Infrastructure and Transportation Committee on 2022-10-31 9:00 AM

Meeting Time: 10-31-22 09:00

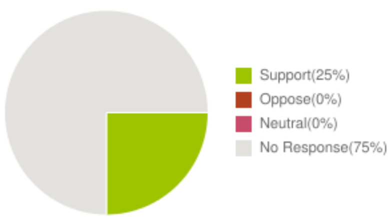
eComments Report

Meetings	Meeting Time	Agenda Items	Comments	Support	Oppose	Neutral
Infrastructure and Transportation Committee on 2022-10-31 9:00 AM	10-31-22 09:00	2	4	1	0	0

Sentiments for All Meetings

The following graphs display sentiments for comments that have location data. Only locations of users who have commented will be shown.

Overall Sentiment



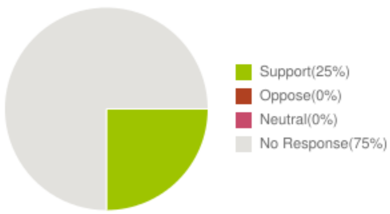
Infrastructure and Transportation Committee on 2022-10-31 9:00 AM
10-31-22 09:00

Agenda Name	Comments	Support	Oppose	Neutral
A G E N D A	2	1	0	0
IT-52 CC 19-248 FERAL ANIMAL MANAGEMENT ON MAUI (IT-52)	2	0	0	0

Sentiments for All Agenda Items

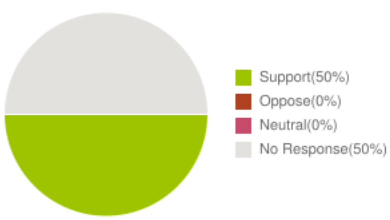
The following graphs display sentiments for comments that have location data. Only locations of users who have commented will be shown.

Overall Sentiment



Agenda Item: eComments for A G E N D A

Overall Sentiment



seth weaver
Location:
Submitted At: 10:52am 10-31-22

the deer population will continue to grow unless we take out the birth rate and reduce 2/3 now. 200k is the carrying capacity. That’s 4k the numbers now... money is good. Hunting is good. Fencing is good though it pushes the deer elsewhere where its not fenced. Fencing is also expensive at 50k per mile. DLNR needs to discuss how to reduce a substantial number asap. its seems hunters want to hunt. let them. We can utilize them but the feds will have to certify for human consumption. Anyways that can be handled after but no one is talking about reducing the herd now… its circular. Fencing does not reduce deer; it moves them elsewhere. Thus impacting watersheds there where they were before.

Must kill 40k deer a year

If you don’t kill 40k deer a year today the population will grow to 200k

Hunters help but won’t kill that many. The total numbers of hunter permits is low. even the DLNR GHP and WCP don't dent the population growth rate. these are the state control permits mostly for night.

Food is important and needs to be thought about how to allocate those recourses

To sell must be overseen buy usda. Expensive. probably need to amend federal meat packing law on exotic game or increase inspectors and infrastructure at cost.

Fencing pushes the deer into other regions and increases the pressure there

As is evident here with testifiers, it seems hunters hunt however the population still grows.

Hunting is a tool and is useful however there aren’t enough hunters to reduce the herds.

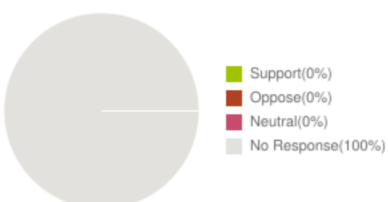
I guess the question is we have to answer is are we okay with 200k deer on maui? Or 100k? Or do we need to reduce the numbers that we have now? Will increasing access reduce deer by 100k a year?

Guest User
Location:
Submitted At: 9:40am 10-31-22

What about creating a database to connect hunters and land owners? Please allow exemption for cross bow use for anybody?
What about possible collaboration with local golf courses and hunters?

Agenda Item: eComments for IT-52 CC 19-248 FERAL ANIMAL MANAGEMENT ON MAUI (IT-52)

Overall Sentiment



seth weaver
Location:
Submitted At: 11:09am 10-31-22

DLNR technical documents and studies

IT Committee
Location:
Submitted At: 8:12am 10-31-22

Testimonies received by IT Committee.

IT Committee

From: Yukilei Sugimura
Sent: Sunday, October 30, 2022 3:01 PM
To: IT Committee
Subject: Fwd: Testimony - Axis Deer Management Plan

Sent from my iPhone

Begin forwarded message:

> **From:** clif.hasegawa@yahoo.com
> **Date:** October 30, 2022 at 2:51:20 PM HST
> **To:** County Clerk <County.Clerk@mauicounty.us>, "Alice L. Lee" <Alice.Lee@mauicounty.us>, "Keani N. Rawlins" <Keani.Rawlins@mauicounty.us>, "Tasha A. Kama" <tasha.kama@mauicounty.us>, Gabe Johnson <gabe.johnson@mauicounty.us>, Kelly King <kelly.king@mauicounty.us>, "Mike J. Molina" <Mike.Molina@mauicounty.us>, "Tamara A. Paltin" <Tamara.Paltin@mauicounty.us>, "Shane M. Sinenci" <Shane.Sinenci@mauicounty.us>, Yukilei Sugimura <Yukilei.Sugimura@mauicounty.us>
> **Cc:** cuechi@mauinews.com, wendy@mauinow.com, Chad Blair <cblair@civilbeat.com>
> **Subject: Testimony - Axis Deer Management Plan**

Members of the Maui County Infrastructure and Transportation Committee

Councilmember Yuki Lei K. Sugimura, Chair
Councilmember Tasha Kama, Vice-Chair
Councilmember Kelly Takaya King
Councilmember Alice L. Lee
Councilmember Michael J. Molina
Councilmember Tamara Paltin
Councilmember Keani N.W. Rawlins-Fernandez

The overpopulation throughout Maui County has reached an optimum crisis. The growing over abundance axis deer population has negatively affected farmers, ranchers, homeowners, landscapers, Maui's forestry, Native Hawaiian plant communities and the other wildlife dependent on these communities.

Chair Yuki Lei Sugimura's statement that keeping the number of axis deer in control about 20,000 need to be culled per year should not be taken lightly. The method of culling is controversial. The use of sharpshooters, reproductive control, sterilization, poisoning to cull deer populations in other States. There are advantages and disadvantages of these methods.

Live capture and relocation seems like a comfortable option, you can get rid of problem deer without killing them, and no one is upset. The problems with this method of deer control are:

1. There are few places available to release these excess deer
2. The procedure of capture and release is very expensive
3. The biggest objection to the procedure is that mortality among relocated animals is very high.

For Maui County overriding concern is that jurisdictionally herds of axis deer migrate over and through land managed by the State of Hawaii, owned and managed by the County of Maui and land owned by private owners.

For Maui County private owners there is overwhelming concern that the unregulated axis deer population has and continues to cause tremendous damage to crops, grasslands, home gardens. However, night hunting on land owned by private has raised safety concerns and intrusion on personal privacy and disturbance of the peace. Additionally, moral and ethical principles have resulted in considerable push back from the community.

Respectfully, I suggest that culling the axis deer population throughout Maui County is the only way to attain control axis deer overpopulation and growth. As an approach the following information is submitted for consideration.

On August 28, 2012, the Maui Axis Deer Harvesting Cooperative (MADHC) became an agricultural producer cooperative in the State of Hawaii. With a mission to provide a vehicle for the Maui community to turn a harmful non-native species into a usable resource that addresses food security with zero waste.

"Group using corral to capture axis deer" The Maui News June 30, 2013
https://www.mauinews.com/news/local-news/2013/06/group-using-corral-to-capture-axis-deer/

> The Maui Axis Deer Harvesting Cooperative, known for its rifle-hunting operations, found a more cost-effective way to capture deer that could create a new market for meat.
>
> The new method involves an octagon-shaped corral about 20 feet long, 20 feet wide and 10 feet high. The contraption, which has a trough for food and water to attract the deer, is fitted with a sliding door that seals off about 15 to 16 deer at a time.
>
> "It works really, really well," cooperative President Michael Tavares said. "We've just finished helping a woman Upcountry who had trouble with pigs and deer in her garden. We were able to capture all the deer and then her pigs started getting trapped too."
>
> Tavares said that the group of volunteer hunters monitors the trap using field cameras for about two weeks – documenting the optimum times for capturing the most deer upon activation. "The human smell is still lingering on it so the deer get really skittish and nervous. But after two weeks they'll start getting curious and start returning for the food and water. That's when we shut the corral on them."

Once the deer are captured, the group will arrange for a U.S. Department of Agriculture inspector to examine the deer for any ailments and diseases.

“With the traps, we’re able to take out more deer at once. We’re still able to shoot one or two on small properties, but on large properties we’re able to take half the herd at one time, and it’s a lot safer too,” Tavares said.

The group spent about 2 1/2 months building the three custom traps, which cost about $8,000 to $9,000 in materials and labor, Tavares said. The group has already patented one or two designs and aims to further improve its functionality.

———————————————

UTILIZE CORRALS AS THE NON-LETHAL MEANS TO TRAP AXIS DEER
EMPLOY HUMANE SLAUGHTER PRACTICES TO PROCES THE AXIS DEER MEAT

Processing methodology may give rise to push back from activists and animal rights groups, as being inhumane and an exhibition of animal cruelty.

"The Humane Slaughter Act acknowledges that Kosher and Halal slaughter can be performed humanely"
[North American Meat Institute https://www.meatinstitute.org/index.php?ht=a/GetDocumentAction/i/130170]

———————————————

THERE ARE NEW MARKETS FOR AXIS DEER MEAT BEYOND HAWAII

THE KOSHER MARKET

Cloven (split) hooved mammals that chew cud, these include cows, sheep, goats, lambs, oxen and DEER are lawful to consume.

Consumers see a kosher certification as a verification that a product is healthy, clean and safe. And while the certification has roots in religious traditions that are thousands of years old, it now speaks directly to the modern consumer’s demand for wholesome foods.

There are 6 million Jews in the United States, according to World Population Review, Jewish people represent only 20 percent of the kosher product consumer base.

[Rabbi Eli Lando, Executive manager of OK Kosher]

The Global Kosher Foods Market is expected to grow by $ 13.73 billion during 2021-2025, progressing at a CAGR (Compound Annual Growth Rate) of 7.48% during the forecast period. [Global Newswire]

———————————————

THE HALAL MARKET

“Halal” means “Permissible” in Arabic and refers to the dietary law of Islam, which practicing Muslims follow. Similar to Kosher food for people of the Jewish faith, Halal food avoids anything derived from swine flesh (pork, bacon, lard, gelatin, etc.) as well as alcohol (beer, wine, etc.). Animals which are considered lawful to consume for Muslims include Halal chicken, beef, lamb, goat, turkey, DEER, and most seafood. [HalaFest]

The Halal Food Market is expected to grow by $ 9.33 billion during 2022-2026, accelerating at a CAGR (Compound Annual Growth Rate) of 5.62% during the forecast period. [Global Newswire]

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In conclusion,

Under the stewardship of Councilmember Yuki Lei Sugimura, The Maui County Council and The Maui Axis Deer Taskforce have successfully grappled with many thorny and complex issues to control and manage the overpopulation of axis deer. At this juncture culling the unregulated herds is the only realistically achievable strategy and approach.

In addition to the foregoing suggestions, updating the outdated Maui Axis Deer Management Plan (2013) and proceeding with an Environmental Impact Statement are highly recommended.

Thank you for the opportunity to submit my testimony.

V/R

Clifton M. Hasegawa
1322 Lower Main Street A5
Wailuku, Hawaii 96793
Mobile: (808) 463-1277
Email: clif.hasegawa@yahoo.com
LinkedIn: https://www.linkedin.com/in/cliftonhasegawa

IT Committee

From: Yuki Lei Sugimura <yukilei.sugimura@gmail.com>
Sent: Sunday, October 30, 2022 11:24 PM
To: IT Committee
Subject: Fwd: Written testimony for Axis deer management is topic of Monday's council committee meeting

You don't often get email from yukilei.sugimura@gmail.com. Learn why this is important

---------- Forwarded message ---------
From: **Syl Cabral** <sylviacabralmaui@gmail.com>
Date: Sun, Oct 30, 2022 at 6:43 PM
Subject: Re: Written testimony for Axis deer management is topic of Monday's council committee meeting
To: Council - Maui County <listserv@civicplus.com>, County Clerk <County.Clerk@mauicounty.us>, Maui_County Council_mailbox <county.council@mauicounty.us>
CC: Alice L. Lee <alice.lee@mauicounty.us>, <gabe.johnson@mauicounty.us>, <shane.sinenci@mauicounty.us>, <tamara.paltin@mauicounty.us>, <tasha.kama@mauicounty.us>, <yukilei.sugimura@gmail.com>

That was Big Island What is there management for deer?
2. I could not access the written testimony https site.
3. Become the Worlds Hawaiian Island Deer Meat Hub.
4. I don't want to kill Bambi and I really do not think u all don't either. Who is the funding for?
5. Yuki needed someone's permission for the picture on a ranch full of jacaranda trees. Everybody else does.

> Axis deer management is topic of Monday's council committee meeting
>
> 1. I am asking that the public be shown all the amounts extended from governor 4 times? State county to control deer
> 2. please provide list of names corporations individuals etc and the amount each has received thus far.
> 3. Use the $600 million and fence the entire islands Maui & Molokai then sell it to big tech.?
> 4. Why does the bus island not have this problem? Too many karen's here.?
> 5. Use funds to build a processing center. Put bounty on deer & let folks get $ each animal.
>
> This is my 3 minute testimony.
>
> https://mauinow.com/2022/10/29/axis-deer-management-is-topic-of-mondays-council-committee-meeting/
>
> --
> Wishing You a Healthy Day,
>
> Syl Cabral's Real Estate Store
> 808 879 9007

--
Wishing You a Healthy Day,

Syl Cabral's Real Estate Store
808 879 9007

--
Yuki Lei Sugimura
Personal email
878-1888 Bus 870-8047 Cell

“The farmer is the only man in our economy who buys everything at retail, sells everything at wholesale, and pays the freight both ways.”
John F. Kennedy

State of Hawaii
Department of Land and Natural Resources
Division of Forestry and Wildlife

TECHNICAL REPORT
No. 07-01

REVIEW OF METHODS AND APPROACH FOR CONTROL OF NON-NATIVE UNGULATES IN HAWAII

March 1, 2007

Table of Contents

INTRODUCTION

Hawaiian ecosystems evolved in the absence of mammalian herbivores and, as a result, are vulnerable to damage by introduced ungulates (Cuddihy and Stone, 1990). Controlling the impacts of introduced ungulates poses a number of challenges for land managers. This report provides a review of individual control methods, a management approach that incorporates consideration for the use of humane methods and public participation through recreational hunting, and recommendations on future use and actions needed to manage ungulates in some areas and to eradicate them from areas of high conservation value.

The purpose of the report is not to provide guidance or discussion on the development of specific ungulate control policies and objectives. Rather, this paper assumes that the land manager has identified objectives consistent with policies, and provides technical information to identify potential tools and procedures that may be used to accomplish those objectives. The paper is not meant to provide information for the management of areas intended for game production, but for areas in which a permanent reduction or elimination of ungulates is the stated objective.

The information contained in the report was compiled through consultation with experts and literature searches. An initial draft of the paper was distributed to a working group of interested parties for review. The working group was invited to participate in a workshop on September 8–9, 2006 at Kilauea Military Camp to provide their views on the various methods for ungulate control, and recommendations on their use. Workshop participants represented 1) individuals and entities engaged in or supporting ungulate control or eradication to protect natural resources, 2) individuals and entities involved in the recreational, nutritional, and cultural use of ungulates through hunting, and, 3) individuals and entities concerned with the humane and ethical treatment of animals by humans. Following the workshop, comments were reviewed and the document was revised. The revised draft was sent to the working group for a second review in October 2006. Comments received following that review were incorporated into this draft. This report describes the different control methods and approaches reviewed and discussed during this process.

The Department has also outlined its approach and procedures at the present time, incorporating research and techniques discussed. It is hoped that this report will also provide guidance for control efforts by other agencies and landowners. For all land managers, fundamental to any ungulate control program is an up-to-date evaluation of the full range of tools available, management flexibility in the choice of methods and approach deployed, and an integrated approach that utilizes multiple methods and approaches.

Included in the report are a list of workshop participants (Appendix 1) and notes of the workshop discussions on this issue (Appendix 2).

REVIEW OF UNGULATE CONTROL METHODS

Safety, feasibility, and effectiveness of methods to control or eradicate ungulate populations vary among target species and the biological and geological features of the habitat in which the work is conducted. Choice of methods requires a complete evaluation of the site and habitat characteristics to plan and implement operations that achieve acceptable levels of these considerations. Determination of the methods and approach to be used must be conducted on a case-by-case basis with the ability to adapt procedures to changing conditions. In most cases, a combination or sequence of methods will be required to achieve the desired objective.

In the review that follows, we discuss methods currently available or in development for the control of ungulates, and cite key advantages and disadvantages of each. Key features that are of interest to constituents that have contributed to the development of this report include considerations of the effectiveness, humaneness, and availability of game resources for public hunting. For the purposes of this paper, we adopt very broad definitions for each.

Effectiveness is here defined as the number of animals removed or killed per unit effort, all else being equal. For example, we state that aerial shooting over pasture land is more effective than aerial shooting over an area that is forested and therefore more difficult to see the animals. As result, more animals are shot per unit of flying time, all else being equal. We have avoided considerations of cost-effectiveness for this paper. A complete analysis of the cost-effectiveness of the methods and approaches detailed here would be well beyond the scope of this report, and could only be done on a site-by-site basis because of the number of site-specific biological, geological, and geographic variables.

Humaneness is here defined as the relative magnitude and duration of pain. We distinguish between non-lethal and lethal methods, the latter being less humane. We also assume that if a snare is untended for more than 24 hours then it is likely to be less humane than a properly placed gunshot. We do not attempt to quantify the relative humaneness of other lethal methods, including toxicants and biological control because information available is insufficient to make a reasonable determination.

Public hunting is defined as licensed hunting in accordance with the state's hunting laws and rules. In addition to the direct use of a public hunting program to harvest animals, driving and translocation also indirectly facilitate public hunting by allowing for game resources to be made potentially available to the public for hunting at another site or time.

Biological control

Biological control is the control of organisms by natural predators, parasites, disease-carrying bacteria or viruses. In the case of feral ungulates, this could involve introducing a predator or a disease organism. Neither of these could be considered a practical means of control for Hawaii's feral ungulates. Introducing a large predator capable of taking pigs, goats, sheep, and deer would likely cause more problems than it would solve, and there are presently no known disease organisms that could be safely introduced without threat to non-target species. Infecting a population of animals with a disease-causing organism has the potential to be highly effective in reducing the number of animals. However, even a low likelihood of infecting domestic livestock or humans makes this technique impractical in most locations (Choquenot et al. 1996). It is not presently practiced or recommended for any of Hawaii's feral ungulate species and appears to hold little promise for safe use in the near future (McGaw and Mitchell 1998).

Bounties

Bounties have been found to be generally ineffective in animal management, and have actually resulted in increases in the target species in many cases (Latham 1960). Problems include fraud (such as bringing in evidence of kills from animals outside the target area), deliberate release of breeding animals, or purposely leaving some animals behind to provide future income (Choquenot et al. 1996). A great deal of literature reports that bounties are ineffective or counterproductive, and interfere with other methods (Australasian Wildlife Management Society online; Choquenot et al., 1996). However, a more recently developed program that is now being implemented for the control of nutria (*Myocaster coypus*) by the Louisiana Department of Wildlife and Fisheries appears to be effective, suggesting that implementation of appropriate procedures and oversight may provide for effective programs in some cases (http://www.wlf.state.la.us/experience/nutriacontrol/nutriacontrolprogram/).

Driving

Driving animals from newly fenced units just before the last section of fence is installed can be an effective way to remove many animals (Henzell 1984). Animals may also be driven from cover into more open areas for aerial or ground shooting. Driving animals has been used successfully in Hawaii, notably in the national parks to reduce goat populations (Katahira and Stone, 1982), and recently by DOFAW to remove mouflon sheep from a 5,000 acre fenced exclosure on North Mauna Kea using a helicopter (DOFAW in prep.).

Where the terrain allows, animals can be herded from horseback, motorcycles, or on foot, and may employ the use of dogs. In rough terrain, helicopters may be more effective (Parkes et al. 1996). Animals may be driven toward ground crews and holding pens, where they may be dispatched, provided to interested individuals, or driven out of an open section of an exclosure if adjacent areas provide an acceptable site for translocation. Care must be taken to avoid moving animals into areas where their presence is undesirable. Driving may be most effective in open areas, and less effective in areas with dense cover that provides animals with opportunities to freeze or hide.

An aerial sheep drive was recently conducted by DOFAW to herd mouflon hybrid sheep out of the 5,000 acre Pu`u Mali exclosure and into an adjacent private ranch (Kukaiau Ranch). The method was very effective, removing 100 animals – approximately 80% of the sheep within the exclosure – within 45 minutes (DOFAW in prep.).

In Australia as many as 1,600 goats have been successfully driven from land areas as large as 50 sq. km (Henzell 1984). Over such large distances, care must be taken to prevent exhaustion (Parkes et al. 1996). Guidelines for humane procedures are provided in Sharp et al. (2005).

Driving	
Advantages	**Disadvantages**

• Can be highly effective to rapidly move large numbers of animals • Non-lethal when conducted properly • Potential to relocate animals to appropriate areas (e.g. for later public or private hunting)	• May require many people • Heavy vegetation and difficult terrain may reduce effectiveness • Limited use at low densities or in unfenced areas • Not effective for some species • May exhaust the animals if not done properly or if area is too large

Fencing and barriers

When adequately maintained, fences and barriers to prevent ingress can limit the presence of animals in management units following control or eradication efforts. Landscape features such as cliffs, lava fields, or ocean may complement fencing in some areas. Where it is impractical (even if technically possible) to build a continuous fence across an area of steep cliffs, smaller sections of strategic fencing, placed to take advantage of natural barriers, may be a cost-effective option (Buddenhagen et al., 2006). Fences also may be fitted with one-way gates at established trails so animals can exit, allowing game resources to continue to be available to the public where appropriate.

A high density of animals on one side of the fence, coupled with a higher-quality food supply on the other, may encourage animals to more aggressively attempt to breach the fence (e.g. Texas Animal Damage Control Service, http://texnat.tamu.edu/symposia/feral/feral-10.htm.). Research is ongoing to better understand pig movements in Hawaii and better guide management planning and implementation of fences (J. Sumiye, pers. comm., DOFAW unpublished data).

To minimize animal injury, care must be taken in choosing fencing materials. For example, 300 mm spacing of vertical wires is preferred for goat mesh, as horned animals may get their heads stuck in smaller mesh (Long and Robley, 2004), although few cases of injury have been reported in Hawaii (DOFAW unpublished data). Visual impacts of fences may be reduced by using recently developed green wire mesh.

Regular inspections and maintenance of fences are critical. Corrosion, storms, falling trees, and vandalism all can result in fence breaches, and rapid response is needed. Once a fence is damaged, it can take considerable effort to locate any animals that may have exploited the breach. A fence that is effective at blocking one type of animal may be useless against another. For example, four-foot fences that are typically used for pigs are ineffective for deer, which simply jump the fence (DOFAW unpublished data). Modifying these fences for deer is expensive, but a modified fence will block both types of animals and may sometimes be cheaper than building a new deer fence from the ground up. Fences as high as 10 feet are recommended for the maximum control of axis deer (*Axis axis*), although depending on terrain a 6 foot fence will deter many deer and 8 foot fences are most common (Anderson, 1999; Barnes, 1993). Double fences and plastic mesh are other options that might be cost-effective alternatives to 8 or 10 feet of wire mesh (see designs at University of Missouri Extension web site).

To prevent ingress of mouflon sheep (*Ovis musimon*) a 6-foot fence is necessary (DOFAW unpublished data). For goats, 4-foot-high hog wire is often used. The fence bottoms must be guarded with a row of barbed wire. Potential springboards (e.g. rock or trees) near fences that goats or sheep can use circumvent fences must be removed. Feral pig (*Sus scrofa*) fences should be at least 3-feet high, with an apron of wire net on the ground or barbed or electric wire near the fence bottom to prevent pigs from forcing their way underneath. For more on ungulate fence specifications see Long and Robley, 2004.

Fence costs vary by terrain, type of fence needed, and accessibility. In Hawaii, many areas require helicopter transport of all materials, equipment, and personnel. As of January 2007, costs range from $50,000-$140,000 per mile (DOFAW unpublished data). The size of the manageable units, and therefore the length of fence and cost of construction and maintenance, varies among sites and species. Although electric fencing may be cheaper than alternatives (Littauer, 1997), they are not generally used by agencies in Hawaii due to potential impacts to endangered bats and seabirds. Lifespan of fences in Hawaii may be less than five years where exposed to sulfur plume and salt spray, to more than 20 years on open, high-elevation slopes away from corrosive elements (H. Hoshide, pers. comm.)

Fencing and barriers	
Advantages	**Disadvantages**
• Highly effective when well constructed and maintained • Non-lethal • May be fitted with one-way gates to allow animals to exit where appropriate • May help to provide a defined management unit	• Short or long term game or native resource damage may occur to an adjacent area due to changes in animal movements • Expensive to build and maintain • May impede public access if not fitted with sufficient gates or access points

Fertility control

Effective fertility control for feral animal populations may hold promise as a valuable, non-lethal tool in the near future. The methods are still in the research and development stage, and are currently not available as a practical control tool for Hawaii's feral ungulates (U.S. Department of Agriculture, 2006; Miller et al. 2004). As of January 2007, there is only one commercially available contraceptive for a wildlife species: OvoControl, which reduces hatching of Canada goose eggs (U.S. Department of Agriculture, 2006). Recent research to develop contraceptives such as GonaCon show promise, but several practical issues remain problematic (Miller et al. 2004). To be practical for use on free-ranging animals, permanent sterility and oral delivery is necessary (Killian et al., 2006; Miller, 2002). Most immunocontraceptive vaccines developed for large mammals require an initial injection followed by a booster shot (Fagerstone et al., 2002). There is considerable cost and effort involved in capture, vaccination, marking, release, and recapture, for a temporary end result.

If effective wildlife fertility control were available, populations of animals with short lifespans—such as rodents—could likely be rapidly reduced. However, for longer-lived animals, damage would continue for years if only fertility control measures were implemented (Fagerstone, 2006).

There is a great deal of interest in wildlife fertility control, and research is now being conducted to address the need for permanent sterility, species specificity, and an effective delivery system (Miller, 2002; U.S. Department of Agriculture, 2006).

Fertility control	
Advantages	**Disadvantages**
• Non-lethal • Could be effective if permanent • May be improved in the future	• Presently not permanent • Requires repeated administration • Delivery to individual animals labor intensive • Oral delivery methods for large scale use not available

Live trapping (cage/box/corral traps)

Trapping allows animals to be taken alive, providing the option of releasing in appropriate areas, providing them to individuals for food or sale, or dispatching when alternatives are not acceptable. Traps are useful tools when combined with other methods to control feral pigs. Timing their use to coincide with low availability of preferred foods may increase success (Barrett and Birmingham, 1994). Timing use of traps during peak breeding season, from November to March in Hawaii, may enhance the probability of catching entire family groups or males that are solitary at other times of the year (Katahira et al., 1993). Since September 2003, a trap and release program at Kulani on the Big Island resulted in the translocation of 460 pigs from two units into a nearby hunting area (DOFAW, unpublished data). Removal of the last 10-20 pigs from the unit is in progress.

Success can be enhanced by prebaiting the area. Prebaiting the trap itself with the gate wired open will allow pigs to get used to entering and feeding in and around the trap and increase the chance of catching multiple animals at once (Littauer, 1997). If many pigs frequent an area, a corral trap may work well. Placing one or two decoy pigs in the trap with plenty of food and water is sometimes an effective means to attract others (DOFAW unpublished data). In Australia, goats are captured in corral traps around water sources (Bellchambers, 2004). Corral traps are not recommended for pristine areas because of the heavy localized damage that can result at the trap site from a high concentration of animals.

Although primarily used as a technique for pig control in Hawaii, live trapping of white-tailed deer for later release has been evaluated on the mainland in response to concerns about the humaneness of shooting (VerCauteren et al., 2005). It is reasonable to look at these studies when evaluating methods to control axis deer in Hawaii. However, it is difficult to find appropriate places to release such animals (Balcones Canyonlands Preserve, 2005).

Trapping is an effective method in certain areas where other methods are not safe or feasible. For example, traps are preferred in urban and residential areas, where discharge of firearms is illegal or unsafe, and where the use of dogs conflicts with other public uses (Debernardi, 1995). Trapping pigs in problem areas, where other methods are not safe or effective, is common in Hawaii. State DLNR staff may provide permits, equipment, and assistance where appropriate to assist landowners to remove nuisance animals. Because of the bulk of the materials and equipment needed, access by road or helicopter is required; costs are generally lower when road access is available.

Numerous trap designs have been used in Hawaii and elsewhere, including box, cage, and corral-type designs (e.g. Barrett and Birmingham, 1994, Choquenot et al., 1996, DOFAW unpublished data).

Trapping	
Advantages	**Disadvantages**
• May be non-lethal • Multiple animals can be taken at once • Can be used where good snare sites are scarce or absent • May catch animals that have developed avoidance behavior to other methods • Non target animals captured may be released unharmed • Allows potential to relocate animals to appropriate areas (e.g. for public or private hunting). • Can be used in residential or urban areas	• Costs are higher where accessibility is limited • Less effective when food is plentiful (bait is less attractive) • Some animals are shy of traps; may not control to zero alone • Must be checked regularly to reset and add bait • May cause high stress levels in some species • Suitable release sites may not be available

Professional (staff or volunteer) shooting – aerial

Professional aerial shooting can result in a rapid reduction of animal numbers and has been used effectively in Hawaii and elsewhere, especially in pristine or sensitive areas or areas that are difficult to access (DOFAW unpublished data; Campbell and Donlan, 2005).

In Hawaii, this method has proven extremely effective at reducing goat populations on steep cliff faces. It also has proven effective for goats in open canopy areas where skilled shooters are able to take animals that appear only briefly in openings in the vegetation (Campbell and Donlan, 2005).

Aerial shooting from helicopters is particularly effective in rapidly reducing numbers where density is high and accessibility is limited (Sharp and Saunders, 2004a), as well as in eradicating the last animals in large protected areas with difficult terrain. Crews may be limited to a skilled pilot and a shooter in high-elevation areas, with a spotter/counter included at lower elevations.

Choice of firearm, ammunition, and shot placement are all factors in the humaneness and success of an aerial hunt. A ground crew in the area to shoot dispersing animals also is highly beneficial (Littauer, 1997).

Shooters may use Judas animals to help locate others of the same species. This technique involves fitting animals with transmitters and releasing them so they will lead shooters to other animals. Use of Judas animals is cited most often in removing remnant populations of highly social animals such as goats (Campbell and Donlan, 2005; Taylor and Katahira, 1988). However, the Judas animal method also can be useful for other species. A trial in New South Wales, Australia, resulted in removing 14 pigs in two hours — animals that one manager stated would have been almost impossible to locate otherwise (New South Wales National Parks and Wildlife Service, 2003). Females are the best Judas pigs (Wilcox et al., 2004; Sharp and Saunders, 2004b). In appropriate fenced areas, Judas animals also can be used to check for other animals that may have breached the fence.

Professional shooting – aerial	
Advantages	**Disadvantages**
• Effective for removal of remnant animals following other methods • Useful for inaccessible or remote areas • Only target animals are taken • Results are immediate (significant animal damage reduction in a short period of time) • Rapid removal of many animals	• Can be hazardous • May be difficult to schedule due to weather/wind considerations • Less effective where animals have significant cover • There may be liability issues for landowners allowing aerial shooting over their property • Regulatory or legal issues may limit availability of certified personnel

Professional shooting (staff or volunteer) – at baited stations

An alternative to active hunting is shooting at baited stations, often at night when animals are more mobile. Where reduced range of ammunition is desirable, such as a residential area or park, this may be done with bows or shotguns with slugs. Suppressors are often used to avoid alarming other animals nearby. A tree stand or "high seat" is generally used to help shooters avoid detection by animals.

In a 16,160-acre park area in Italy, a five-year pig control project (1988–1993) used a combination of cage traps and shooting from high seats on the same days. Traps took 327 pigs, and 159 were shot from high seats (Debernardi et al., 1995). Kessler (2002) reported that shooting pigs at baited stations worked better than cable snares in the Northern Marianas due to the lack of established pig trails in the control area.

Shooting at baited stations is frequently used on the mainland U.S. to control deer. Take of more than 10 deer per bait site per night is reported as common (Wisconsin Department of Natural Resources, 2003). Effectiveness drops with density as remaining animals grow wary, but reducing shooting to one or two consecutive nights per week can enhance take compared with more frequent shooting (Wisconsin Department of Natural Resources, 2003). This shooting method can facilitate good shot setup and may be less stressful to animals than being chased.

Professional shooting – at baited stations	
Advantages	**Disadvantages**
• May take advantage of animals' night feeding without the hazards of hiking	• Relies on animals to come while shooter waits; there may be long waits with no

through darkness • Target specific • Complements other methods; may capture trap-wary animals	results, particularly at low densities • May not be as attractive to volunteers as active hunting • Bait may provide a food source for other pest animals such as rats, allowing them to increase in number

Professional shooting (staff or volunteer) – on the ground with dogs

Using dogs to locate and bring game to bay is a proven and long-practiced technique. The experience of all parties concerned is a factor in success: hunters, dogs, and target animals. Various types of dog training are used to increase take and reduce impacts on non-target animals. Recent successes in removing goats from islands have demonstrated the effectiveness of specialized dog training (Campbell and Donlan, 2005).

In Hawaii and elsewhere, professional ground shooting with dogs has proven effective at reducing pig populations to low densities (Katahira and Finnegan, 1993, Choquenot et al. 1996). Prohunt New Zealand has devised a system for shooting goats in forested areas using a line of hunters with trained dogs. The hunters are in radio contact, and each dog is trained to chase and hold a goat until the nearest hunter can shoot it. This method is designed to reduce the number of animals that escape their first encounter with ground shooters (Parkes et al., 2002). Kessler (2002) reported that similar methods were less effective for pigs, which tend to break back through the line. Use of Judas animals can increase effectiveness.

Working at night when animals are most active can give dogs more opportunities to locate scent. However, tracking animals in the dark can be hazardous, particularly in rough terrain. Night shooting at baited stations avoids the need to chase down the animals.

Professional shooting – on the ground with dogs	
Advantages	**Disadvantages**
• Effective for target animals that have evaded other methods • With multiple teams, a number of animals can be taken in a relatively short time	• Dogs may be injured or killed when baying large boars

Public hunting with dogs

Public hunting can provide a valuable service in aiding property owners with feral ungulate problems and contribute to native resource management by reducing ungulate populations. Historically, hunting has been shown in a number of places to maintain animal populations below carrying capacity on a landscape level. This was indicated, for example, by the wide-ranging increase in ungulate densities in Australia and New Zealand, when WW II deprived the areas of hunters, ammunition, and gasoline and other supplies.

In Hawaii, pig hunting in heavy cover is usually accomplished with the use of dogs. The dogs locate, chase, grab, or bay the game, which is then dispatched by the hunter with a gun, knife, or spear. This method has been effective in many areas in Hawaii for pigs but is not approved for other species of ungulates (Chapter 13-123-22, Hawaii Administrative Rules).

Directed public hunting is usually most effective when ungulate densities are high. Because of lower hunter success and participation, effectiveness typically is reduced where animal densities are low or as animals are removed from an area (Kennedy and Misaki, 2001; Katahira and Stone, 1982). Effectiveness also is highly dependent on terrain and access and may be very low in remote areas.

Public hunting with dogs	
Advantages	**Disadvantages**
• Effective where densities are high • Facilitates the use of knife or spear methods, which can be used in residential or other high-usage areas • Hunting with dogs may take animals that have avoided other methods • Provides public access to game resources	• Inadequately trained dogs may take non-target animals • Effectiveness lower where densities are low and access is limited • Not approved for species other than pigs

Public hunting without dogs

Hunting of ungulates using firearms without dogs can be effective, although effectiveness is usually lower compared to hunting with dogs. Hunting with bow and arrow is an effective method without dogs. As with other public hunting programs, effectiveness is highest when game densities are high, and declines as numbers decrease or is reduced in areas of lower game densities.

Public hunting without dogs	
Advantages	**Disadvantages**
• Effective where densities are high • Provides public access to game resources	• Effectiveness lower where densities are low and access is limited

Snaring

Cable snares consist of a loop of steel cable fastened to a secured or heavy object and situated so that animals are caught as they pass through a narrow area. Rope leg snares are an alternative to cable snares. Snares are low cost and many snares can be set in a relatively short time. Snares are frequently more effective than hunting or shooting when animal densities are low; especially in rugged terrain with significant cover (DOFAW unpublished data). Snares are often needed to capture animals that have evaded other methods and are frequently the only remaining method feasible to eliminate particular animals (Littauer, 1997; Buddenhagen et al., 2006; Katahira et al., 1993). A key success factor is ensuring that snares are placed in the home range of every pig in the area to be cleared (Anderson and Stone 1993).

In a remote area of Kipahulu Valley on Maui, a successful eradication of feral pigs was achieved using snares (Anderson and Stone, 1993). To capture both adult and juvenile pigs, snares were set 5–20 cm above the ground. Over a period of 45 months, 228 pigs were snared – a management action that resulted in rapid recovery of this highly valued natural area.

Although cable neck snares are very effective, if tended infrequently they are generally less humane than a properly placed gunshot. Tending more frequently during initial use periods and setting snares to maximize the likelihood of catching the animal around the neck and on a slope can speed death. Use of telemetry devices to alert technicians when an animal is captured can increase humaneness (Marks, 1996), but shorter response times may be logistically impractical. Research is ongoing to develop faster-killing snares to address issues of humaneness.

Snaring	
Advantages	**Disadvantages**
• Effective for pigs and goats • May catch very wary animals • Effective for low densities or particular animals for which all other methods fail	• Non-target dogs or other animals may be susceptible • Snares must be removed before hunting with dogs in the same area • Usefulness may be limited by availability of suitable anchors points • Effectiveness may be compromised over time if not set correctly

Toxicants

Although toxicants are used in other parts of the world and have been found to be the most cost-effective technique for feral pig control (Choquenot et al., 1996), none are currently registered for use on ungulates in the United States. Hawaii's attendees at the 2006 National Conference on Wild Pigs in Alabama reported that a group of mainland landowners was lobbying to get toxicants approved for use on feral pigs. The biggest impediment to registering such a toxicant for use in the U.S. is likely the cost and effort required to comply with data requirements of the U.S. Environmental Protection Agency (Littauer, 1997). Use of approved toxicants in Hawaii may be less problematic than other continental areas where non-target mammals are a concern. Research is ongoing to improve baits and toxicants for feral pigs (see Australian Alps Cooperative Management Program, 2005, for examples). Research also is being conducted on the use of poisoned foliage to control deer and goats. Although no toxicants are currently approved for use for ungulate control in the U.S., they are used elsewhere, and are used widely for the control of other pests, such as rodents, in the U.S. Further development of this method is warranted and may provide an effective means for control.

Toxicants	
Advantages	**Disadvantages**
• Can rapidly reduce the number of animals • Can be aerially distributed in remote areas, • Effective at taking trap-wary animals	• Not presently approved for use in the U.S. • EPA approval procedures extensive and lengthy

	• May take non-target species

MANAGEMENT APPROACH AND RECOMMENDATIONS

The Division has the responsibility to protect and preserve native species and habitats in Hawaii, and to promote public hunting. The goals and objectives for these mandates are often in direct conflict when dealing with management of ungulates across Division-managed lands. With regard to ungulate control, the Division's approach is to protect native resources while allowing public access to game resources to the greatest degree that is safe, feasible, and effective, and to deploy the most humane methods available to eliminate threats from ungulates to sensitive native resources. Much of the interest in the issue concerns how the Division and other landowners implement control programs and what methods are used. This section provides a general framework for the ungulate control program on Division-managed lands that integrates these needs and concerns, and may be useful for ungulate control programs conducted by other landowners as well.

On Division-managed lands, overall guidance for the ungulate control program is provided on a strategic landscape scale in DOFAW's Draft Management Guidelines. The guidelines identify land use priorities based on vegetation characteristics and identify management objectives with regard to ungulate control and the public hunting program. Detailed implementation plans are generally drafted on a site-specific basis in accordance with the management guidelines.

The Draft Management Guidelines were last revised nearly five years ago and require revision. Further, while detailed implementation plans are available for some areas, no single document integrates the guidelines with specific implementation plans. The Division is committed to revising and updating the guidelines as integrated site-specific implementation plans are developed.

Control or elimination of non-native ungulates is essential to maintain the biological integrity of sensitive native ecosystems in many areas. The Division's overall approach emphasizes public access to game resources and deployment of the most humane methods of control when possible. Within this framework, safety, human impacts to sensitive ecosystems, feasibility, and effectiveness of alternative methods to reduce or eliminate ungulate numbers vary among target species and the biological and geological features of the habitat in which the work is conducted.

Choice of methods requires a complete evaluation of the site and habitat characteristics to plan and implement operations that achieve an appropriate balance among these considerations. Analysis of alternate methods is required to guide and inform management actions to be implemented. In most cases, deployment of several methods concurrently or sequentially is required to achieve the desired objectives (Wilcox et al., 2004; Campbell and Donlan, 2005; Cruz et al., 2005). Fundamental to success is the ability to adapt approaches to different sites and changing conditions.

The overall guidance for the development of the strategic approach requires a clearly stated management objective, including timelines and funding levels. Timelines are essential to ensure that animals are eliminated faster than they reproduce, and that the level of ongoing resource damage is taken into consideration. Constraints imposed by funds and time must be incorporated into the overall approach that seeks effectiveness, public access to game resources, and deployment of humane methods.

The Division management approach includes the following steps and actions:

1. Determine the methods to be used to prevent ingress following control activities (e.g. fencing, natural barriers, etc.).

   Barriers to prevent ingress are the most effective method to reduce the numbers of animals to be removed over time following initial removal actions. The size of the management units needed, and therefore the cost of construction and maintenance, varies among sites and species. Where feasible and cost-effective, barriers should be deployed. However, in some cases, barriers may be cost-prohibitive or may require multiple years of sequential appropriations to complete, leaving sensitive native resources at risk. In these cases, alternative methods of control are needed and a decision analysis is needed to guide long term planning.

2. Determine the feasibility and acceptability of non-lethal driving and one-way gates.

   Consideration of methods to relocate animals should be one of the first methods evaluated. Driving and one-way gates allow game resources to continue to be available to the public and avoids unnecessary killing of the animals. However, driving requires that relocation does not pose a threat to sensitive resources or conflict with management objectives for other areas or landowners. Further, driving is not effective for some species or sites.

3. Determine the feasibility and effectiveness of public hunting.

   Use of public hunting is incorporated into control programs when safe, feasible, and effective. Public hunting should be used to reduce numbers as much as possible before progressing to the use of other lethal methods. Effectiveness of public hunting depends on hunter success and participation. For highly fecund species such as pigs, levels of take must be relatively high to effect a reduction in the size of the population (e.g. Hess et al., 2006). Monitoring and analysis is necessary to determine the effectiveness toward removal objectives and is needed to guide management decisions.

4. Determine the feasibility and effectiveness of a trapping program.

   Where passive relocation and public hunting are not effective, a trapping program using staff or volunteers may be a next step. Trapping provides the opportunity to allow game resources to continue to be made available to the public in cases where the animals can be relocated to areas not at risk or where the animals can be made available to the public in the traps. Traps can be used to capture animals missed by hunting.

5. Evaluate other staff control methods designed to complete the objectives once the above methods are no longer feasible or effective. These include staff ground and aerial shooting, trap and shoot, and use of snares. Where snares are used the initial deployment is tended, followed by less frequently tended use.

   In many cases, approaches 1-4 above will contribute toward the management actions but will not be sufficient to complete the desired objective. In these cases, a decision analysis is conducted to plan staff actions. Use of snares is deployed as a last resort for animals that cannot be effectively removed by other means.

These sequential steps are analyzed and used on Division-managed lands and may provide a potential model for use on other lands.

Recommendations

1. Improve communication of ungulate control plans, methods and approaches, and activities to the public.
2. Employ a step-wise, adaptive approach that incorporates a variety of techniques to meet control objectives.
3. Consider use of non-lethal methods when safe, feasible, and effective.
4. Utilize public hunting for ungulate control when safe, feasible, and effective, to reduce numbers as much as possible before progressing to the use of other lethal methods.
5. Use snares in combination with other methods and as a last resort where other methods are not effective to meet control objectives.
6. Continue to review and update methods to maintain adaptive management approach.
7. To maximize effectiveness, employ a wide variety of methods.
8. Continue to review statutory, regulatory, and policy guidance to maintain and enhance program effectiveness.
9. Improve monitoring of native ecosystems and ungulate impacts to guide management decisions.
10. Continue and enhance opportunities for the public and volunteers to participate in ungulate control efforts.
11. Revise and update DOFAW's Draft Management Guidelines as site-specific implementation plans are developed.
12. Collaborate with the game management working group and other organizations and individuals to assess the feasibility and effectiveness of the development of a game management plan for the island of Hawaii. Consider plans for other islands.

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APPENDIX 1

Ungulate Control Methods Working Group
September 8–9, 2006
Kilauea Military Camp

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APPENDIX 2

Ungulate Control Methods Working Group
September 8–9, 2006
Kilauea Military Camp
Workshop Notes

Overview

Detailed notes and a summary of discussion that occurred at the workshop on September 8-9 are provided below. One of the first discussions at the workshop resulted in rapid consensus that everyone is fatigued with conflict and the lack of progress over this issue, and all would like to see some resolution before they retire or die. The participation of all interested parties in the workshop was appreciated. The Division is responsible for both preservation of native species and providing hunting opportunities. It is hoped that participating in this process, and drafting and distribution of this report will help provide information as we seek to move forward with actions that can balance both of these Division mandates. The following are general observations on the discussions: JJ: I think we should more strongly emphasize that these are just workshop notes and not a list of items that were most strongly agreed upon.

Stakeholder positions and priorities

The comments, positions and priorities of the individuals in the workshop on the various methods described in the report generally reflected the interest group they represented. The conservation interests supported methods and operations that controlled ungulates most efficiently with limited resources and provided the most protection of native plants and animals. These individuals stressed the importance of keeping all control methods available because of the difficulty of the task, the broad range of situations on the ground, and the ability of individual animals to adapt and evade various methods.

Hunters support hunting first and foremost and were not supportive of methodologies that waste resources, particularly objecting to toxicants, aerial shooting and untended cable neck snares. Some hunters objected to any control activity that does not include recovering the meat, and stressed the importance of preserving hunting opportunities. One hunter stated that of all control methods discussed, hunters prefer box traps next to hunting.

Animal welfare groups support those methodologies that do not involve animal suffering and seek to minimize animal suffering in all situations, including hunting and animal control activities. Participants from these groups were concerned about use of untended cable neck snares, aerial shooting, toxicants and about the care and treatment of hunting dogs, as well as use of hunting dogs near populated areas because of the threat to pets. These participants also expressed the most interest in fertility control, and advocated more research in this area.

Humaneness

There was not consensus on humaneness on most issues. The discussion on the use of snares, as one of the most contentious issues, illustrated the differences in opinion and values. Animal welfare groups and some hunters expressed opposition to use of snares in any situation for humane reasons. Others expressed sentiment that untended cable neck snares should be used - but only in remote areas. Others suggested that other methods should be used first to reduce animal densities so fewer animals are snared. Some land managers also suggested that where snares can be frequently tended, they may be appropriate for use in other areas where pets and people would not be at risk. Others stressed that there are situations in which no other method will remove the last few animals from an area, and without snaring as a tool, resource protection goals cannot be met.

Those practicing control stated that they continue to search for better and more humane control methods. A potentially more humane snare was discussed, which is currently investigating by various parties.

Representatives of animal welfare groups and others expressed concern over the care and use of hunting dogs. It was suggested that dogs should be microchipped, and that how they are cared for should be addressed. A Big Island hunter stated that the County is currently looking at this issue.

There was consensus among ungulate control advocates that humaneness for native species, some of which are very rare, is also an issue, and that allowing introduced animals to prey on native species and spread disease through their habitat is inhumane.

Game management and ungulate control plans needed

Workshop participants were unanimous in agreeing that comprehensive planning for ungulate management in Hawaii is badly needed. Consensus was reached to recommend that the Division seek funding to draft both an ungulate control plan and a game management plan for each island and for each ungulate species. Unanimous agreement by all stakeholders on this point is significant, and obtaining adequate resources to produce comprehensive, high-quality ungulate strategy plans for each island is a high priority.

Separation of land use

There were many comments that a significant problem in the past has been a failure to separate the land uses of hunting game mammals and preserving other resources.

Managers of lands designated for protection stressed that on lands identified for protection, fencing followed by an intensive effort to remove all ungulates as rapidly as possible would have two significant benefits. First, it would allow the fastest and most complete recovery from ungulate damage, and second, it would enhance humaneness by avoiding the endless ongoing animal control that would be needed if some number of animals continued to live and reproduce in areas mandated for protection.

A Big Island hunter stated that a problematic land-use issue for many hunters has been that when an area has been identified for ungulate removal, hunters are expected to hunt elsewhere, but the food supply for game in the remaining GMAs does not support enough animals to provide quality hunting.

There were comments suggesting that a lack of planning has resulted in inadequate management of GMAs and that a review of lands should be performed to (a) more clearly identify lands to be managed primarily for hunting, and (2) identify and prioritize lands for ungulate control. Furthermore, the GMAs should be enhanced as needed to provide a satisfactory hunting experience.

Cautious optimism was expressed that completion of game management and ungulate control plans would allow for best-practices management of GMAs for game production and natural areas that require ungulate control to protect other resources.

The complete group memory for this workshop follows this summary of areas of highest agreement. The facilitator would like to thank all participants for their willingness to listen to each other and work together around issues which elicited vastly different points of view.

- **There needs to be a review of snaring that looks at tended versus untended – types of snares and humaneness – when and where to use snares – practicability and expense**
- **The terms "remote areas" and "units of suffering" need to be defined**
- **Public hunting is an important component of control but can't reach ultimate goal in an area where that goal is eradication**
- **All management areas and methodologies need to be well planned for maximum effectiveness**
- **Should have comprehensive game management plan and ungulate control plan island by island**
- **These strategic plans need appropriate input from all stakeholders early in the process**
- **Need to define GMAs and goals for each GMA area**
- **We all recognize and thank volunteers as an important part of the work we do**
- **Hunting should be used as the first method in clearing an area of game as long as it is practicable**
- **The report should have a new introduction which would be all the whereases in the Resolution; also need an executive summary on methodologies and recommendations**
- **Separate out the planning section and discussion**
- **Present the methodologies in alphabetical order**
- **Put all hunting methodologies together**
- **Next draft needs to get to folks so that 2 weeks is provided for review**
- **The participants recommend that the Department identify the resources and budget for a good Game Management and Ungulate Control planning process island by island – including a public input process that starts early**
- **The participants recommend that no statewide task force be formed**

<u>FRIDAY EVENING SEPTEMBER 8, 2006 - GROUP MEMORY</u>

The meeting began Friday evening at 5:30. The facilitator noted that the purpose of the meeting was to provide an opportunity for stakeholders to discuss and make comments and recommendations on the draft report prepared by DLNR to respond to SR 26. DLNR is responsible under the Resolution for the final report and has agreed to consider all comments and recommendations made at this meeting. The DLNR representatives also agreed to append this document to the final report.

Everyone introduced themselves and talked about why this issue was important to them. The following reasons were shared:

- Need to have a working group of the various interests to discuss this draft
- Hunting and conservation need to work together
- It is part of my job to deal with ungulates and conservation
- Assisting DOFAW with information
- Need to identify and protect areas that need protection as well as those appropriate for hunting
- It's time to resolve the conflicts
- Care about native forests – understand that hunting is important to many individuals – interested in finding balance
- Part of my job is to find balance in this area
- Introduced animals are a problem; interested in finding ways to deal with them in a humane and effective manner
- Here to represent present and future hunters
- Have to control ungulates in TNC holdings, looking for tools – want to kill as few animals as possible while providing protection
- Be of assistance and learn
- I manage water resources and am concerned about hunting issues
- Involved in this issue toooooooo long – want resolution before I retire
- Here to represent hunters on Kauai and conservationist
- To provide a voice for the animals
- Resolve issues before I retire – where want hunting – where it should not take place
- Four participants also shared that their boss made them come

The group next talked about the draft document and its history.

- It was noted that a variety of people authored the report including Ed, Randy, Mary and others
- The Resolution that was being responded to came from Senator Kokubun's office as the result of a Bill that hunters were suggesting be introduced that session requiring the DLNR to check their snares daily – they also noted that the snares do not work as designed for a quick kill – they often snare the animal around the snout or middle which causes suffering and a slow death if the snares are not checked daily
- I feel that the Resolution called for a neutral report – I do not feel this draft report is neutral but is written as a justification for killing pigs
- Regardless of the history DOFAW was tasked to write the report
- We need to start identifying and setting up areas for sustainable yield hunting and areas where it is important that all ungulates be removed
- Disappointed with the process of this report – the Resolution called for hunters to be part of a working group – I don't feel we were involved in the draft – the report should just focus on what the Resolution asked for, methodology review and recommendations – everything else should be removed from the draft. I am also concerned that the document arrived just Wednesday afternoon which did not provide adequate time for review prior to the meeting

- I thought the report got to the point
- There needs to be more discussion concerning the incompatibility between hunting and conservation – more on the current conflict
- Non-consultation with stakeholders mentioned in the Resolution during the draft development is a problem
- The hunting groups have strong reservations about the draft document
- I don't have a problem reworking the draft to address the Resolution and focus on methodologies
- When the Department sends documents out for review they need to provide enough time for review and comment
- The document needs to be stripped to methodologies and recommendations as the Resolution stated
- The department noted that written comments would be accepted until October 2, 2006
- It was noted that local research and successes in the area of ungulate control needed to be sited in the report – one example: at the prison site 200 pigs removed through trapping

The group decided to begin the discussions in the morning with methodologies and to discuss these one by one to make recommendations and comments. They will then discuss recommendations and then the entire structure of the report including the introduction. The group prioritized the order in which they wanted to discuss the methodologies. The following order was decided on.

1. Snaring
2. Public or sport hunting
3. Cage and box traps
4. Fencing
5. Directed volunteer hunting with knives and dogs
6. Professional aerial shooting
7. Professional ground hunting with dogs
8. Toxicants
9. Fertility control
10. Judas animals
11. Biological controls
12. Bounties
13. Shooting at baited stations
14. Driving

There was some discussion on combining the hunting categories but the group decided to keep them separate at this time.

SATURDAY, SEPTEMBER 9, 2006 – GROUP MEMORY

Methodologies Discussion

Snaring

- Snaring is effective
- It is the only way to get 100% of the animals out of an area
- It is not humane, especially unattended snares when they snare an animal in an area other than the neck
- The frequency of monitoring snares goes directly to the degree of inhumaneness of the method
- There is a new kind of snare (safety pin mechanism) that is more accurate in getting an animal around the neck – can still snare unintended animals
- Need to map and tend snares so that they are not left active in the forest forever
- Hakalau used a combination of hunting and snaring to eradicate – hunting lowered numbers but when hunting was no longer productive used snares to clear area
- Snares are used by setting up transects and then mapping where the snares are placed – snares are only lost when pigs break them – checking is done periodically and they are removed when done
- Snaring is also used with intensive monitoring and when the area is cleared the snares are removed
- The amount of time between checking snares varies by program, can be up to 2 months
- Need to look at unattended snaring and current snare type versus the Collarum (safety pin type) for humaneness
- Snares if used should be used in remote locations that have already been through hunting and trapping – should be used as a last resort (the term "remote" needs to be defined)
- The issue of cost between attended and unattended snares needs to be assessed
- Not claiming snares are humane – that is why they are used at the end of the clearing process when other methods have done what they can – but they are the only effective tool for removing the last few animals – should continue to look at new technologies that could reduce the use of snares
- When we look at humaneness we also need to consider the humaneness of allowing ungulates to foster and spread disease to other species such as native birds
- There needs to be a review of snaring that looks at attended versus unattended – types of snares and humaneness – when and where to use snares – practicability and expense
- Unattended may be appropriate for remote areas
- Unattended snares are necessary to reach eradication in an area
- Look at developing criteria for use of snares area by area
- Should be working toward being able to achieve eradication without the use of snares
- Managers of areas that need to remain ungulate free for protection and restoration needs must have all tools available and discretion to use them
- Snares are needed both in eradication areas and also in ungulate damage control areas

Public or Sport Hunting (undirected hunting)

- What is the goal? If the goal is to use as a management tool then it is directed hunting
- Hunting can not accomplish eradication in areas and this continuing discussion tying hunting to eradication is holding up the discussion on sustainable hunting areas and their establishment
- Undirected hunting is not a control tool

- When an area needs eradication or management use public hunting first – provide for the activity including providing access i.e. opening gates to Mt. Kaʻala etc.
- Some felt that undirected hunting does provide for assistance with management as it impacts the total population – others pointed out that hunting focuses on the males of the species and for control you need to focus on the females and young
- Hunting is not humane unless it is a head shot – dogs terrorize animals
- Public hunting is an important component of control but can't reach ultimate goal in an area needing eradication.
- There are issues connected with hunting concerning humane treatment of dogs, lost dogs etc.
- For proper management outcomes to be achieved public hunting must be directed
- Need to gather data on effectiveness of hunting as a management tool – it was noted that Tanya would have some information from the Kulani experience

<u>Trapping (box, cage and corals)</u>

- For this methodology to be successful it needs road access, bait availability, staff time to bait, tend and relocate animals, more effective with high densities of animals, good for use in rural and residential areas
- Supported by hunting community as animals can be relocated to other areas for sport hunting
- This method could be used as a way to deliver sterilants before animals are released
- The method requires regular monitoring of traps
- Must match trap design to animal needing to be trapped i.e. side door hinge is better for pigs
- The open air nature of this methodology makes it more humane as it decreases capture anxiety
- Hunters want use to be after area is sport hunted
- There will be data available soon from use of this methodology in Manoa
- A plus is that the method does not drive animals to other areas instead it brings them in and can attract them from a large area
- Traps require staff time to tend them
- Should be some assessment on the pros and cons what works for what type of animal
- If trapped animals are not relocated meat can be salvaged
- Bait and bait effectiveness is a problem – issues that impacts baits are the area the trap is in and what food is available in the area – then need to find effective bait in large quantities that is eco-friendly, affordable and does not attract vermin or unintended species to trap which can be a problem
- The problem with traps is that they do not always work – when the animal density is low – bait is taken by other animals which leads to unintended impacts

<u>Fencing</u>

- Effective with one way gates
- If the intent is to eradicate an area and keep it that way fencing is the only tool
- It is expensive

- Once an area is cleared and kept that way it is humane as it requires no future killing to take place
- Should be fencing sustainable yield areas for hunting
- Fencing changes animals migration habits and trails – can be inhumane if it blocks the way to a water source for animals
- Fences are vulnerable to vandalism and acts of nature – falling trees etc. – some of the vandalism may stem from a lack of clarity on the goals and why the area is fenced
- What happens outside the fence – where do animals go and how does the fence impact them are questions that have not been answered
- It is essential to have an inspection and maintenance program with fencing
- New species that need control may make existing fences obsolete i.e. deer with pig fences
- Type of fence can impact animals and cause unintended kills such as bats
- Need new specification to control new species with fences i.e. deer and mouflon
- Fences can be hazardous to native species bats and petrels – function of height and barbed wire etc.
- Fences help to avoid regional eradication needs
- There is some research that shows that a high wire outside of existing fences with flags on it may work for deer

<u>Directed volunteer hunting with dogs and knives</u>

- Method used in residential areas
- A downside is that the dogs could pose a safety problem for residents – not appropriate in some areas
- Look at access need to areas where directed hunting could be effective
- Should consider closing high recreational areas occasionally for trail work and hunting to control ungulate populations in these areas (Tantalus, Na Pali coast)
- Can also use bows and arrows in these areas where the forest meets the residences
- Look at controlled night hunts – many felt this was not safe – others noted that it is expensive but as part of a strategy with fencing and done right in remote areas it can be very effective – this has proven somewhat effective at Pelekuna as part of a strategy
- Very successful when there is a high density of animals and the area is accessible
- Provides a way to get hunters to areas that are not normally accessible
- Animal rights folks do not view these methods as humane as the quickness of the kill is questionable
- With any of the tools noted the quickness of kill goes to the experience of the hunter

<u>Professional aerial shooting</u>

- Should be allowed if accurate and humane with a quick kill
- Less damaging in remote areas because use helicopter rather the ground access
- The method is limited to use by state employees only - even if applied on private land – when on private land private landowner must assume liability
- Hunters oppose to this method – waste of meat and considered wanton shooting
- Method is highly effective – in rugged areas it is the only effective method
- Aerial in the view of animal rights folks is completely inhumane can not verify kill

- Others felt that you could not always bring the animal out with other methods and did not see the difference
- In the areas where it is most effective hunters could not access let alone retrieve the meat
- Most effective method in the world for certain types of areas when practiced by professional hunters – also the animal carcass provides nutrients back into the depleted eco-system
- Aerial is used as last resort when an area is not huntable – the impacts of doing nothing in these instances are increased erosion which impacts reefs etc. – most of these impacts mean a loss of non-renewable resources as opposed to renewable resources such as goats
- New Zealand is considered by animal rights groups as the most inhumane - so we should not be referencing or looking at them
- It was noted that this was used effectively in Makua where unexploded ordinance made other methods impossible
- Exploring a system of fencing animals in would keep them out of areas that necessitate the use of this methodology
- This is a method that allows quick compliance with mandates
- Cost effective with high density areas example: an area that was reduced to 35% of its original density by hunting was eradicated after 2 aerial shoots
- State hunting education program tell hunters to go for a vital shot not a one shot head shot
- There is a lot of training involved for people that are going to practice this method
- Areas of Molokaʻi recovered very fast without fencing after one of these shoots – it restored stability and allowed the ecosystem to regenerate

<u>Toxicants</u>

- No approved label for use of toxicants in the US – should not even be discussing
- There is an effort currently underway to make them legal in the US
- They were used at one time and then made illegal because they were indiscriminate as to what animal they harmed
- The spreading of the toxicant into the human consumptive food chain as well as the impact on native species is a concern
- Hawaiʻi as a state has a low number of target mammals for toxicants
- Water quality is also an issue with use of toxicants
- They are currently used in the rest of the world – usually as the first tool for knocking out a population
- It is very inhumane
- Need to continue to track and look at research

<u>Fertility Controls</u>

- Need to increase research in this area – there is GonaCon (lasts three years) – it is injectable and works on pigs and produces no side effects when the meat is consumed
- Need to increase funding for research
- Still have damage happening from the animal after release for the rest of its life

- Doesn't help in situations where eradication is the goal
- Need to continue to track research in this area
- Problem also is that you have to catch enough females for it to be effective
- Will become more feasible if one is developed that is permanent and can be delivered orally
- Biologist can predict the threshold of efficiency – how many pigs you need to impact to make it an effective control mechanism

Judas Animals

- Very effective in situations of low density of animals
- Also very effective when coupled with aerial shooting and or corralling or penning
- Also effective with directed hunting
- There are questions about which sex is most effective and what length of time to leave an animal in the area
- It is really a tactic not a method – as a tactic it narrows the search area to increase efficiency of other methods
- It is also effective for managing fence breeches
- Also for long term monitoring within fenced areas

Biological Controls

- Extremely risky
- Very cruel to purposely introduce disease to a population
- Biological controls are predators also

Bounties

- Risky as it may attract individuals with low skill levels thus decreasing the number of quick kills
- Money not the best motivator for this type of work
- It could encourage some individuals to leave some of the population behind so that they can continue to collect bounties
- If you employ bounties or contracts you need to make sure the outcome desired is clear and that it is achieved
- It encourages cheating
- Viable for specific area with access control to check hunter going in and coming out

Shooting at baited stations

- If it works it can be effective
- Hunters don't like because it is a "canned" hunt
- Has all the problems listed associated with bait under trapping
- Could provide for a high degree of humane (one shot) kills – more humane then chasing and terrorizing with dogs – meat can be harvested
- It might be appropriate in a site where forests meet residential uses
- Concentrates animals which could encourage the spread of disease

Driving

- Effective in certain types of sites i.e. those with fencing or natural barriers to drive to
- Pushing animals from one area to another could create problems
- Should end with a corral or trap situation so that meat can be harvested
- Good because animals don't know how to avoid a drive
- The degree of success is determined by the criteria and the site – example Pohakuloa was not successful with a drive and aerial shooting because there were too many places for the animals to hide and wait it out
- May need to do driving on the ground with horses in some areas for it to be effective
- May not be feasible in large remote areas
- Report could discuss areas where this would be effective and where not

The group next discussed the recommendations section of the document.

Planning

- All management areas and methodologies need to be well planned for maximum effectiveness
- As part of planning we need to decide what areas are for sustainable yield hunting and what area need eradication
- Need to look at the idea of fencing sustainable hunting areas
- Fencing good idea for areas where eradication is goal but not for hunting areas
- Planning needs to be done Island by Island not statewide as there are too many variables and differences Island to Island – on some Islands may have to go to a regional basis
- Once goals are set for certain areas need to identify obstacles to reaching those goals
- It was pointed out that the big Island is trying to write a Game Management Plan (GMP)

Establishment of a Task Force

- We did this all in '93 and there was no follow through – need a task force to keep the momentum going
- The hunting folks are clearly identified as needing to be at the table – the problem is identifying who can represent them
- Need to have multiple representatives from all stakeholder groups
- Statewide for a task force is too hard - there are too many island differences as noted in the planning discussion
- Don't need a task force – need the State to set some policy around where the need is preservation and where the use is hunting
- No task force is needed the State just needs to do its job (the discussion on a task force was deferred till later in the meeting)

Strategic Management Plan

- Yes we need one
- Need by Island or district not statewide
- Strategic plan needs appropriate input from all stakeholders
- Should do at Island level
- Need to define GMAs and goals for each area

- Also need to look at ways to confine GMAs
- Look at areas that might develop as high recreational areas in the future that might impact uses and goals

Statute Revision

- The law governing that only state employees can do aerial shooting on private land needs to be looked at
- Need to look at the ability of the state to go on private land to control invasive species early
- Forest reserves where animal control is necessary should have exemptions on bag limits and access
- Lands designated to preserve native species should be deregulated for maximum animal control – example NARs being managed as GMAs
- Conservation land use permits should not have the same process for activities that are geared toward the conservation goals of the area and those that are not
- Need to make doing conservation work on conservation land easy
- Chapter 343 requiring EAs and EISs need to be applied consistently on the state and private side
- Language in the draft speaks to facilitating state access for all landowners concerned if this is to be construed as the state can force access to private lands – not in favor of this
- Need to regulate appropriately for the use proposed by the goals for the area
- Noted that statute was fixed on liability for injured volunteer – does not mean that the landowner won't get sued but can use as defense
- Need to increase the ease of access to information on animal control activities (OIP regulations). Disclosure for private public partnerships should be the same as if the entire entity is state
- Need clarification on the vehicles to get information
- Need to provide transparency as to where the hunting fees go i.e. how they are spent – this information is on the DOFAW web site – you can track the revolving fund – amounts what is spent and on what are all available

Volunteers

- We all thank them as an important part of the work we do
- Need to provide more and better training
- Look at investing in building volunteers by providing funding for a volunteer coordinator
- Volunteer oversight and management is an issue for landowners as it pertains to liability
- Can we look at partnerships with the state as all volunteers being covered under state liability?
- Volunteers are essential to control programs

Hunting

- Hunting should be used as the first method in clearing an area of game as long as it is practicable

- There are different goals for hunting in different areas and these need to be clear and established
- Need to clarify and change terminology according to goal for the area
- Pristine areas risk introduction of alien species from anyone or thing entering the area including conservation workers, volunteers and hunters
- Increase access to areas appropriate for public hunting
- Hunting areas should be managed to insure a good hunting experience for the license fee and need to be large enough that you are not hunting in a zoo
- The idea of setting up hunting preserves is unique to this group
- Currently there is no game management plan and we need one
- Game management plans need to include management of hunting dogs (micro-chips, lost dogs, number and care of animals are all issues)
- Counties need to be part of this discussion
- There needs to be work done to increase the percentage of hunters who get a hunting license
- It was noted that state hunter education programs deal with education around native species - in a 12 hour course 1.5 hours is spent on endemic species
- Enforcement needs to be increased
- Look at hunting fees to provide enforcement as it is a dedicated fund
- Consider specializing DOCARE officers by resource area i.e. specialization Mauka or Makai

Game Management Areas

- Need to clarify terms and goals
- Should have comprehensive game management plan and ungulate control plan island by island
- Need to address relocation of animals as regards issues such as transportation, humaneness, and disease
- Fence GMAs
- Improve habitat in desired hunting areas to attract animals
- State land of non-importance next to GMAs should be planted with food sources to raise the capacity in the area and attract animals – if fenced one way fences could be used
- Increase research on game animals
- Encourage hunter volunteers to help with management an example is index surveys
- Game management and hunting staff at DLNR need to be looked at and held responsible to do their job
- GMAs qualify as an expenditure under the legacy land acts
- The Big Island has identified a game enhancement area – the need is to come up with a plan to improve habitat in this area
- There is a lack of trust between the department and the public based on the public's perception that there is no follow through on commitments – meetings like this take place and yield good ideas and then nothing happens – plans and reports seem to go on shelves – implementation needs to be done by the department and their employees and we do not see this happening

Report Structure – the group discussed their recommendations to the department concerning the structure of the report to the legislature.

- Confine the report to what was asked for in the Resolution
- Introduction should just give a brief overview of the context
- Do an executive summary on methodologies
- The strategic plan introduction on page 5 is good and should be retained
- The term "units of suffering" needs to be defined
- If page 6 stays in the discussion on humaneness needs to be toned down
- Need to clarify environmental damage from non-control of ungulates and how it also causes units of suffering in native populations
- If the introduction is kept it needs lots of work to correct factual errors
- Need a new introduction which would be all the whereases in the Resolution and an executive summary on methodologies and recommendations
- Need to add in section 1 a statement about the compatibility or lack there of between ungulates and native species
- Start the body of the report with section 2 on methodologies beginning on page 7
- If humaneness section stays in revamp it
- Separate out the planning section and discussion
- Present the methodologies in alphabetical order
- Put all hunting methodologies together

Next Steps discussion

- Next draft needs to get to folks so that 2 weeks is provided for review
- The participants recommend that the Department identify the resources and budget for a good Game Management and Ungulate Control planning process island by island – including a public input process that starts early
- The participants recommend that no statewide task force be formed (revisit of task force discussion)
- Participants asked who the point person would be as the report moves forward – the point person designated by the Department is Ed

Modeling Scenarios for the Management of Axis Deer in Hawai'i1

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Modeling Scenarios for the Management of Axis Deer in Hawai'i[1]

Steven C. Hess,[2,3,6] *and Seth W. Judge*[4,5]

Abstract: Axis deer (*Axis axis*) are invasive species that threaten native ecosystems and agriculture on Maui Island. To mitigate negative effects, it is necessary to understand current abundance, population trajectory, and how to most effectively reduce the population. Our objectives were to examine the population history of Maui axis deer, estimate observed population growth, and use species-specific demographic parameters in a VORTEX population viability analysis to examine removal scenarios that would most effectively reduce the population. Only nine deer were introduced in 1959, but recent estimates of >10,000 deer suggest population growth rates (*r*) ranging between 0.147 and 0.160 even though >11,200 have been removed by hunters and resource managers. In VORTEX simulations, we evaluated an initial population size of 6,000 females and 4,000 males, reflecting the probable 3F:2M sex ratio, with annual removal rates of 10%, 20%, and 30% over a 10-year period. A removal rate of 10% resulted in a positive growth rate of 0.103 ± 0.001. A 20% removal rate resulted in only a slightly negative growth, while a 30% removal rate resulted in -0.130 ± 0.004. By increasing the ratio of females removed to 4F:1M in the 30% harvest scenario, the decline nearly doubled, resulting in -0.223 ± 0.004. Effectively reducing axis deer will most likely require an annual removal of approximately 20–30% of the population and with a greater proportion of females to increase the population decline. Selective removal of males may not only be inefficient, but also counterproductive to population reduction goals.

Keywords: *Axis axis*, axis deer, Hawai'i, invasive species, Maui, population modeling

Herbivorous mammals have been introduced on oceanic islands throughout the world, often with devastating consequences for native biota (Coblentz 1978, Courchamp et al. 2003). The adverse ecological effects of non-native ungulates in the Hawaiian Islands have been well-documented in more than 58 studies (Leopold and Hess 2017).

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Management actions have eradicated some feral ungulate species from enclosed portions of mostly federal lands in Hawai'i, resulting in measurable ecosystem recovery (Hess 2016). However, management has been difficult to achieve throughout larger landscapes, especially for wild ungulate species that have never been domesticated. Ungulate populations have persisted or have increased in some cases despite large numbers of removals over long periods of time, and because of conflicting mandates to protect native species while providing hunting opportunities (Banko et al. 2014, Leopold and Hess 2017). Strategies for more effective large-scale control or eradication programs of wild ungulates based on species specific mating systems and population dynamics have not been developed. One such wild ungulate species introduced to Hawai'i is axis deer (*Axis axis*) which have a polygynous mating system and have not been domesticated (Hess 2008).

Axis deer were first introduced to the island of Moloka'i as a gift to King Kamehameha V in 1868. Populations were then established for hunting on Lāna'i in 1920, and on Maui in 1959 and have reached high levels of abundance, becoming problematic to ranching, agriculture, and conservation of natural areas in Hawai'i (Tomich 1986). Axis deer populations are female-biased, comprising as much as 70% of individuals, and 95% or more of dams give birth to fawns after reaching maturity as early as 6–10 months of age resulting in rapid annual population growth rates ranging from 20 to 30% (Anderson 2003).

Deer abundance reached an estimated 7,500–11,000 on Maui by 2013 since their introduction in 1959 (Tom Gieder, Wildlife biologist, unpublished data). Deer on Maui have caused more than one million USD of damage each year to vegetable crops, sugarcane fields, vineyards, ranches, golf courses, and ornamental plants at resorts (Hess 2016). Although resource managers generally remove all ungulates from federal lands throughout Hawai'i, deer are difficult to manage on some inaccessible state-owned lands, while other lands are managed for sustained-yield hunting (Hess 2016). Despite lifting hunting seasons and bag limits for deer on public lands and commercial removals of large numbers, deer remain abundant on Maui, with no apparent lasting measurable decrease (Hess et al. 2015). It is unclear what level of removals would be necessary to make a sustained reduction in abundance. Moreover, it is likely that population reductions may be achieved more efficiently by focusing efforts on females rather than by lifting all restrictions on hunting. Hence, population viability modeling may demonstrate expected outcomes by examining the ability of different management scenarios to effectively reduce the axis deer population.

We hypothesized that increasing the proportion of females removed would favor reduced population growth rates and provide more efficient control strategies. Our objectives were to examine the population history of axis deer on Maui, and retrospectively estimate observed population growth, and then use species-specific demographic parameters in a population viability analysis to examine removal scenarios that would most effectively reduce the population. We ran simulations where 0%, 10%, 20%, and 30% of the estimated annual population abundance was removed each year. We then adjusted the ratios of males and females removed to explore how sex bias may affect population change.

MATERIALS AND METHODS

Observed Population Growth

We compiled dates of axis deer introduction, abundance observations over time, and records of removals through large scale management actions on the island of Maui (1,883 km^2; 20° 48′ N, 156° 20′ W) to calculate plausible rates of growth (λ) in a simple population model (Eberhardt 1987) (Table 1). Beginning in 1959, three males and six females were introduced to Maui (Kramer 1971). The State of Hawai'i Division of Forestry and Wildlife (DOFAW) reported estimates in the 1990s and 2000s, and the Maui Invasive Species Committee (MISC) continued to monitor the axis deer population. Most population estimates collected from 1960 to 2013 lacked methodological details. However, recent population estimates were determined by line-transect aerial surveys. T. Gieder (written comm.) estimated densities ranging from 4.6 to 58.1 deer/km^2. The total geographic range on Maui had not

TABLE 1

Reported Axis Deer (*Axis axis*) Abundance Estimates and Removals Since Their Introduction to the Hawaiian Island of Maui in 1959

Year(s)	Point Estimate	Lower Estimate	Upper Estimate	Removals	Reference
1959	5	–	–	–	Kramer 1971
1960	9	–	–	–	Kramer 1971
1968	–	85	90	–	Kramer 1971
1995	–	3,000	4,500	–	Anderson 2003
1997–2000	–	–	–	1,500	Anderson 2003
2000	–	2,000	4,000	–	Anderson 2003
2001	2,000	–	–	–	CGAPS 2011
2003–2008	–	–	–	39	Lepczyk and Duffy 2019
2011	12,000	–	–	–	CGAPS 2011
2013	7,009	4,673[a]	10,281[a]	400	Gieder/DOFAW, unpubl.
2014	–	–	–	2,575	DOFAW unpubl.
2015	–	–	–	2,827	DOFAW unpubl.
2016	5,706	3,992[a]	8,156[a]	3,859	Gieder/DOFAW, unpubl.
2016	449[b]	–	–	–	J. Muise, KIA Hawai'i, unpubl.
Total	–	–	–	11,200	–

[a] 95% confidence interval.
[b] Survey area did not overlap with Gieder/DOFAW (unpubl. data).

been defined, but Gieder (written comm.) used a mean density of 9.1 deer/km^2 and estimated a total population of more than 10,000 deer within a 1,100 km^2 area. The highest reported abundance of 12,000 deer was in 2011, before nearly 10,000 deer were removed (Table 1). We plotted lower and upper abundance estimates or confidence intervals where available and calculated annual population growth rates (λ) by solving Eberhardt's (1987) simple model for population projections:

$$N_2 = (N_1 * \lambda) - R$$

We searched for minimum values of λ corresponding to 0.1% increments, that when projected from the founding population number (N_1), simultaneously satisfied abundance observations, number of removals (R), and yielded terminal abundance (N_2) greater than most recent abundance estimates. The annual multiplicative growth rate λ was then approximated by the exponential growth rate term (r):

$$\lambda = e^r$$

This simple modeling approach relied on an assumption that the rate of population growth was fixed over time and the population had not reached density-dependent limitation, which has probably not yet happened given the short history of the species on Maui.

VORTEX Population Modeling

We modeled the axis deer population on Maui under various management scenarios of population removal using the population viability analysis program VORTEX (Lacy 2000, Lacy and Pollak 2014, Lacy et al. 2018). VORTEX provides a matrix population modeling framework that can simulate the extinction process of wildlife populations by comparing the relative effects of potential management scenarios on population growth or persistence (Reed et al. 1999, Fantle-Lepczyk et al. 2018). The program can also be used to estimate the number of removals necessary to control abundance or eradicate invasive species (Pruett-Jones et al. 2007, Licht 2014). A standard life table calculates exponential growth rate (r) by solving the Euler equation:

$$\sum(l_x m_x e^{-rx}) = 1,$$

in which l_x and m_x are the age-specific mortality and fecundity rates, respectively for age class x to $x+1$ and the summation is over all age classes (Lacy 1993, Lacy et al. 2018). The program then estimates the effect of environmental variability, demographic stochasticity, and genetic stochasticity on wildlife populations. The simulations move through a series of discrete and sequential annual population processes, such as reproduction, dispersal, mortality, and harvest (Lacy and Pollak 2014). Optional parameters include the random processes of catastrophes, inbreeding depression, and density dependence.

The population viability analysis provides annual mean population abundance, mean population growth rates, probability of extinction, and estimate of time to extinction. The program allows users to input annual harvest or removals, which in this case could represent either public hunting or culling by management agencies. We modeled several simulations (described below) to determine the baseline rate of population growth of axis deer, the percent of mortality that would need to occur for the population to remain stable, and the percent of additional mortality (by culling) to cause population decline. Furthermore, we investigated how the disproportionate removal of sexes affected the outcome of control efforts. We chose 1,000 iterations of each scenario for improved precision (Lacy et al. 2018). We assumed one closed population and modeled axis deer over a 10-year period. We chose this duration because most preliminary simulations yielded meaningful results (sharp decline in growth or reaching carrying capacity) within 10 years.

Baseline Model Parameterization

We primarily used demographic data from the Hawaiian Islands to parameterize the VORTEX model (Table 2). Where data were lacking from Hawai'i, we cited research on the demography of axis deer in their native habitat or other locations (Schaller 1967, Ramesh et al. 2012).

Reproduction Parameters — Axis deer are polygynous and an estimated 95% of females >1 year of age breed and 27% of males breed, starting at 2 years of age (Graf and Nichols

TABLE 2

Demographic Parameters Applied in VORTEX Population Viability Analysis Simulations of Axis Deer (*Axis axis*) on the Hawaiian Island of Maui

Parameter	Value	Reference
Mating system	Polygynous	Walker 1964
Female age of first reproduction	1	Chapple 1989
Male age of first reproduction	2	Graf and Nichols 1966
Percent adult females breeding	95	Graf and Nichols 1966
Percent of males breeding	27	Pariwakam 2006
Maximum age of reproduction	10	Gogan et al. 2001
Maximum lifespan	10	Gogan et al. 2001
Maximum number of progeny	2	Graf and Nichols 1966
Sex ratio at birth	1: 1	Graf and Nichols 1966
Mean number of progeny	1.5 ± 0.5 (SD)	See text
Percent first year mortality	35 ± 0.5 (SD)	See text
Percent adult mortality	25 ± 0.5 (SD)	See text
Inbreeding depression:		
Lethal equivalents	3.14	See text
Recessive alleles	50%	See text
Starting population	10,000	See text
Carrying capacity	$22{,}000 \pm 200$ (SD)	See text

1966, Pariwakam 2006). Gogan et al. (2001) examined necropsies during the axis deer control effort at Point Reyes National Seashore, California, and estimated the maximum lifespan and age of reproduction at 10 years of age for both sexes. In VORTEX, we set the mean number of progeny to 1.5 ± 0.5 (SD) fawns per brood in a normal distribution. Occurrences of twinning have been documented in Hawaiʻi (Graf and Nichols 1966) and Texas (Fuchs 1977). However, twinning was rarely observed in zoo births (Crandall 1964, Schaller 1967). Based on observed high population growth rates substantiated by simulations, some twinning likely occurred. Furthermore, gestation is approximately 235 days (Chapple et al. 1993), and if fawns die early, dams can give birth a second time within a year (Crandall 1964).

Sex Ratio of Population — Anderson (2003) reported a 30–50% male population based on observations and removals. Gogan et al. (2001) reported the age and sex structure of axis deer removals during control effort at Point Reyes National Seashore. Males accounted for approximately half of all the removals; however, females accounted for more than twice the deer <1 year of age. In our simulations, we opted for a 40% male population, which was the midpoint of Anderson's (2003) observations. Female-biased populations are not unusual in cervid populations, because bucks are often sought for trophies (Jenks et al. 2002). There was scant data regarding sex ratio at birth of axis deer; Graf and Nichols (1966) noted a likely equal ratio of males to females on the islands of Molokaʻi and Lānaʻi, which we used in our simulations.

Inbreeding Depression and Mortality Rates — The impact of inbreeding depression has not been reported in axis deer. We presumed some effect because of the small founding population in Hawaiʻi, but because of the reported high densities on Maui, we assumed no deleterious effects to population growth. Nevertheless, we chose a mean inbreeding coefficient and estimate of lethal equivalents for mammals of 3.14 (*F*) and 50%, respectively, as was reported for mammals by Ralls et al. (1988). Most axis deer mortality estimates come from their native range on the Indian subcontinent, where large predators are present. In their native range, Schaller (1967) reported that 48% of fawns were depredated during their first year. Mortality of yearlings and adult bucks were about 35% (Schaller 1967). Given that there are no large predators in Hawaiʻi, we presumed mortality was lower. Although feral dogs (*Canis lupus familiaris*) are common in Hawaiʻi the effect of feral dog predation is unknown. Dogs have depredated larger white-tailed deer *Odocoileus virginianus* (Huegel et al. 1985) and we presumed similar depredation occurs in Hawaiʻi. We assumed predation rates to be lower in Hawaiʻi than India, so we reduced Schaller's (1967) mortality rate for each age class. After running several preliminary simulations, we reduced percent mortality estimates to 35 ± 0.5 (SD) for age 0–1 and 25 ± 0.5 (SD) for ages 1–2 years and >2 years for both sexes.

Carrying Capacity and Starting Population Estimate — We reviewed reported density estimates of axis deer on Maui to estimate carrying capacity. The highest density estimate on Maui was 58 deer/km^2 (T. Gieder, written comm.). However, density estimates vary by area depending on land ownership, foraging resources, and barriers that may impede immigration. Given the uncertainty of aerial survey estimates, we chose a more conservative median density estimate of 20 deer/km^2, which equated to a carrying capacity and best estimate standard deviation of 22,000 ± 200 SD deer in the 1,100 km^2 range on Maui (T. Gieder, unpubl. data.). Based on aerial survey data, Gieder (written comm.) estimated an overall abundance of approximately 10,000 deer in a 1,100 km^2 area of Maui, which is what we used in population simulations. We used a function in VORTEX that accounts for estimated birth and death rates to determine a "stable age distribution" for each of the 10 age classes, while maintaining a sex ratio of 40% males in each simulation (Table 3).

TABLE 3

Age Classes of a Starting Population of 10,000 (60% Female and 40% Male) Axis Deer (*Axis axis*) on the Island of Maui in VORTEX Population Viability Analysis Simulations

Age	Females	Males
1	2,232	1,488
2	1,411	941
3	890	594
4	563	375
5	355	237
6	224	150
7	142	94
8	90	60
9	56	38
10	36	24
Total	5,999	4,001

A stable age distribution was calculated by a function in VORTEX that accounts for birth and death rates.

Sensitivity Evaluation

We performed a sensitivity analysis in VORTEX to evaluate the importance of demographic or population parameters that lacked certainty. These evaluations examined a range of input values, set by the user, to estimate how a parameter will affect population growth. The sensitivity parameter is defined as:

$$S_x = \frac{(\Delta X/X)}{(\Delta\text{parameter}/\text{parameter})}$$

where ΔX is the change in the observed response of the parameter under examination. We evaluated the sensitivity of 10 parameters including the percent of females and males breeding, the mean number of progeny, mortality of males and females at different lifestages, and sex ratio at birth, and levels of inbreeding depression by adjusting lethal equivalent values. Parameters were evenly spaced across the range of values, according to a "Latin Hypercube" design (Lacy et al. 2018). The parameter space was sampled 1,000 times using a random selection of a value from each parameter. We provided values of the baseline model, the range of values evaluated, and resulting minimum and maximum values in population growth for each model parameter evaluated in the sensitivity analysis (Table 4).

TABLE 4

Demographic Parameters for Axis Deer (*Axis axis*) on the Island of Maui and in Their Native Range that Lack Certainty in the Published Literature

Parameter	Baseline	Min Tested	Max Tested	*r*-min	*r*-max	% Variance
Mean brood	1.5	1	2	0.0519	0.3261	27.4
% Females breeding	95	85	100	−0.0029	0.2091	21.2
% Males breeding	27	17	37	0.027	0.0816	5.5
Female mortality (0–1)	35	28	48	0.049	0.2583	20.9
Female mortality (>1)	25	15	35	0.0629	0.1293	6.6
Male mortality (0–1)	35	28	48	0.0709	0.1011	3.0
Male mortality (1–2)	25	15	35	0.0935	0.2294	13.6
Male mortality (>2)	25	15	35	0.027	0.0847	5.8
Inbreeding depression[a]	3.14	0	6.14	0.1007	0.2507	15.0
Sex ratio at birth	50	40	60	0.2075	0.2464	3.9

The baseline parameter values and range of values tested (Min tested and Max tested) in a VORTEX sensitivity analysis are provided, as well as the resulting minimum and maximum growth rates (*r*) and percent (%) variance of each parameter. Results with the largest variance are most likely to affect the population viability model.

[a] Inbreeding depression expressed as lethal equivalents (*F*).

RESULTS

Observed Population Growth Rates

A growth rate (*r*) of 0.25 was required to achieve the estimated 85–90 deer in 1968. Abundance increased in the early 2000s to an estimated 12,000 deer in 2009. Overall, estimated minimum and maximum population and growth ranged between 0.147 and 0.160 (Figure 1).

VORTEX Management Scenarios

Starting with 6,000 females and 4,000 males and without hunting or control, the mean baseline growth rate (*r*) was 0.208 ± 0.001 (SE) and the population reached carrying capacity in 3 years. With annual removal of 10% of the starting population (600 female and 400 male removals), the population increased at a mean growth rate of 0.103 ± 0.001 (SE) and reached a carrying capacity at 10 years (Figure 2). By applying annual removals of 30% (1,800 females and 1,200 males the first year), the mean growth rate declined to -0.130 ± 0.004 and after 10 years the population was $2{,}759 \pm 15$ deer. After female removals of four for every male in another 30% annual removal scenario (2,200 females and 800 males the first year), the population growth rate declined sharply to -0.223 ± 0.004 and mean population of $1{,}086 \pm 6$ deer at 10 years (Figure 2). These parameter values and five scenarios of Maui's axis deer population trajectories modeled are presented in Tables 4 and 5.

VORTEX Sensitivity Analysis

Mean brood (or occurrence of twins), percent of males breeding, juvenile female mortality, and sex ratio at birth had the largest ranges of minimum and maximum growth (Figure 3), and thus the highest likelihood of affecting population growth models (Table 4).

DISCUSSION

Modeling observed population growth indicated that Maui axis deer had life history characteristics that maintained steep population growth despite the large numbers of

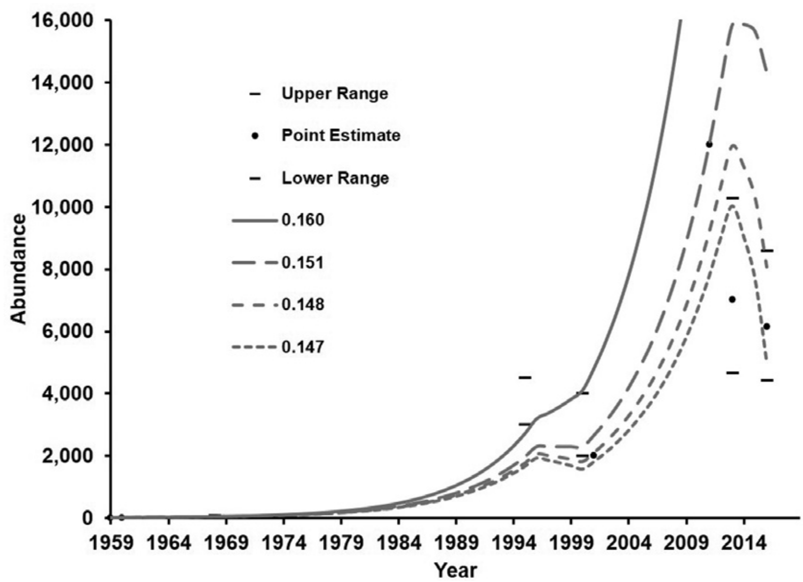

FIGURE 1. Estimated population growth (*r*) of axis deer (*Axis axis*) since their introduction to the Hawaiian island of Maui in 1959. Simple population projections were used to approximate reported abundance (*y*-axis) after accounting for removals using methods from Eberhardt (1987). Abundance and removal data are from Table 1.

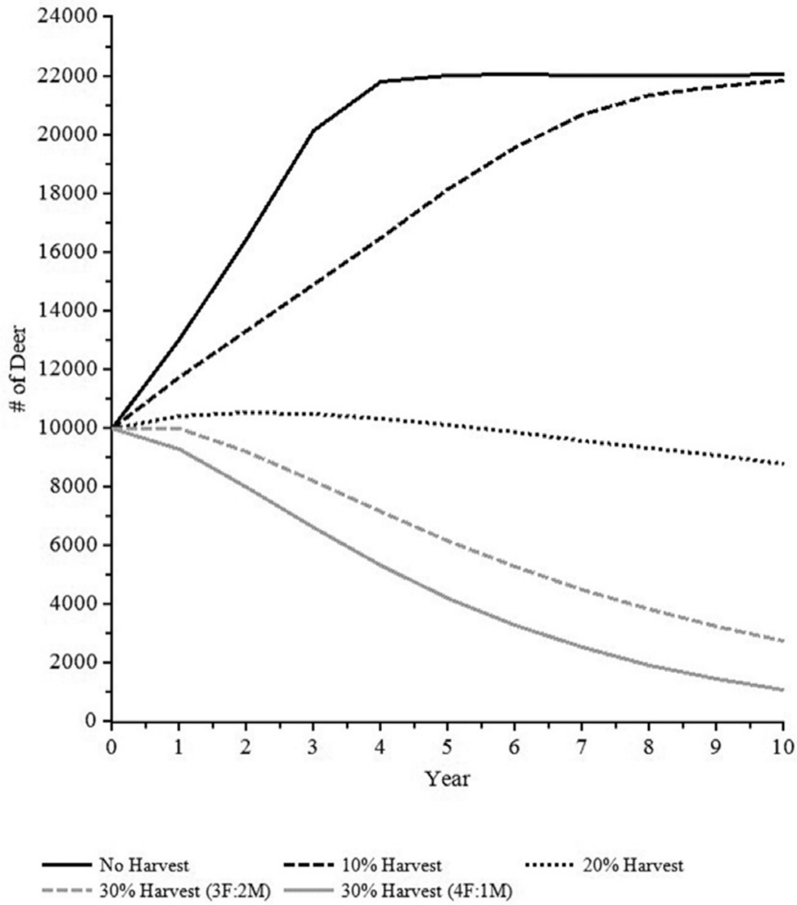

FIGURE 2. Simulated mean population growth rates of axis deer (*Axis axis*) from the Hawaiian island of Maui during four levels of removal intensity using program VORTEX. Simulations of 1,000 iterations were initialized with 10,000 individuals (6,000 females and 4,000 males). The five scenarios include projected abundance without harvest (solid black line), a population with an annual harvest of 10% and 20% the annual population estimate and two 30% harvest scenarios where three females were removed for every two males (gray dashed line) and another where four females were removed for every male (solid gray line).

TABLE 5

Mean Growth Rates of Axis Deer (*Axis axis*) on the Island of Maui Estimated in 1,000 Iterations in Program VORTEX

Annual Removal Scenario	Mean Growth Rate ± SE	Mean Population Estimate after 10 yr ± SE
No harvest	0.208 ± 0.001	Carrying capacity at 3 yr
10% harvest	0.103 ± 0.001	21,819 ± 22
20% harvest	−0.015 ± 0.003	8,786 ± 49
30% harvest (3F:2M)	−0.130 ± 0.004	2,759 ± 15
30% harvest (4F:1M)	−0.223 ± 0.004	1,086 ± 6

Scenarios include removals of 10%, 20%, and 30% the annual estimate of a starting population of 6,000 females and 4,000 males. Each scenario removed three females for every two males, except where we increased the ratio to four females for every male in the last 30% harvest scenario.

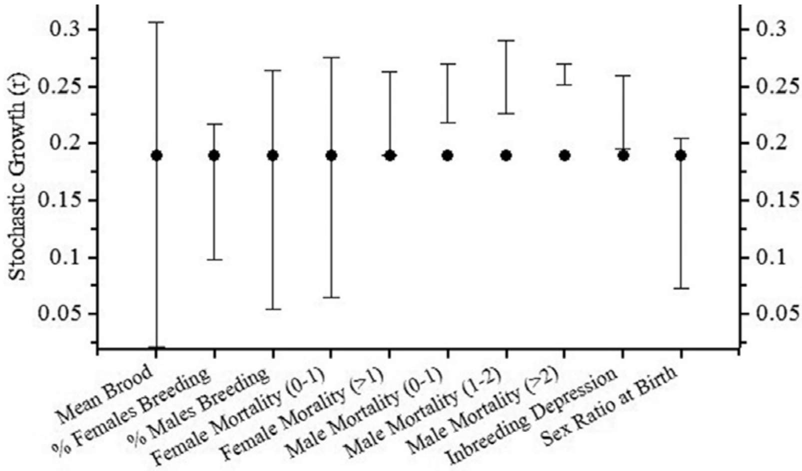

FIGURE 3. Range of stochastic growth rates of each parameter that lacked certainty modeled in a VORTEX sensitivity analysis of axis deer (*Axis axis*) on the Hawaiian island of Maui. The black dot represents the baseline scenario growth rate. Parameters with the longest lines have the greatest effect in VORTEX modeling scenarios.

animals that were removed. The growth rate (r) may have initially exceeded 0.25 if historical abundance estimates were accurate. Reproduction parameters needed to achieve this rate of growth include some combination of adult female-biased sex ratios, low female mortality, and more than occasional twinning. Data on perinatal mortality was notably lacking; however, we assumed it was low because no diseases or parasites that could affect mortality have been documented on Maui (F. Duvall, Hawai'i Division of Forestry and Wildlife, written comm.). We lacked substantive data on twinning and first-year survival, but our sensitivity analysis results corroborate that both parameters have the highest influence in our VORTEX simulations are important for actual population growth.

Deer on Maui may have initially encountered favorable habitat conditions in the absence of intraspecific competition and predation that facilitated high fecundity and survival of young animals. In our VORTEX simulations we applied a modest population density of 20 deer/km^2 to estimate a carrying capacity of 22,000 deer. However, Maui's axis deer population may reach abundances much higher than our simulations. The core population in central Maui occupies a 300 km^2 area without barriers. Densities of deer in areas of East and West Maui are higher than the core population (T. Gieder, written comm.), but those areas are smaller and separated by barriers on private and public lands. In areas of Nepal, axis deer reached densities exceeding 200/km^2 (Moe and Wegge 1994). Thus, in favorable foraging conditions without consistent hunting or culling, the Maui axis deer population could possibly reach an abundance previously undocumented and cause further economic damage and degradation of native ecosystems.

The VORTEX simulations demonstrated that reducing axis deer population growth requires a sustained and rigorous management effort of annual harvest. Reducing the population required annual removals of 30% of each annual estimate could be a challenging target for resource managers. Furthermore, our modeled time to a population reduction to approximately 1,086 in 10 years may be unrealistically rapid, because the effort to removal animals typically increases as the population declines (Gogan et al. 2001, Banko et al. 2014, Judge et al. 2017). Judge et al. (2017) monitored the eradication effort of mouflon sheep from a 65 km^2 area in Hawai'i

Volcanoes National Park from 2003 to 2017. Removals averaged 6.5 sheep/staff day but the effort expended to remove each sheep increased nearly 15-fold during the last 3 years of the program (Judge et al. 2017). Eradication was not achieved until a smaller 26 km^2 subunit was completely enclosed with fence in 2012. Similarly, population reduction of axis deer in areas of Maui may only be accomplished with a consistent effort in fence-enclosed units. Our management simulations also emphasized the importance of determining baseline abundance estimates to set ungulate management targets and set benchmarks for monitoring the success of control efforts.

Given that 95% of adult females breed at only 1 year of age emphasizes the importance of targeting females of all ages during control efforts. Because of their polygynous breeding system, removing males may not reduce productivity. Consistently biased removal of adult males was identified among the factors leading to the failure to reduce axis deer abundance in Argentina (Gürtler et al. 2017). Gogan et al. (2001) also found that simulated removals of only male axis deer and fallow deer *Dama dama* resulted in populations of both species reaching carrying capacity within a decade, whereas the removal of only females led to the eventual extirpation of both species. Some state game management agencies have implemented "earn-a-buck" programs whereby hunters were required to harvest either young or female white-tailed deer without antlers before harvesting an adult male, which has reportedly increased the harvest of female deer, improved the adult sex ratio, and proven beneficial for forest regeneration and biodiversity (Van Deelen et al. 2010, Boulanger et al. 2011).

A more common management response to overabundant ungulates is to remove all restrictions on hunting. However, unrestricted hunting may lead to a disproportionate removal of males, which are sought for trophies (Stephens et al. 2008, Hess et al. 2015). While severe reductions of either sex can ultimately cause population decreases, in practice, reducing a large proportion of either sex is exceedingly difficult as the population declines (Judge et al. 2017). In such cases, an insufficient number of male removals would likely result in a counterproductive increase in the proportion of females in a population and a consequent increase in the per capita rate of growth, whereas moderately disproportionate removals of females would be more likely to reduce abundance. Therefore, limiting male removals may be a more effective way to reduce abundance or eradicate deer populations. Regardless of whether removals are conducted individually by hunters or by culling, population reduction could be achieved more efficiently by the disproportionate removal of females. The removal of a substantial proportion of males may not only be inefficient, but also counterproductive to any population reduction goals.

Limitations of this research are due to the lack of a comprehensive understanding of total abundance and its change over time, data on the age and sex structure of the population, the proportion of pregnant females in the population, fetal sex ratio, proportion of females bearing twins, and perinatal survival. Precise estimates for the overall abundance of axis deer on Maui would be challenging and expensive to obtain given their evasive behavior and size and complexity of the island. In addition, annual removal data were variable and fragmentary, and abundance was probably underestimated in most cases by unknown amounts. These deficiencies in data most likely resulted in underestimates of overall productivity as well as the true population growth rate. Nonetheless, a repeatable index of abundance could be useful if the design were sensitive enough to reflect changes over time due to removals or mortality from periodic drought-induced starvation. Data on the age and sex structure of the population could be obtained by well-designed observational surveys that are geographically representative to capture annual changes due to recruitment and mortality events. Data on the proportion of pregnant females in the population and proportion of those bearing twins could be obtained from necropsies of animals harvested by hunters or from management removals providing that these data are representative of the entire population. Perinatal survival estimates could be obtained by comparing data from observational surveys of age and sex composition to necropsy data. A well-designed comprehensive population-monitoring scheme is important to determine if management actions result in intended effects. The sex ratio of the population within different age groups and how this relates to population change is a key parameter of any such monitoring.

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Exploring Public Support for Large-Scale Commercial Axis Deer Harvests in Maui, Hawaii

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Abstract: Commercial harvests have been effectively employed to manage wildlife populations across the world. Although commercial harvesting of the nonnative, invasive axis deer (*Axis axis*) in Maui, Hawaii, occurs at small scales and only on private lands, there is potential for large-scale implementation to be used as a population management tool. To investigate local stakeholder interest in a hypothetical, large-scale commercial harvest of axis deer, we used an online survey of individuals and businesses in Maui to analyze their attitudes towards axis deer populations and management, their experiences with axis deer, and potential to utilize axis deer venison and products, as relevant. We found evidence of public support for commercial harvesting to be employed as one of the many tools available to manage axis deer populations. Additionally, we documented support on both the supply-side and demand-side for axis deer-derived products that may be available if large-scale commercialized harvesting were implemented. We leverage these results to contribute to conversations about commercial wildlife harvesting in the United States by challenging assumptions that the practice is inconsistent with the public's perceptions of the North American Model of Wildlife Conservation and suggesting policies and programs that would ease axis deer commercial harvest growing pains.

Keywords: *Axis axis*; cervid; commercial harvest; invasive species; population management

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1. Introduction

Recreational hunting is recognized as a useful wildlife management tool contributing to livelihoods, culture, and leisure [1]. Cervid species throughout Europe and North America, in particular, have increased to the extent that recreational hunting is considered vital to achieving population management goals [1]. However, there is also acknowledgment that, in many contexts, recreational hunting alone is not enough to reduce overabundant wildlife populations. For example, Blossey et al. [2] found that recreational hunting was not sufficient to reduce white-tailed deer (*Odocoileus virginianus*) populations in central New York State, USA, nor their browse rates and associated ecological impacts (e.g., seedling depredation). This is particularly true of nonnative, invasive species that benefit from life-history characteristics that allow them to thrive in new habitats (e.g., rapid growth, high fecundity, high tolerance of a range of habitat conditions, and a lack of natural predators [3]). In these instances, recreational hunting opportunities are not adequate to control invasive species populations [4].

A variety of wildlife population control methods are used in attempts to manage overabundant population numbers (e.g., sterilization, trap and transfer, culling/

sharpshooting [2,5,6]), yet each requires financial resources that are not always available [3], unlike recreational hunting. As such, wildlife managers have explored and implemented commercial harvests as another management tool, where allowing hunters to profit from the sale of harvested wildlife creates a financial incentive for hunters to harvest beyond their personal thresholds [6]. Globally, commercial harvests have been effectively implemented to manage native wildlife populations, such as urban western gray kangaroo (*Macropus fuliginosus*) populations in southwestern Australia [7], and nonnative wildlife populations, such as red deer (*Cervus alaphus*) in New Zealand [8].

Similarly, the strategy has been utilized to attempt to control various nonnative, invasive fish species (e.g., black carp (*Mylopharyngodon piceus*), bighead carp (*Hypophthalmichthys nobilis*), and silver carp (*H. molitrix Valenciennes*)) in the United States [3]. Although commercial harvests of white-tailed deer have been discussed [2,6], the United States has yet to see the commercial harvest of any native mammals due to its perceived incompatibility with the North American Model of Wildlife Conservation (NAMWC) and associated regulations [6]. However, the commercial harvest of nonnative invasive species has the potential to operate outside of the fundamentals of the NAMWC.

Axis deer (*Axis axis*) are native to India, Nepal, Bhutan, Bangladesh, Sri Lanka, and Pakistan, where large carnivores regulate populations. In 1867, eight axis deer were introduced to the Hawaiian island of Molokai as a gift to King Kamehameha V, and without natural predators, competition, or mortality-affecting diseases/parasites [9], the population increased to nearly 7000 within 30 years [10]. Small populations were transported to other Hawaiian islands, including Maui in 1959, for the purpose of providing hunting game, and populations exploded in many of these instances, as well. Today, an estimated 50,000 deer inhabit Maui alone [11], and the deer have caused ecological and socioeconomic damage throughout the island, including the degradation of native ecosystems (due to a lack of coevolution with cervid species), over USD 1 million in damage to crops, golf courses, and ornamental gardens [9], and deer–vehicle collisions [11]. Despite their high cultural, economic, aesthetic, and recreational values as recognized by local residents and hunters in Maui and across the islands [11,12], the damage axis deer cause has prompted the governor's "30 by 30" plan to fence 30% of the state's priority watersheds by 2030 in an attempt to protect them from axis deer [11]. However, criticisms of the plan highlight problems with fencing in general; fencing can be prohibitively expensive, it is not always effective in keeping persistent deer out, and merely excludes deer from areas rather than reducing populations [11].

To encourage population control via recreational hunting, Hawaii's Department of Forestry does not restrict axis deer hunting on public lands with bag limits or seasons [9]. Further, commercial harvesting of the nonnative axis deer in Hawaii is permitted on private lands when conducted in accordance with stringent United States Department of Agriculture (USDA) oversight for food safety; but it is not legal on public lands and is currently only conducted at very small scales due to these regulations [11]. Although axis deer commercial harvesting is in its infancy, it represents a significant opportunity for population control if it is allowed to mature in scale.

A key component of exploring the large-scale viability of commercial harvesting as a population management strategy for axis deer (or other mammals) in the United States is understanding stakeholder support. Indeed, wildlife management agencies rely on surveys of stakeholders to measure preferences towards and support for population management alternatives, particularly as they relate to cervid [13] and nonnative, invasive [14] species management. However, as Lohr et al. [12] note, human dimensions research for Hawaii's terrestrial species is limited, and studies documenting stakeholder support for axis deer management alternatives are lacking. The purpose of this research was to help fill this gap and to serve as an exploratory study to investigate local stakeholder preferences for management alternatives, specifically focusing on interest in a hypothetical, large-scale commercial harvest and its subsequent axis deer-derived products. To achieve this aim, we surveyed individuals and businesses in Maui (island) and analyzed their attitudes towards axis deer populations and management, their experiences with axis deer, and the potential to utilize axis deer venison and products, as relevant. Our goal was to use these results to provide evidence of the level of local support for commercial harvests as a population control strategy and contribute to conversations about commercial wildlife harvesting in the United States by challenging assumptions that the practice is inconsistent with the public's perceptions of the NAMWC and suggesting policies and programs that would ease commercial harvest growing pains.

2. Methods

We developed two different survey instruments for this study, both of which received IRB approval (University of Delaware Human Subjects Approval # 544885-1) and resulted in data analyzed using StataBE 17 statistical software. The first instrument was designed to explore the perceptions of individuals who lived or hunted in Maui related to axis deer populations and management. The instrument included attitudinal questions about population growth and its effects on people and the environment, questions measuring preferences towards population management alternatives (e.g., fencing, trap and transfer; each of which included a brief description of the alternative), questions about perceptions of large-scale commercial harvesting as a population control strategy, and demographic questions. To reduce the length of the survey for any given respondent, respondents who indicated that they had purchased a Hawaiian hunting license within the past two years were asked about their willingness to participate in a hypothetical commercial axis deer harvest. Those who had not purchased a Hawaiian hunting license within the past two years were asked about their willingness to potentially purchase axis deer-derived goods.

We administered the survey online using Qualtrics survey software and we collected data from January through March 2014 using a combination of systematic random sample and convenience sample approaches [15], which involved dissemination over a variety of channels. First, we used the Maui Yellowbook "Business and Resident: 2014–2015" section to generate a random selection of 1000 residents. Approximately five residents per page were selected by selecting every tenth resident listed. If the tenth entry was a business, the next residential entry listed was selected. We mailed a one-page, push-to-web letter [16] to each address, which included information explaining the background and purpose of the survey and a shortened web link to the survey. Additionally, web links to the survey were published in articles in *The Maui News* and *Maui Now* local newspapers, as well as shared on the latter's Facebook page. Finally, to increase the likelihood of reaching hunter respondents, we shared the survey information and web link on multiple Maui hunting group online bulletin boards and with various hunting groups and axis deer hunting guides so they could forward it to their membership and clients. Each channel used to distribute the survey provided potential respondents with the same information regarding the purpose of the survey and research, how to complete the survey, and informed consent information.

The second instrument was designed to investigate local Maui businesses' interests in offering axis deer venison and other products that would be available should large-scale commercial harvesting be adopted as a population control strategy. Using extensive Google searches, we generated a sampling frame of locally owned and operated businesses that might be impacted by such a large-scale commercial harvest based on the products or the services the business offered. Specifically, we searched for local hunting guides, businesses in the food industry (e.g., restaurants, chefs, grocery stores, delis, meat suppliers), pet food companies, zoos/animal sanctuaries, businesses in the jewelry industry (e.g., jewelers, bead sellers/manufacturers), and leather smiths/tanners. Using the Google searches and follow-up phone calls to businesses, we generated a list of 133 viable email addresses of businesses that fit into one or more of these categories. Given the small available sampling frame, we attempted a census [15] by emailing each address with information about the study, the purpose of the research, and the link to the survey. We programmed logic into the instrument to ensure that only relevant questions were displayed based on the type of business participating in the survey. The initial email and four reminder emails were sent from September through December 2013.

3. Results

3.1. Individual Survey

A total of 180 respondents completed at least 75% of the survey and were included in data analysis. Approximately 56% of respondents were male and ages ranged from 18 to 79, with an average age of 52 years old (SD = 13.77). Most respondents (93.10%) indicated they primarily resided in Maui, whereas 3.45% lived in another Hawaiian island and the remainder lived in another US state or country. Over half of respondents (59.30%) had a bachelor's or graduate degree, 16.28% had an associate's degree, and 23.26% had a high school degree or equivalent. The majority of respondents (71.11%) owned land in Maui, with most of these respondents (83.59%) owning <1.2 ha (3 ac), 11.72% owning 1.2–4.1 ha (3–10 ac), and 4.69% owning >4.1 ha (10 ac).

Approximately 65% of respondents believed that there were a lot more deer in Maui as compared to the previous five years. An additional 17.22% of respondents believed there were a few more deer, 7.78% believed populations were about the same, 3.89% believed there were either a few less or a lot less, and 6.67% were unsure. Along with a perception of the increased axis deer population, there also was an accompanying perception of damage. A total of 29.13% of landowners had experienced damage from axis deer on their property, where 19.69% of landowners had experienced landscaping/yard damage, 13.39% experienced agricultural damage, 11.02% experienced damage to personal gardens, 3.15% had fencing damaged, and 1.57% experienced competition for forage in their cattle pastures.

In response to the perceptions of increased populations and damage, 42.22% of respondents indicated the axis deer population should be greatly decreased, 32.22% believed the population should be decreased, and 20.00% believe it should stay the same. Of note, no respondents indicated axis deer populations should be greatly increased, 2.78% believed they should increase, and 2.78% were unsure. Recreational hunting was the most supported management alternative, on average, with commercial harvesting and fencing also garnering support (Table 1). On average, respondents were neutral regarding support for the remaining alternatives, although the prospect of not taking any management action was not supported. We then specifically asked about concerns regarding the potential for large-scale commercial axis deer harvesting as a population management strategy and 34.27% did not foresee any problems, 42.70% foresaw few and/or minor problems, 18.54% of respondents indicated they foresaw many and/or serious problems with this strategy, and 4.49% were unsure.

Of the 45 respondents who indicated they had purchased a Hawaiian hunting license within the past two years, 71.11% only or primarily hunted axis deer, 17.78% occasionally hunted axis deer but mostly hunted other species, and 11.11% had never hunted axis deer. Greater than a third of respondents who had hunted axis deer (37.50%) spent over 100 days within the past two years hunting axis deer. Approximately 23% had hunted between one and 39 days within the past two years, 20.00% had spent 40 to 99 days, and 20.00% were unsure. Nearly half (46.15%) of hunter respondents indicated they would be interested in participating in a commercial axis deer harvest, 38.46% indicated they might be interested, and 15.38% were not interested. More than half of hunter respondents indicated their hunting behavior would change if they could sell axis deer meat they had harvested, with 27.50% indicating they would hunt much more often and 25.00% indicating they would hunt a little more often. Nearly a third (32.50%) indicated their behavior would not change, whereas 5.00% said they would hunt much less and 10.00% were unsure. Approximately 35% of hunter respondents strongly agreed or agreed they would benefit from being able to sell harvest axis deer meat, whereas 32.50% neither agreed nor disagreed, 5.00% disagreed or strongly disagreed, and 10.00% were unsure.

Table 1. Support for management actions of axis deer among respondents of the individual survey, in Maui Island, Hawaii, USA, 2014.

		Percentage of Response (%)					
	Mean	**Completely Support (1)**	**(2)**	**Neutral (3)**	**(4)**	**Do Not Support at All (5)**	***n***
Recreational hunting	1.59	76.00	8.57	4.57	2.29	8.57	175
Commercial harvesting	2.10	54.29	16.00	9.14	6.29	14.29	175
Fencing	2.13	51.15	13.22	17.82	7.47	10.34	174
Hired sharpshooting	2.84	34.69	10.98	16.76	10.40	27.17	173
Contraceptives	2.96	34.88	5.23	20.35	8.14	31.40	172
Trap and transfer	3.10	32.56	7.56	13.95	9.30	36.63	172
Take no management action	4.26	7.74	4.17	11.90	6.55	69.64	168

Of the 128 non-hunter respondents, 71.88% indicated they would be interested in purchasing axis deer meat at the store and/or as a dish in a restaurant. Similarly, 68.63% of non-hunter respondents who owned pets (n = 102) were interested in purchasing pet food or treats (e.g., axis deer bones, antlers, or hooves as chew toys) made from axis deer meat/parts. Approximately 47% of non-hunter respondents who wore jewelry (n = 86) were interested in purchasing jewelry made from axis deer antler beads.

3.2. Business Survey

Of the 133 businesses in our sampling frame, 22 completed the survey (Table 2), representing a response rate of 16.54%. Four hunting guides responded, two of whom served as part-time hunting guides mostly for novice bowhunters and two of whom worked as guides as their main source of income. All four guides noted that they did not believe current customers' behaviors would change if hunters could sell the axis deer meat they harvested; however, two indicated that they might see a small increase in new customers (i.e., hunters who had never hunted with a guide before), whereas the other two did not believe they would see any change in new customers. When asked about concerns regarding the potential for large-scale commercial axis deer harvesting as a population management strategy, two did not foresee any problems. One guide foresaw a few and/or minor problems, citing access to deer herds as a potential issue, and another guide foresaw many and/or serious problems, noting that "illegal poaching and liability would heavily increase on private land, which would be a safety issue". Similarly, when asked about their (dis)agreement regarding if businesses would benefit from customers being able to sell their harvested venison, one strongly agreed they would benefit, one agreed, one neither agreed nor disagreed, and one disagreed, citing the potential for poaching as a problem.

Table 2. Survey responses from businesses in Maui Island, Hawaii, USA, 2013.

	Number Contacted	**Number Responded**
Hunting guide	6	4
Restaurant/catering industry	19	9
Grocery store/deli	39	1
Meat supplier	5	2
Zoo/animal sanctuary	2	1
Pet food company	11	2
Jewelry industry	50	3
Leather smith/tanner	1	0
Total	133	22

Nine respondents categorized themselves as some combination of a restaurant, café, catering business, and/or personal chef. All of these respondents answered that they cater to customers preferring local and organic products and none of these respondents currently offer venison products or dishes. All but one respondent indicated they would be interested in offering axis deer venison products or dishes, where the exception was a vegan restaurant. Of those interested in offering axis deer venison, five indicated this was due to the added benefit of helping to control deer populations and three indicated this was unrelated to the overpopulation problem.

One grocery store responded to the survey, indicating they cater to customers who prefer to buy local and organic products. Although the store did not sell venison at present, the respondent answered they would be interested in selling ground axis deer venison in the future, particularly due to the added benefit of helping to control deer populations. Two businesses described themselves as meat suppliers, where only one indicated they cater to customers preferring local and organic products. One supplier noted they would be interested in buying axis deer venison because they carried farmed New Zealand venison, although it was not a top-selling item. This respondent was interested in axis deer venison because "a local, wild product would have a lot more customer interest". The other meat supplier indicated they were not interested in supplying axis deer venison due to a perceived lack of demand.

Two pet food companies responded, both indicating they cater to pet owners looking for organic and local pet food. They both noted an interest in buying axis deer meat or parts for their food/treats. One respondent was interested in buying axis deer meat, meaty bones, bones stripped of meat, antlers, hooves, livers, and hearts, whereas the other stated they would have to explore which deer parts were marketable but was not interested in including axis deer bones stripped of meat or antlers in their product line. Similarly, the one respondent from a zoo/animal sanctuary indicated they currently purchase beef and chicken for their five carnivorous bird species, but would only potentially be interested in purchasing axis deer meat for their tiger "if the price were substantially cheaper than beef or chicken and if the meat was inspected". The respondent indicated the zoo was not interested in buying carcasses, meaty bones, bones, antlers, hooves, or other axis deer parts.

Two jewelry makers responded to the survey, both of whom stated their customers are predominantly from US states other than Hawaii. One indicated that, although they do not often use beads in their jewelry, they would be interested in using axis deer antler beads because cattle bone beads carved in traditional Polynesian designs tend to be very popular. This respondent was also interested in selling packages of pre-made axis deer antler beads. The other jewelry maker respondent was not interested in making jewelry from axis deer antler beads nor selling packages of beads due to a perceived lack of demand. One bead seller/manufacturer responded indicated they would be interested in selling packages of pre-made axis deer antler beads but did not have the equipment to create beads if given axis deer antlers.

4. Discussion

Our findings provide two key takeaways regarding the potential to use large-scale commercial axis deer harvesting as a population management strategy. First, we provide evidence that there is public support for commercial harvesting to be employed as one of the many tools available to manage axis deer populations. Our results mimicked patterns found in public perceptions of white-tailed deer population control studies, where recreational hunting is the most preferred management alternative, but additional alternatives (e.g., sharpshooting) are often supported when recreational hunting alone cannot achieve population goals [17,18]. In fact, our study found that commercial harvesting was more supported than hired sharpshooting in this context. Second, we documented support on both the supply-side and demand-side for axis deer-derived products that may be available if large-scale commercialized harvesting were implemented. As VerCauteren et al. [6] note, commercial harvests are only feasible if there is a demand for markets to exist for deer products. Notably, recent research has linked novice hunter interest in obtaining local food and game meat to the growing "locavore" movement [19], and our study offers an initial indication that Maui consumers may share this interest in local organic meat and products. Due to the exploratory nature and age of this research and associated methodology, we recognize that these results are not necessarily representative of the populations discussed, although axis deer populations have continued to increase in the time between the survey was conducted and present. The small sample size and response biases, particularly from the convenience sample, may limit the generalizability of our survey findings [15], but we contend that the data collected achieves the purpose of this study in serving as an exploration of previously unstudied local stakeholder preferences and attitudes.

More generally, this study contributes to the limited literature regarding commercial harvest as a wildlife population control strategy, particularly in a United States setting. Although the NAMWC expressly prohibits commercial markets for game as a direct reaction to the unsustainable harvest and decimation of wildlife populations due to market hunting, there have been arguments that the NAMWC paradigm must be amended to account for new realities [6,20]. Furthermore, there is also a recognition that the NAMWC has always allowed for exceptions, including exceptions of the elimination of commercial markets for wildlife, as fur markets, commercial fisheries, and captive cervid breeding all exist today within the NAMWC [20].

We argue that developing the necessary policies and programs to feasibly implement a large-scale commercial harvest of axis deer in Maui would be an ideal case to pilot commercial harvesting for cervid population control in the United States as the jurisdiction is geographically contained and public support for population control is likely greater for such an invasive, nonnative species, as compared to native species. Currently, food safety regulations and associated logistics are the greatest hurdles to a large-scale commercial harvest. The few, small-scale commercial harvest operations in Maui must report straight to the USDA as Hawaii does not have a meat inspection service [11]. Thus, for each harvest, a USDA inspector must accompany the harvester and examine each deer prior to harvest. Successful harvesting can only involve a single shot to the skull, rendering the deer immediately unconscious [11]. Furthermore, the lack of state resources available to inspect and approve game meat processors means that the harvester must bear the burden of providing processing as well [11].

Hawaii must allow for creative solutions to these regulatory issues while still ensuring food safety. As VerCauteren et al. [6] suggest, proof of proficiency and training in harvest techniques and proper handling of meat in the field could be provided by all who aim to participate in commercial harvesting as a way to avoid the cost of hiring a USDA inspector each harvest. A plan of work with a private meat-processing facility with proper food safety oversight would also be necessary [6], or Hawaii could modify the strategy employed by other states that have successfully developed public–private partnerships between deer processors and recreational hunters seeking to donate their venison [11]. Alternatively, a small fleet of mobile game abattoirs could be funded by the state and made available for rent. These mobile game meat abattoirs are gaining popularity in South Africa as an effective way to safely process game meat in the field during excess game culling operations on private wildlife ranches [21]. By allowing for innovative approaches to comply with food safety regulations, Hawaii can simultaneously and more effectively control invasive species that cause negative human–wildlife interactions and ecological damage and provide residents with a sustainable supply of locally sourced protein and other organic products.

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