28 January 2016
Pete Warzybok
3820 Cypress Drive #11, Petaluma, CA 94952
707-781-2555 ext. 344
pwarzybok@pointblue.org

Hazing Effectiveness of a Large Gull Colony During the Non-breeding Season

PETE WARZYBOK[1] *Point Blue Conservation Science, 3820 Cypress Drive Petaluma, CA 94954, USA*

RUSSELL W. BRADLEY *Point Blue Conservation Science, 3820 Cypress Drive Petaluma, CA 94954, USA*

DAN GROUT *Grout Biological Consulting, 719 Swanton Road, Davenport, CA 95017, USA*

RICHARD GRIFFITHS *Island Conservation, 2161 Delaware Ave., Suite A, Santa Cruz, CA 95060, USA*

WINSTON VICKERS *Oiled Wildlife Care Network, UC Davis School of Veterinary Medicine, One Shields Avenue, Davis, CA 95616[1], USA*

GERARD J. MCCHESNEY *U.S. Fish and Wildlife Service, Farallon National Wildlife Refuge, 1 Marshlands Road, Fremont, CA 94555, USA*

[1] pwarzybok@pointblue.org

ABSTRACT Non-lethal hazing techniques for dissuading presence of gulls are commonly used in a variety of management actions. However, rarely are the effectiveness of hazing non-breeding gulls at a non-food source nor various methods quantitatively assessed, singly or in concert, to both remove gulls and limit impacts on non-target species. We addressed these questions at the Farallon National Wildlife Refuge, in the context of a proposed introduced house mouse (*Mus musculus*) eradication. Methods being considered for removing mice include the aerial application of rodent bait containing a rodenticide which will pose a risk of exposure to some non-target wildlife such as western gulls (*Larus occidentalis*), which breed in large numbers and roost in variable numbers in the non-breeding season. In a 16 day hazing trial conducted in November and December 2012, we evaluated the effectiveness of a combination of non-lethal wildlife hazing techniques including biosonics, pyrotechnics, lasers, reflective objects and effigies, for temporarily reducing gull numbers at the South Farallon Islands. We examined the relative effectiveness of these tools for dissuading gulls as well as the impact of these treatments on pinnipeds and other non-target bird species present on the islands. The hazing trial successfully demonstrated the feasibility of keeping gulls off the islands for an extended period of time (in this case a 12 day interval) while having relatively minor impacts on other species, namely other seabird species and pinnipeds. There were significant differences between individual hazing techniques both in terms of their effectiveness and their disturbance to non-target species. Lasers, effigies and techniques that combined auditory and visual stimulus had the highest hazing efficiency. These results provide valuable guidance for resource managers when choosing appropriate techniques for their individual hazing applications.

KEY WORDS deterrence, eradication, hazing, non-lethal, South Farallon Islands, western gull, *Larus occidentalis*

Non-lethal hazing of wildlife is an important tool used by resource managers to reduce wildlife damage, decrease harmful interactions with humans and protect wildlife from harm (Gilsdorf et al. 2003; Gorenzal et al. 2004). Examples of its application include deterring gulls from landfills (Cook et al. 2008; Baxter and Allan 2006; Curtis et al. 1995), reservoirs (Duffiney 2006; Golightly 2005) and airports (Belant and Martin 2011; Washburn et al. 2006), reducing the impact of Canada geese in urban and rural environments (Smith et al. 1999), reducing crop damage by foraging birds (Nemtzov and Galili 2006) and reducing the impact of oil spills on waterbirds (Gorenzal et al. 2006; Ronconi et al. 2004).

Non-lethal hazing techniques include a suite of physical, visual and auditory methods that may be used to disperse or dissuade wildlife from an area (Belant 1997; Gorenzal et al. 2008). Previous studies have demonstrated the utility of several non-lethal hazing methods including biosonic devices that broadcast alarm, distress or predator calls (Whitford 2008); pyrotechnics which frighten wildlife through a combination of noise, light and movement (Gorenzal and Salmon 2008); lasers (Gorenzal et al. 2010; Werner and Clark 2006; Blakwell et al. 2002); visual deterrents such as kites, balloons and mylar tape (Seamans et al. 2002, Gorenzal and Salmon 2008); effigies (Seamans et al. 2007); and helicopters (Marsh et al. 1991).

Many studies have examined the effectiveness of both lethal and non-lethal control of wildlife in order to decrease human-wildlife conflicts (Fall and Jackson, 2002, Baruch-Mordo et al. 2013 ADD other references) but relatively few have sought to use deterrence for the protection of the wildlife from human actions (Gorenzal et al. 2010 and other references). In addition, few studies have quantitatively assessed the impacts of hazing techniques on non-target species (Taylor and Kirby 1990).

The South Farallon Islands, part of the Farallon National Wildlife Refuge, are recognized as a globally important bird area and are home to more than 300,000 breeding seabirds as well as low numbers of migrating birds (Birdlife International 2015, Richardson et al. 2003). In addition, the Refuge serves as an important breeding and haul out site for pinnipeds including Northern elephant seal (*Mirounga angustirostris*), harbor seal (*Phoca vitulina*), Steller sea lion (*Eumetopias jubatus*), Northern fur seal (*Callorhinus ursinus*) and California sea lion (*Zalophus californianus*). During the nineteenth century, human activity on the islands resulted in the introduction of invasive house mice (*Mus musculus*) that have had both direct and indirect negative impacts on the unique native ecosystem of the islands (USFWS 2013)..

The United States Fish and Wildlife Service, which manages the Farallon National Wildlife Refuge, has proposed eradicating the introduced mice to help restore the native island ecosystem and conserve the populations of native wildlife (USFWS 2013). The proposed alternatives for mouse removal include the island-wide application of bait pellets containing rodenticide. This method has proven effective for other island eradication projects worldwide (Howald et al. 2007, Keitt et al. 2011, Mackay et al. 2011) but carries the risk of non-target exposure (USFWS 2013). Other studies indicated that the bait products being considered for mouse eradication (Brodifacoum -25D Conservation and Diphacinone-50 Conservation) would remain available and palatable to mice and other wildlife for between 7 and 101 days depending on the intensity of rainfall (Griffiths et al. 2013; USFWS 2013).

The occurrence of marine birds on the South Farallon Islands is strongly seasonal, with the greatest numbers present during the spring and summer breeding period (Desante and Ainley

1980(?), Ainley and Boekelheide 1990). The timing of the proposed operations to eradicate mice would therefore likely take place during the fall or early winter, when numbers of birds are lowest and when breeding activities would not be disrupted (USFWS 2013). However, long-term data on seasonal occurrence indicates that Western Gulls, as well as several species of wintering gulls (*Larus* spp.), will be present in varying numbers during this time period (Desante and Ainley 1980; Grout and Griffiths 2012; Pott and Grout 2012; Richardson et al. 2009; Point Blue Conservation Science, unpubl. data). This potentially puts them at risk of lethal exposure to rodenticide through direct ingestion of baited pellets or by scavenging carcasses of poisoned mice.

The purpose of this study was to demonstrate the ability to minimize the risk of rodenticide exposure to gulls by deterring them from the islands for the duration of the period that bait remains available. Non-lethal hazing techniques were selected for the trial to ensure the least impact on the species of concern. Effective mitigation for potentially harmful wildlife interactions is of great interest to many resource managers but information about the relative effectiveness of different tools can be difficult to obtain. Herein, we present a robust trial of many non-lethal wildlife hazing techniques and quantitatively evaluate their effectiveness in order to provide information to resource managers and allow them to make informed decisions on which hazing tools would be most useful in any given situation. Specifically, we evaluate the effectiveness of the hazing trial to reduce gull numbers, the relative effectiveness of the different hazing treatments for dissuading gulls and the impact of hazing activities on non-target species including pinnipeds and other bird species present on the islands. Although this study was conducted for the specific purpose of dissuading gulls from ingesting rodenticide, the knowledge generated can be applied to many other situations, including other eradication projects, oil spills, contaminated water sources and any other situations where it is necessary to haze birds.

STUDY AREA

This study was conducted at the South Farallon Islands (37°42'N 123°00'W), part of the Farallon National Wildlife Refuge, located 48 km west of San Francisco, California. The South Farallon Islands consist of two main islands, Southeast Farallon Island (SEFI) and West End Island (WEI; also known as Maintop Island), as well as several smaller offshore islets and rocks totaling approximately 49 ha. They are home to 13 breeding species of marine birds, five species of pinnipeds and a large diversity of migratory birds each year. With more than 300,000 breeding birds, they are the largest seabird breeding colony in the contiguous United States and include globally important populations for ashy storm-petrels (*Oceanodroma homochroa*), Brandt's cormorants (*Phalacrocorax penicillatus*), western gulls (*Larus occidentalis*) (Ainley and Boekelheide 1990).

Approximately 18,000 western gulls currently nest on the islands. Most nest on SEFI where they are spread relatively uniformly where space is not taken by densely nesting Brandt's cormorants and common murres; they nest in low densities on WEI and other islets (Penniman et al. 1990, Warzybok et al. 2014). Following the breeding season, numbers of western gulls at the islands decline sharply to a minimum in September and October. By early November, birds begin to return to roost or visit their territories. Numbers gradually increase over the remainder of the fall and winter, and by mid-March most of the breeding population has returned (Penniman et al. 1990). During the non-breeding season, daily numbers vary dramatically, and often birds are only present from near dusk to early morning. Birds may either be visiting breeding territories or in roosts, such as intertidal zones or other non-breeding areas. Also during the fall and winter, varying numbers of other gull species (*Larus* spp.) visit the islands to roost (Desante and Ainley 1980), mainly in intertidal areas and from late afternoon until early morning.

This study was conducted between November 18, 2012 and January 6, 2013, including pre- and post-trial monitoring. This period was selected to coincide with the likely timing of the proposed mouse eradication operation when overall marine bird numbers are near their annual minimum and outside of seabird and pinniped breeding seasons (USFWS 2013).

METHODS

Hazing Trial Design

The hazing trial was split into three distinct phases with each phase having its own specific objective (Table 1). Baseline numbers of gulls and pinnipeds were recorded prior to initiation of the hazing trial (the pre-trial period) while post-trial monitoring was conducted in order to determine the rate at which gulls resumed normal attendance patterns and to document any potential lasting impacts on pinnipeds. The impact of hazing activity and individual techniques on pinnipeds was continually assessed throughout the study.

Phase 1 of the trial aimed to evaluate the relative efficacy of specific techniques for hazing gulls and to determine the effective range of individual hazing tools. Responses of other bird species in the area were also noted. Each hazing tool was tested up to five times in areas where gulls were present. Phase 2 aimed to simulate likely hazing activity in the event of an eradication effort and to evaluate the overall effectiveness of a gull hazing operation at reducing the number of gulls present on the islands. Anecdotal evidence from Phase 1 trials was used to inform the deployment of the different hazing treatments in order to have the greatest effect. Hazing was conducted almost continuously from both SEFI and WEI whenever gulls were present. Phase 3 continued hazing operations but at a reduced scale and only from SEFI. The goal during phase 3 was to determine if both main islands could be effectively hazed using only ground-based personnel on SEFI. All hazing tools and combinations, with the exception of the helicopter and Zon cannons, continued to be used during this phase. During Phase 3, gulls were allowed to roost in certain localized areas where mice may not be present and bait may not need to be applied, including some small offshore islets and intertidal areas. These areas were treated as temporary refugia for gulls where they may potentially be allowed to roost during a mouse eradication operation.

A total of 21 different avian hazing tools were tested during this study and are listed below along with the standard abbreviations used throughout this report. These included:

- 6 biosonic devices - Bird Gard Super Pro® with 4 directional speakers (bg), Bird Gard Super Pro® with 4 speaker multidirectional tower (bgm), Bird Gard Super Pro Amp® (bga), Long-range Acoustic Device LRAD 100x™ (LRAD) , Marine Phoenix Wailer® (Wailer, wail), and Zon® propane cannon (zon);
- 5 pyrotechnic devices - Starter pistol caps (cap), Bird Bangers®/Bird Bombs® (bangers, bng), Screamer Sirens®/Bird Whistlers® (screamers, scr), Shell crackers® (crackers, crk) and CAPA rockets® (rkt);
- 3 lasers - Penlight laser pointer (green light) (las1), Avian Dissuader® (red light) (las2) and Aries Bird Phazer Laser® (green light) (las3);
- 5 passive visual deterrents – kites (kt), balloons (bal), mylar tape (my), owl decoys (owl) and western gull effigies (ef);

- 2 active mechanical deterrents - human presence (hum) and a Robinson R22 helicopter (helo).

In addition, we tested multiple combinations of individual hazing treatments for a grand total of 29 unique hazing treatments. The most common combinations tested were multiple different pyrotechnics (pyro), pyrotechnics in combination with biosonics or helicopter passes (pyroplus) and helicopter passes combined with the LRAD (helirad). A full description of each hazing treatment as well as a complete list of all unique combinations tested and their standard abbreviations are presented in Appendix A.

Gull distribution and abundance

Dawn gull counts were conducted on a daily basis by experienced ground based observers between November and March in 2010 and 2011 in order to establish a baseline population estimate for gulls on the islands during the fall and winter period. Counts were conducted at dawn because most gulls visiting the islands during this period arrive near dusk, roost for the night, then depart in the early morning. Although several species of gulls occur on the islands during this period (predominately western gulls), gulls were not separated to species for ease of counting. These counts were continued in 2012 for the two weeks prior to the hazing trial and again for several weeks after the conclusion of hazing. To allow a more detailed assessment of the impact of specific hazing treatments used during the trial, the islands were divided into 49 discrete sectors. During the trial, gull counts were conducted at the start of hazing activity each day in each area (usually near dawn); daily maximum dawn numbers were then determined by summing these earliest gull counts. Estimated numbers of individuals for other bird species in the area were also noted.

During all phases of the trial, trained observers recorded gull numbers and their location multiple times per day at regular intervals as well as the number of gulls present in the targeted area prior to application of the hazing treatment. They also identified and enumerated pinnipeds present in the area and all non-target avian species. During and after the treatment, observers determined the level of response by visually estimating the proportion of the original number of gulls and other birds which remained after the conclusion of hazing activity. The immediate response of birds to hazing activity was categorized into one of two possible behaviors: 1) no response; and 2) flushed. For those that fell into the 'flushed' category, it was further noted what proportion of those individuals either: 1) immediately departed the area; or 2) circled and returned to the same area to roost.

The impact of hazing activity on gull population abundance was evaluated in two ways: 1) by examining changes in numbers of gulls roosting on the island during the trial period and 2) by comparing averaged weekly counts made between the last week of November and the first week of January in 2010 and 2011 with those conducted prior to, during and after the hazing trial. . To evaluate changes during the trial, numbers of gulls present in the 10 day period immediately prior to hazing activity were comparied with 1) the number of gulls present during Phase 2 of the trial, and 2) a 10 day period in early January. We expected that by early January gulls would have re-acclimated to the island after the cessation of hazing. Daily maximum number of gulls present at dawn in the period prior to, during and after the hazing trial were used for all comparisons. We acknowledge that daily counts of gulls prior to, during, and after the trial are not independent (i.e., counts are likely influenced by size of the gull population present the previous day). However, this was an unavoidable constraint of the trial design. Therefore we used repeated measures ANOVA to test for significant differences in mean gull counts between time periods to counter this lack of independence between samples. Paired t-tests were employed after the ANOVA to compare between individual time periods.

Overall effective daily hazing rates were also determined by calculating the percent difference between the daily maximum gull count and the daily minimum gull count as determined by the regular surveys. By this method, days on which we were able to clear all gulls off the island were considered to be an effective hazing rate of 100%.

Effectiveness of individual treatments

In order to evaluate the effectiveness of individual hazing treatments, we created a metric called "hazing efficiency" which was equal to the product of the proportion of gulls that flushed times the proportion of gulls that departed the area for any given hazing event. So a hazing efficiency of 1 would mean all gulls targeted were flushed from the roost and moved away from the area. Hazing efficiencies of less than 1 indicate that either some gulls did not flush (i.e., were unaffected by the hazing method) or some gulls flushed and then returned to the same roost.

Individual hazing treatments were evaluated relative to each other based on their mean and median hazing efficiency across all trials for each treatment. Significant differences between treatments were determined using ANOVAs on logit transformed data. The logit transformation was used to transform proportional data in order to run parametric statistical tests. This common transformation reduces the influence of ones and zeros in the data so that it more closely approximates a normal distribution (Zar 1999).

Passive hazing treatments are those methods which can be placed in an area and do not need to be attended to in any way. These included the use of Western Gull effigies, plastic owl decoys, "Big-eye" balloons, mylar tape and raptor-shaped kites. We evaluated the effectiveness of these passive hazing tools by comparing gull counts before and after their deployment in a specific area. Significance of effect was determined using paired t-tests for each deployment area.

In addition, we evaluated the effect of hazer proximity on the hazing efficiency of the different treatments. GPS locations were collected for each hazing event and mapped using ArcGIS. Linear distances were then calculated from the hazer location to the approximate center of the gull roost. In order to determine the effect of proximity on hazing success, we calculated the mean and maximum distances for each hazing method for which we were 100% successful in hazing the targeted gulls. Significant differences between treatments were determined using ANOVAs. We further evaluated the effectiveness of individual pyrotechnics whenever possible. We chose to use a threshold of 90% effective hazing for this analysis due to the fact that sample sizes became too small and eliminated too many groups if the threshold of 100% was employed as above.

Impacts to non-target species

We assessed the impacts of hazing activities on the five species of pinniped that reside on the South Farallon Islands year round: Northern elephant seal, harbor seal, Steller sea lion, Northern fur seal, and California sea lion. All hazing activities were conducted in accordance with the Marine Mammal Protection Act and an Incidental Harassment Authorization (IHA) issued by the National Marine Fisheries Service for this trial.

As part of an ongoing research program, weekly surveys of all pinnipeds present on land portions of the islands are conducted throughout the year. Data from the last five years (2007-2011) were averaged to determine 'historical' attendance patterns for each species. We compared these historical numbers with pinniped counts prior to and after the hazing trial to evaluate the impact of hazing activities on pinniped abundance and distribution. We tested for a significant effect of hazing on overall numbers by comparing the pre- and post-hazing counts (after controlling for seasonal trends) as well as comparing 2012 numbers with the historical mean. Comparisons were made separately for each of the five pinniped species present on the island.

Behavioral responses of pinnipeds to individual hazing activities were documented by counting all animals present in the target area immediately prior to the initiation of any hazing technique and recording the proportion of the animals that reacted. Responses of pinnipeds were categorized into three possible behaviors: 1) no response; 2) moved (moved > 1m from initial location); and 3) flushed (animal moved to the water).

Although individual species did show some differences in their response, we grouped all species together for the purpose of this analysis. This allowed us to maintain sufficient sample sizes to allow comparison of hazing treatments. We calculated both the mean and median proportion of pinnipeds disturbed as a result of each hazing treatment and used this as a measure of the relative impact of the treatments. Medians were considered a valuable parameter to consider due to the high occurrence of zeros in the data set which had a disproportionately large impact on mean values.

As with the gull hazing, we also evaluated the effect of hazer proximity on pinniped response by calculating the mean and minimum distances for which there was no pinniped disturbance observed. These distances were calculated for each hazing treatment for which there was a sufficiently large sample size to evaluate differences.

The hazing trial was conducted during the time of year when the majority of breeding seabirds are not present on the island. However, we did want to determine the impact of the trial on other non-target bird species. Species of interest included common murre (*Uria aalge*), Brandt's cormorant, brown pelican (*Pelecanus occidentalis*), black oystercatcher (*Haematopus* *bachmani*), other shorebirds, and raptors. We noted the presence and number of individuals of these species during deployment of the various hazing techniques and recorded the number of birds affected and the type of response.

RESULTS

Gull abundance and daily hazing effectiveness

Overall gull numbers on the South Farallon Islands before the hazing trial were intermediate relative to the previous two years (Fig. 1). Average dawn countss during the 10 days immediately prior to the hazing trial was 3,716 birds in 2012. This is approximately 32% lower than the same period in 2011, but more than three times greater than during 2010.

Hazing activity had a significant impact on the numbers of gulls on the South Farallon Islands relative to the pre-trial and post-trial periods ($F=21.91$, $p<0.0001$, $df=3$). Gull numbers were dramatically reduced during Phase 2 (full-island hazing effort) and remained low during Phase 3 (hazing from SEFI only) when hazing effort was reduced. Gull counts during Phase 2 of the trial were significantly reduced when compared to the 10-day period immediately preceding hazing activity ($t=10.8225$, $p<0.01$, $df=17$; Fig. 2) as well as the 10-day period in early January after hazing had concluded ($t=-7.3007$, $p<0.01$, $df=18$; Fig. 2).

The average number of gulls present on the islands for any length of time during the day for Phase 2 was only 327, compared to 3,700 over the ten days prior to hazing. Gulls likely arrived during the night and were often present in the morning only for a brief period (<30 min) prior to the start of daily hazing or were on isolated roosts not targeted for hazing. In contrast, historical seasonal trends indicate that gull numbers typically increase during this same time period (Point Blue unpublished). The average number of gulls present on the island during the same ten day period was 4,795 in 2010 and 9,102 in 2011. This represents a 93% to 96% reduction in the number of gulls present when compared to previous years (Fig. 1) and is significantly different from both previous seasons (2010 $t=6.1246$, $p<0.01$, $df=9$; 2011 $t=6.5316$, $p<0.01$, $df=9$).

The daily hazing success rate for Phase 2 and Phase 3 of the trial was between 92% and 100% and averaged 98%. In other words, hazing efforts were 98% effective at chasing gulls off the island and away from areas that would be baited during an eradication effort.

Hazing efficiency of individual treatments

We calculated the mean and median hazing efficiency for each of the individual hazing treatments and all combinations of treatments tested (Appendix 2). However, some treatments were used infrequently and sample sizes were too small to make meaningful comparisons. After visually examining the data, we decided to group similar treatments together if there were no noticeable differences in their hazing effectiveness. For example, there was no difference in median hazing efficiency between the Avian Dissuader and the Aries Phazer (see Appendix 2) so these treatments were combined into the category “laser” for the purposes of analysis. We also combined both of the smaller Bird Gard Super Pro 4 speaker biosonic units (combined data hereafter referred to as bg4), all of the pyrotechnics (pyro) and all of the treatments which combined pyrotechnics with additional hazing treatments (pyroplus). This had the effect of reducing the overall number of treatment groups and increasing the sample size within each group, thereby allowing for more robust comparisons.

There was a significant difference between treatments (Anova: $F=2.93$, df 9; $p<0.002$; Fig. 3A) with lasers, helirad, pyrotechnics and pyrotechnic combinations (pyroplus) being, on average, more efficient at hazing gulls than either of the smaller Bird Gard Super Pro units (bg4) and the helicopter by itself. Gulls appeared to be tolerant to the noise and presence of this small helicopter, limiting its effectiveness as a hazing tool unless it was used in conjunction with other methods (e.g., helirad). Other treatment groups were statistically similar to each other.

Among the individual pyrotechnics employed, CAPA rockets and screamers were on average more efficient than bangers and crackers (Fig. 3B). Caps, when used in isolation, were not effective and were not used after the first few tests. When caps were removed from the analysis, there were no significant differences between pyrotechnic types (Anova: F=0.63, p=.7079, df=6). Therefore, we feel justified in grouping all pyrotechnics together for subsequent analyses.

Effective distances of individual treatments

Distance between the hazer and the intended target was not a reliable indicator of success for most hazing tools tested. Regressions of hazing efficiency vs. distance in general revealed no significant relationship (F=.18, R^2=0.0004, p=0.67). There was a significant relationship between distance and hazing efficiency for bioacoustic devices (F=31.18, R^2=.2036, p=0.0001, df=123) but this did not provide a high degree of predictive power as indicated by the low r-squared value. However, our goal was to determine effective distance for the various hazing treatments tested. In other words, how far away the hazer could be (or conversely how close they needed to be) in order to clear all gulls from a targeted area.

There were significant differences between groups (Anova: F=131, 9 df; p<0.0001; Fig. 4). Lasers (when used in low light situations at dawn and dusk) were, on-average successful at significantly greater distances (800-1000 meters) than most other treatments whereas the Wailer and Bird Gard biosonic units were only effective over relatively short distances (50-110 meters). LRAD and Zon cannons were effective over intermediate distances (150-300 meters).

Pyrotechnics, CAPA rockets and cracker shells were, on-average, effective at distances up to 400-500 meters while screamers and bangers were effective up to 150-250 meters, though these differences were not statistically significant (Anova: F=2.84, p=0.113, df=3).

As with the bird hazing efficiency analysis, there were no direct correlations between linear distance to the nearest pinniped and proportion of animals disturbed. We calculated the mean and minimum distance between the hazer and the nearest pinniped for which no disturbance was recorded. There were no significant differences found between groups but general patterns were observed. Pyrotechnics, LRAD and Zon caused disturbance to pinnipeds at a greater distance (80-100 meters), on average, than other methods tested which did not disturb animals at distances greater than 50 meters (Fig. 7).

Non-target impacts of gull hazing treatments

We observed little impacts to non-target birds as a result of the hazing activity. Common murres only attended the colony on four days during the trial period and only small numbers of cormorants and pelicans were observed roosting on the island during the day. Of the 493 active hazing events during Phases 2 and 3 of the trial, only 37 caused disturbance to non-target birds (~7%). Of those, there were 22 which disturbed roosting cormorants, 10 events which disturbed murres, six events which disturbed roosting Brown Pelicans and six events which flushed shorebirds from intertidal roosts, primarily black oystercatchers. For shorebirds, cormorants and pelicans the disturbance usually caused the birds to take flight and then return to their roosts. Murres on the other hand typically went to sea and did not return to roost on land again that day. There did not seem to be any difference between the individual hazing treatments in their likelihood to disturb non-target birds; Bird Gards, Helicopter hazing, LRAD, pyrotechnics and lasers all caused disturbance, but there were not sufficient sample sizes to test this statistically.

The overall impact of gull hazing activities on pinnipeds was also minimal. Pre-trial counts for all species were statistically similar to (two tailed tests - Northern Elephant Seal: $t = 1.686$, $p = 0.106$, df =22, Harbor Seal: $t = 0.347$, $p = 0.732$, df=22, California Sea Lion: $t = 1.068$, $p = 0.297$, df=22) or higher than (Steller Sea Lion: $t=3.751$, $p=0.001$, df=22, Northern Fur Seal: $t = 4.125$ $p < 0.001$, df=22) numbers observed during the same period in the previous five years. Fur seals in particular were present in greater numbers than the prior five year average owing to their recent and continuing rapid population growth (Berger et al. 2016, in prep).

Likewise, comparing one month of surveys pre- and post-gull hazing trial, three pinniped species showed no significant differences in numbers before and after the trial: Harbor Seals ($t = 1.198$, $p = 0.270$, df=7), Steller Sea Lions ($t = 1.306$, $p = 0.233$,df=7) (Fig. 5), and California Sea Lions ($t = 1.096$, $p = 0.309$, df=7;). The other two species showed significant declines: Northern Elephant Seals ($t = 6.328$, $p < 0.001$, df=7) and Northern Fur Seals ($t = 3.721$, $p = 0.008$, df=7) (Fig. 5). However, these declines are consistent with regularly observed seasonal trends as juvenile elephant seals and most fur seals depart the island at this time (REF PINNIPED REPORT). The post-trial numbers for both elephant and fur seals were not significantly different from their number during this period for the past five years (Northern Elephant Seals: $t = 0.193$, $p = 0.849$, df=24, Northern Fur Seal: $t = 1.136$, $p = 0.267$, df=24). Thus we conclude that there were no major impacts to pinniped abundance from the trial.

Effect of individual treatments on pinnipeds

There was a significant difference in mean pinniped disturbance between treatments (Anova F=128, 10 df; p<0.001), with pyrotechnics and pyrotechnics in combination with other treatments causing the greatest level of disturbance to pinnipeds whereas biosonic hazing methods showed little effect on pinniped behavior (Fig. 6). Overall, biosonic hazing methods caused disturbance to less than 3% of pinnipeds present in hazing target areas including no observed disturbance (moving >1m or flushing) for elephant seals or harbor seals. In contrast, pyrotechnic hazing methods elicited much stronger responses from most pinniped species. Greater than 15% of California sea lions and approximately 5% of Steller sea lions were disturbed when pyrotechnics were employed. Harbor seal disturbance rates were high with more than 20% of the animals flushing in the presence of pyrotechnics. However, elephant seals showed little to no visible reactions to pyrotechnics. Postive responses in other species were primarily driven by the loudest of the pyrotechnic devices, the CAPA rocket. In general, for all hazing treatments, California sea lions (due to their high densities) and harbor seals were the most sensitive to being disturbed while Northern Elephant Seal and Northern Fur Seal were rarely affected. Steller sea lions generally exhibited a mild response to hazing activities but were also present less frequently than other species. Lasers consistently had no effect on pinniped behavior and were not included in statistical analyses.

Passive Hazing Summary

Counts of gulls prior to hazing treatments were significantly lower in the presence of effigies. Simple T-tests for each area demonstrate significantly lower gull counts when effigies were present (AP t = -3.0575, p = 0.008, df=8; BP t = -2.1985, p=0.0226, df=14; MB t = -2.2406, p=0.0209 df=14; MF t = -2.1085, p=0.0365 df=7; WSP t = -1.8451, p=0.0491, df=9). In nearly all cases, gulls abandoned roosting areas immediately following the placement of effigies and did not return until effigies were removed. Other passive hazing methods were not statistically analyzed because they were not used often and the sample sizes were too small to draw any statistically supported conclusions.

DISCUSSION

This study was designed and conducted with two main objectives. The first was to demonstrate that it is possible to keep the majority of Western Gulls off the South Farallon Islands for a period of time in order to minimize their potential exposure to rodenticide during a possible mouse eradication effort. The second was to test the efficacy of a variety of individual hazing techniques and tools in order to assess their utility for future hazing efforts, such as during the mouse eradication, oil spills, or other circumstances. These two objectives sometimes conflicted with each other in which case the overall goal of reducing gull numbers took precedence over testing individual methods. This resulted in some unavoidable compromises in data quantity and quality for individual hazing treatments. However, we believe that the overall results are valid and provide valuable information on the relative effectiveness and impact of the hazing treatments tested both alone and in various combinations.

Overall hazing success

Results from this study clearly demonstrated that a well planned and executed hazing operation can effectively reduce the number of gulls present in an area (in this case the South Farallon Islands) and minimize the number of individuals that would be likely to come into contact with potentially harmful substances, including rodenticide, oil, pesticides and other hazards, at least for a period of two weeks (the duration of this trial) and probably longer. Hazing efforts resulted in significantly reduced gull numbers when compared to the same time period in previous years as well as in comparison to pre-trial counts in the same year. Western gulls roosting on the islands were reduced from an average of approximately 3,700 present on the island prior to the trial to only a few hundred individuals present for any length of time during the day by the end of Phase 2. Daily hazing efficiency also increased as the trial progressed, resulting in 100% of the birds present on the island during any given day being successfully hazed. The high hazing efficiency achieved resulted in effectively no gulls being present for the majority of each day. In addition, gull distribution around the island was significantly altered such that by the end of the trial, birds were only present far out in the intertidal zone and on a few scattered and wave washed offshore islets.

We did not conduct comprehensive surveys at night but anecdotal evidence indicates that if gulls were successfully hazed off the island at dusk they did not return until after sunrise. Gulls were not detected during random nighttime searches using a high powered spotlight and they were not heard calling. Furthermore, when we were able to successfully haze all gulls off the island by dusk, our surveys the following dawn revealed no roosting birds. It is unlikely that birds that were forced to find a different roost for the night due to our hazing activity would return to the island during the night and depart again before sunrise. However, if more nocturnal activity of gulls were to occur, based on these results lasers could be very effectively used to deter their presence.

Gull hazing effectiveness in this trial appeared to be greater than other reported studies. For example…However, these other studies were conducted at locations where gulls or other scavengers visited for food (cite references) or along transit corridors (cite references). This differs from most gulls visiting the Farallones in fall and early winter, when attendance at the islands is mainly to roost. If gulls were visiting the islands to feed, hazing effectiveness may have been much lower. Likewise, if hazing were conducted closer to or during the breeding season, it may be more difficult to keep birds from attending breeding sites.

Hazing treatments

In all, we tested 21 different individual hazing treatments as well as multiple combinations of these tools throughout the hazing period. Although we were not able to test each method individually in all situations, we were able to demonstrate significant differences in overall hazing efficiency amongst the tools tested. In general, active hazing treatments that involved both sound and motion were more effective than one dimensional treatments or passive treatments. Likewise, there were significant differences in the level of pinniped disturbance caused by the various hazing methods with louder and more active treatments such as pyrotechnics and pyrotechnics combined with biosonics causing greater disturbance than other methods.

For all hazing treatments, when evaluating impacts to pinnipeds, California Sea Lions were the most sensitive to being disturbed while Northern Elephant Seal and Northern Fur Seal were rarely affected. This likely reflects both relative differences among the species in their response as well as vastly different encounter rates during the trial. For example, sea lions were present in the target area 94% of the time that a hazing treatment was deployed, whereas fur seals were only present 13% of the time. The localized nature and low numbers of fur seals in December prevented them from being exposed to many of these techniques, thereby limiting our ability to evaluate their response. We observed little impact to non-target bird species as a result of hazing activity. Few non-target species were present during the hazing trial, but when they were present, hazing typically caused them to flush from their roosts. The disturbance was typically short lived for shorebirds, cormorants and pelicans, which usually took flight and then returned to their roosts. Common murres typically departed the colony when disturbed. However, this behavior is typical for this species in response to other disturbance events (e.g. peregrine falcon predation) during the non-breeding season and infrequent events appear to have limited impact on the birds. Impacts would be much greater if these hazing methods were employed during the breeding season as murres and other breeding species would likely depart the colony for a period of time, thereby leaving eggs and/or chicks exposed.

The least useful tools tested were mylar tape and balloons. These tools were difficult to deploy, often broke down or were ripped off their tethers and lost, and appeared to have little effect on the gulls. Kites were moderately effective when deployed after birds were flushed utilizing other techniques, but they were difficult to keep aloft in strong winds. As a result, these tools were not tested frequently and were hardly used after the first few days of the trial. Likewise, the Zon propane cannon was not often effective in our trial. It is worth noting, however, that this treatment, though less efficient on average, had a median efficiency of 1. This is likely a result of several malfunctions early in the hazing trial which rendered the treatment ineffective and reduced average efficiency of this method. While low sample sizes for these treatments make it impossible to make a quantitative assessment of their true effectiveness, there appears to be little evidence to support their use under the conditions typically expected at the South Farallon Islands (i.e., strong winds and foggy, wet conditions). The only passive hazing treatments that were routinely effective were the western gull effigies. These were particularly effective at dissuading birds from returning to a roosting site after another treatment method had been used to flush them. Gull numbers were dramatically reduced after the deployment of effigies and remained low for the duration of time they were present. Aside from any disturbance caused during their deployment, effigies had no impact on pinnipeds or other bird species present in the area. Although they are only effective over a short range, effigies proved to be an especially efficient tool during this trial and are recommended as a continuing deterrent once wildlife have been successfully dissuaded from any undesirable areas. Acclimatization was not detected during this relatively short trial, but could be expected over longer periods, requiring periodic movement or reinforcement of the effigies with other hazing methods.

Lasers, pyrotechnics and various combinations of pyrotechnics with additional hazing devices were the most effective at dispersing gulls from their roosts. Pyrotechnics and pyrotechnics combined with other hazing treatments had the highest overall hazing efficiency (mean efficiencies over 70%) and were effective over long distances up to 700m. Although there were no statistically significant differences observed among the individual pyrotechnic devices deployed, the general pattern observed was that CAPA rockets and cracker shells were more efficient for longer distances whereas the bangers and screamers were most effective over short to medium ranges. However, these treatments also had the most substantial effect on non-target species, often resulting in disturbance to other roosting birds and pinnipeds. Pyrotechnics and especially pyrotechnics combined with other tools caused the greatest amount of disturbance to pinnipeds of all the tools tested. Screamers (due to no abrupt bang sound) and CAPA rockets (that deployed to a greater height or distance offshore before exploding) appeared to have reduced impact on pinnipeds in comparison to the bangers and cracker shells.

It is clear from this trial that pyrotechnics are a good choice for wildlife managers when there is a need to deter birds or other wildlife from an area for an extended period and when disturbance to non-target species is not a major concern. However, great care should be exercised when deciding that pyrotechnics are required. In addition to non-target disturbance, there are safety issues to consider. These devices are powerful and potentially dangerous, to both humans and wildlife, if they are not used properly. Furthermore, high winds may alter the expected trajectory of the pyrotechnics, leading to greater non-target impacts. We would not recommend their use in situations where human or wildlife safety is a concern such as in urban areas or areas with high fire danger.

Lasers were especially effective over long distances when used at dawn and dusk while it was still dark enough for the birds to see the beam. They were useful both for clearing roosting gulls and also discouraging them from landing. An added benefit of lasers was that they caused no disturbance to pinnipeds making them both highly efficient and non-disruptive. Furthermore, it is possible to achieve a greater degree of accuracy in targeting individuals or groups that are to be dissuaded from an area than with other methods tested. We tested three different types of lasers with varying power and intensity during the trial. There was no noticeable difference in median hazing efficiency between the Avian Dissuader and the Aries Phazer (Appendix 2). Both were highly effective over distances up to a kilometer. The small penlight laser was less powerful and was typically only effective over a moderate range (150-300 meters) in full darkness. These tools would be most effective at preventing birds from roosting overnight but are not effective for daylight deterrence.

Biosonic hazing devices, including all Bird-Gard units, the Wailer and the LRAD were generally intermediate in both their hazing efficiency and in their level of disturbance to pinnipeds. All amplified biosonics worked over a moderate distance of a few hundred meters and generally caused low levels of disturbance to pinnipeds unless deployed at very close range.

These devices worked moderately well on their own, but were considerably more effective when combined with another hazing device such as pyrotechnics or the helicopter. Of all biosonics tested, the LRAD seemed to be the most effective and also offered the ability to directionally project sounds so as to better target individual gull roosts without non-target disturbances. The LRAD was particularly effective when deployed from the helicopter circling over the gull roost. This treatment, termed the helirad, combined the visual stimulus of a mobile, large and relatively noisy object with a predator or distress call to great effect. This treatment was equally as effective as pyrotechnics and pyrotechnic combinations but with surprisingly lower pinniped disturbance. The helirad was also highly effective in dissuading gulls from returning to the island to roost for the night. Gulls would approach the island in large numbers just before dusk. The helirad was deployed to "intercept" these individuals, causing them to alter direction and depart the island to find an alternative night roost.

Although we tested a large range of hazing treatments, there were other options available which were not employed during this study. Permission from the Federal Aviation Administration to deploy Unmanned Aerial Systems (UAS) was not obtained in time to include testing of this technology in the trial. However, tolerance by gulls to the noise and presence of the R22 helicopter suggests that UASs are likely to have limited effectiveness as a hazing tool unless they can be deployed in conjunction with other methods such as a LRAD or pyrotechnics. The helicopter did prove to be an invaluable resource for detecting and monitoring gulls in areas that were difficult to observe from the ground. Based on these observations, we see UASs as a potentially valuable and highly efficient tool for detection and real time monitoring of the effectiveness of future hazing operations, especially those that span large areas, though they may be less effective as a hazing tool.

Dogs are another potential hazing tool (Gilsdorf et al. 2002) that may be effective on the Farallones; however the testing of this method was not included because of resource limitations. Lethal hazing techniques such as removing a single individual to dissuade a group from returning to an area have proven effective elsewhere (Jones et al. 1996) but were not included because of the desire to minimize the impacts of the trial.

Effect of proximity

We expected that there would be some negative relationships in which the effectiveness of any particular treatment would decrease with linear distance. However, our data did not show this. While there were significant differences between hazing treatments in terms of the average distance for which they were effective, there were no significant relationships between distance and effectiveness for any individual method. There are several possible reasons for this. During the course of the trial, we chose tools specific to the hazing target and did not specifically test each treatment at varying distances. If the gull roost was relatively far from the hazer, then we chose a treatment that was most likely to impact the target. Also, there was a large amount of variation in the effectiveness of each hazing treatment regardless of distance. This may be due to other variables such as weather, temporal proximity to another hazing event or gull density which was not considered during this analysis.

Likewise, there were no significant relationships between hazer proximity and pinniped disturbance. For example, when using the Bird Gard Super Pro Amp (bga), the average distance for which no disturbance was noted was 46m. The minimum distance for which there was no disturbance was 22m (also the minimum distance for which the bga was used). This would seem to suggest that if you use the bga when pinnipeds are more than 50m away there should be relatively little disturbance. However, disturbance was also noted at far greater distances at times, in some instances up to 136m. In fact the greatest number of animals disturbed occurred at the greatest distance. A similar pattern emerges for other hazing methods where there are times when they can be used in relatively close proximity to pinnipeds without any effect and other times where animals that are relatively far away will move or flush in response. This may have been due to accumulated subtle disturbances from repeated hazing treatments in short periods, or other factors.

As with hazing efficiency, there were general differences between hazing treatments in the average distance required for no disturbance. Pyrotechnics, pyrotechnics combined with another method, LRAD and Zon cannons caused disturbance to pinnipeds at a greater distance, on average, than other methods tested. The results suggest that to minimize impacts, hazers should be farther away, on average, from pinnipeds when using Zons, LRAD or pyrotechnics than when using other hazing treatments. It should also be noted that for those treatments that involved an auditory component, the sound emitted did not always occur at the hazer location. For the biosonics such as the Bird Gard and LRAD units this was typically the case, but for pyrotechnics it could be highly variable. In some cases the sound was generated at a short (i.e. Zons, caps) or medium distance (shell crackers, bangers, screamers) from the hazer. In other cases the sound could actually emit from point a long distance from the hazer as in the case of CAPAs. CAPAs were sometimes intentionally directed at an angle to the birds if they were near pinnipeds in order to get the loud bang but not be close to the pinnipeds. Recognizing that it was not possible to obtain data on how close the sound occurred to the birds versus the hazer’s physical location, our analysis represents our best effort. However, it should be noted that we were not able to completely account for the effect of distance.

This project set out to do several things and compromises in data quantity and quality were inevitable. Insufficient independent tests of the specific treatments were completed to allow robust quantitative analysis of all of their individual effectiveness. There was also the necessary focus on gulls and relatively few other bird types present which limits the scope of our conclusions. However, despite these limitations, we believe that the lessons learned from the Farallones trial will provide valuable guidance to resource managers for planning future avian hazing operations.

MANAGEMENT IMPLICATIONS

This study serves to effectively demonstrate differences in the relative effectiveness of the treatment methods tested for gulls and their impact on non-target species. Almost all methods tested, with the exception of mylar tape and balloons, proved effective in certain circumstances and should be considered as part of a resource manager's hazing toolbox. Lasers, pyrotechnics and combined treatments (e.g. pyrotechnics with biosonics) proved to be the most effective overall and will ultimately be the best choices for dissuading persistent species, especially if non-target impacts are not a concern. Passive hazing techniques, particularly effigies, worked well to prolong the impact of other methods and can be effectively employed to increase the period of time that wildlife is deterred from interacting with potential hazards. However, no treatment is perfect in every situation and all have drawbacks which can limit their effectiveness. Lasers, while extremely efficient at dissuading gulls and minimizing impacts on pinnipeds, are only effective when it is dark; Pyrotechnics are more likely to impact non-target species; Biosonics have limited range. All treatments may be influenced by wind, weather and physical constraints. Therefore, it is important to consider individual circumstances and project goals when selecting which hazing treatment to employ and to have multiple treatment options available. Although acclimatization to hazing treatments was not detected during our study, it is likely to occur over prolonged periods or when a potentially hazardous area is particularly attractive to wildlife (e.g. food source or nesting colony during the breeding season). The ability to deploy a variety of treatments and to frequently change the approach will help to mitigate this problem. Ultimately, it will be up to resource managers to decide which hazing treatments are most appropriate to use depending on the individual application and wildlife species involved.

Finally, the results of these trials may only apply to similar situations, where gulls or other species are hazed at a time when they are visiting the site to roost as opposed to feeding, breeding or certain other uses. Hazing effectiveness may be dramatically different in those other situations.

ACKNOWLEDGEMENTS

The hazing trial was made possible due to support from the Luckenbach Trustee Council oil spill settlement funds, the National Fish and Wildlife Foundation Coastal California Restoration Settlement Funds Grant #8001.04.034554, and the California Department of Fish and Wildlife's Oil Spill Response Trust Fund through the Oiled Wildlife Care Network (OWCN) at the Wildlife Health Center, School of Veterinary Medicine, University of California, Davis. Special thanks also go to Todd Weitzman of Bird Gard, LLC for the loan of seven BirdGard biosonic units for the duration of the trial.

Many agencies and individuals were involved in developing the trial plan. We are grateful for the support we received from Jonathan Shore (USFWS), Jim Tietz and Ryan Berger (Point Blue), Paul Gorenzel (OWCN), Valerie Burton and Eric Covington (USDA-APHIS WS), and

Tommy Hall (IC). We would also like to thank the following for field assistance: John Warzybok, Sara Acosta, Holly Gellerman, Kyra Mills-Parker, Paul Steinberg, Liz Ames, and Lara White. Sansone Company and the U.S. Coast Guard provided invaluable support in transporting supplies and freight to the island.

The following permits were acquired to conduct the hazing trial Section 7 Biological Opinion and Incidental Harassment Authorization for marine mammals (IHA) from the National Marine Fisheries Service; Bureau of Alcohol, Tobacco, and Firearms for the use and storage of explosive pest control devices (EPCD); ;

USFWS: Wilderness Minimum Requirements from USFWS; and Permit No. XXXXXX to conduct low overflights in the Gulf of the Farallones National Marine Sanctuary.

LITERATURE CITED

Ainley, D.G. and R.J. Boekelheide (Eds.). 1990. Seabirds of the Farallon Islands: Ecology, Dynamics, and Structure of an Upwelling-system Community. Stanford University Press, Stanford, CA.

Baxter, A.T. and J.R. Allan. 2006. Use of raptors to reduce scavenging bird numbers at landfill sites. Wildlife Society Bulletin 34 (4):1162-1168.

Belant, J.L. 1997. Gulls in urban environments: Landscape-level management to reduce conflict. Landscape and Urban Planning 38:245-258.

Belant, J.L., and J.A. Martin. 2011. Bird harassment, repellent, and deterrent techniques for use on and near airports: A synthesis of airport practice. Airport Cooperative Research Program – Washington : Transportation Research Board X, 32p.(ACRP Synthesis;23).

BirdLife International. 2013. *Hydrobates homochroa.* The IUCN Red List of Threatened Species 2013: http://dx.doi.org/10.2305/IUCN.UK.2013-2.RLTS.T22698562A49929777.en

BirdLife International. 2016. Important Bird and Biodiversity Area factsheet: Farallon Islands. http://www.birdlife.org

Blackwell, B.F., G.E. Bernhardt and R.A. Dolbeer. 2002. Lasers as nonlethal avian repellents. Journal of Wildlife Management 66(1):250-258.

Cook, A., S. Rushton, J. Allan and A. Baxter. 2008. An evaluation of techniques to control problem bird species on landfill sites. Environmental Management 41:834-843.

Curtis, P.D., C.R. Smith and W. Evans. 1995. Techniques for reducing bird use at Nanticok Landfill near E.A. Link Airport, Broom County, New York. Eastern Wildlife Damage Control Conference. 6:67-78.

Desante, D. and D.G. Ainley. 1980(?). Avifauna of the South Farallon Islands. Studies in Avian Biology.

Duffiney, T. 2006. Overhead grid line systems to exclude waterfowl from large bodies of water. Bird Strike Committee USA/Canada, 8th Annual Meeting, St. Louis, MO. Abstract only; http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1019&context=birdstrike2006

Gilsdorf, J.M., S.E. Hugnstrom and K.C. VerCauteren. 2003. Use of frightening devices in wildlife damage management. USDA National Wildlife Research Center – Staff Publications. Paper 227.

Gilsdorf, J. M., Hygnstrom, S. E., and VerCauteren, K. C. 2002. Use of frightening devices in wildlife damage management. *Integrated Pest Management Reviews* **7**(1), 29-45.

Golightly, R.T. 2005. Western Gull Management Options at Castaic Lake. Unpublished report for the Metropolitan Water District of Southern California, Humboldt State University, Department of Wildlife, Arcata, CA.

Gorenzal, W.P., P.R. Kelly and D.A. Whisson. 2004. The Office of Spill Prevention and Response – applying bird hazing techniques in oil spill situations. Vertebrate Pest Conference 21:287-290.

Gorenzal, W.P., P.R. Kelly, T.P. Salmon, D.W. Anderson and S.J. Lawrence. 2006. Bird hazing at oil spills in California in 2004 and 2005. Vertebrate Pest Conference 22:206-211.

Gorenzal, W.P. and T.P. Salmon. 2008. Bird hazing manual – techniques and strategies for dispersing birds form spill sites. University of California Agriculture and Natural Resources, Oakland, California. Publication 21638. 102 pp.

Gorenzal, W.P. T.P. Salmon and R. Imai. 2010. Response of water birds to hazing with a laser. Vertebrate Pest Conference 24 In press.

Grout, D. and R. Griffiths. 2012. Farallon Islands Restoration Project - A Report on Trials undertaken to inform Project Feasibility and Non-Target Risk Assessments. Unpubl. report, Island Conservation, Santa Cruz, California, USA.

Grout, D. R. Griffiths, M. Pott, R. Bradley, P. Warzybok, W. Vickers, D. Milsaps and G. McChesney. 2013. Hazing Western Gulls on the South Farallon Islands. Appendix E: South Farallon Islands Invasive House Mouse Eradication Project: Draft Environmental Impact Statement. Federal register #FWS-R8-NWRS-2013-0036 http://www.regulations.gov

Jones, S. T., Starke, G. M., and Stansell, R. J. 1996. Predation by birds and effectiveness of predation control measures at Bonneville, The Dalles, and John Day dams in 1995. US Army Corps of Engineers

Howald, G., C.J. Donlan, J. Galvan, J. Russell, J. Parkes, A. Samaniego, Y. Wang, D. Vietch, P. Genovesi, M. Pascal, A. Saunders and B. Tershey. 2007. Invasive rodent eradication on islands. Conservation Biology 21:1258-1268.

Keitt, B., K. Campbell, A. Saunders, M. Clout, Y. Wang, R. Heinz, K. Newton and B. Tershey. 2011. The Global Islands Invasive Vertebrate Database: a tool to improve and facilitate restoration of island ecosystems. *In* C. Veitch, M. Clout and D. Towns, eds. Island invasives: eradication and management, IUCN, Gland, Switzerland.

Mackay, J. E. Murphey, S. Anderson, J. Russell, M. Hauber, D. Wilson and M. Clout. 2011. A successful mouse eradication explained by site-specific population data. *In* C. Veitch, M. Clout and D. Towns, eds. Island invasives: eradication and management, IUCN, Gland, Switzerland.

Marsh, R.E., W.A. Erickson and T.P. Salmon. 1991. Bird Hazing and Frightening Methods and Techniques (with emphasis on containment ponds). Other Publications in Wildlife Management. Paper 51. http://digitalcommons.unl.edu/icwdmother/51.

Nemtzov, S.C. and E. Galili. 2006. A new wrinkle on an old method: successful use of scarecrows as a non-lethal method to prevent bird damage to field crops in Israel. Vertebrate Pest Conference 22:222-224.

Penniman, T.M., M.C. Coulter, L.B. Spear, and R.J. Boekelheide. 1990. Western Gull. *In* D.G. Ainley and R.J. Boekelheide, Eds. Seabirds of the Farallon Islands: Ecology, Dynamics, and Structure of an Upwelling-system Community. Pp. 218-244. Stanford University Press, Stanford, CA.

Pott, M. and D. Grout. 2012. Results of a Pilot Gull Hazing Trial on the Farallon National Wildlife Refuge. Unpublished report, Island Conservation, Santa Cruz, California, USA.

Richardson et al. 2009.

Ronconi, R.A., C.C. St. Clair, P.D. O'Hara and A.E. Burger. 2004. Waterbird deterrence at oil spills and other hazardous sites: potential applications of a radar-activated on-demand deterrence system. Marine Ornithology 32:25-33.

Seamans, T.W., B.F. Blackwell and J.T. Gansowski. 2002. Evaluation of the Allsop Helikite as a bird scariing device. Vertebrate Pest Conference 20:129-134.

Seamans, T.W., C.R. Hicks and K.J. Preusser. 2007. Dead bird effigies; a nightmare for gulls? Bird Strike Committee Proceedings, 9th Annual Meeting, Kingston, Ontario.

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. 42pp.

United States Fish and Wildlife Service. 2013. South Farallon Islands Invasive House Mouse Eradication Project: Draft Environmental Impact Statement. Farallon National Wildlife Refuge, Fremont CA.

Washburn, B.E., R.B. Chipman and L.C. Francoeur. 2006. Evaluation of bird response to propane exploders in an airport environment. Vertebrate Pest Conference 22:212-215.

Werner, S.J. and L. Clark. 2006. Effectiveness of a motion-activated laser hazing system for repelling captive Canada geese. Wildlife Society Bulletin 34(1):2-7.

Whitford, P.C. 2008. Successful uses of alarm and alert calls to reduce emerging crop damage by resident Canada geese near Horicon Marsh, Wisconsin. Vertebrate Pest Conference 23:74-79.

Zar, J. H. 1999. Biostatistical analysis, fourth edition. Prentice Hall, Upper Saddle River, New Jersey, USA

FIGURE CAPTIONS

Figure 1. Mean number of gulls counted on the South Farallon Islands between late November and early January, 2010-2012. Counts are presented as the mean weekly value (± standard error) during the hazing trial period. Active gull hazing was conducted during the first two weeks of December 2012.

Figure 2. The maximum number of gulls present at dawn on the South Farallon Islands between the pre-trial phase and post-trial phase.. Full island active hazing efforts occurred during Phase 2.

Figure 3. Mean (± standard error) and median hazing efficiency by general treatment group (panel A) and by pyrotechnic type (panel B). See Appendix A for treatment legend and description of treatment groups.

Figure 4. Mean (± standard error) and maximum effective distance by treatment group. See Appendix A for treatment legend and description of treatment groups.

Figure 5. Post-trial Farallon Pinniped numbers for mid-December to mid-January. Historic data (2007-2011/2) compared with pre-trial data from 2012/2013. Mean monthly values with standard errors are plotted. Species shown are California sea lion (Zal), Northern elephant seal (Mir), harbor heal (Pho), Steller sea lion (Eum), and Northern fur seal (Cal).

Figure 6. Effect of individual hazing tools on pinniped disturbance. Presented are mean ± standard error (dark gray) and median values (light gray). Median value was zero unless

otherwise shown. Data presented for all pinniped species combined. See Appendix A for explanation of treatment abbreviations.

Figure 7. Mean ± standard error (dark) and minimum distance (light) required for zero disturbance to pinnipeds for different hazing tools. Data presented for all pinniped species combined. See Appendix A for explanation of treatment abbreviations.

Table 1. Descriptions of Farallon Gull Trial Phases

Phase	Scope	Area	Duration	Dates
Pre-trial	Assessing baseline numbers of roosting gulls prior to any hazing activities. Some historic data from previous seasons was also used to inform planning and seasonal comparisons.	SEFI and WEI	10 days	November 18 – 27, 2012
1	Assessing the effectiveness of individual hazing methods on gulls and effects on other birds on the South Farallon Islands	SEFI and small areas of WEI	5 days	November 28 – December 2, 2012
2	Assessing the effectiveness of a hazing operation to reduce gull numbers across the South Farallon Islands	All areas	9 Days	December 3 – 11, 2012
3	Assessing the effectiveness of hazing from SEFI to reduce gull numbers across the South Farallon Islands	SEFI and most of WEI	3 days	December 11-13, 2012
Post-trial	Assessing number of gulls returning to roost on Farallon Islands two weeks after the conclusion of all hazing activities	SEFI and WEI	10 days	December 28, 2012 – January 6, 2013

APPENDIX A. HAZING TREATMENTS TESTED

The following appendix lists all 21 individual hazing treatments and 8 combined treatments for a total of 29 unique treatments tested. For each, we describe the hazing treatment, how it was used and provide detailed product descriptions for each hazing treatments tested.

Description (*abbreviation*)	**Use**	**Location**
Human Movement *(hum)*		
Movement of people on foot across the island	Monitoring and setting up hazing equipment occasionally flushed gulls from roost sites	Various locations
Effigies *(ef)*		
Effigies are models of animals or human forms (scarecrows) used with the intent of scaring birds.	Effigies consisting of dead Western Gulls (beach wrecked carcasses) were attached to 8ft poles by nylon fishing line. Approximately 15 effigies were used during Phases 2 and 3 of the trial.	Various locations at persistent gull roosts (See Figs. 3 & 19)
Owl Decoy (owl)		
Owl decoys are plastic models designed to mimic predatory birds in order to dissuade birds.	Owl decoys were deployed in several areas after gulls had been frightened off using some other means in order to deter them from returning to the area. The decoys were placed atop 8ft poles which were planted in the ground near a gull roost.	
Mylar Tape *(my)*		
Mylar is a reflective plastic ribbon colored on one side. It is often tied to poles or suspended from overhanging lines, where its motion in the wind creates a humming or crackling sound and it reflects sunlight.	Mylar tape was deployed at a few locations to discourage gulls from roosting.	Mussel Flat (MF) and Blowhole Peninsula (BP) (See Fig. 3)
Kites *(kt)*		
Kites (traditional and inflatable) in the shape of predators or painted with predators can be used to deter birds.	Two types of kites were deployed, a raptor shaped standard kite and an Allsopp Helikite helium-filled balloon kite. Both kite designs aimed to mimic aerial predators to frighten and disperse birds.	These were flown or positioned as close to intertidal gull roost areas as possible, usually on the Marine Terrace (E-Ter) or Aulon

		Peninsula (AP). See Fig. 3.
Balloons *(bal)*		
Inflatable mylar "big-eye"/"scare eye" balloons (Bird-X Inc. 300 N Oakley Blvd. Chicago, IL 60612) are highly reflective and mimic a predator's eye. They are often tied to poles or suspended from overhanging lines where it can move in the wind and reflect sunlight.	Balloons were used infrequently at a few roost locations to try to discourage gulls from roosting.	Positioned as close to intertidal gull roosts areas as possible on the Marine Terrace (E-Ter) and Mirounga Beach (MB). See Fig. 3.
Lasers *(laser) – 3 types*		
Lasers are concentrated light beams used in low lighting conditions to disperse or deter birds.	Three different lasers of varying power and intensity were used during the trial, a small 5mW green penlight (las1), a red Avian Dissuader™ (Sea Technology, Inc., Albuquerque, NM; las2), and a green Aries Bird Phazer Laser® (JWB Marketing LLC, 2308 Raven Trail, West Columbia, SC 29169) (las3). Lasers were generally used in the early morning and the evening when light levels were low. They were effective at both flushing gulls from the islands and at deterring flying gulls from landing on the islands. Lasers were known to be less effective during daylight hours except at close range (Pott and Grout 2012), so limited testing of this tool during the day was undertaken. On moonless nights, spotlights were sometimes used to estimate numbers of gulls prior to flushing them with a laser.	Lasers were used primarily from Lighthouse Hill and West End locations. See Fig. 3.
Zon cannons *(zon)*		
Propane cannons, also called gas exploders, produce a loud, directional blast similar to that emitted by a 12-gauge shotgun.	Zon® Mark 3 cannons (Sutton Ag Enterprises, 746 Vertin Ave, Salinas, CA 93901) were tested but due to issues associated with moisture and sound levels, Zons were only occasionally used during the trial. Zons were triggered on command to flush gulls that were roosting or returning to roost areas.	Zons were established in three locations on west Marine Terrace (W-Ter) and at Sea-lion Cove (SLC). See Fig. 3.
Bird Gard Units *(3 types - bg, bgm, bga)*		
Biosonics, or bioacoustics,	Three different Bird Gard biosonic units	Birdgard units were

as a hazing method, involves using animal alarm or distress calls to alter the behavior of a target species.	(Bird Gard, LLC, 270 E. Sun Ranch Drive, P.O. Box 1690, Sisters, OR 97759) were tested: 1) A Bird Gard Super Pro® with four small speakers (bg); 2) a Bird Gard Super Pro® with a 4 speaker multi-directional speaker tower (bgm) and; 3) a Bird Gard Super Pro-Amp® with 20 amplified multi-directional speakers on a tower. Each unit was pre-programmed with a combination of recorded gull distress calls and hawk, peregrine falcon, and eagle calls, and was triggered on command or randomly to flush gulls or deter them from returning.	moved around the island and used at many locations.
Marine Phoenix Wailer*(wailer; wail)*		
The Marine Phoenix Wailer is a biosonic device designed to prevent birds from alighting on the water and typically used to discourage birds from landing on oil slicks.	The Marine Phoenix Wailer® (Phoenix Agritech. P.O. Box 10, Truro, Nova Scotia.B2N 5B6,Canada) is a large, multi-speaker biosonic hazing tool. For the trial, the sound-emitting component of the Wailer was removed from its marine floats and placed on the ground above a gull roost. It was programmed to play pre-recorded distress and predator calls.	The Wailer was positioned predominantly within the Marine Terrace area above Mussel Flat (MF). (See Fig. 3)
Long Range Acoustic Device *(LRAD)*		
A powerful but portable directional speaker which can be made to play pre-recorded sounds.	Predator and distress calls were played both from the ground and later from a helicopter, to flush gulls from roost sites and deter them from resettling. (LRAD Corporation, 16990 Goldentop Road, STE A, San Diego, CA 92127)	Used at several locations across the island and from the air.
Pyrotechnics *(pyro) – 5 types*		
Pyrotechnics describe a wide variety of tools that can be used to haze birds. Pyrotechnics are primarily an auditory stimulus, creating a loud bang or report, but many charges also produce bright flashes, spiraling light, and smoke.	Pyrotechnics of varying types were tested. These included Starter pistol caps (0.22 caliber "crimp blanks" or acorn caps), Bird Bangers®, Screamer Sirens®, and CAPA rockets® (Reed-Joseph International Company, 800 Main Street, Greenville, MS 38701); Bird Bombs®, Bird Whistlers®, and Shell Crackers (Sutton Ag Enterprises, 746 Vertin Ave, Salinas, CA 93901), were tested. Caps, bangers/bombs and screamer/whistlers were fired from 15mm hand held launchers by trained and qualified personnel. Quieter or less disturbing	Various locations around the island

	charges were used first when near or close to pinnipeds, to minimize any unnecessary disturbance, to gauge the range of these devices and evaluate whether habituation by pinnipeds to their use was possible. Pyrotechnics were often used in conjunction with other hazing methods to disperse birds that were already in the air.
Helicopter *(helo)*	
Helicopters present both an auditory and visual stimulus that can be used to flush roosting birds or dissuade them from landing.	A small Robinson 22 helicopter (Robinson Helicopter Company, 2901 Airport Drive, Torrance, CA 90505) was used principally for monitoring the presence of gulls and pinnipeds on the islands, as well as to transport personnel and equipment to West End. It was also later used as a tool for hazing gulls in less accessible locations.
Combined Treatments	
Pyrotechnic Combinations	
We tested three specific combinations of pyrotechnics to evaluate their synergistic effects. All three treatments combinations contained one or more primarily visual pyrotechnics with one or more loud bangs. These included bangers combined with screamers, screamers combined with cracker shells and screamers combined with CAPA rockets.	
BirdGard and Pyrotechnics *(bgapyro; pyroplus)*	
BirdGard units were used in combination with pyrotechnics. Typically the Bird Gard was triggered to play a predator or distress call in order to flush gulls from their roost. This would be followed immediately by the deployment of one or more pyrotechnics to dissuade the gulls from returning.	
LRAD and Pyrotechnics *(lradpyro; pyroplus)*	
The LRAD unit was used in combination with pyrotechnics. Typically the LRAD was triggered to play a predator or distress call in order to flush gulls from their roost. This would be followed immediately by the deployment of one or more pyrotechnics to dissuade the gulls from returning.	
LRAD and Helicopter *(helirad)*	
The LRAD unit was used from the helicopter to haze gulls from less accessible locations or to discourage gulls from approaching the island to roost.	
Laser and helicopter *(helolas)*	
Lasers were used to flush roosting gulls from land. Helicopter hazing then followed to disperse gulls and dissuade them from landing again. This combination was used infrequently because the lasers were only effective in low light conditions when the helicopter could not fly.	
Pyrotechnics and helicopter *(pyroplus)*	
Pyrotechnics were used to flush roosting gulls from land. Helicopter hazing then followed to disperse gulls and dissuade them from landing again.	

APPENDIX B: HAZING EFFICIENCY BY TREATMENT TYPE

Listed are the specific hazing treatments or combination of treatments used, the general treatment categories and abbreviations used in the analysis along with the mean (± standard error) and median hazing efficiency for each treatment and the number of times each treatment was deployed.

Hazing Treatment	Treatment Category	Specific Treatment Abbreviation	Combined Treatment Abbreviation	Mean Hazing Efficiency	S.E.	Median Hazing Efficiency	N
Bird Gard Super Pro - 4 speaker	Biosonic	bg	bg4	0.33	0.14	0.00	12
Bird Gard Super Pro - Speaker Tower	Biosonic	bgm	bg4	0.67	0.14	0.70	7
Bird Gard Super Pro Amp	Biosonic	bga	bga	0.61	0.06	0.80	45
Long Range Acoustical Device (LRAD)	Biosonic	lrad	lrad	0.58	0.06	0.66	46
Marine Wailer	Biosonic	wail	wail	0.57	0.13	0.86	14
Zon propane cannon	Biosonic	zon	zon	0.63	0.18	1.00	8
Starter pistol cap	Pyrotechnic	cap	pyro	0.00	0.00	0.00	3
Banger	Pyrotechnic	bng	pyro	0.58	0.16	0.50	3
Screamer	Pyrotechnic	scr	pyro	0.83	0.05	0.90	23
Cracker Shell	Pyrotechnic	crk	pyro	0.76	0.00	0.76	1
CAPA Rocket	Pyrotechnic	rkt	pyro	0.81	0.09	0.98	12
Banger with Screamer	Pyrotechnic	bngscr	pyro	1.00	0.00	1.00	1
Screamer with Cracker Shell	Pyrotechnic	scrcrk	pyro	0.90	0.10	0.90	2
Screamer with Rocket	Pyrotechnic	scrrkt	pyro	0.70	0.21	0.80	3
Penlight Laser	Laser	las1	las	0.42	0.30	0.25	3
Avian Dissuader	Laser	las2	las	0.83	0.05	1.00	43
Aries Phaser	Laser	las3	las	0.69	0.03	1.00	146
Helicopter	Mechanical	helo	helo	0.50	0.06	0.50	38
Human	Mechanical	hum	hum	0.57	0.19	0.70	6
Bird Gard with pyrotechnic	Combined	bgapyro	pyroplus	0.61	0.09	0.63	15
LRAD with Pyrotechnic	Combined	lradpyro	pyroplus	0.78	0.16	0.90	4
Helicopter with Pyrotechnic	Combined	pyrohelo	pyroplus	0.92	0.04	1.00	12
Helicopter with LRAD	Combined	helirad	helirad	0.73	0.06	1.00	34
Helicopter with laser	Combined	helolas	helo	0.67	0.17	0.50	3
Big-eye Baloon	Passive visual	bal	bal	na	na	na	3
Kite	Passive visual	kt	kt	na	na	na	2
Mylar tape	Passive visual	my	my	na	na	na	2
Owl Decoy	Passive visual	owl	owl	na	na	na	1
Western Gull Effigy	Passive visual	ef	ef	na	na	na	7