Evaluating the use of non-lethal hazing techniques to minimize potential exposure of Western Gulls to rodenticide from a proposed rodent eradication on the South Farallon Islands

Report to the Oiled Wildlife Care Network

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LAY ABSTRACT

Introduced House mice pose a threat to the Ashy Storm-petrel and other native species of the South Farallon Islands. The United States Fish and Wildlife Service, which manages the Farallon National Wildlife Refuge, has proposed that mice be removed from the islands to restore the island's unique ecosystems and wildlife. Methods being considered for removing mice include the application of rodent bait by helicopter. However, the bait, that contains a rodenticide, poses a risk to some non-target wildlife such as Western Gulls. To confirm if the risk to Western gulls could be effectively mitigated through the use of wildlife hazing techniques, a trial was completed in the fall of 2012. The trial that tested a range of hazing tools such as biosonics, pyrotechnics, lasers, reflective objects and effigies (dead gulls tied to a pole) successfully demonstrated that gulls could be kept off the islands for an extended period of time. The trial also demonstrated that most hazing techniques had no significant negative impact on other wildlife present such as seals and sea lions. The trial provided confidence that the risk to gulls can be reduced to low levels if a mouse eradication took place. Results from the trial will be used by the USFWS in planning for the proposed mouse eradication but will also be useful to other agencies engaged in hazing wildlife such as the Oiled Wildlife Care Network.

SCIENTIFIC ABSTRACT

Introduced House mice (*Mus musculus*) pose a threat to the Ashy Storm-petrel and other native and endemic species of the South Farallon Islands. The United States Fish and Wildlife Service, which manages the Farallon National Widlife Refuge, has proposed their eradication as part of continuing efforts to restore the islands' ecosystem and conserve the populations of native species. 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*). 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. 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 USFWS in planning for the proposed mouse eradication as well as other resource

managers, such as oil spill responders when choosing appropriate techniques for their individual applications. Although the suite of tools tested appears sufficient to minimize the risk to gulls during the proposed mouse eradication, provision should be made for the use of additional hazing methods to ensure the risk to gulls is minimized.

INTRODUCTION

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, ballons and mylar tape (Seamans *et al.* 2002, Gorenzal and Salmon 2008); effigies (Seamans *et al.* 2007); and helicopters (Marsh *et al.* 1991). In this study, we evaluated a variety of hazing methods in order to test their efficacy in minimizing the risk of rodenticide exposure to Western Gulls during proposed mouse eradication on the South Farallon Islands, California. We also assessed impact from hazing activity to non-target species[1] including pinnipeds and roosting shorebirds and evaluate their potential efficacy for use in hazing birds away from oil spill areas.

The South Farallon Islands lie approximately 30 miles west of San Francisco, California and are part of the Farallon National Wildlife Refuge (Fig. 1). The islands are home to 13 breeding species of marine birds, five species of pinnipeds and countless migratory birds each year. With more than 300,000 breeding birds, they are the largest seabird breeding colony in the contiguous United States (Ainley and Boekelheide 1990) and include globally important populations for Ashy Storm-petrels (*Oceanodroma homochroa*), Brandt's cormorants (*Phalacrocorax penicillatus*) and Western gulls (*Larus occidentalis*). During the 1800's, 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 native wildlife, most notably on Ashy Storm-petrels (*Oceanodroma homochroa*) (a California species of special conservation concern and IUCN listed endangered species) and other native and endemic species of the Farallon Island ecosystem.

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[1] For the purposes of this report a non-target species was defined as a species that is likely to be unaffected by the proposed mouse eradication but could be affected by hazing methods.

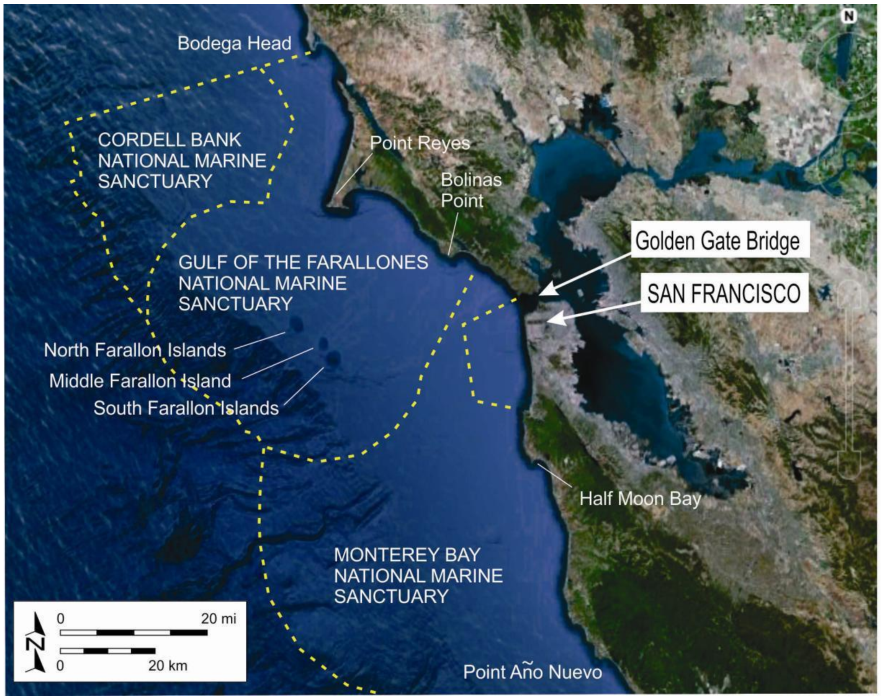

Figure 1. Map showing the location of the South Farallon Islands

The United States Fish and Wildlife Service, which manages the Farallon NWR, has proposed the eradication of introduced mice as part of their continuing effort to restore the islands ecosystem and conserve the populations of native wildlife (USFWS 2013, Draft Environmental Impact Statement (DEIS)). Part of the proposed mouse removal methods includes 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, DEIS).

The occurrence of marine birds on the South Farallon Islands is strongly seasonal, with the greatest number and diversity present during the spring and summer breeding period (Ainley and Boekelheide 1990). The timing of the proposed operations to eradicate mice would therefore likely take place during the late fall when most resident seabirds are not present (USFWS 2013, DEIS). However, long-term data on seasonal occurrence indicates that Western Gulls are likely to be present during this time period (Grout and Griffiths 2012, Pott and Grout 2012). This potentially puts them at risk of lethal exposure to rodenticide through direct ingestion of baited pellets or by scavenging carcasses of poisoned mice.

Previous studies have indicated that the bait pellets likely to be used during the eradication (Conservation-25D Brodifacoum or Diphacinone-50 Conservation) would remain available and palatable to gulls for between 7 and 101 days depending on the intensity of rainfall (Griffiths *et al.* 2013; USFWS 2013, DEIS). The purpose of this study was to demonstrate the ability to minimize the risk of exposure by deterring gulls 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. Herein, we evaluate the effectiveness of the hazing trial to reduce gull numbers, the relative hazing effectiveness of the different hazing treatments for dissuading gulls and the non-target impact of these treatments on pinnipeds and other bird species present on the island. The knowledge generated has application not only to this project but also to other situations where hazing of birds is required, such as oil spill response operations.

METHODS

Study approach and treatments used

This study was conducted on the South Farallon Islands, Farallon National Wildlife Refuge, between November 27 and December 15, 2012. This period was selected to coincide with the likely timing of the proposed mouse eradication operation when overall marine bird numbers are at their annual minimum and before the start of elephant seal breeding. The South Farallon Islands consist of two main islands, Southeast Farallon Island (SEFI) and West End Island (WE) as well as several smaller offshore islets and rocks totaling approximately 120 acres (Fig 2).

Figure 2. Aerial view of the South Farallon Islands. The two main islands are Southeast Farallon Island (SEFI) and West End Island (WE).

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 and post-trial monitoring of gulls and pinnipeds was undertaken in order to determine the rate at which gulls resumed normal roosting patterns and to document any lasting impacts on pinnipeds. The impact of hazing activity and individual techniques on pinnipeds was continually assessed throughout the study.

Table 1. Trial Phases

Phase	Scope	Area	Duration	Dates
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 WE	5 days	November 28 – December 2, 2012
2	• Assessing the effectiveness of a hazing operation to reduce gull numbers across the South Farallon Islands	Island-wide	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 WE	3 days	December 11-13, 2012

Phase 1 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 eradication 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 continuously from both SEFI and WE 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. Gulls were allowed to roost in certain localized areas where mice may not be present and bait may not need to be applied, including several small off-shore islets and tidally submerged roosts. 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), 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).

A full description of each hazing treatment and how it was used is presented in Appendix 1. 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 hazing (pyroplus) and helicopter hazing combined with the LRAD (helirad). See Appendix 2 for the complete list of all unique hazing treatments tested along with their standard abbreviations.

Although proposed, permission from the Federal Aviation Authority to deploy Unmanned Aerial Vehicles (UAV) was not obtained in time to include testing of this technology in the trial. However, in our discussion of the results of the trial we infer some aspects of the potential effectiveness of UAV's from data collected on the utility of the helicopter. 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 although proven effective elsewhere (Jones *et al.* 1996) were not included because of the desire to minimize the impacts of the trial.

Gull distribution and abundance

Dawn gull counts were conducted on a daily basis by experienced ground based observers on the South Farallon Islands between November and March in 2010 and 2011 in order to establish a baseline population estimate for gulls on the island during the fall and winter period. 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. During the trial, maximum dawn numbers were determined by summing gull counts made during the earliest period of hazing activity in each area on each day. Estimated numbers of individuals for other bird species in the area were also noted. To allow a more detailed assessment of the impact of specific hazing treatments used during the trial, the island was divided into 49 discrete sectors.

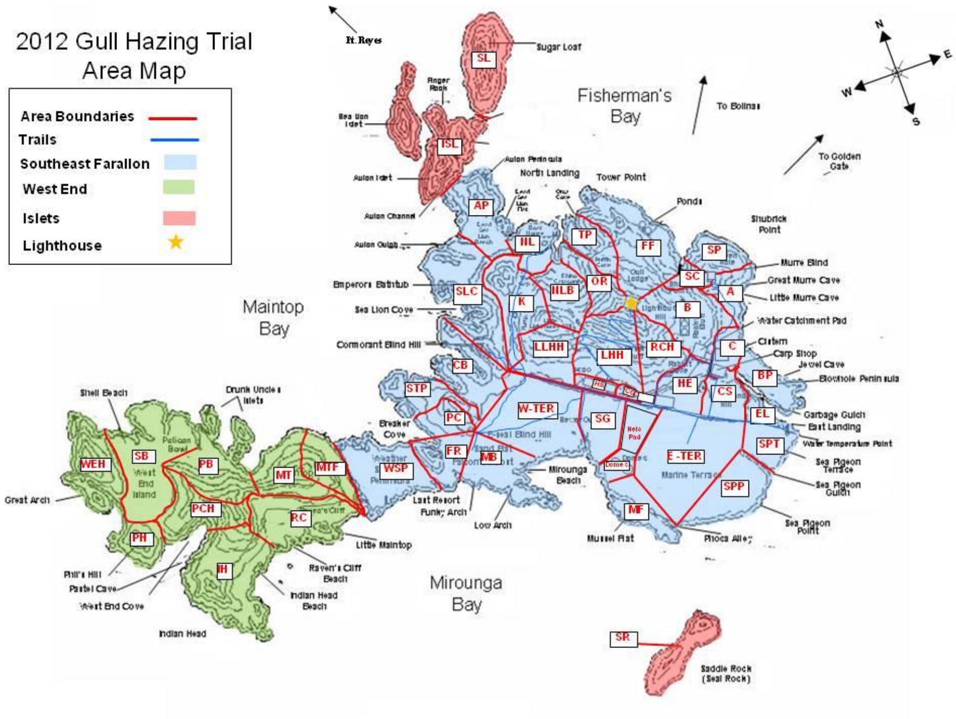

Fig. 3. Sectors used for monitoring gull numbers and behavior during the hazing trial on the South Farallon Islands. The colored areas denote Southeast Farallon Island (blue), West End Island (green) and offshore islets (red).

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-targeted 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.

Analysis

The impact of hazing activity on inter-annual gull population abundance was evaluated 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. We also examined the overall effectiveness of the hazing effort in reducing the number of gulls roosting on the island. We did this by comparing the number of gulls present in the 10 day period immediately prior to hazing activity 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. We used the daily maximum number of gulls present at dawn in the period prior to, during and after the hazing trial for all comparisons. Paired t-tests were used to test and evaluate differences in gull numbers between time periods.

We also determined overall effective daily hazing rates 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%. We acknowledge that daily counts of gulls prior to and during the trial are not independent i.e. counts are likely influenced by the size of the gull population the previous day. However, this was an unavoidable constraint of the trial design. Paired t-tests were again used to evaluate differences in the effective daily hazing rates between trial phases.

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 all gulls flushed but some simply circled and returned to the same roost. Since the main objective of this project was to test our ability to move 100% of the gulls from any baited areas, this seemed an appropriate measure.

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 proportion data in order to run parametric statistical tests. This common transformation reduces the influence of ones and zeroes in the data so that it more closely approximates a normal distribution.

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 projected onto a map 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 wherever 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.

Effectiveness of Passive Hazing treatments

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.

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 (*Mirounga angustirostris*), Harbor seal (*Phoca vitulina*), Steller sea lion (*Eumetopias jubatus*), Northern fur seal (*Callorhinus ursinus*), and California sea lion (*Zalophus californianus*). 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 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 (area targeted for hazing treatment) immediately prior to the initiation of any hazing technique and recording the proportion of the animals that reacted. Responses of pinnipeds were categorized into four possible behaviors: 1) no response; 2) alert (animal raised head, looked around or shuffled position); 3) moved (moved > 1m from initial location); and 4) flushed (animal moved to the water). During analysis, we deemed “disturbance” to be any time that an animal either moved more than one meter or flushed into the water. We did not consider animals being alerted as a significant disturbance.

Although individual species did show some differences in their response, we decided to group 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 seabirds are not present on the island. However, the impact of the trial on other non-target species present was recorded as part of other long term monitoring programs and anecdotal observations, and to inform the Oiled Wildlife Care Network (OWCN) a supporter of this trial, about the potential response of these species if hazed during an oil spill response. 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 before the hazing trial were intermediate relative to the previous two years (Fig 4). The average number of gulls on the South Farallon Islands 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.

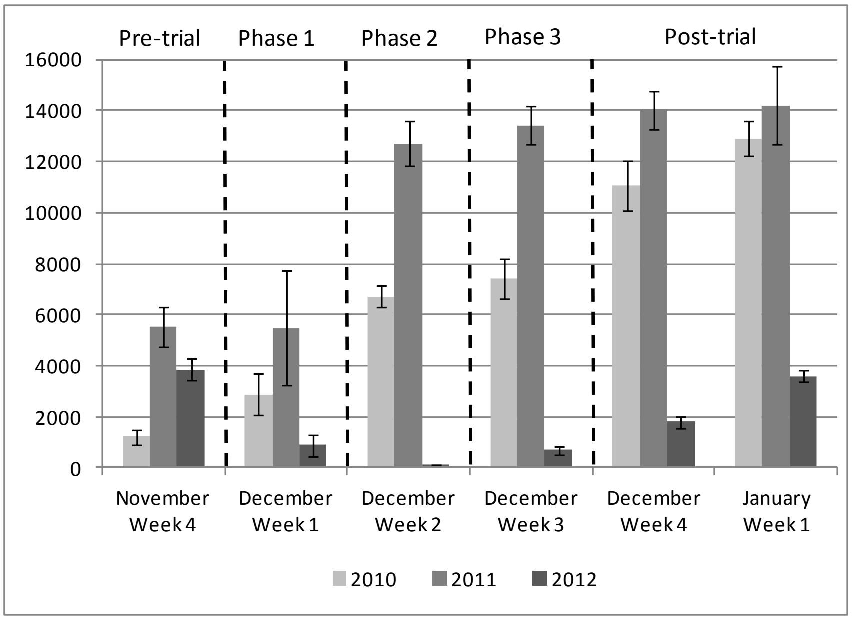

Fig. 4. Mean number of gulls present on the South Farallon Islands during the 2010, 2011 and 2012 fall/winter seasons. Active gull hazing was conducted during the first two weeks of December.

Hazing activity had a significant impact on the numbers of gulls on the South Farallon Islands. Gull numbers were dramatically reduced during Phase 2 and remained low during Phase 3 when hazing was undertaken solely by ground based personnel on SEFI (Fig. 5). Hazing efficacy appeared to remain high during Phase 3 even though the majority of WE was only hazed at dawn and dusk using lasers from the SEFI Lighthouse (Fig. 2). Gull counts during Phase 2 of the trial (the active hazing period) were significantly reduced when compared to the 10-day period immediately preceding hazing activity ($t=10.8225$, $p<0.01$, $df=17$; Fig 5) as well as the 10-day period in early January after hazing had concluded and birds had returned to the islands ($t=-7.3007$, $p<0.01$, $df=18$; Fig 5).

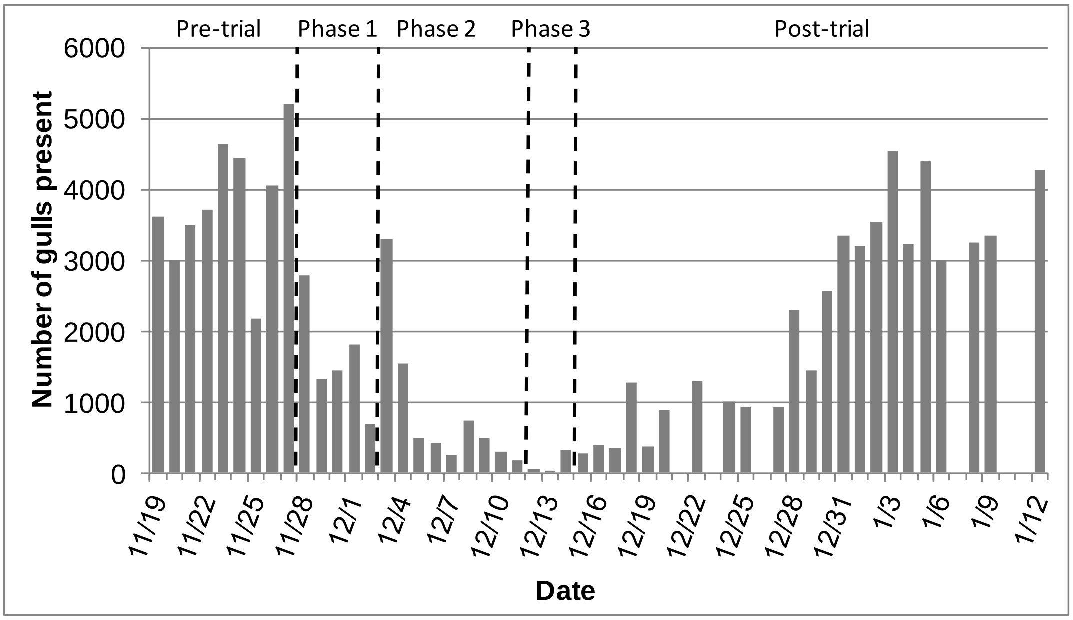

Fig. 5. The maximum number of gulls present at dawn throughout the course of the gull hazing trial. The dashed vertical lines delineate the different phases of the trial (see Table 1). Full island active hazing efforts occurred during Phase 2.

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 were often only present for a brief period (<30 min) prior to 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. 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 4) and is significantly different from both previous seasons (2010 $t=6.1246$, $p<0.01$, $df=9$; 2011 $t=6.5316$, $p<0.01$, $df=9$).

Daily hazing success

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

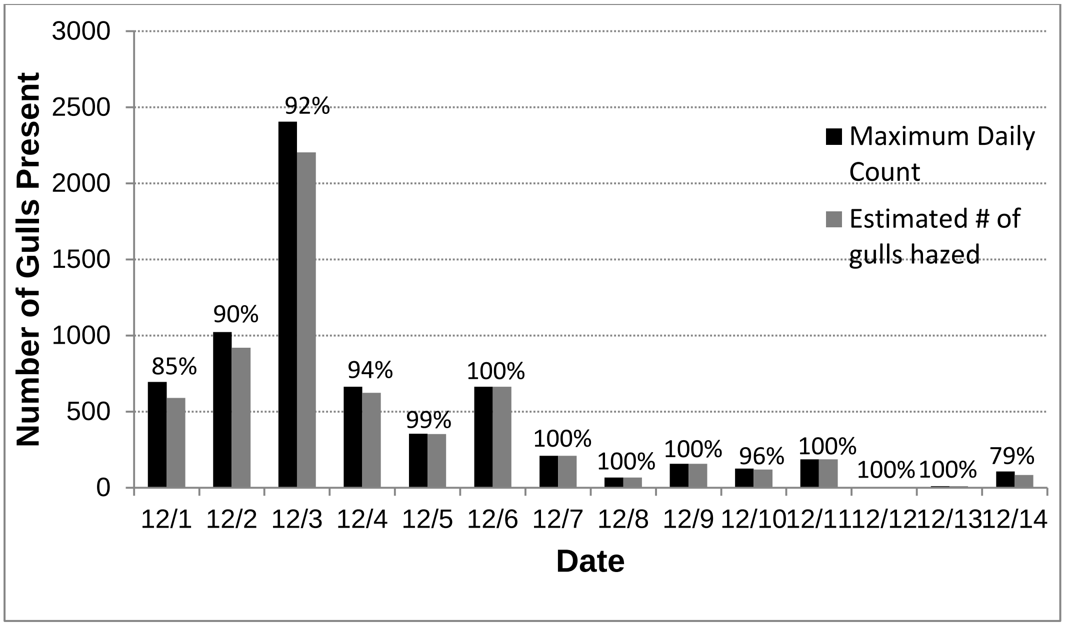

Fig. 6. The maximum number of gulls present on the South Farallon Islands at any given time (based on 1/2 hourly gull counts) and the estimated number that were successfully hazed during a gull hazing trial completed in December 2012. Percentages represent the daily hazing effectiveness. Hazing efforts were reduced on December 14 due to departure of staff.

Changes in gull distribution

There were noticeable changes in the pattern of gull attendance around the islands. During the pre-trial phase gulls were more or less evenly distributed around the common intertidal roost areas as well as in some territorial areas away from the water. By the end of the trial, they were generally restricted to small flocks, farther out in intertidal areas or on offshore islets (Fig. 7). Gull numbers were dramatically reduced and they shifted their distribution towards the extremities of the island during Phase 2. During Phase 3, gulls were confined to small roosts far out in the intertidal and on islets. Islets where gulls were allowed to roost included Sea Lion Islet, Saddle Rock and Sugarloaf (Fig. 7.) and these birds did not appear to attract other gulls.

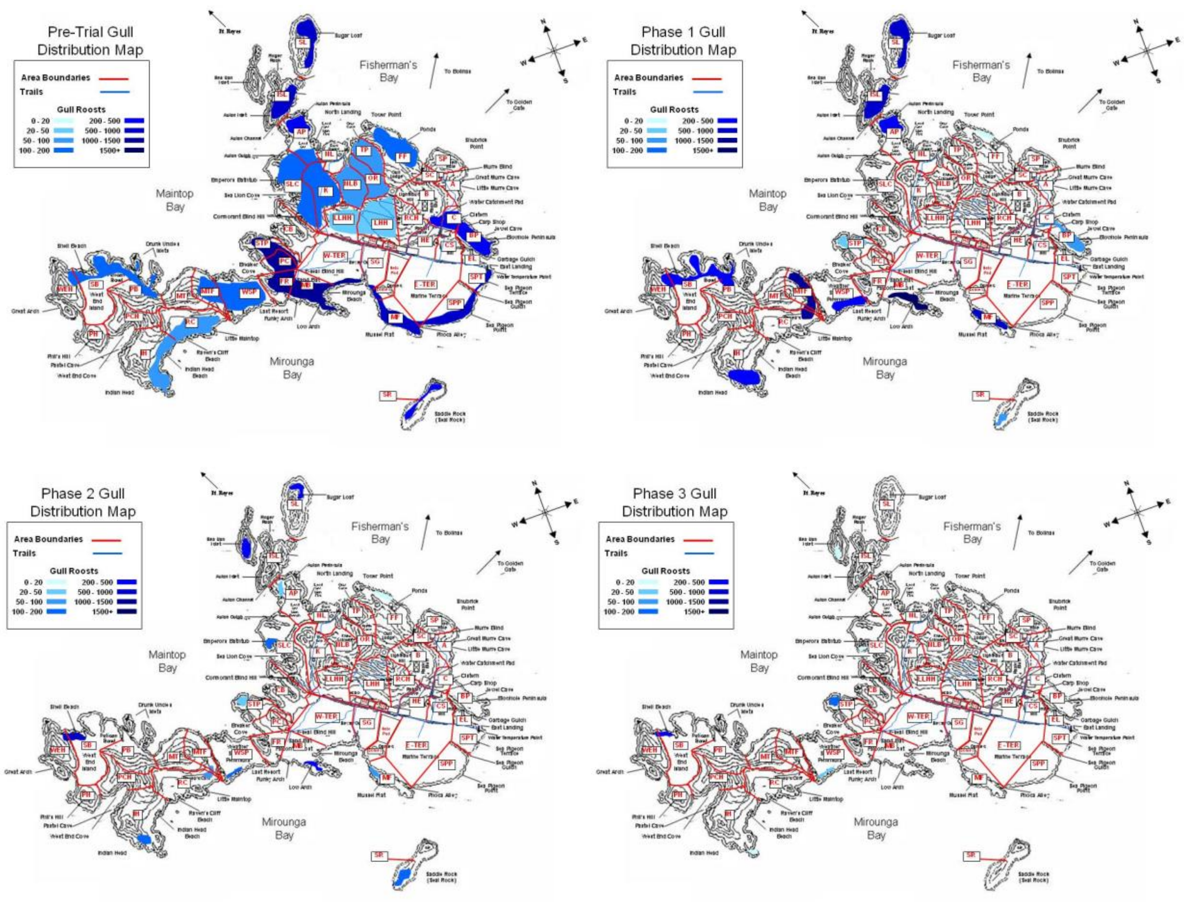

Fig. 7. Location of the main gull roosting sites prior to and during a gull hazing trial completed on the South Farallon Islands. Monitoring began on November 28, 2012.

Following the trial Western Gulls were slow to resume roosting on the South Farallon Islands and average weekly gull counts did not reach their pre-hazing trial level until approximately three weeks after hazing ceased (Fig. 5). In addition to overall reduced gull abundance, spatial changes in gull distribution were observed during the trial. In general, gulls were kept off the marine terrace and other upland territorial areas throughout the trial period. The highest concentrations of gulls at the initiation of hazing activities (Phase 2) were on WE (primarily Shell Beach, Indian Head and Maintop), the Islets, Mussel Flat and Mirounga Beach. There were also large concentrations on Blowhole, Aulon Peninsula, Weather Service Peninsula and Study Point Peninsulas (Fig. 7).

Hazing efficiency of individual treatments

We calculated the mean and median hazing efficiency for each of the individual hazing treatments (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 (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.

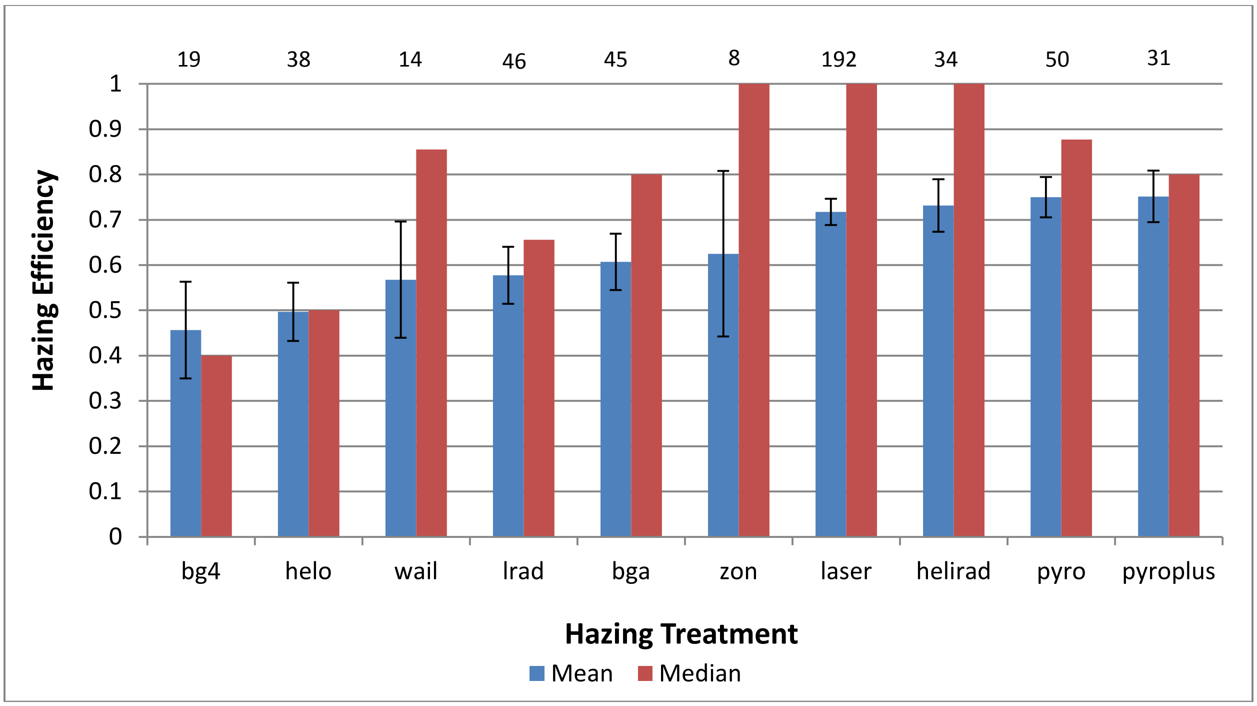

Figure 8: Mean (± standard error) and median hazing efficiency by treatment group. See Appendix 2 for treatment legend and description of treatment groups. Values along the top x axis indicate sample size.

There was significant difference between treatments (Anova: $F=2.93$, df 9; $p<0.002$; Fig. 8) 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 the 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. It is worth noting that the Zon propane cannon, 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.

Among the individual pyrotechnics employed, CAPA rockets and screamers were on average more efficient than bangers and crackers (Fig. 9). Caps, when used in isolation, were not effective and were not used after the first few tests. When caps are 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.

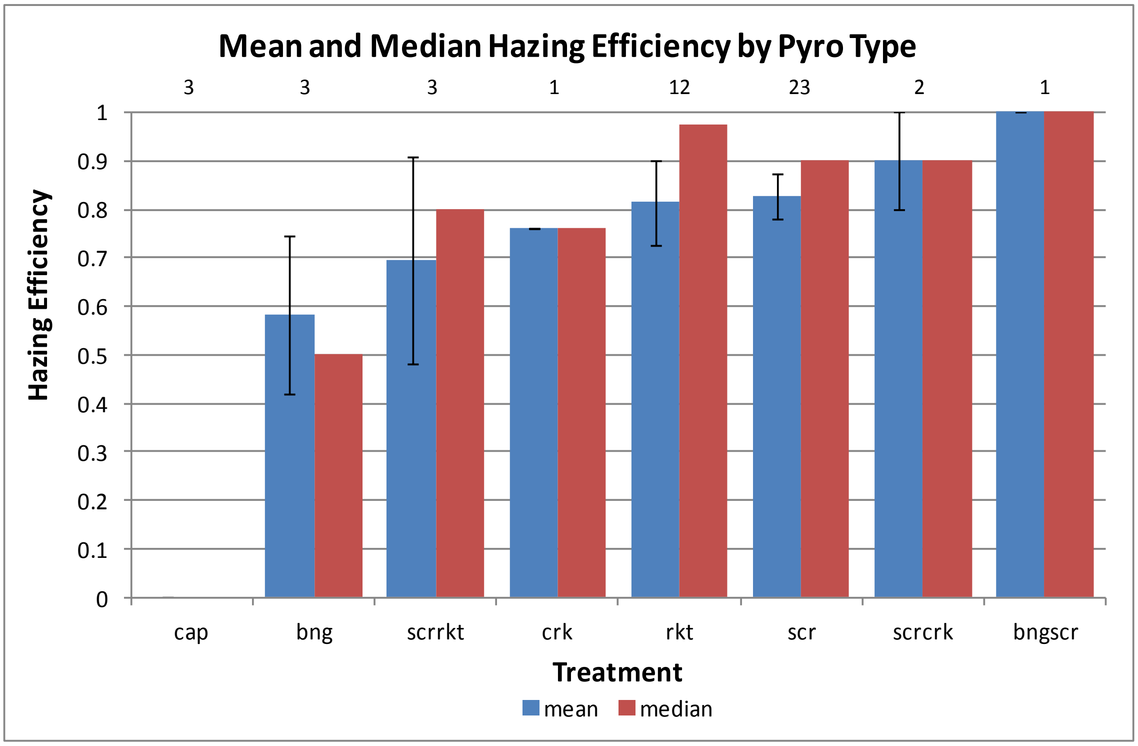

Figure 9: Mean (± standard error) and median hazing efficiency by specific type of pyrotechnic or combination of pyrotechnics used. See Appendix 2 for treatment legend and description of treatment groups. Values along the top x axis indicate sample size.

Effective distances of individual treatments

Distance between the hazer and the intended target was not a reliable indicator of success. Regressions of hazing efficiency vs. distance in general and individually for each hazing method revealed no significant relationships.

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.

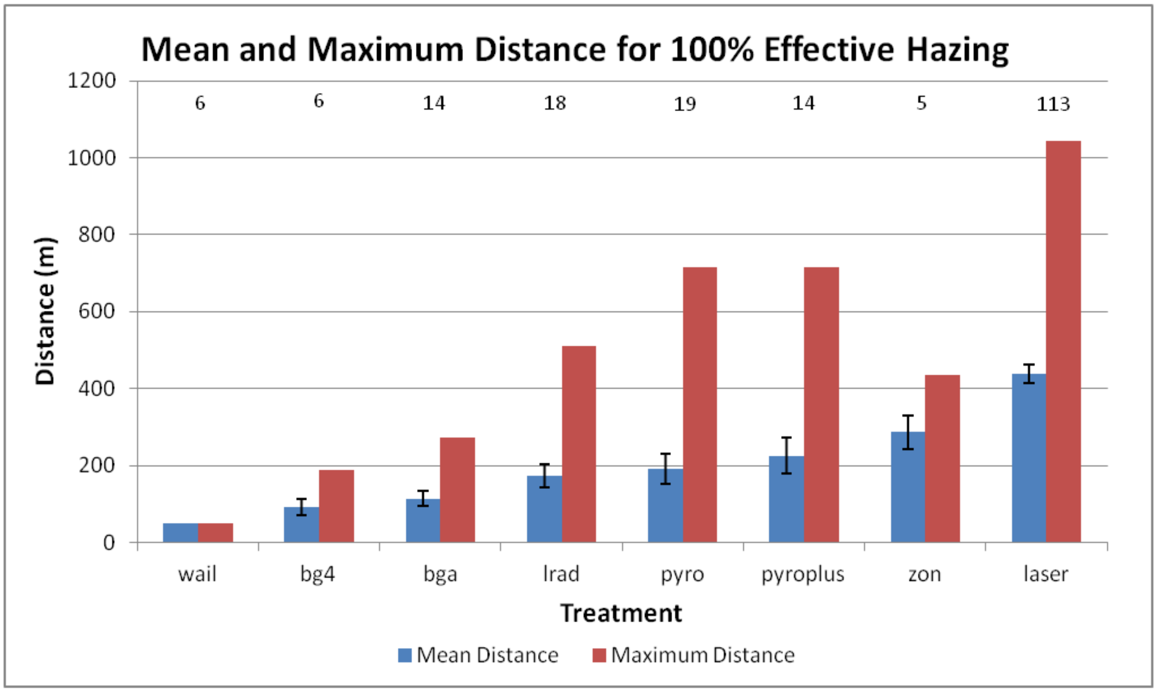

Figure 10: Mean (± standard error) and maximum effective distance by treatment group. See Appendix 2 for treatment legend and description of treatment groups. Values along the top x axis indicate sample size.

There were significant differences between groups (Anova: F=131, 9 df; p<0.0001; Fig. 10). Lasers (when used in low light situations at dawn and dusk) were successful at significantly greater distances than most other treatments whereas the Wailer and Bird Gard biosonic units were only effective over relatively short distances.

Figure (11) below shows the relative effective distances for each of the individual pyrotechnics tested (not including combined pyrotechnic treatments). In general, CAPA rockets and cracker shells were effective at greater distances than screamers and bangers, though there were no statistically significant differences between the different treatments (Anova: F=2.84, p=0.113, df=3).

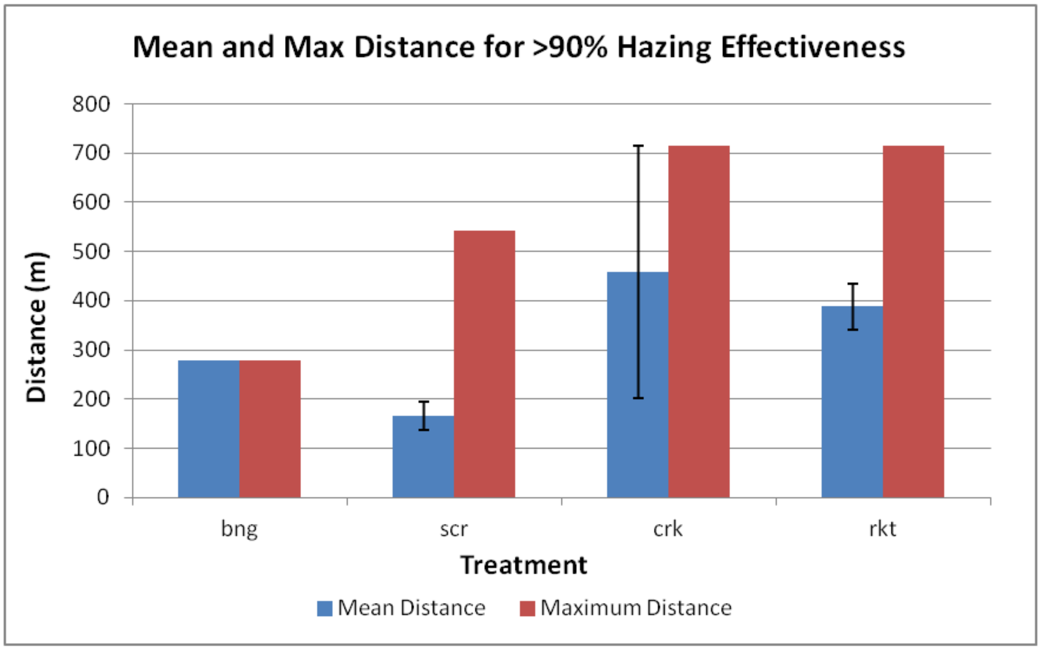

Figure 11: Mean (± standard error.) and maximum distance for which >90% hazing efficiency was achieved for each of the individual pyrotechnic treatment types. See Appendix 2 for treatment legend and description of the different pyrotechnics used.

Non-target impacts of gull hazing treatments

We observed little impacts to non-target birds as a result of the hazing activity. Because the trial was conducted during the time of year when the majority of seabirds are not present on the island, overall numbers of non-target species were not determined. However, in order to assess the potential for hazing other species in an oil spill situation, we did note the presence and numbers of individuals of all bird species that were present when hazing was conducted and made a general estimate of the number of birds affected and the type of response.

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 Common Murre, six events which disturbed roosting Brown Pelican and six events which flushed shorebirds from intertidal roosts. 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.

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 (Fig12). Fur seals in particular were present in greater numbers than the prior five year average owing to their recent and continuing rapid population growth.

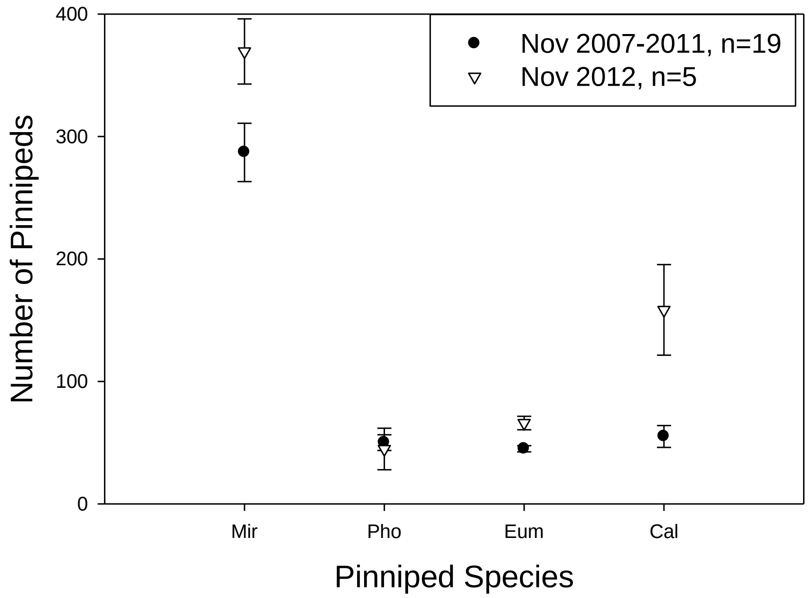

Fig. 12. Pretrial Farallon Pinniped numbers for November. Historic data (2007-2011) compared with pre-trial data from 2012. Mean monthly values with standard errors are plotted. Species shown are Northern Elephant Seal (Mir), Harbor Seal (Pho), Steller Sea Lion (Eum), and Northern Fur Seal (Cal)

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. 13), and California Sea Lions ($t = 1.096$, $p = 0.309$, $df = 7$; Fig. 14). 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 13). However, these declines are consistent with regularly observed seasonal declines as juvenile elephant seals and most fur seals depart the island at this time. 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.

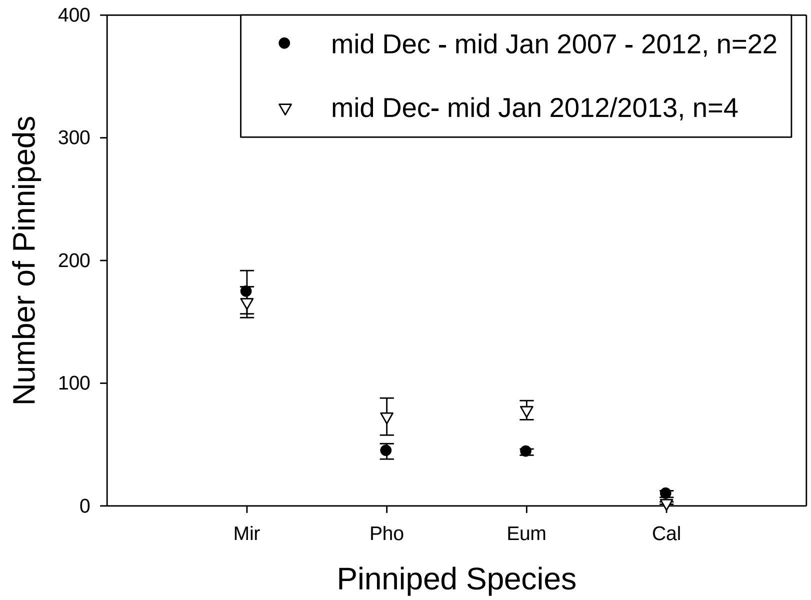

Fig. 13. Post-trial Farallon Pinniped numbers for mid-December to mid-January. Historic data (2007-2011/2) compared with pre-trial data from 2012/2013. Mean monthly values with standard errors are plotted. Species shown are Northern Elephant Seal (Mir), Harbor Seal (Pho), Steller Sea Lion (Eum), and Northern Fur Seal (Cal).

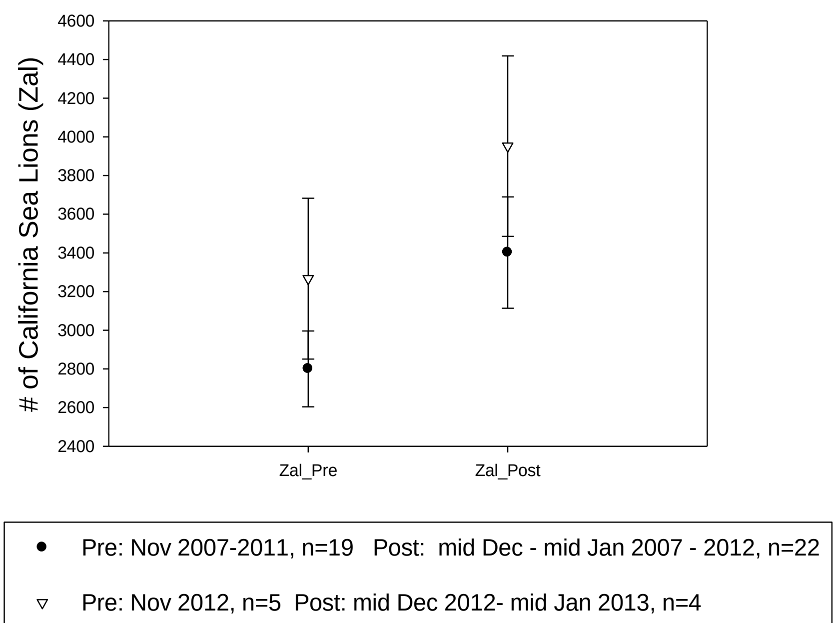

Fig. 14. Pre and Post Trial Farallon California Sea Lion (Zal) numbers. Historic data (2007-2011/2) compared with trial data from 2012/2013. Mean monthly values with standard errors are plotted.

Effect of individual treatments on pinnipeds

Biosonic hazing methods had little effect on pinniped behavior, with no significant disturbance (moving >1m or flushing) observed for elephant seals and harbor seals, and less than 3% of the animals disturbed for all other species when present in hazing target areas (Fig 15).

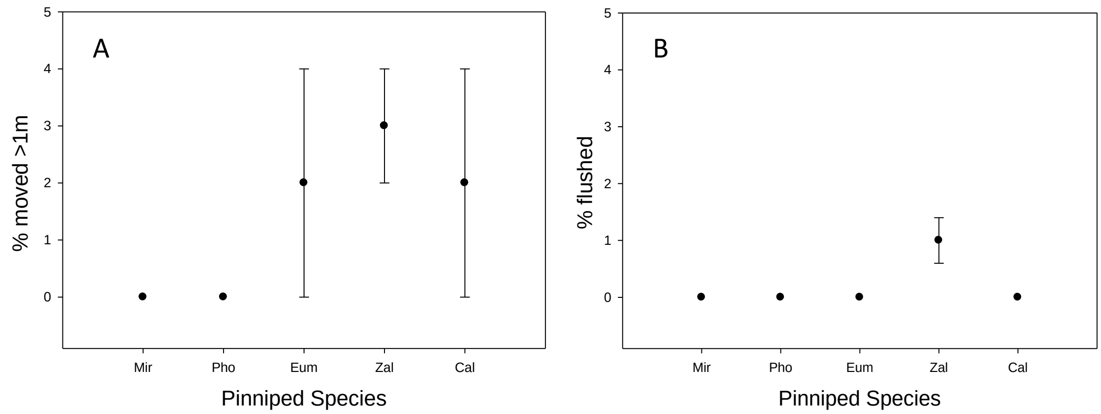

Fig. 15. Biosonic gull hazing tool effects on Farallon Pinnipeds in target areas (total n=103). Methods used include Bird Gard, Wailer, LRAD, and LRAD from Helicopter. A) Percentage of pinnipeds moved >1m with standard error; and B) percentage of pinnipeds flushed with standard error. Species are Northern Elephant Seal (Mir), Harbor Seal (Pho), Steller Sea Lion (Eum), California Sea Lion (Zal), and Northern Fur Seal (Cal)

Pyrotechnic hazing methods elicited greater responses from marine mammals. Greater than 15% of California Sea Lions and approximately 5% of Steller Sea Lions were disturbed when pyrotechnics were employed (Fig. 16). Harbor seal disturbance rates were high with more than 20% of the animals flushing in the presence of pyrotechnics (Fig. 16 B). This response was primarily driven by the loudest of the pyrotechnic devices, the CAPA rocket.

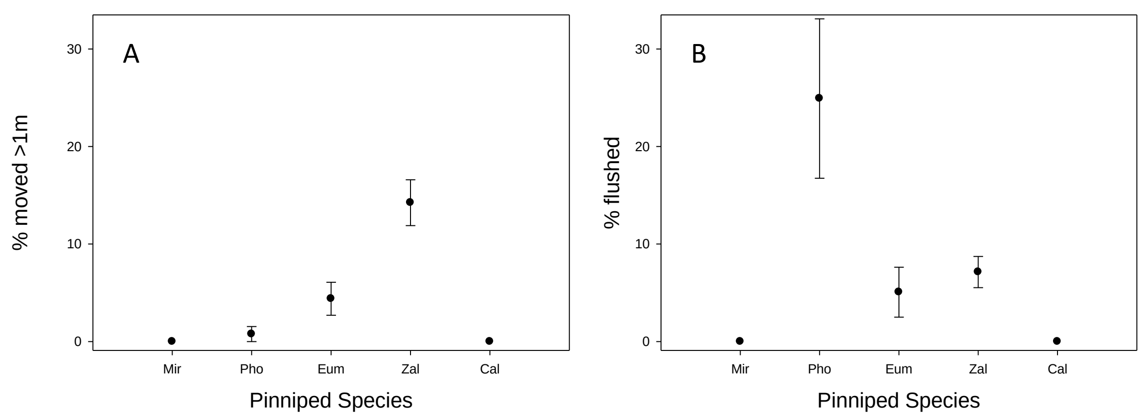

Fig. 16. Pyrotechnic gull hazing tool effects on Farallon Pinnipeds in target areas (total n=91). Methods used include screamers, bangers, and CAPA rockets. A) Percentage of pinnipeds moved > 1m with standard error; and B) Percentage of pinnipeds flushed with standard error. Species are Northern Elephant Seal (Mir), Harbor Seal (Pho), Steller Sea Lion (Eum), California Sea Lion (Zal), and Northern Fur Seal (Cal)

In general, for all hazing treatments, California Sea Lions were the most sensitive to being disturbed while Northern Elephant Seal and Northern Fur Seal were rarely affected.

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. 17). Lasers consistently had no effect on pinniped behavior and were not included in statistical analyses.

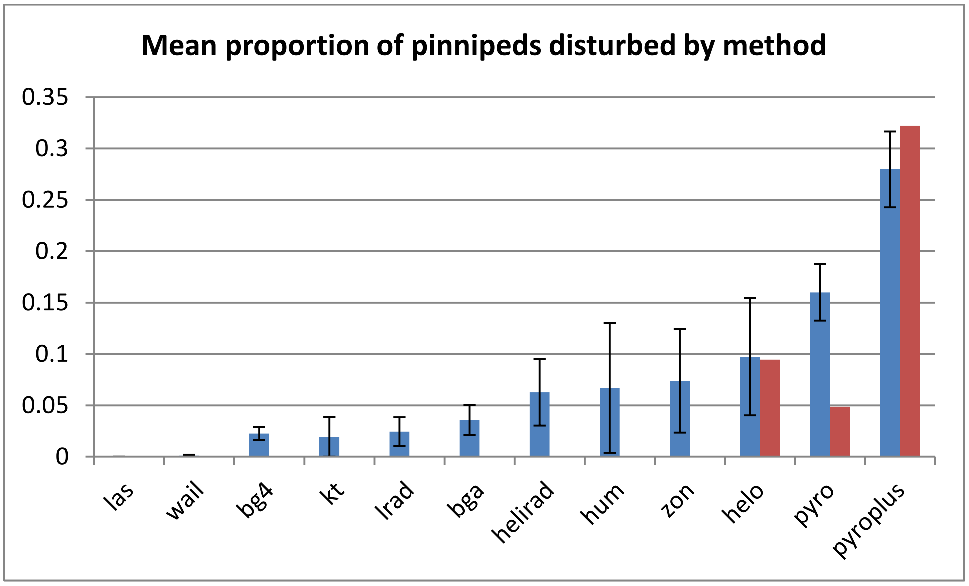

Fig. 17. Effect of individual hazing tools on pinniped disturbance. Presented are mean ± standard error (blue) and median values (red). Data presented for all pinniped species combined. See Table 1 for explanation of treatment abbreviations.

Effect of proximity on disturbance

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, on average, than other methods tested (Fig. 18).

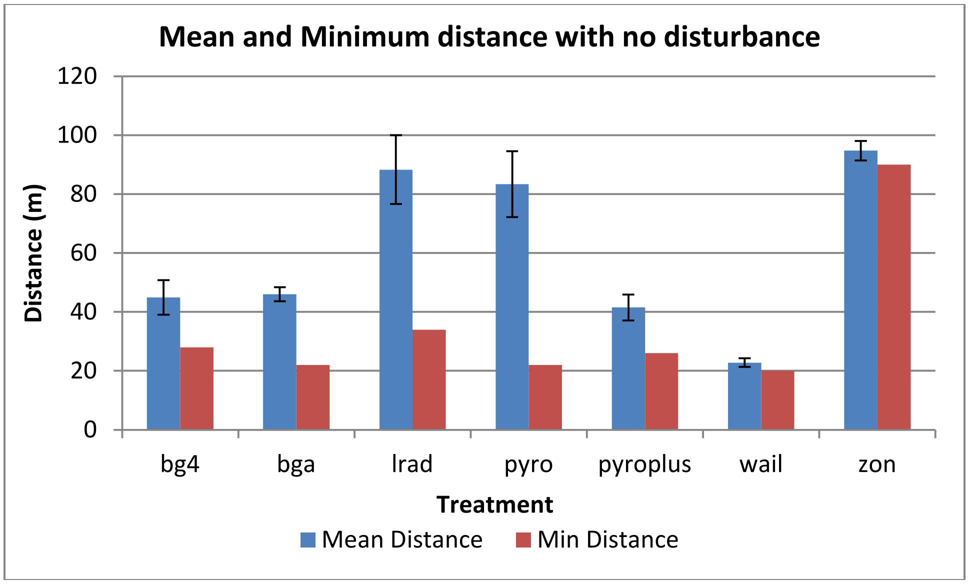

Fig. 18. Mean ± standard error (blue) and minimum distance (red) required for zero disturbance to pinnipeds for different hazing tools. Data presented for all pinniped species combined. See Appendix 2 for explanation of treatment abbreviations.

Passive Hazing Summary

We tested the effectiveness of passive hazing devices such as effigies, owl decoys, kites and mylar tape by comparing gull counts before and after their deployment (Fig. 19). These figures illustrate the reduction in Western Gull numbers when the effigies and other passive hazing devices are present. 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 are 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). 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.

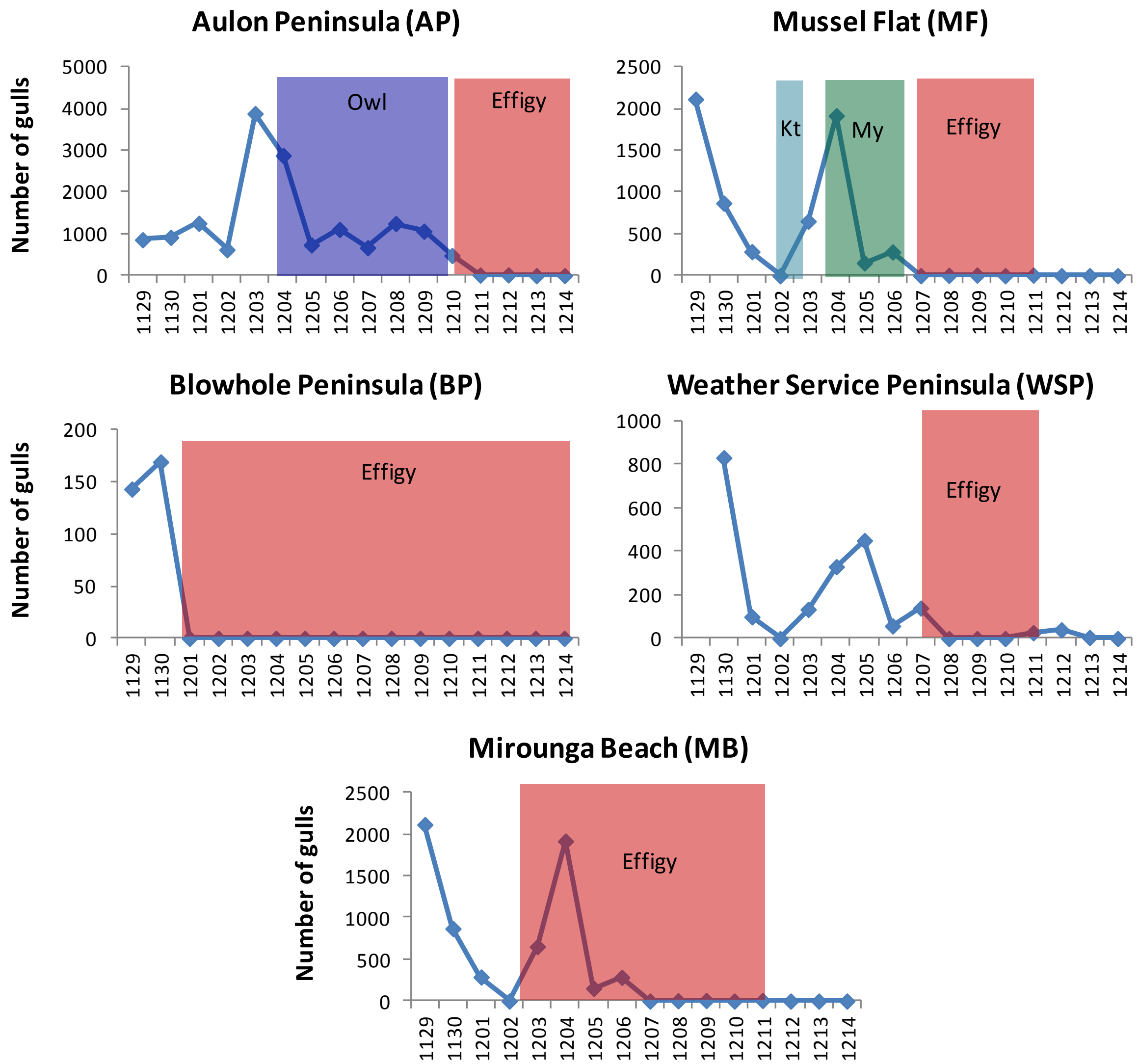

Fig. 19. Western Gull counts in the presence and absence of passive hazing tools for each hazing sector where passive hazing tools were deployed (see Fig. 3 for locations). Passive hazing tools included Western Gull effigies, kites (kt), mylar tape (my) and owl decoys (owl).

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 the proposed mouse eradication. In addition, we wished to test the efficacy of a variety of individual hazing techniques and tools in order to assess their utility in future hazing efforts, such as during the mouse eradication or an oil spill. 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 on the South Farallon Islands and minimize the number of individuals that would be likely to come into contact with rodenticide. 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 by the end of the hazing period. 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 where they would not be expected to come into contact with rodent bait.

We were not able to 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 at dusk, our surveys the following morning 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. This gives us confidence that successful daytime hazing operations, like those we achieved during phase 2 of the trial, will prevent birds from encountering bait, even when no hazing activity occurs at night. We also believe that should more nighttime activity of gulls be detected during the actual rodent removal operation, that lasers could be very effectively used to deter their presence as needed.

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, 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.

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. As a result, these tools were not tested frequently and were hardly used after the first few days of the trial. 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. 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. As depicted in Figure 19, 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.

Lasers, pyrotechnics and various combinations of pyrotechnics with additional hazing devices were the most effective at dispersing gulls from their roosts. These treatments also had the most substantial effect on other bird species present. These treatments all had mean hazing efficiencies over 70% and were also effective at the greatest distances.

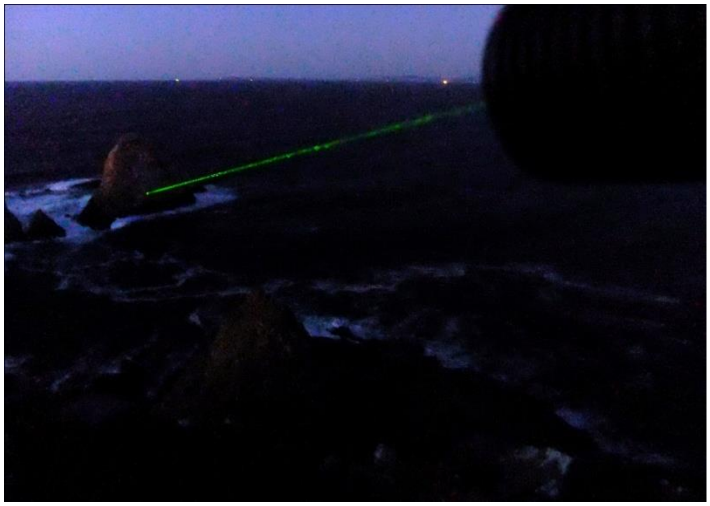

Fig. 20. Aries Phazer being used to haze roosting gulls from Sugarloaf at dusk.

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. 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 relatively short range.

Pyrotechnics and pyrotechnics combined with other hazing treatments had the highest overall hazing efficiency. They were effective over long distances, up to 700m and unlike the lasers were equally useful during all times of the day. 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. 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.

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 unfamiliar object with a predator or distress call to great effect. This treatment was equally as effective as pyrotechnics and pyrotechnic combinations but with 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.

Tolerance by gulls to the noise and presence of the R22 helicopter suggests that UAV’s are likely to have limited effectiveness as a hazing tool unless they can be deployed in conjunction with other methods such as a LRAD. However, the helicopter proved invaluable as a method of detecting and monitoring gulls in areas that were difficult to observe from the ground. Based on these observations, we see UAV’s as offering a highly efficient method for monitoring in real time the effectiveness of future hazing operations especially those that span large areas.

Effect of proximity

One of the objectives of this study was to determine the effective distances for each of the different hazing treatments. 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 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 disturbance 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 flushes 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 impact, 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 CAPA's. CAPA's were sometimes intentionally directed at an angle to the birds if they were near pinnipeds in order to get the loud bang but not 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, the analysis in this report 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. However, the data and analyses presented serve to effectively demonstrate significant differences in the relative effectiveness of the treatment methods tested for gulls and their impact on non-target species. The lessons learned from the Farallones trial will provide valuable guidance to resource managers and oil spill responders for planning and implementing future avian hazing operations.

ACKNOWLEDGEMENTS

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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 (PRBO), Paul Gorenzel (OWCN), Valerie Burton and Eric Covington (USDA-APHIS WS), and Tommy Hall (IC). We would also like to thank the volunteers who contributed to the trial effort including: 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.

All actions conducted during the trial complied with the specific permit and authorization requirements specified in the following Hazing Trial permits:

- **NOAA-NMFS: Section 7 Biological Opinion and Incidental Harassment Authorization (IHA)** (Addresses monitoring, avoidance and minimization of impacts to pinnipeds during the trial)

- **ATF:** Permit issued by the Bureau of Alcohol, Tobacco, and Firearms for the use and handling of explosive pest control devices (EPCD) issued on November 9, 2012.

- **USFWS**: Wilderness Determination to allow for access the Wilderness Areas of the Refuge. Categorical Exemption issued by the USFWS Refuge Manager.

- **Gulf of the Farallones National Marine Sanctuary:** Permit allowing helicopter over flights.

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APPENDIX 1: Hazing methods and product descriptions for all hazing treatments used in a 2012 Gull Hazing Trial on the South Farallon Islands.

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)
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)*		
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. Lasers were known to be less effective during daylight hours except at close range (Pott and	Lasers were used primarily from Lighthouse Hill and West End locations. See Fig. 3.

	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.	
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 *(bg, bgm, bga, bg4)*		
Biosonics, or bioacoustics, as a hazing method, involves using animal alarm or distress calls to alter the behavior of a target species.	Three different Bird Gard biosonic units (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.	Birdgard units were 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)*		
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 (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. Quieter or less disturbing charges were used first when near or close to pinnipeds, to minimize any unnecessary disturbance, to	Various locations around the island

	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.

Method Combinations

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 2: 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.

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