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# Response of Water Birds to Hazing with a Red Laser

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**ABSTRACT:** The use of lasers to prevent oiling of waterbirds at a spill is a new concept. Little is known about how some species that could occur at a spill would respond. The objectives of this study were to: 1) identify species that respond to the laser, 2) document the immediate response of waterbirds to the laser, 3) determine if laser treatment during the early evening reduces bird numbers over the course of a night, and 4) determine if the laser treatment has any lasting effect over the short term after treatment has ended. The study was conducted in 2 parts. In Part 1, we used 5 locations in the Sacramento Valley of California. We visited the sites at dusk from October 2007 - March 2008 and opportunistically used the laser on any birds encountered. At each test session, we recorded ambient light levels and the species and number of birds. We fired the laser, then recorded the immediacy and type of responses and the number of birds remaining. A response was considered favorable if the bird left the site. For Part 2, we used a 20-ha marsh in Woodland, Yolo County, California. The study, conducted in March 2008, was divided into 3 periods (pre-treatment, treatment, and post-treatment) of 5 days each. We counted birds in the morning and at dusk each day. During the treatment period, we counted the birds at dusk, fired the laser, and then counted any remaining birds. We recorded the same information as described above for the random tests. In part 1, we tested the laser on 18 evenings and fired the laser 129 times at 2,000 birds consisting of 25 species. Overall, 1,212 (61%) birds responded favorably. High proportions of pelicans and cormorants (100%), herons and egrets (99%), geese (93%), and diving ducks (85%) responded favorably. No grebes, coots, shorebirds, gulls responded favorably. Only 10% of the dabbling ducks responded favorably to treatment. In Part 2, we fired the laser 74 times at 3,036 birds consisting of 16 species. Overall, 2,251 (74%) birds responded favorably. High proportions of herons (98%) and dabbling ducks (93%) responded favorably, but only 46% of the diving ducks responded favorably. No coots responded favorably. There was a significant decrease in bird numbers immediately after laser treatment. Bird numbers recorded the next morning were not significantly different from the levels present just before the laser treatment the evening before. There was a significant decrease of 47% in the average number of birds on the treated area from the pretreatment period ( $\bar{x} = 873.7$ ;  $SD = 151.8$ ) to the treatment period ( $\bar{x} = 463.9$ ,  $SD = 171.3$ ). Thereafter, the number of birds during the 5-day post-treatment period ( $\bar{x} = 530.8$ ,  $SD = 206.6$ ) was not significantly different from that during the treatment period. Suggestions are provided on using the laser at a spill event.

**KEY WORDS:** hazing, laser, oil spill, waterbirds

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## INTRODUCTION

The use of lasers to haze birds is a relatively new development. Most hazing efforts have been undertaken with the goal of reducing crop damage or resolving human health and safety issues. Formal tests to evaluate lasers have involved double-crested cormorants (*Phalacrocorax auritus*) on night roosts near aquaculture facilities (Glahn et al. 2000), common eiders (*Somateria mollissima*) and common goldeneyes (*Bucephala clangula*) on mussel farms in Scotland (Ross and Furness 2002), Canada geese (*Branta canadensis*) in captivity (Blackwell et al. 2002, Werner and Clark 2006), Canada geese on lakes or reservoirs near urban areas (Delph 2001, Holevinski et al. 2007, Sherman and Barras 2004) and gulls (*Larus* spp.) on reservoirs near airports (Baxter 2007) and at a landfill (Chipman et al. 2004).

The use of lasers to prevent or limit oiling of birds at an oil spill is a new concept that has not been evaluated. The species mentioned above could occur at an oil spill. However, little is known how other species (e.g., coots, grebes, herons, dabbling ducks, and diving ducks) that could potentially occur at a spill would respond to hazing with a laser. The laser could represent an important new

tool for hazing birds at spills, particularly at night or low-light situations. Currently there are few options for night-time hazing.

The objectives of this study were to: 1) identify the species of waterbirds that respond to laser light, 2) document the immediate response of waterbirds to laser light, 3) determine if laser treatment during the early evening reduces bird numbers over the course of a night (as evidenced by birds present the next morning), and 4) determine if the laser treatment has any lasting effect on waterbirds over the short term (5 days) after treatment has ended.

## STUDY AREAS AND METHODS

### Part 1

For objectives 1 and 2, we conducted random tests at 5 different locations in the Sacramento Valley of California (Table 1). These locations were known to be used by birds and were situated relative to nearby structures or human activities such that the laser could be safely used.

We visited the sites at dusk on different evenings during the period from late October 2007 through mid-

**Table 1. Locations of sites used to test species responses to laser treatment in Part 1 of the study.**

| Location     | Nearest town    | County          | Description  |
|--------------|-----------------|-----------------|--|
| Collins Lake | Oregon House    | Yuba            | 650 ha lake  |
| Lake Solano  | Winters         | Yolo and Solano | 1 km stretch of Putah Creek near diversion dam, ~4 ha surface area.              |
| Road 25      | Woodland        | Yolo            | Irrigation ditch and impoundment alongside a road, ~2.7 km, 5.3 ha surface area. |
| Putah Creek  | Davis           | Yolo            | Impoundment in an arboretum, 0.6 ha  |
| Linden Road  | West Sacramento | Yolo            | Irrigation and flood water basin, 1.5 ha   |

March 2008 and opportunistically used the laser on any birds encountered. At the start and end of each evening's treatment sessions (exposure to laser light), we used a light meter to measure the ambient light levels (taken and then averaged from the cardinal directions). We recorded the species and number present, fired the laser at the birds, then recorded the number remaining. We tested the laser around dusk but not under darkness. After using the laser, the available light had to be sufficient for us to see and count any remaining birds. Each test firing of the laser at a bird or group of birds was termed a session.

We used an Avian Dissuader, a Class 3B 50-mW helium-neon red laser (Feather-Light Technologies LLC, Lebanon Junction, KY), on the birds. The laser treatment was standardized in such a manner as to improve accuracy. The laser was first fired at the ground in front of the operator, lined up with the target, and then steadily raised towards the target. This procedure allowed the operator to easily follow the red laser dot as it moved towards the target. The laser dot was steadily brought to bear on the target, then when on the target, if necessary, the laser was moved rapidly back and forth, around and onto the target. The target was considered nonresponsive if there was no favorable response after 2 or 3 exposures of 10 seconds each; a response was considered "favorable" if the birds left the site.

The immediacy of birds' responses was recorded as: none, immediate, or delayed (e.g., it took a few seconds or more before the birds responded). The type of response was recorded as none, took flight, swam away, flapped away over the water, ran away, walked away, alert only, or dived. If the bird flew, then the flight response was further classified as flew away out of sight, landed nearby (e.g., on the same pool), or landed on an adjacent site. A response was considered favorable if the bird left the site by any means (e.g., flying, running, or swimming).

## Part 2

For objectives 3 and 4, we selected a study site in Woodland, Yolo County, along County Road 25 (Rd 25). The site was a man-made marsh of about 20 ha. The marsh, which extended for 0.8 km alongside Rd 25, consisted of stands of cattails and bulrush interspersed with pools of open water. We divided the marsh into 4 distinct count areas, based on the pools of open water that were separated and delineated by the emergent vegetation. One area was selected at random to be an untreated site. The remaining 3 areas received the laser

treatment. Due to their proximity to one another, we did not consider the treated areas to be distinct plots or independent of one another, thus we pooled the count data for subsequent analysis and considered that data to represent a total count for the treated portion of the marsh. Due to its proximity to the treated area, the untreated portion of the marsh did not represent an independent control site, but rather served as an example of how bird numbers in an untreated portion of a laser-treated marsh might change. There were no other sites nearby with similar habitat conditions or species composition to serve as an independent control plot.

The study, conducted in March 2008, was divided into 3 time periods of 5 days each: pre-treatment, treatment, and post-treatment. We counted birds twice a day, once in the early morning and then again at dusk. Counts for each pool were done from a vehicle parked at a fixed point on the side of Rd 25. During the treatment period, we counted the birds on the control area first, then moved to the first pool to be treated. We would count the birds, use the laser, then count any remaining birds. The process would then be repeated for the remaining 2 pools to be treated. We recorded the same information (e.g., ambient light levels, response to laser treatment) as described above for the random tests.

We applied the laser treatment at the Rd 25 marsh in a standardized manner that differed somewhat from the technique used in the random tests. We fired the laser from a vehicle while parked at a fixed location next to each treated pool. We slowly made up and down movements of the laser around or on the target birds while generally sweeping horizontally across the area either from left to right or from right to left. Individual birds or groups of birds encountered during the sweep received up to 6 to 8 sec of targeting if they did not react immediately. At the end of the first sweep, if any birds remained, a second and if necessary a third sweep were made across the area. We considered birds non-responsive if they remained after 3 sweeps.

## RESULTS

### Part 1

We tested the laser at 5 locations on 18 evenings (Table 2). We fired the laser 129 times at 2,000 birds consisting of 25 species (Table 3). Overall 1,212 (61%) of 2,000 birds responded favorably by leaving the area. High proportions of pelicans and cormorants (100%), (85%) responded favorably. Grebes, coots, shorebirds herons and egrets (99%), geese (93%), and diving ducks

**Table 2. Number of test days, sessions (number of times the laser was fired at target birds), and the number of birds targeted at 5 locations during Part 1 of the study.**

| Location     | Test days | Sessions   | Number targeted |
|--------------|-----------|------------|-----------------|
| Collins Lake | 3         | 8          | 130             |
| Lake Solano  | 3         | 31         | 170             |
| Road 25      | 9         | 66         | 1357            |
| Putah Creek  | 2         | 21         | 338             |
| Linden Road  | 1         | 3          | 5               |
| <b>Total</b> | <b>18</b> | <b>129</b> | <b>2000</b>     |

and gulls did not respond favorably to laser treatment. Only 10% of the dabbling ducks responded favorably to treatment. Out of 129 sessions, all birds either left the area on 75 occasions (58%) or did not on 51 occasions (40%). A partial response, where some birds stayed and others left, occurred only during 3 sessions (Table 4).

**Table 4. Number of sessions in which none of the birds responded favorably, some of the birds but not all responded favorably, or all of the birds responded favorably in Part 1 of the study.**

| Group <sup>a</sup> | Number of sessions |                |               |
|--------------------|--------------------|----------------|---------------|
|                    | None responded     | Some responded | All responded |
| Grebes             | 5                  | 0              | 0             |
| Pelicaniformes     | 0                  | 0              | 2             |
| Hérons, egrets     | 1                  | 0              | 20            |
| Geese              | 0                  | 1              | 16            |
| Dabbling ducks     | 22                 | 0              | 6             |
| Diving ducks       | 8                  | 2              | 30            |
| Raptors            | 2                  | 0              | 1             |
| Coots              | 10                 | 0              | 0             |
| Shorebirds         | 1                  | 0              | 0             |
| Gulls              | 2                  | 0              | 0             |
| <b>Total</b>       | <b>51</b>          | <b>3</b>       | <b>75</b>     |

<sup>a</sup> See Table 3 for the species in each group.

**Table 3. Bird groups, number of species in each group, sessions (number of times the laser was fired at target birds), birds targeted and responding favorably to laser treatment in Part 1 of the study.**

| Group <sup>a</sup> | Species   | Sessions   | No. targeted | No. responding (%) |
|--------------------|-----------|------------|--------------|--------------------|
| Grebes             | 1         | 5          | 6            | 0 (0%)             |
| Pelicaniformes     | 2         | 2          | 16           | 16 (100%)          |
| Hérons, egrets     | 4         | 21         | 208          | 206 (99%)          |
| Geese              | 2         | 17         | 412          | 385 (93%)          |
| Dabbling ducks     | 3         | 28         | 372          | 38 (10%)           |
| Diving ducks       | 8         | 40         | 665          | 566 (85%)          |
| Raptors            | 2         | 3          | 3            | 1 (33%)            |
| Coots              | 1         | 10         | 37           | 0 (0%)             |
| Shorebirds         | 1         | 1          | 1            | 0 (0%)             |
| Gulls              | 1         | 2          | 280          | 0 (0%)             |
| <b>Total</b>       | <b>25</b> | <b>129</b> | <b>2000</b>  | <b>1212 (61%)</b>  |

<sup>a</sup> Group: grebes - pied-billed grebe (*Podilymbus podiceps*); Pelicaniformes - American white pelican (*Pelecanus erythrorhynchos*), double-crested cormorant (*Phalacrocorax auritus*); herons and egrets - great blue heron (*Ardea herodias*), great egret (*Ardea alba*), snowy egret (*Egretta thula*), cattle egret (*Bubulcus ibis*); geese - Canada goose (*Branta canadensis*), greater white-fronted goose (*Anser albifrons*); dabbling ducks - mallard (*Anas platyrhynchos*), gadwall (*Anas strepera*), cinnamon teal (*Anas cyanoptera*); diving ducks - canvasback (*Aythya valisineria*), ring-necked duck (*Aythya collaris*), lesser scaup (*Aythya affinis*), common goldeneye (*Bucephala clangula*), bufflehead (*Bucephala islandica*), hooded merganser (*Lophodytes cucullatus*), common merganser (*Mergus merganser*), ruddy duck (*Oxyura jamaicensis*); raptors - red-tailed hawk (*Buteo jamaicensis*), great horned owl (*Bubo virginianus*); coots - American coot (*Fulica americana*), shorebirds - greater yellowlegs (*Tringa melanoleuca*); gulls - ring-billed gull (*Larus delawarensis*).

**Table 5. Number of sessions with favorable or unfavorable responses under differing light levels during Part 1 of the study.**

| Response    | Lux  |      |
|-------------|------|------|
|             | ≤300 | ≥301 |
| Favorable   | 50   | 15   |
| Unfavorable | 42   | 13   |

We tested the laser in light conditions that ranged from 0.1 to 1154.2 lux. (For the purpose of comparison, a light level of 0.1 lux is equivalent to a full moon, 10.8 would be twilight, 107.5 lux would be a very dark day, and 1,075.3 lux would be an overcast day.) The average light level during the tests was 209.6 lux ( $n = 122$ ,  $SE = 22.8$ ). There was no relationship between light levels and the outcome of the laser treatment ( $\bar{x} = 0.005$ ,  $df = 1$ ,  $P = 0.94$ ). Most favorable and unfavorable outcomes occurred when light levels were <300 lux (Table 5).

## Part 2

During the 5 evenings of treatment, we fired the laser 74 times at 3,036 birds consisting of 16 species (Table 6). Overall, 2,251 (74%) of 3,036 birds responded favorably by leaving the area. High proportions of herons (98%) and dabbling ducks (93%) responded favorably. Coots did not respond favorably to laser treatment. Only 46% of the diving ducks responded favorably to treatment. Out of 74 sessions, all birds either left the area on 27 occasions (36%) or did not on 31 occasions (42%). A partial response, where some birds stayed and others left, occurred during 16 sessions (Table 7).

The average light level at the start of the evening tests was 783.0 lux ( $n = 5$ ,  $SE = 102.75$ ), with a range from 533.8 to 1154.2 lux. The average light level at the end of the evening tests was 18.2 lux ( $n = 5$ ,  $SE = 1.7$ ) with a range from 13.5 to 23.2 lux. There was no difference in the average lux level at the start of laser treatment for each day ( $F = 1.8$ ;  $df = 4, 15$ ;  $P = 0.18$ ) nor at the end of laser treatment ( $F = 0.33$ ;  $df = 4, 15$ ;  $P = 0.86$ ).

**Table 6. Bird groups, number of species in each group, sessions (number of times the laser was fired at target birds), birds targeted and responding favorably to laser treatment in Part 2 of the study.**

| Group <sup>a</sup> | Species   | Sessions  | No. targeted | No. responding (%) |
|--------------------|-----------|-----------|--------------|--------------------|
| Hérons             | 1         | 6         | 1501         | 1470 (98%)         |
| Dabbling ducks     | 7         | 14        | 208          | 194 (93%)          |
| Diving ducks       | 7         | 46        | 1278         | 587 (46%)          |
| Coots              | 1         | 8         | 49           | 0 (0%)             |
| <b>Total</b>       | <b>16</b> | <b>74</b> | <b>3036</b>  | <b>2251 (74%)</b>  |

<sup>a</sup> Group: herons - black-crowned night heron (*Nycticorax nycticorax*); dabbling ducks - mallard (*Anas platyrhynchos*), gadwall (*Anas strepera*), northern pintail (*Anas acuta*), American wigeon (*Anas americana*), northern shoveler (*Anas clypeata*), cinnamon teal (*Anas cyanoptera*), green-winged teal (*Anas crecca*); diving ducks - canvasback (*Aythya valisineria*), ring-necked duck (*Aythya collaris*), lesser scaup (*Aythya affinis*), bufflehead (*Bucephala islandica*), hooded merganser (*Lophodytes cucullatus*), common merganser (*Mergus merganser*), ruddy duck (*Oxyura jamaicensis*); coots - American coot (*Fulica americana*).

**Table 7. Number of sessions in which none of the birds responded favorably, some of the birds but not all responded favorably, or all of the birds responded favorably in Part 2 of the study.**

| Group <sup>a</sup> | Number of sessions |                |               |
|--------------------|--------------------|----------------|---------------|
|                    | None responded     | Some responded | All responded |
| Hérons             | 1                  | 3              | 2             |
| Dabbling ducks     | 1                  | 0              | 13            |
| Diving ducks       | 21                 | 13             | 12            |
| Coots              | 8                  | 0              | 0             |
| <b>Total</b>       | <b>31</b>          | <b>16</b>      | <b>27</b>     |

<sup>a</sup> See Table 6 for the species in each group.

**Table 8. Number of birds present just before laser treatment in the evening, immediately after laser treatment, and the next morning after treatment during Part 2 of the study.**

| Date             | Number of birds          |                                     |                                      |
|------------------|--------------------------|-------------------------------------|--------------------------------------|
|                  | Present before laser use | Present immediately after laser use | Present next morning after laser use |
| 10 March 08      | 767                      | 54                                  | 677                                  |
| 11 March 08      | 759                      | 423                                 | 476                                  |
| 12 March 08      | 624                      | 104                                 | 393                                  |
| 13 March 08      | 368                      | 11                                  | 178                                  |
| 14 March 08      | 377                      | 38                                  | 352                                  |
| $\bar{x} \pm SD$ | 579.0 $\pm$ 196.9        | 126.0 $\pm$ 169.4                   | 415.2 $\pm$ 182.3                    |

**Table 9. Average number of birds per count for 5 species over the pretreatment, treatment and post-treatment periods (5 days each) on the untreated and treated areas during Part 2 of the study.**

| Species                   | Average number of birds $\pm$ SD |              |                |                        |
|---------------------------|----------------------------------|--------------|----------------|------------------------|
|                           | Pretreatment                     | Treatment    | Post-treatment | Significant difference |
| Black-crowned night heron | 262 $\pm$ 43                     | 239 $\pm$ 88 | 222 $\pm$ 32   | No <sup>a</sup>        |
| Canvasback                | 144 $\pm$ 18                     | 94 $\pm$ 79  | 89 $\pm$ 38    | No <sup>b</sup>        |
| Ring-necked duck          | 209 $\pm$ 52                     | 41 $\pm$ 60  | 11 $\pm$ 6     | Yes <sup>c</sup>       |
| Lesser scaup              | 308 $\pm$ 116                    | 32 $\pm$ 40  | 5 $\pm$ 4      | Yes <sup>d</sup>       |
| Ruddy duck                | 40 $\pm$ 21                      | 55 $\pm$ 7   | 55 $\pm$ 19    | No <sup>e</sup>        |

<sup>a</sup> Kruskal-Wallis test,  $P^2 = 3.8$ ,  $df = 2$ ,  $P = 0.15$

<sup>b</sup>  $F = 2.6$ ;  $df = 2, 27$ ;  $\chi^2 = 0.09$

<sup>c</sup> Kruskal-Wallis test,  $\chi^2 = 18.1$ ,  $df = 2$ ,  $P = 0.0001$ ; pretreatment > treatment = post-treatment

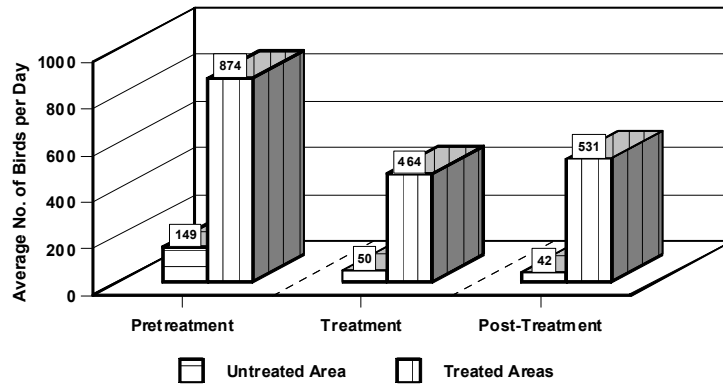
<sup>d</sup> Kruskal-Wallis test,  $\chi^2 = 21.7$ ,  $df = 2$ ,  $P = 0.00002$ ; pretreatment > treatment = post-treatment

<sup>e</sup>  $F = 1.8$ ;  $df = 2, 27$ ;  $\chi^2 = 0.19$

Regarding objective 3, we found there was a significant difference ( $F = 7.83$ ;  $df = 2, 12$ ;  $P = 0.007$ ) when comparing bird numbers before laser use, immediately after laser use, and the morning after laser use. Fisher's LSD multiple comparison test showed that bird numbers immediately after the laser treatment ( $\bar{x} = 126.0$ ,  $SD = 169.4$ ) were less than the two other time periods (Table 8), and that bird numbers recorded the next morning ( $\bar{x} = 415.2$ ,  $SD = 182.3$ ) were not different from the numbers present just before the laser treatment the evening before ( $\bar{x} = 579.0$ ,  $SD = 196.9$ ). Regarding objective 4, we found there was a significant decrease of 47% ( $F = 15.25$ ;  $df = 2, 27$ ;  $P = 0.00004$ ) in the average number of birds on the treated area from the pretreatment

period ( $\bar{x} = 873.7$ ;  $SD = 151.8$ ) to the treatment period ( $\bar{x} = 463.9$ ,  $SD = 171.3$ ). Thereafter, the average number of birds during the 5-day post-treatment period ( $\bar{x} = 530.8$ ,  $SD = 206.6$ ) was not significantly different from that during the treatment period (Figure 1). We observed a similar pattern of change on the untreated portion of the marsh with pretreatment > treatment = post-treatment numbers (Kruskal-Wallis test,  $\chi^2 = 9.4$ ,  $df = 2$ ,  $P = 0.009$ , Figure 1). Average bird numbers on the untreated portion of the marsh decreased by 67% from the pretreatment to treatment period.

Individual species reacted differently to the laser treatment. Most black-crowned night herons (98%) responded favorably to the laser treatment (Table 6) by



**Figure 1. Average number of birds per day (2 counts per day) over the pretreatment, treatment and post-treatment periods (5 days each) on the untreated and treated areas during Part 2 of the study.**

taking flight immediately. However, the same number were present the next day. There was no significant change in heron numbers over the 3 time periods of the study (Table 9). There also was no change in the numbers of canvasback over the 3 time periods (Table 9). Canvasbacks were not as predictable in their response to laser treatment as were the herons. Out of 8 sessions during the treatment period (Table 10), all canvasbacks either left the area on 2 occasions (25%) or did not on 3 occasions (38%). A partial response, where some canvasbacks stayed and others left, occurred during 3 sessions. The numbers of 2 species of diving ducks, the lesser scaup and the ring-necked duck, declined significantly during the treatment period and remained low during the post-treatment period as well (Table 9). Like the canvasback, the response of the scaup and ring-necked ducks were not always predictable. Out of 20 sessions during the treatment period, all scaup or ring-necked ducks either left the area on 8 occasions (40%) or did not on 5 occasions (25%). A partial response, where some scaup and ring-necked ducks stayed and others left, occurred during 7 sessions (Table 10). There was no change in the number of ruddy ducks over the course of the study (Table 9). On no occasion did all targeted ruddy ducks respond by leaving the area due to the laser (Table 10). In fact, ruddy ducks did not respond at all to the laser during the majority of sessions (82%).

**Table 10. Number of sessions when a given percentage of birds responded favorably to laser treatment during Part 2 of the study.**

| Species                   | 0% | 1 - 49% | 50 - 99% | 100% |
|---------------------------|----|---------|----------|------|
| Black-crowned night heron | 1  | 0       | 3        | 2    |
| American wigeon           | 0  | 0       | 0        | 1    |
| Cinnamon teal             | 0  | 0       | 0        | 1    |
| Gadwall                   | 0  | 0       | 0        | 1    |
| Green-winged teal         | 0  | 0       | 0        | 1    |
| Mallard                   | 1  | 0       | 0        | 6    |
| Northern shoveler         | 0  | 0       | 0        | 3    |
| Bufflehead                | 3  | 1       | 0        | 1    |
| Canvasback                | 3  | 2       | 1        | 2    |
| Common merganser          | 1  | 0       | 0        | 0    |
| Hooded merganser          | 0  | 0       | 0        | 1    |
| Ring-necked duck          | 2  | 2       | 2        | 3    |
| Ruddy duck                | 9  | 0       | 2        | 0    |
| Lesser scaup              | 3  | 2       | 1        | 5    |
| American coot             | 8  | 0       | 0        | 0    |

## DISCUSSION

All of the species targeted in this study could potentially occur at an oil spill. In responding to a spill, personnel responsible for hazing birds must decide which tools to use, a decision in large part based on efficacy. It is apparent that some species, namely herons, egrets, and geese, react immediately and dependably to the laser. Dabbling and diving ducks responded favorably on most occasions, although there were some times when they did not or only partially responded. During the random tests at 5 different locations (Part 1), only 10% of dabbling ducks responded favorably as opposed to 93% on the fixed study site (Part 2). Most of the dabbling ducks in random tests were mallards targeted on an impoundment in an arboretum. The area was frequented by people during the day and early evening. We can speculate that mallards at this site were habituated to human presence and other disturbances, and therefore they may have been less likely to respond favorably to the laser. Road 25, used for Part 2 of the study, was remote, had infrequent human presence, and was 1.6 km distant from the Yolo Bypass, a waterfowl hunting area. These factors may have predisposed the birds to react to disturbance and may have enhanced the response to the laser.

Some birds were problematic. Ruddy ducks usually did not respond favorably. Coots never responded favorably. Pied-billed grebes responded to the laser by diving or skittering across the water, but never to the extent that they left the area. It is likely that all grebes and other birds (e.g., loons) that typically dive rather than fly away in response to danger are poor candidates for hazing with a laser. Gulls, targeted on 2 occasions, did not respond favorably. This result was unexpected. Baxter (2007) dispersed over 30,000 gulls roosting on 2 reservoirs in the United Kingdom using a laser. Only 4 sweeps of the laser across water were needed to move all gulls from each site. In the present study, gulls on both occasions were on land. In one instance the birds did not respond at all, while in the second instance the gulls responded to the laser by either jumping or flying up briefly and then landing again. None left the area.

As a stand-alone tool used just once in the evening, the laser caused an immediate decrease in bird numbers but did not deter birds from returning by the next morning, and aside from scaup and ring-necked ducks,

did not have any lasting impact once treatment ended. A notable example was the night herons. Herons left the roost in the marsh immediately upon treatment but were present in the same numbers the next morning. Baxter (2007) found a similar situation at gull roosts. His initial treatment was to use the laser at dusk and clear the birds. The gulls were present by the next morning. Adding 2 additional sweeps with the laser equidistant through the night also failed to prevent the gulls being present the next morning. Gulls stopped returning to the roost only after laser treatment was increased to every 30 minutes throughout the night.

At an oil spill where night-time hazing was required, laser treatment could begin at dusk or earlier under conditions of heavy overcast or fog. The laser could be used repeatedly as needed to clear birds from the desired locations. Monitoring for returning birds would be necessary and hazing with the laser might be required throughout the night. Other hazing techniques (e.g., pyrotechnics, roving patrols from a boat) could be used for species not responding to the laser.

Lasers have several advantages that may be important at an oil spill. Lasers are light in weight, easy to carry, and have long range, up to 2.2 km or more depending on conditions. The portability and long range of a laser allow hazing personnel to efficiently and effectively treat a large area. In comparison, a propane cannon unit (which includes a propane tank) is less portable, has a smaller effective range, and is more difficult to deploy. Lasers can be used at night. Lasers are silent and can be used at locations where noise, particularly at night, is a concern. Lasers can be used in situations where flammable spill materials might prevent the use of pyrotechnics.

We did not test the laser at any coastal or bay locations. Additional testing should be undertaken at brackish or salt-water locations to increase the number of species evaluated. In particular, we need more information on how cormorants, gulls, terns, shorebirds, loons, and marine ducks will respond to laser treatment.

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