Summary Report of Mountain Lion Hazing/Deterrent Devices Testing aimed at Reducing Livestock Predation and Associate Mountain Lion Depredation Permits

University of California – Davis Agreement A37682 Amendment #2 SANDAG Contract #5005298 Amendment #2 (S890571)

Task 2

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Executive Summary

This document seeks to provide the San Diego Association of Governments (SANDAG) a summary of the activities on Task 2 (Agreement #A37682/MOU #5005298/ AMENDMENT NO. 2 (S890571)) related to the educational efforts, and testing and use of deterrent devices and strategies, undertaken by the UC Davis Wildlife Health Center mountain lion project team with the goal of reducing domestic animal and mountain lion mortalities in the County. Being killed after depredating domestic animals, usually small livestock or pets, is the number one source of mortality for mountain lions in San Diego County and California as a whole (Benson et al. 2023, Vickers et al. 2015). Low overall survival rates are a concern in the San Diego County mountain lion population, and reducing livestock predation and associated mountain lion mortalities is a high priority. Our UC Davis mountain lion study team has worked to reduce losses of domestic animals and mountain lions for many years. This report details the work conducted under this contract, as well as other funding, to advance animal owner education regarding proper husbandry of their domestic animals, and to explore strategies and tools that can assist owners in that effort. This is one of the goals of our study team not only in San Diego County but throughout California.

Deterrents to mountain lion depredation can take the form of securing animals in predator-proof structures at night, livestock guardian dogs, and various other strategies and devices that can diminish the likelihood of predation. The vast majority of mountain lion mortalities secondary to depredation in southern California, as well as the rest of the state, involve small groups of sheep or goats kept in rural or semi-rural settings. Obviously, putting animals into secure housing at risky times of day (before dusk to after dawn) is the gold standard of protection for domestic animals, and trained livestock guardian dogs are also generally effective. However, because of the expense of guardian dogs, they are primarily used with large commercial flocks or herds of livestock. Thus our primary focus in San Diego County has been on education of owners of small livestock in regards to proper securing of those animals, or in the event that is not possible, on trying to provide them with alternative deterrents that can reduce risk to their animals (and the possible loss of mountain lions).

The San Diego County mountain lion population is primarily a part of the genetically distinct eastern Peninsular Range mountain lion population east of I-15, but some San Diego County mountain lions are part of the separate genetically distinct Santa Ana Mountains population in west of I-15 (Gustafson et al. 2018, 2022; Ernest et al. 2013). Both populations have been petitioned for listing as threatened under the California Endangered Species Act, increasing the urgency of the need to reduce mortality threats in the San Diego County population.

Our team's efforts under this contract have fallen into two main categories during this contract period, as well as previous to this study period:

1. Education
2. Deterrent testing

1. Education:

   Our efforts in the education realm during this study period have centered on a) giving general community presentations, especially in areas where depredations are more common; b) working with groups such as the UC Extension Service, 4-H Clubs that they oversee, the Mountain Lion Foundation, the California Department of Fish and Wildlife (CDFW), and other animal owning groups to help them understand the threat posed to both domestic animals and mountain lions by inadequate husbandry practices and to educate others themselves; c) developing specific curricula for 4-H Clubs to use to teach proper livestock protection practices to reduce risk from predators; d) working with CDFW conflict specialists to be certain that messages that they, and we, are putting out are the same, as well as seeking opportunities to work with people who have suffered depredations to help them reduce future risk; e) communicating to all interested parties the results of deterrent testing and other experimental methods that can reduce risk to domestic animals from predation.

2. Deterrent testing

   Uses of deterrent devices to reduce depredation of domestic animals is an area of research that other researchers and groups have pursued but that is difficult to accomplish with wild mountain lions due to their wide-ranging nature. Choice of devices and strategies for our team to test was based on previous work done by the UCD team in this area, on the large body of knowledge Dr. Vickers has helped accumulate through his work as the hazing and deterrence director for oil spill response with the UC Davis Oiled Wildlife Care Network, collaborations with UC Extension Services, CDFW, USDA Wildlife Services, and other researchers. More recently, the team's thinking has been influenced by participation in a hazing and deterrent summit held at UC Davis in 2023 where Dr. Vickers was the keynote speaker (Figure 1). That two-day summit featured national and international speakers on the subject of hazing and deterrence covering many different species and techniques, leading to the emergence of a wider array of ideas for application to mountain lion depredation prevention that the UCD team will be incorporating into their testing and education efforts going forward.

Figure 1. Wildlife Hazing and Deterrence Summit logo.

The UCD team's participation in the newly formed Hazing and Deterrence Working Group (Figure 2) will also help expand the team's research-based knowledge of best measures for prevention of depredation. Besides the devices and strategies detailed below, others are emerging that can contribute to livestock protection from predators and reduction in secondary losses of mountain lions.

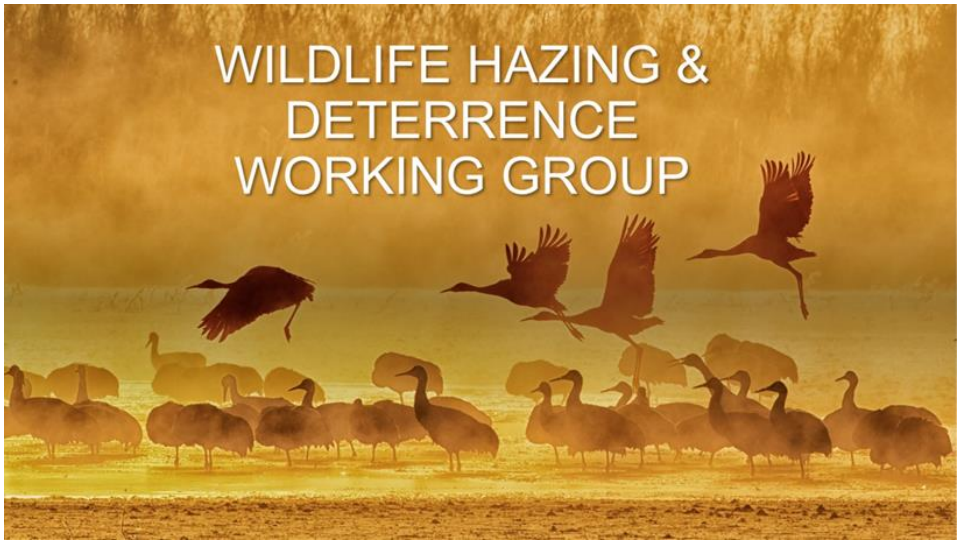

Figure 2. Hazing and Deterrence group logo.

During the Agreement time-period (2021-2023), UC Davis WHC personnel and collaborators were able to assess the responses of mountain lions to many types of deterrent devices (n=16 different devices and tools alone or in combination; Figure 3). These have included:

1. Mr Beams Solar Wedge Security Lights® – motion-triggered light
2. Building mounted security lights – motion-triggered light
3. Continuous outdoor lighting
4. Foxlights® – random lights different colors in different directions to mimic flashlight moving around
5. Predator Guard ® solar powered predator deterrent LED light units – constant light to mimic eyes of a predator
6. Wasatch Wildlife Product® FurFinderR® predator calls - Programmable speakers with human voice or other sounds that play for 15 seconds approximately every 5 minutes from dusk to dawn

7. Margo Supplies Squawk Boxes® – loud outdoor programmable speakers – random or continuous human voice or other sounds
8. “Ora” – Programmable units from student Vedant Srinivas – random and motion-triggered human voice or other sounds and light
9. Programmable sound and light units from Cal State Northridge electronics engineer Aaron Nanas – random and motion-triggered human voice or other sounds
10. Solar sound and light security alarm units - siren type sounds and light - motion-triggered
11. Hulpre Outdoor motion sensor alarms – siren type sound and light – motion-triggered
12. Margo Supplies Gadflys®– siren type sound and light – motion-triggered
13. Campark TC17 Cellular Trail Camera®: cellular camera capable of transmitting pictures and videos remotely. It has built-in a high-sensitivity sound-collecting microphone and speakers allowing one to listen and speak using an app.
14. Vectronic street tags® – UHF transmitters that trigger GPS collars in vicinity to increase frequency of GPS point acquisitions
15. Vectronic electronic fence – programming in some Vectronic collars that notifies the researcher when a mountain lion collar takes a data point within a programmed geographic area – pairing of street tags and electronic fences allows rapid detection of collared mountain lions within preprogrammed boundaries.
16. Opaque plastic or fabric shielding around pens to block the mountain lion’s view of the interior and reduce the likelihood of jumping the fence.

Figure 3. Various devices and strategies tested by the UC Davis team.

Based on our preliminary results outlined below of greater than 50% success at altering mountain lion behavior and directing them away from the device or livestock pen, we recommend using deterrent devices as a part of depredation prevention in those instances where securing livestock at night in predator-proof enclosures or use of trained livestock guardian dogs is not possible.

No electronic device or other strategy can replace secure housing at night, the gold standard of livestock protection from predators, and we urge all livestock owners to use that strategy if at all possible. We feel that though definitely not foolproof, deterrent devices and strategies, especially when combined and changed over time, can affect mountain lion behavior and reduce the likelihood of livestock losses. We feel that the use of devices and strategies such as those we tested, and others, can promote mountain lion-human coexistence in fragmented/urbanizing landscapes such as southern California.

Introduction.

Large carnivores are key components of ecosystems providing a suite of direct and indirect stabilizing effects on them (Ripple et al. 2014). However, humans have disrupted ecosystems through habitat destruction and extirpation of large carnivores, resulting in constriction of their geographical range and a decline in the number of these taxa. That is the case of mountain lions (*Puma concolor*), an apex carnivore that although has historically occurred throughout the Americas, has been extirpated or decimated in much of their former range in the past 200 years (Cougar Management Guidelines Working Group, 2005).

In California, mountain lions are considered a “specially protected mammal” (Cal. Fish & Game Code § 4800(a)). As a result, hunting of mountain lions is generally prohibited, and there are restrictions on taking, injuring, possessing, transporting, importing, or selling mountain lions (Cal. Fish & Game Code § 4800(b)). However, some exceptions allow for the removal or killing of mountain lions if they are perceived to be an imminent threat to public health or safety or pose a threat to the survival of threatened, endangered, candidate, or fully protected sheep species (Cal. Fish & Game Code § 4801). Furthermore, if a mountain lion damages or destroys livestock or other property, a person may request a permit to “take” the mountain lion (Cal. Fish & Game Code § 4802). The California Department of Fish and Wildlife (CDFW) is responsible for issuing depredation permits, which authorize the removal of mountain lions in such cases.

In southern California, mountain lions live in a human-dominated fragmented, and urbanizing landscape which may result in more cases of human-mountain lion conflicts. Mountain lion mortality due to depredation permits issued after mountain lions killed domestic animals is considered their leading cause of death in San Diego County as well as across the rest of the state (Benson et al. 2023; Vickers et al., 2015).

This highlights the need to find mitigation tools to reduce livestock depredation by mountain lions. Currently, there is no consensus as to which tools and techniques are most useful and under what circumstances, or on the associated tradeoffs between time of duration and effectiveness levels (Miller et al., 2016).

Table 1 summarizes contemporary conflict mitigation techniques for predator / livestock conflict that are most applicable to mountain lions. Modified from Miller et al. (2016).

Non-lethal	**Predator Removal/Lethal**
Deterrents Aversive stimuli Disruptive stimuli Visual restriction Behavior conditioning Behavior modification *Preventive Husbandry* Fencing Guard-dog/guard animal Herder/sheperd/guards Secure Penning Livestock breeding Separation from predator habitat Deterrents Visual restriction between predator and prey *Indirect management of land/prey* Buffer zone Core zone Grazing management Land use modification	Lethal population reduction Retaliatory killing of offending animal Problem animal removal Problem animal relocation Population control

Within the non-lethal conflict mitigation techniques, preventive husbandry and deterrents have demonstrated the greatest potential but also the widest variability in effectiveness in reducing livestock losses (Miller et al., 2016).

We hypothesized that our deterrent device suite employed would be effective on more than 50% of the occasions based on current literature on the use of deterrents in mountain lion-livestock conflicts (see Ohrens et al., 2019; Guerisoli et al., 2021; Kertson et al., 2022).

Material and Methods.

Education:

For the first focus of this task (Task 2 in associated SANDAG agreement noted above), we utilized education and collaborations to enhance awareness of depredation impacts on livestock and mountain lions and encouraged preventive husbandry practices such as nighttime confinement in secure pens or guard dogs, as well as potentially using deterrent devices. The emphasis on the education side has been focused on kids in 4-H programs as well as the general public who may own domestic animals in rural areas. Partnering with CDFW, UC Extension, and the Mountain Lion Foundation has extended the reach of those efforts. In the case of 4-H clubs we worked with the UC Davis Extension office at the School of Veterinary Medicine and the Mountain Lion Foundation to develop a peer reviewed curriculum for 4-H leaders around the country to use to teach 4-H kids proper husbandry for protecting their animals from predators (Figure 4). That curriculum has also been accessed for use by other educational organizations such as CDFW, UC Extension, and the San Diego Zoo that outreach to the general public and those groups specifically that own livestock, especially small livestock. In addition, on several occasions UCD veterinarians or staff have been in contact with livestock owners after depredations and have provided consultation on measures they could take to prevent further losses, and assistance in some cases improving their livestock enclosures.

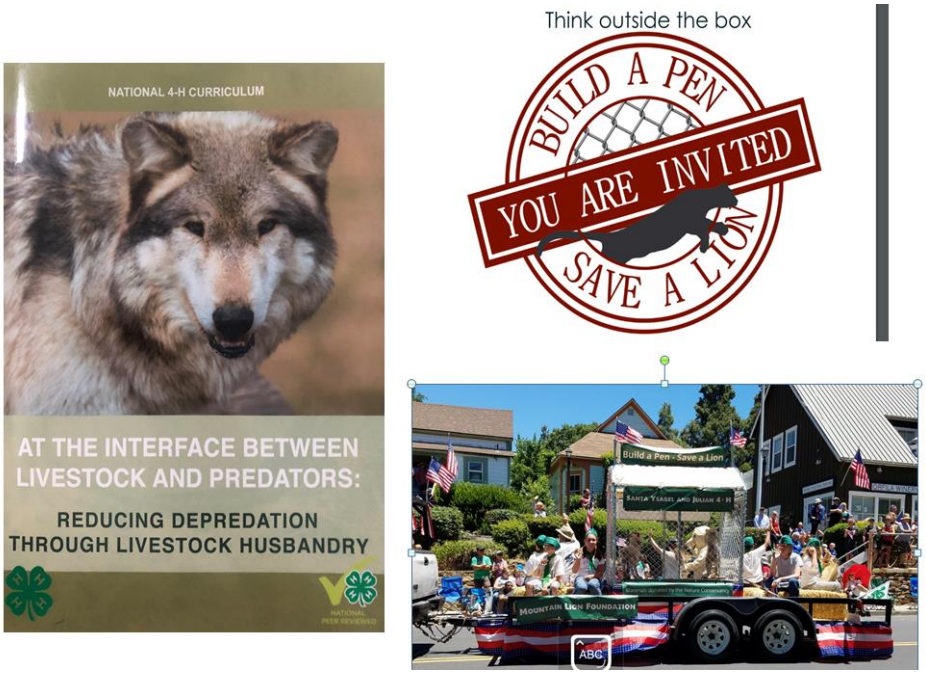

Figure 4. Upper left-Cover of 4-H curriculum book; Upper right – Logo for educational event organized by the Mountain Lion Foundation and 4-H in San Diego County; Lower right- parade float created by Julian, CA 4-H Club highlighting the value of securing animals in pens.

Testing deterrents and other strategies:

For the second focus of this task, we employed multiple strategies to gain insight into the responses of mountain lions to protective measures that might be employed in the absence of secure housing at night. When opportunities arose at livestock depredation sites and owners wished to take advantage of our assistance we placed deterrent devices to deter the animal from returning to livestock enclosures and assessed the mountain lion's response.

Testing was also done in experimentally contrived (bait stations set up for mountain lion captures) and opportunistic situations (along travel corridors) with both GPS-collared and un-collared mountain lions in the wild. Testing was done primarily in our southern California study area but we also took advantage of opportunities to test deterrents and strategies in our study areas in the Tehachapi and Gabilan mountain ranges.

We evaluated the effectiveness of several types of non-lethal deterrents and strategies on mountain lions, primarily, and other carnivores opportunistically when they were feeding at our mountain lion bait sites (Figure 3; Addendum 1). Most devices tested were commercially available devices but we also worked with a graduate electrical engineering student at Cal State Northridge, and a national science award-winning high school student from the Seattle area who both developed devices with the capability to play custom sounds and light both randomly and when triggered by motion. The purpose of working with these students was to try to develop devices with more total capabilities than those currently on the market.

Historically, most of our deterrent work that was not conducted at depredation sites has focused on our collared male mountain lions that found bait placed for capture of other mountain lions. Because those bait sites represented artificial feeding supplementation for those animals, and the sites were intended for trapping of un-collared mountain lions, we utilized those opportunities to test behavioral responses of those already-collared males to the devices. We felt that situation most closely approximated a depredation situation where a mountain lion that has depredated would likely return to a livestock pen and potentially take additional animals.

Additionally, we tested mountain lion behavior when both male and female mountain lions (collared and uncollared) encountered deterrent or other devices along travel corridors. Although we were able to conduct testing regularly during 2021 and 2022 in our southern California study area, most of the previously collared males had dropped their collars in 2023 and the one remaining did not operate in areas where we were baiting. However, we were able to do some testing of devices and education strategy in our other study areas during that year.

We considered the use of the device to be effective if the target species involved in the event would leave the area. We considered partial success or failure if the individual left but it came back within 24 hours or did not leave respectively.

Results (including some testing prior to the current contract period).

Mountain lion events.

Testing in association with depredation events.

When informed of depredation events by California Department of Fish and Wildlife personnel where livestock owners were interested in cooperation with the research, our team or collaborators placed deterrent devices in strategic locations where a returning mountain lion would be expected to encounter them. The devices tested included Foxlights combined with Predator Guard devices in two tests prior to the current period, and during the current period Gadfly devices alone in three tests, Gadfly devices combined with blinding material placed on fencing in one test, blinding material alone in another test, motion triggered house lights combined with Mr. Beams solar wedge security lights in another case. These were all short-term efforts to assess behaviors when the mountain lion returned over one to three days post-depredation. Cameras were placed at all sites to try to capture the behavioral responses of the mountain lions when encountering the devices.

Education alone was also tested in concert with CDFW personnel on two occasions and in both cases, the animal owner made no husbandry/confinement changes and subsequently suffered additional losses the following night.

In five depredation cases, the offending mountain lion was captured, and GPS collared then released.

M294:
One of those collared individuals (M294) was collared after depredating goats on two occasions at one site. The owner of the goats was given advice on strengthening his pen after the first occasion but did not do so, and M294 returned. On both occasions he was still in the pen when CDFW arrived. On the first occasion he was darted and transported to a nearby wild area and released. On the second occasion he was darted and our UCD team placed a GPS collar on him before he was released in a wild area. After the second depredation the owner made changes to his pen structure and did not have more depredations though M294 later came by the site again. After being collared M294 depredated at two other locations where the UCD team was notified and was able to place Gadfly devices the next day. At one site M294 returned the following night and did not try to enter the pen or depredate again, though human presence was also increased in the area of the pen. However, the cameras did not capture the direct response to the Gadflys if they were triggered.

At the second site M294 was able to enter a barn and was still inside when CDFW wardens arrived. He was again darted and transported a distance away. Gadflys were placed around the barn where a lion might approach, and the barn strengthened. M294 did return the following night and did not reenter the barn, but we did not observe triggering of the Gadflys on our cameras. We were unable to classify either of the two tests as successful or unsuccessful in regards to the Gadflys, but successful in terms of the strengthening of the pens and increased human presence in one case. Unfortunately, M294 was later killed in response to approaching unsecured livestock at another location, though no depredation occurred before he was shot. As a side note, this owner was cited by CDFW for an unjustified killing.

F307:
In a case where recurring mountain lion visitation and several depredations had been documented, capture of one offending mountain lion was accomplished (F307). In the case of F307, her return visits to the area allowed us to test her responses to devices in a number of ways. Testing of deterrents to restrict her entry over a fence into a conserved area seemed to cause her to alter the locations where she crossed the fencing, but because of long expanses of fencing the entire length could not be completely outfitted with deterrents (Figure 5). A long-term effort was instituted where an array of devices were utilized both on fencing and in the habitat and trails where F307 commonly traveled. This array included at different times and in different combinations Gadfly units, two Squawk boxes, two Ora units, Wasatch calls, solar and Hulpre motion sensor alarms, and blinding material on fencing. Testing along travel routes did demonstrate that alteration of F307's route was accomplished most of the time by

an array of devices playing human voices (Figure 6). However, in other instances she did not appear to change behavior when encountering areas in the general habitat where devices were deployed that were playing voices and other sounds randomly or when triggered by motion.

Figure 5. F307 with GPS collar

Because the collar on F307 was programmed to respond to UHF signals from Vectronic street tags (Figure 6) with an increase in GPS point acquisition, and the collar had an electronic fence programmed in that surrounded the site, UCD personnel were notified when she crossed the electronic fence. That allowed the team to notify personnel in key locations to respond with human presence. This measure was effective at preventing further depredations. However, a subsequent visit by an uncollared mountain lion resulted in a depredation after it entered pens in an area where no deterrent devices were deployed.

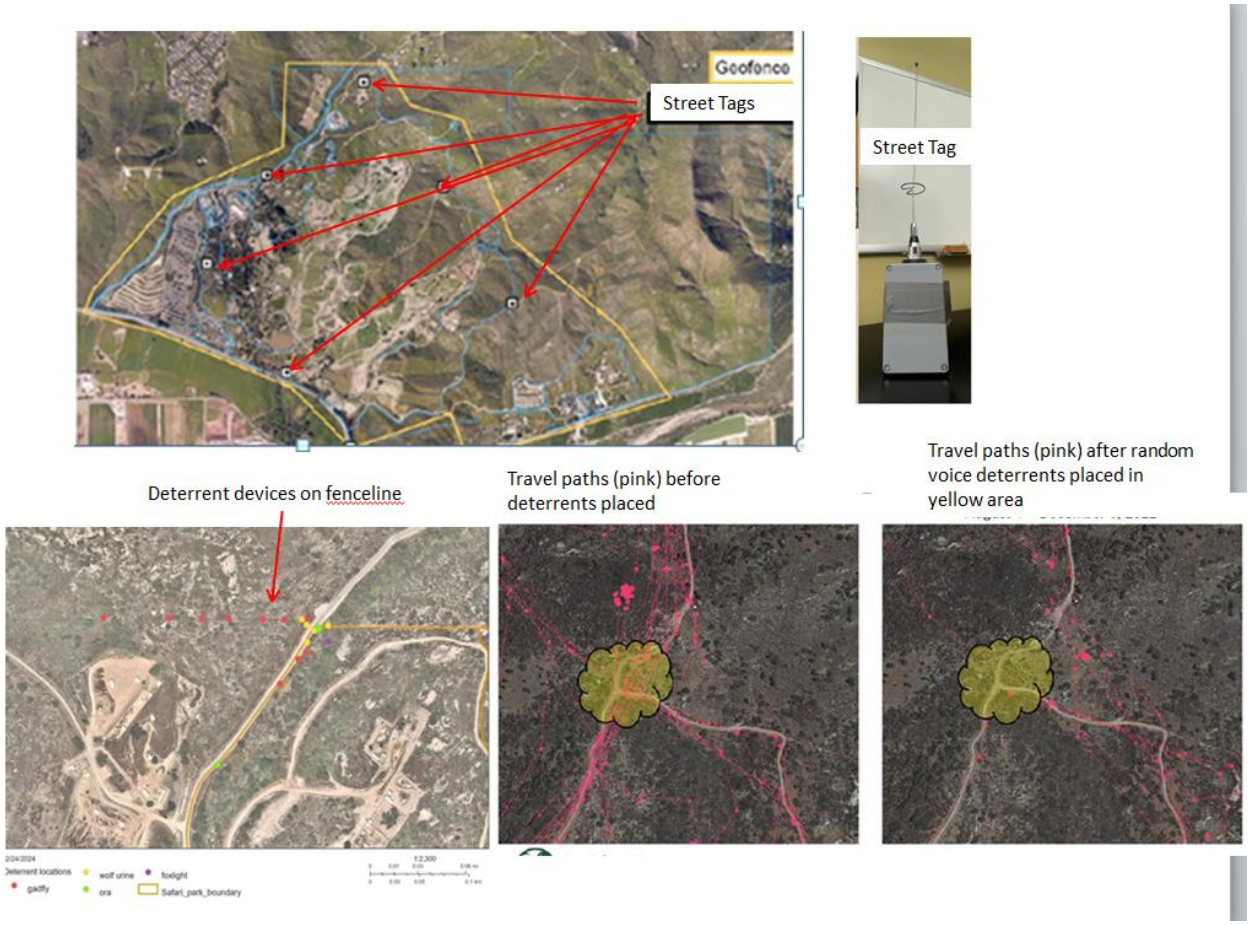

Figure 6. Locations where Street tags and geofence were utilized, deterrent devices placed on fenceline, and deterrent random voice devices placed in travel paths.

M338:

In the case of another site, the depredating individual (M338) was captured and collared and the owner counseled by CDFW and the UCD team to securely house their animals at night. M338 returned to the site the following night and because the owner had not instituted secure housing or deterrents another depredation occurred. After that, another site visit by CDFW resulted in the owner securing the animals at night which prevented further depredation at that site. A presentation to the local community also raised awareness and likely increased protections at other farms. No other depredations have occurred by M338 or other mountain lions in that immediate area since then to our knowledge.

M32:

In a case where an emu in an open corral was killed, the mountain lion (M32, a mountain lion collared approximately 10 years earlier as a juvenile but whose collar had dropped earlier as scheduled) was re-collared and released. The owner instituted additional lighting where he had smaller birds in covered pens. M32 did return to the site 3 days later and did not depredate any smaller birds, so the increased lighting could not be judged as successful or

unsuccessful with certainty – we judged this to be partial success for lighting. Unfortunately a month later he depredated at a nearby location where no devices or adequate husbandry were in place and was killed.

M108:
In this case, the mountain lion (M108) had killed a sheep in an open pen and was captured and collared the following night when he returned. The owner was counseled by CDFW and UCD personnel but was unable or unwilling to alter his husbandry except to add a large longhorn bull to the pen with his sheep. Though M108 remained in the general area he did not return to the site and depredate again until the bull was taken out of the sheep pen to be allowed to graze in another area. At that point M108 depredated again and was recaptured and euthanized by the CDFW team. This was deemed a success for use of a guard animal, but a failure of education alone since the owner did not otherwise improve his housing,

In device testing at additional depredation sites where the offending mountain lions were not collared:

One mountain lion had depredated goats in an open pen and the UCD team visited and the remaining goats were confined in secure housing. The UCD team placed multiple Foxlights around the pen where the depredation had occurred to assess the animal's response. When the mountain lion returned it hesitated for a period and then left when it encountered the Foxlights, but subsequently overcame hesitation and walked past a Foxlight to re-enter the pen where the depredation had occurred (Figure 7). Nevertheless the education provided and the improved housing of the remaining animals did prevent further depredations. Education was deemed successful but Foxlights unsuccessful in this case.

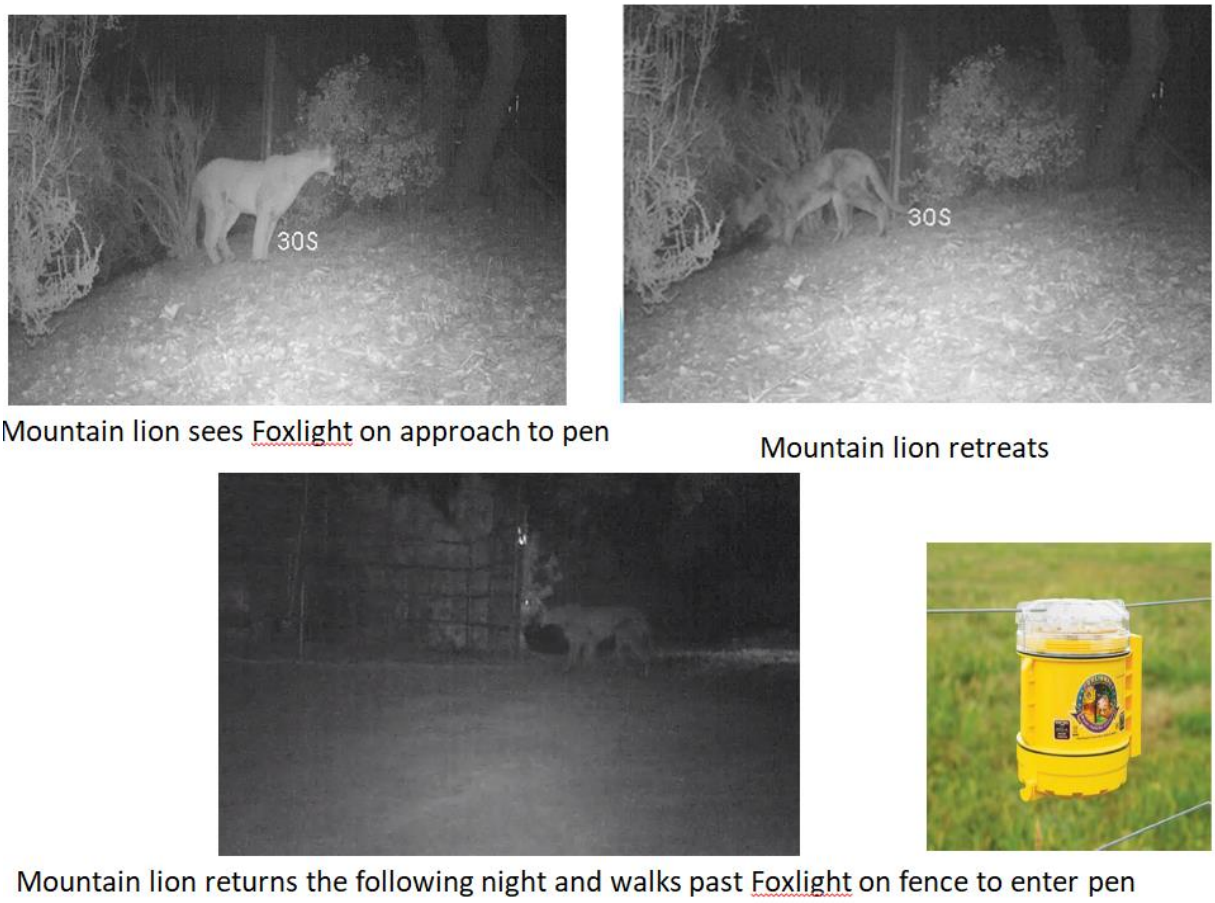

Figure 7. Test of multiple Foxlights at depredation site.

In another case, a mountain lion had depredated house cats left outside at night and the UCD team visited and provided education. This prompted the owner to start bringing the remaining cats in at night. The owner did not want any sound emitting devices placed near his house so a motion triggered security light was installed on the house and several Mr. Beams motion-triggered security lights on flashing mode were deployed in the yard and near a game trail next to the house. A mountain lion subsequently used the game trail near the house despite the extra lighting. Education was deemed successful in this case but motion-triggered lights unsuccessful.

At another site where a goat was depredated in an open pen, an un-collared mountain lion did not reenter the pen with the remaining goat after encountering two Gadfly units twice in relatively short succession. Blinding material had also been placed on the fencing of the pen so that the animal could not see where it would land if it jumped the fence (Figure 8). The mountain lion did not return that night. This was deemed a successful test. However, the owners did not institute bringing the goats into more secure housing or fully deploy shielding

and Gadflys and lost another goat to depredation 1-2 weeks later. So education was deemed unsuccessful in this case.

Mountain lion approaching pen with 2 Gadflys and plastic sheeting on fence to block lion's view of where it would land if it jumped the fence

Gadfly going off

Mountain lion fleeing

Figure 8. Test of Gadflys combined with blinding material on fence.

At another site where blinding material alone was deployed around a pen where a goat depredation had occurred, and other goats were still present but in a secure cage inside the pen the following night. No re-entry by the mountain lion occurred based on tracks. However, it was not clear from the cameras deployed whether the animal had returned to the outside of the pen or not, and no tracks were found. This test was not classified as successful or unsuccessful.

At another site, our Gadfly units were deployed by a UC Extension collaborator on a depredated calf that was left in the field where it had been killed and fed on by a female mountain lion and two large kittens. When the family group returned the following night, the Gadfly frightened away the kittens but the female fed on the calf again despite the Gadflys going off. This was deemed a partial success.

At another site a depredation had occurred due to a mountain lion gaining entry to a barn under a small opening at the bottom of a gate. After a site visit by the UCD team the gate was repaired. A Foxlight was placed near the barn, and Predator Guard units placed on each of the gates into the barn pens. The mountain lion did return and did not approach the gates but did jump onto the low roof of the barn at the end away from the Foxlight. It walked near the gates with the Predator Guards but did attempt to get in any of them. After failing to enter from the roof the mountain lion left and did not return.

Testing at artificial bait sites, trap sites, and travel paths in wild habitat.

This mode of testing occurred on 8 individual mountain lions on 17 occasions. Devices tested included Wasatch calls playing human voices or other sounds randomly, Gadfly units, Wasatch units and Gadfly units combined, and Campark TC17 Cellular Trail Cameras.

Devices were placed near artificial bait stations where collared male mountain lions were feeding (n=3 encounters; Figure 9), travel paths typically used by mountain lions (n=12 encounters; Figure 10), and trap stations (n=1 encounter; Figure 11). Devices were successful in deterring or causing deviation of animals from their travel path in 87.5% (14/16) encounters. We consider one other occasion to be partially successful since the mountain lion visited the site again within 24 hours. Interestingly, one of the successful encounters involved an uncollared male that reversed course on a trail after encountering a Wasatch call playing a mountain lion whistle – a sound generally assumed to be attractive rather than repelling (Figure 9). This indicates that the effects of deterrents in some cases may be due to the unexpected nature of the sound and/or light versus its exact nature.

Figure 9. M316 approaching an artificial bait station with Margo Gadfly device on tree.

Figure 10. M332 looking at the Campark camera deterrence device prior to leave the trap site.

Male mountain lion on trail encounters Wasatch device playing intermittent mountain lion whistle intended as attractant

Animal paused on hearing first whistle, then when sound occurred a second time he reversed course and went back the way he camer

Figure 11. Mountain lion encountering a Wasatch device playing a lion whistle on a trail.

In those cases when the deterrence device was considered ineffective, the behavior of the mountain lion showed indifference or curiosity. In one instance, M321 approached the device

(Margo Gadfly combined with human voice recordings) sniffed it and did not flee the area. This emphasizes the importance of understanding the capabilities of the device being used.

In total, we recorded success of failure of deterrent devices or strategies on 30 occasions (depredation sites, trails, bait sites, trap sites) involving 19 mountain lions (10 M, 5 F, 4 Unknown gender). We could identify 11 of the mountain lions involved (8 males and 3 females) thanks to collaring efforts carried out by our research team.

From all the events that involved Margo Gadfly® (Margo Gadfly® alone or in combination with human voice recordings, n=12), we considered it was effective in 66.6% of the cases (8/12). Wasatch calls® alone or in combination with Gadfly) were effective in 61.5% of the cases (8/13). Campark TC17® was effective in the only instance we could try it on.

As another point of information that may inform strategies of livestock owners to deter mountain lions, our GPS data was recently utilized in an analysis of mountain lion movement and habitat use in relation to light sources on the ground (Barrientos et al. 2023). That analysis indicated that point source light alone on the landscape reduces the likelihood of mountain lion use of habitat and travel through an area. Though brightly lighted livestock pens and approaches to those pens may contribute to overall light pollution in an area, and could be detrimental to some other wildlife species, it could be useful as a tool to prevent depredation by animals like mountain lions that depend on stealth. Likewise, clearing brush and other vegetation from the areas around livestock pens could be beneficial for the same reason of allowing the prey animals to be alerted to the presence of a mountain lion.

We also had the opportunity to test one device (Campark TC17 Cellular Trail Camera®) on artificial bait stations for mountain lions on nine occasions where other species that may predate livestock found the bait and began feeding (black bear, n=3; and coyote, n=6). The device was successful in deterring coyotes in 83.3% (n=5). A single case occurred where a coyote encountered a Gadfly device at a depredation site and it also fled. Black bears were deterred by the Campark cell camera and left in all cases. See further details below.

Coyote events.

Although this species is not the target species of the study, we opportunistically recorded all events involving coyotes since they also cause livestock losses and our testing may aid in the management of the species. Opportunistic testing took place at our artificial bait sites, intended to attract mountain lions prior to a cage-trap capture attempt.

We registered six cases involving coyotes at our bait sites using Campark TC17 cell camera®. We considered the device effective in 83.3% of the cases (n =5). In one case, a coyote did not react to the device and kept feeding on the carcass after habituation to the sounds (Figure 12). In another instance, a coyote came back to the bait station five days later, but it fled when the device turned on. In four cases, human voice plus clapping was enough to deter the coyote

from the carcass, in two instances we used conspecific howling and puma vocalizations, respectively, both effective in deterring the coyotes from feeding on the bait.

Figure 12. Coyote feeding on a bait station (white triangle).

Black bear events.

We also tested the Campark TC17 cell camera on black bears that fed on artificial bait stations (n=3). On two occasions a female with cubs was present at the site. The device was effective in deterring the bears in all instances, though one female responded aggressively to the voice from the camera, then led her cubs away (Figure 13). Later she came back to drag the carcass away from the deterrent site.

Figure 13. Female bear exploring the Campark TC17 cell camera before feeding with cubs at an artificial bait station.

Discussion.

Deterrence devices have proven to be effective mitigation tools in mountain lion-livestock conflict (Ohrens et al., 2019; Guerisoli et al., 2021). In our literature search, non-lethal deterrents used in mountain lions include: guard dogs, aversive conditioning, audio and visual deterrents. All non-lethal deterrent evaluations except aversive conditioning (Alldredge et al., 2019) came from South America, and they all agree on the benefits that they provide in reducing livestock depredations (Gonzalez et al., 2012; Zarco-González and Monroy-Vilchis, 2014; Ohrens et al., 2019; Guerisoli et al., 2021). However, the quality of the research designs and subsequent findings varied considerably among studies, adding a certain level of ambiguity to the effectiveness of such devices (Kertson et al., 2022). On the other hand, one of the strengths of those studies lay in the engagement of the community experiencing the conflicts while applying/evaluating non-lethal treatments, highlighting the importance of connecting with local citizens to build trust among parties (Kertson et al., 2022). We consider outreach also fundamental during our efforts in this matter in California.

Auditory and visual deterrents applied in our preliminary study are similar to those found in the literature. Lights, sirens, human recordings, and/or human noises have also been described to be successful in dealing with mountain lion-livestock conflicts (Zarco-González and Monroy-Vilchis, 2014; Ohrens et al., 2019; Guerisoli et al., 2021). One of the novelties of our study is the inclusion of a cell camera that provides video and audio at operator option in real-time, so we can modulate the level of the “human” interaction while trying to deter the mountain lion. Previous research that tested human recordings at mountain lion feeding sites showed that mountain lions fled more frequently, took longer to return, and reduced their overall feeding time by more than half in response to hearing humans (Smith et al., 2017). These results suggest the potential efficacy that this tool may have in deterring mountain lions. However, at this time, we don’t have enough occasions to infer the level of effectiveness of this device. We will increase our efforts in applying this tool throughout all our research sites.

We also found in the literature that the successful use of auditory deterrents in mountain lions came from non-commercial (i.e., no marketed available) deterrents (e.g., noises reproduced by a 100-W loudspeaker connected to a sound amplifier and powered by a nine-cell lead–acid battery, Zarco-González and Monroy-Vilchis, 2014). In this study we primarily employed commercially available deterrents so we can advise the purchase of the device to livestock producers/livestock owners in our study area, facilitating the use of the deterrent in all types of livestock operations promptly if a conflict is identified.

Future directions regarding our efforts in deterrence device testing include developing a custom device called an Ora with optional motion and light sensors, programmable sounds, and louder speakers, as well as testing other options that are being utilized or tested by other researchers. These will potentially include the use of motion in deterrent devices, automating of pen gates and feeding bins, new methods of distributing educational materials such as the previously mentioned 4-H curriculum, and other combinations.

Conclusions.

Although our sample size is limited and continuation of this task is advisable to infer more robust conclusions, our preliminary results indicate that some of the the mitigation tools and strategies tested here are effective in the majority of cases. We were able to successfully deter mountain lions, as well as coyotes and bears, in a variety of scenarios. The most promising tools are those devices that include noises (e.g., sirens) and human voices (e.g., recordings and real-time human noises especially when very loud). Overall, initial responses were most pronounced to the Gadfly motion activated units, and the Campark trail cameras, though responses were not the same for all animals, and some returned and triggered the units multiple times. In two cases the animals ignored the device after the first exposure. In other cases where sounds were unique such as voices and even a lion whistle from a predator call, the response of the animals varied between retreat and approach out of curiosity. This emphasizes that generalizations are not completely possible due to each animal's individual personality or characteristics even within a species.

We recommend pairing the use of deterrents with local community outreach and education to ensure a successful coexistence with mountain lions in human-dominated landscapes, reducing livestock depredations due to mountain lions as well as mountain lion mortality due to conflict with humans.

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