even

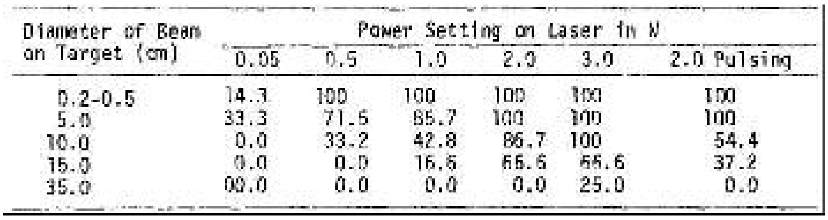
Table 2. Response of starlings to high-intensity (2-3 W) laser light (expanded and pulsing, 200 pulses/min)



Perch hops in first few minutes	Perch hops in last few minutes
103/1.5	13/2
20/5	10/5
20/1.5	0/2
25/1	0/2
40/1	20/1
41/3	0/2
22/2	0/2
44/2	0/2
32/1	3/2
12/2	0/2
33/3	0/2
$\bar{X} = 35.6 \pm 24.5$	$\bar{X} = 4.1$

22/2 = 22 hops in 2 minutes

Table 3. Percent of the Mallard ducks avoidinq laser light of different intensities under simulated daylight



Diameter of Beam on Target (cm)	Power Setting on Laser in W					
	0.05	0.5	1.0	2.0	3.0	2.0 Pulsing
0.2-0.5	14.3	100	100	100	100	100
5.0	33.3	71.5	85.7	100	100	100
10.0	0.0	33.2	42.8	86.7	100	54.4
15.0	0.0	0.0	16.6	66.6	66.6	37.2
35.0	00.0	0.0	0.0	0.0	25.0	0.0

more important. For example, a plane flying at 600 miles per hour will travel 10 miles in 60 seconds indicating that if the bird is 10 miles away, it only has 60 seconds to avoid the plane. This points out another problem which we will discuss later, that is, the effective distance over which a laser beam can elicit an avoidance response. If the bird is only 1 mile away and the plane is traveling at 600 miles per hour, then the bird has to respond in 6 seconds or collide with the aircraft. Aqain, as with the starling, the concentrated laser beam elicited the greatest and fastest avoidance response; avoidance is almost immediate.

The duck identified the laser beam as the source of irritation and in some cases would bite at it, whereas the starling did not seem to recognize the source of irritation. This explains somewhat why the ducks elicited a distress call when exposed to hiqh-intensity light and the starlinq did not. If the starling realized what the distress was (grabbing the bird) it too elicited a distress call. Equally important to an individual bird response is the response of a group of birds to the coherent laser light, since the beam cannot possibly hit every bird in the group. Although our groups were small (3 birds per group) there was a group avoidance response. The individuals not affected by the laser beam followed birds trying to avoid the beam.

GULLS. The gulls like the starlings, are diurnal birds, active during the daylight hours and quiet during the dark. Thus, one would expect them to have some mechanism for filtering out intense solar radiation. Although the expanded laser beam seemed to irritate the gulls (head-shaking, eye-rubbing) more than it did the starlings, the only laser beam that elicited an avoidance response was the concentrated beam of at least 0.5 W intensity (Table 5). The lack of a demonstratable group avoidance (found in starlings and ducks) response in the gulls miqht well depend on the size of the test cage (60 ft). The gulls had established a pecking order and were afraid to get too close to each other; thus, if the dominant bird moved to another area, the subordinate bird did not follow. Since the gulls associated the distress call with the intense light (bite at beam), they did utter a distress call and we know that under natural conditions a gull distress call will cause the birds to leave the area at least temporarily.

PROBLEMS FACED BY AIRCRAFT. The problem of air strikes is largely a function of airport location and construction. Runways built on or near ideal bird habitats bring birds and aircraft into conflict. The low, flat areas ideal for airports are frequently associated with water or marshland vegetation, which may be the breeding or roosting sites of larqe water birds or flocking, smaller, perching birds. The general construction of airports and large open spaces with extensive areas of short-cut grass provide a large amount of plant and invertebrate material to attract birds. Under conditions such as described, the majority of bird strikes would occur below 6000 feet and 60 percent below 2000 feet, at least for commercial airlines. For militray aircraft, approximately 95 percent of the bird strikes happen below 2000 feet and about 70 *percent* below 500 feet. Thus, we *are* faced with two basic problems in controlling birds: (1) to keep the birds off the runway to minimize the probability that aircraft approaching and landing and taking off and climbing to altitude encounter birds and (2) to keep birds that are flying at low altitudes out of the path of low-flying planes, especially high-speed militray aircraft. Seven

Table 4. Mean time to avoidance in Mallard ducks exposed to various laser light ranges under simulated daylight (sec.)

Diameter of Beam on Target (cm)	0.05	0.5	1.0	2.0	3.0	2.0 Pulsing
0.2-0.5	10.2	6.7 ± 2.7	9.0 ± 4.6	2.8 ± 2.4	15	5.7 ± 2.1
5.0	22.0	33.3 ± 6.5	24.3 ± 6	16.6 ± 2.6	0.0	15.8 ± 2.0
10.0	--	9.3	8.6 ± 1.9	16.3 ± 4.6	18.6 ± 3.7	9.9 ± 2.1
15.0	--	--	28.4	23.7 ± 7	15.2	28.9 ± 6.3
35.0	--	--	--	--	16.5	--

Means are ± one standard error of the mean.
Only birds eliciting an avoidance response are included in the mean values.

Table 5. Percent of the gulls avoiding laser liqht of different intensities

Diameter of Beam on Target (cm)	Power Setting on Laser (W)					
	0.05	0.5	1.0	2.0	3.0	2.0 pulsing
0.2-0.5	8.3	89.3	91.5	85	71.3	89.5
1.0	0	12.5	25	55.6	37.5	16.7
2.0	0.0	10	37.2	33	17.7	0.0
5.0	0.0	0.0	14.3	8.3	0.0	6.2
10.0	0.0	0.0	0.0	0.0	0.0	0.0
15.0	0.0	0.0	0.0	0.0	0.0	0.0

F-104 jets were lost in Canada because of bird strikes at low-altitude, high-speed flight.

Several factors enter into the design of a bird control under these conditions:

1. species specificity,
2. pulsing or continuous light,
3. effective distance and effective power,
4. habituation, and
5. speed of the aircraft (avoidance time).

Now let's take each factor separately and apply it to the laser as a means of control. Many diverse ways (noise makers, distress call, falcons) of scaring birds have from time to time been tried to control birds around airports, but have generally been found wanting. They have been inadequate mainly because they are either species-specific or the birds habituate to them. The best control would be one that is nonspecies specific and that the birds would not habituate to. The laser system used in these tests fulfulls both these requirements as long as the beam is irritating (concentrated). None of the species tested (repeatedly) failed to avoid a concentrated laser beam of at least 0.5 W, indicating it was nonspecies specific and they did not habituate to it.

Once expanded (light intense but not capable of burning) the continuous laser beam was no longer species specific under the laboratory condidions, in fact starlings, and gulls to a lesser extent, could look directly into the beam without snowing avoidance response. Pulsing laser light (expanded beam) did increase the initial activity of the starlings. Mallards were also sensitive to laser beams (pulsing and continuous) expanded up to 6 inches in diameter and showed little habituation to these beams at high intensities. It becomes clear that equally as important as laser intensity to species specificity is whether the laser is pulsing or continuous. Though a diurnal bird would not usually fly at night, if scared by a landing or leaving aircraft flying over their roost at night, they might fly toward a continuous light source, whereas a pulsing light (100-200 pulses/min) would seem to elicit an avoidance response. The nocturnal flying birds would most likely be repelled by either pulsing or continuous laser light.

It is obvious that the nonspecificity of the concentrated laser beam is due to the burning and not the light itself (especially since this highly aimed beam affects the bird even when aimed at the leg). For example, the time it took to move a mallard duck with the concentrated beam at 0.5 W was approximately 7 seconds. At this intensity the duck was hit with light at an intensity of 14.6 W/cm^2; in 1 second this is equivalent to 14.6 J/cm^2; and in 7 seconds (mean avoidance time) it is equivalent to 102.2 J/cm^2 or 24.7 cal/cm 24.7 cal/cm^2. This is enough heat to raise 1 gram of water to 24.7° C. This was the minimum tested power capable of eliciting an avoidance response in starlings and gulls. Schaefer (1968) found that 6 J/cm^2 is required to ignite flight feathers. Powers as low as 0.3 W.cm^2 were capable of eliciting an avoidance response in duck. It should be pointed out that the concentrated laser beam would elicit an avoidance response no matter where it hit the bird, althouqh the response was faster if the beam was aimed at the unfeathered portions (eye and bill).

The large size of airports (runways) and the high flight speeds of modern aircraft indicates that the effective distance of any control system will be extremely important in its use. Knowing the diameter of the laser beam needed to elicit a response at variuos power settings (W), one can calculate the effective distance of the laser.

The dispersion of the laser beam as it travels from the laser only, or from a laser/telescope combination where the focal point of one lens in the telescope exactly overlaps the focal point of the other lens is expressed by the equations

$$\theta = 1.22 \frac{\lambda}{D} \qquad (1)$$

$$R(2 \times \theta) = d \qquad (2)$$

$d + D$ = dispersion of beam at distance R

λ is the wavelength (cm),
D is the diameter of the beam at the output of the laser *or* telescope,
R is the distance to target,
θ is the angle of dispersion, and
D is the dispersion at distance R

If we consider a diameter of from 0.2 to 0.5 cm (0.5 W or better) as the only laser beam which is not species-specific, it becomes obvious that the laser by itself will not be very efficient since its effective distance is extremely short (in 5 m the beam will be 0.55 cm in diameter). In 1 km the beam will be 80.15 cm in diameter (using only the laser). What is important is that now (using the telescope) at 1 km the beam is only 6.9 cm in diameter, whereas is was 80.15 cm in diameter using only the laser. It should be pointed out here that we have been discussing only those laser beams that were capable of bringing about 50 percent of better avoidance in the laboratory. This does not mean that a beam 1 m in diameter in the wild would not cause a flying bird to avoid the plane. Soloman (1970) has reported that radar has shown night-flying geese to avoid a landing plane with its landing lights on. It is obvious that those birds were not irritated by intense light, they just saw the plane in time to avoid it. Under these conditions the laser with its greater effective distance would give the birds more time to avoid the aircraft, avoidance time being extremely important in high-speed, low-altitude flight.

We are concerned with a light source (laser beam) intense enough to bring about an avoidance response for control of birds on the runway, and we would thus need additional optics capable of delivering an intensely concentrated beam at a distance of at least 1000 meters.

PROBLEMS IN USE OF LASER AS A CONTROL. When considering the problems (hazards) of using intense light as a bird control one must think in terms of the two control situations: (1) control of resident birds at the airport, and (2) control of birds encountered in flight. If the control in the airport situation is to be non species specific, then either a concentrated laser beam will be used or an expanded beam of much greater power since it takes at least 6 J/cm^2

to be irritating to the bird. This presents a human hazard since the acceptable safety limit to the human eye for irradiation from the argon laser is 20 mW for 1 ms (Pressley, 1971). In our experiments it took at least 500 mW to get an avoidance response from starlings and gulls; this is well above the safety limit. One possible way of alleviating the danger to the human eye would be to use a laser emitting in the infrared wavelengths, to which the human eyes are not as sensitive. Another problem is that the more concentrated the beam, the more accurately it has to be aimed, indicating either that it has to be manned continually or radar aimed.

Though some birds might respond to a lower intensity beam (not eye irritating), it is possible that on cold days that heat energy contained in the laser beam would actually attract the birds instead of repelling them. Lustick (1969, 1970, 1971) has shown that birds, when at ambient temperature below their lower critical temperature, will use incoming solar radiation between the wavelengths of 400 to 1400 nm to decrease the energy cost of maintaining a constant body temperature, and, thus, bask under artificial sunlight at low ambient temperatures.

With any light source, especially around airports (usually built in low-lying marsh areas) fog is going to disrupt the light efficiency as a control method by cutting down on its intensity and effective distance.

These same problems will occur in flights, except that in flight the concentrated beam becomes more dangerous since it would be extremely difficult to aim. For example, a landing plane using a long-range laser beam might focus on another plane, or something or someone on the ground. Also the system described in this study is water-cooled, requiring 2.2 gallons of water per minute, thus making it difficult to mount on an airplane. However, there are argon lasers that are air cooled also capable of putting out high-energy pulses. These would function as long as continuous laser energy is not needed.

SUGGESTED METHOD OF USE AND FEASIBILITY OF THE ARGON LASER AS A BIRD CONTROL.

Again we have to consider the two control situations: (1) birds inhabiting (nesting, feeding) the runways and immediately adjacent areas, and (2) birds or bird flocks encountered in level flight. As mentioned previously, the concentrated laser beam is nonspecies specific and would seem to be the best means of dispersing birds that are on the runways. In fact, resident birds exposed to an irritating laser beam a few times would soon learn to avoid the area. A system similar to that used with biosonics (Busnel and Givan, 1968) might be set up with lasers. Lasers equipped with zoom telescopes positioned so that they could scan the entire field 4 inches above the ground could be controlled from a central point. Birds land on a particular part of the field and the observer turns on the laser scanning that portion of the field. To increase safety one would want a 6 inch high black metal shield around the perimeter of the field to trap the beam. An infrared laser would work equally well as the argon device with less hazard to the human eye. The number of lasers required would depend on the type of telescope used (effective distance). An alternative to this method would be a mobile unit with the laser mounted in it. This method would be less expensive but would require a person to aim it accurately. This concentrated beam would be the only feasible way of denying all birds the airfield as a habitat.

Another method of keeping birds off the airfield that needs further research is a combination laser and distress call. Biosonics (amplifying the taped distress call to birds) has been somewhat successful but the birds soon habituate to it, or return to the area after the sound stops. The resson for this is that there is no actual distress. By combining the concentrated laser beam with the distress call it is possible that the bird, after a few exposures will no longer habituate to the distress call. Here we are using the laser to reinforce the distress call.

In flight we are faced with a different problem. In this instance, I do not think a concentrated (irritation) laser beam could be used, though Shaefer (1968) has suggested using lasers to burn the flight feathers off of the birds in the path of airplanes. What should be used is an expanded laser beam of low intensity with the advantage of laser light over regular landing lights beinq a greater effective distance, thus giving birds a longer time to avoid the plane. For example, a laser and telescope combination that emitted a beam 6 inches in diameter (2W) would disperse to only 14 inches in diameter in 10 kilometers. The power of 1 cm in front of the laser would be 11 mW/cm^2, and in 10 kilometers the power would be 2 mW/cm^2. Also it should be a laser pulsing approximately 100 to 200 per minute, thus diurnal birds at night would not be attracted toward the aircraft and at the powers just described the laser would not be irritating to the human eye. Here the use of radar to foreward the pilot that he is apt to fly into a flock of birds would increase the efficiency of this method. If no other planes were in the area and the pilot were flying in level flight, a more intense expanded beam could be used and the bird would have even greater time to avoid the plane.

Question: Do birds have problems seeing the light?

Answer: If you know something about bird vision, they can scan an entire area. A bird flying over a field sees a mouse without really concentrating on that mouse. But a mammal would have to literally concentrate on it. A bird has a tramendous diencephalon for vision; it is the best thing a bird really has, its vision. It could see the light, especially if the light is scanning from side to side, which it would do if the mirror were not rigid.

Question: What about the use of laser beams in control of birds?

Answer: Once again, the concentrated beam would move those birds 1-2-3, but it could also put a hole in a tree. If the birds were on the ground, in some places it would be all right to do that. You control lasers; you don’t let the beam go out. You don’t want laser beams being scattered at random; you need *to* be able to *control* the beam. You can divert it with mirrors or stop it with a little metal plate. I use copper plate painted black, and this will stop it.

Question: How about the use of glass mirrors?

Answer: If glass mirrors were used, the beam would bounce all over the place. In fact, we have tried mirrors in order to pinpoint the beam. I can get the beam down to .4 micron in diameter, but at this size, damage can result to individual cells. Lasers are dangerous. They are coming out with all kinds of radiation precautions on lasers.

Question: Does the laser seem to be the best method of bird control at airports?

Answer Well, they've tried radio waves without any results. The Air Force tried at Midway, about 150 different ways of controlling birds. There the problem was the albatross that nested everywhere. They tried men running around with big red placards chasing birds off the runways. And they put guy lines twenty feet above the ground, so the birds could not fly over. They killed 80,000 birds one day; the next day they had 90,000 birds sitting back on the runway. They tried just about everything they could, jet engines, radar; nothing would work. They were really a problem. Airline pilots flying into Boston turn on their radar full blast to remove the birds. The bigger the bird, the greater the hazard. They have taken four-pound birds and fired them out of cannons at windshields at 600 miles an hour in trying to get damage estimates. But it doesn't have to be a big bird. Starlings or blackbirds have choked the intake ports of Lear jets. It is a big problem and it is something that needs to be investigated further, because it is not only costing money; it is also costing some lives.

Literature Cited

Bridges, C. 1962. Visual pigments of the pigeon (*Columbia livia*). Vision Res. 2:125-137.

Busnel, R. and J. Givan. 1968. Prospective considerations concerning bioacoustics in relation to bird scaring on airfields. Symp. Inst. Bio. No. 17. The Problems of Birds as Pests. Academic Press, pp. 17-28.

Crescitelli, F. 1958a. The natural history of visual pigments. Ann. N.Y. Acad. Sci. 74:230-255.

Crescitelli, F. 1958b. The natural history of visual pigments. Photobio: Proc. 19th Ann. Biol. Coolog. Oregon State C. pp. 30-51.

Crescitelli, F., B. Wilson and A. Lilyblade. 1964. The visual pigments of birds. 1. The turkey. Vision Res. 4:275-280.

Ducker, G. and G. Tiemann. Die Entwicklug der Farbigen Ol kugein in der Retina Von *Anguis fregillis*, *Lacerta agilis*, und *Lucerta vivparce* Farbsehvermogen (Reptilia, *L. acertilia*). A. Morph. Tiere 71:105-115, 1972.

Hamilton, Wendt. Coleman. 1933. Trichromatic vision in the pigeon as illustrated by the spectral line discrimination curve. J. Comp. Psych. 5:183-191.

Kramer, G. 1961. Long-distance orientation. Biology and Comparative Physiology of Birds. Academic Press, pp. 351-369.

Lashley, K. 1916. The colour vision of birds, 1. The spectrum of the domestic fowl. Animal Beh. 6:1-126.

Lustick, S. 1970. Absorption of radiant energy in redwinged blackbirds (A*gelaius phoenicece*s). Condor 72:471-473.

Lustick, S. 1969. Bird energetics: effects of artificial radiation. Science. 163:387-390.

Lustick, S. 1971. Plumage colour and energetics. Condor. 73:121.

Matthews, G. 1955. Bird Navigation. Cambridge Univ. Press. New York.

Matthews, L. and B. Matthews. 1939. Owls and infrared radiation. Nature. 143:983.

Meanley, R. 1971. Blackbirds and the southern rice crop. Res. Publ. 100. U.S. Dept. Int. Fish and Wildl. Serv. pp.64.

Pressley, R. (ed) 1971. Handbook of lasers. Chem. Rubber Co. Cleveland, Ohio, pp.631.

Pumphrey, R. 1961. Sensory organs: vision. Bio. and Comp. Physio. Birds. Marshall (ed) Academic Press, pp. 55-68.

Schaefer, G. 1968. Recent developments in bird scaring on airfields. Prob. of Birds as Pests. Symp. Instit. Bio. No. 17. pp. 50.

Sillman, W. 1969. The visual pigments of several species of birds. Vision Res. 9:1063-1077.

Soloman, V. 1970. Bird hazards to aircraft. Proc. 5th Bird Cont. Seminar pp. 39-45.

Wald, G. 1937. Photo-labile pigments of the cnicken retina. Nature. 140:545-546.

Wald, G. 1958. Retinal chemistry and the physiology of vision. Vis. Prob. of Colour. Sump. No. 8, Nat. Phys. Lab. H.M.S.O. pp. 7-61.

Walls, G. 1942. The Vertebrate Eye and Its Adaptive Radiation. Hafner, N.Y.

Watson, J. 1915. Studies on the spectral sensitivity of birds. Pap. Dept. Marine Biol. Carnegie Inst. Wash. 7:87-104.

Winner, R. 1959. Field-feeding periodicity of black and mallard ducks. J. Wildl. Manage. 23:197-202.

Wildlife Leaflet 409. 1959. U.S. Dept. of Int. Fish and Wildl. Serv. Bur. Sport Fish, and Wildl.