Identifying & Prioritizing Marking Methods for Non-Surgically Sterilized Cats & Dogs Scientific Think Tank

May 16-18, 2013
Phoenix, AZ

Overview

On May 16-18, 2013, the Alliance for Contraception in Cats & Dogs (ACC&D) convened a Think Tank on identifying and prioritizing marking methods for non-surgically sterilized cats and dogs. The meeting was held in Phoenix, Arizona, with financial support from PetSmart Charities. ACC&D undertook this initiative in response to the growing need for a means to identify animals who have been treated with a non-surgical sterilant or long-term contraceptive. The Think Tank focused on cats and dogs, particularly free-roaming populations, who have undergone non-surgical interventions. However, the value is not limited to these animals—improved marking methods could have benefits for surgically sterilized animals as well.

The mission of ACC&D is to expedite the successful introduction and to support the distribution and promotion of non-surgical methods to sterilize cats and dogs. ACC&D's vision is to reduce animal death and suffering worldwide by enhancing the tools available to humanely control their populations. Non-surgical approaches can be less expensive, less labor-intensive, and require shorter recovery times than surgery, allowing more animals to be treated quickly and safely.

We gratefully acknowledge PetSmart Charities for sponsoring this Think Tank.

This was ACC&D's fifth scientific Think Tank. Prior Think Tanks have addressed:

- Population modeling as a tool to guide the design and implementation of contraceptive approaches to best achieve stabilization or reduction of population size
- Delivery technologies that could be used to precisely control administration of slow-release, timed-release, or multi-dose treatments
- Methods to improve immunocontraceptive vaccines for sterilization of dogs and cats
- Gene silencing and immunocontraception as research areas with promise for achieving the goal of a non-surgical sterilant

The marking methods Think Tank sought to identify the most promising near-term and long-term methods to mark animals treated with a non-surgical sterilant. Towards this end, ACC&D convened experts from diverse fields, each invited for his or her capacity to contribute varied and valuable insights on the challenge. Experts in population and wildlife biology, dog and cat reproductive biology, software and database design, and animal identification technologies such as radio frequency identification (RFID) joined individuals experienced in vaccination and sterilization initiatives of free-roaming cats and dogs for this Think Tank. Experts in invention and innovation were also involved as participants and facilitators.

ACC&D
Alliance for Contraception in CATS & DOGS

Attendees

Foundation and Nonprofit Representatives:

(See "Resources and Symposia" at www.acc-d.org for bios of participants.)

*Joyce Briggs, MS	President, Alliance for Contraception in Cat & Dogs, Portland, OR
*Valerie Benka, MS, MPP	Project Manager, Alliance for Contraception in Cat & Dogs, Portland, OR

Scientific and Expert Panel:

*John Boone, PhD	Senior Biologist, Great Basin Bird Observatory, Board of Directors, SPCA of Northern Nevada
Kelly Coladarci, CVT	Program Manager, Humane Society International
Bruce Earnest	ASPCA Field Responder - Consultant
*Amy Fischer, PhD	Teaching Associate and Extension Specialist, Department of Animal Sciences, University of Illinois
John Friar	Founder, Wise Monkey Foundation
Stan Gehrt, PhD	Associate Professor and Wildlife Extension Specialist, School of Environment and Natural Resources, The Ohio State University
Michelle Kutzler, DVM, PhD	Associate Professor of Companion Animal Industries, Department of Animal and Rangeland Sciences, Oregon State University
*Cynthia Mills, DVM, MPH	Veterinarian and Science Writer
Anne Olscher	Co-founder, Animal ID Solutions, Inc.
Gene Pancheri	Proctor & Gamble Research Fellow (retired), winner, InnoCentive challenge
William Perlman	Inventor and Technology Consultant, runner-up, InnoCentive challenge
Sheilah Robertson, BVMS, PhD	Assistant Director, Animal Welfare Division, AVMA
Aileen L. Walden	Director of Community Programs and Support, Alley Cat Allies

Dorian Simpson, Managing Director of Planning Innovations Group, facilitated the meeting supported by Ed de la Fuente (co-founder of Planning Innovations Group). They collaborated with Think Tank planning committee members to design the event agenda.

*Denotes planning committee members.

Background

Overview of the Challenge

ACC&D seeks to advance and expedite the introduction of safe and effective alternatives to surgical sterilization for animal populations. Alternatives to surgery could become a key tool for managing populations of cats and dogs seeking adoptive homes, controlling populations of free-roaming dogs internationally, and enhancing trap, neuter, return (TNR) programs for feral cats. Other key U.S. markets for non-surgical alternatives include low-income families for whom surgical sterilization is a financial burden, and pet owners who oppose surgery but do not object to sterilization of their pet.

In 2011, approximately 78% of owned dogs and 88% of owned cats were spayed or neutered in the United States.[1] However, less than 3% of the un-owned cats in the United States are sterilized.[2] This leads to large numbers of kittens entering shelters every year, and large numbers of free-roaming cats either left in communities or euthanized in shelters. Consequently, in the United States, controlling feral or free-roaming cat populations is a key goal.

Free-roaming dog populations present a public health risk in many parts of the world, where dog bites are the overwhelming source of human rabies cases and dogs are often feared as a result.[3] Controlling loosely owned, community, and stray dog populations is difficult in countries where a lack of trained small animal veterinarians, insufficient funding, and sometimes social and cultural attitudes result in a relatively low percentage of the dog population receiving surgical sterilization.

Since ACC&D began efforts to advance development and introduction of non-surgical sterilization methods, an important question has been how treated animals will be recognized when there may be no physically visible indicators of treatment. The need for a method to mark treated animals has become increasingly necessary as non-surgical contraceptive and sterilization methods, including Suprelorin® and Zeuterin™/EsterilSol™ are now available in some countries, and other technologies are being tested in the field.[4] Joyce Briggs, ACC&D President, described a Canadian program studying the use of Suprelorin implants in female dogs. The researchers implant microchips in the dogs to provide individual identifying information and use index cards with photographs of each dog to identify individuals in the field from a distance. This system highlights the unmet need for an identification method that can be applied to a large population; identify animals in poor lighting or other conditions where visual recognition would be difficult; or be effective when multiple personnel, who may have different levels of familiarity with the animal population in question, are involved in identification efforts.

Such a marking method could have applications beyond non-surgical sterilization. It was pointed out during the Think Tank that certain spay surgery approaches (both flank and midline, including laparoscopic techniques) may yield scars that are very small and nearly impossible to see under fur. Therefore, surgical-based population control programs could also benefit from development of a safe and clearly visible marking method.

ACC&D Marking Think Tank Participants

[1] American Pet Products Association 2011-2012 National Pet Owners Survey

[2] Wallace JL and Levy JK. Population characteristics of feral cats admitted to seven trap-neuter-return programs in the United States. 2006. *J Feline Med Surg*. 8(4):279-284..

[3] Human rabies. World Health Organization website (http://www.who.int/rabies/human/en/), accessed July 5, 2013.

[4] A non-surgical sterilant by definition yields permanent sterility. Non-surgical contraceptives are *not* permanent; they vary in the length of time they render an animal unable to reproduce.

Prior ACC&D Efforts in the Area of Animal Marking

As a first step to addressing this marking challenge, ACC&D reviewed current methods used to mark, identify, and/or track animals, including wildlife and livestock. The chief uses of each method were summarized, as well as the pros and cons related to the application of each method to cats and dogs. Pain associated with application and/or requirement for sedation or anesthesia, ease of application, ease of detection, and expense were evaluated for each method. This overview of existing options helped define the desired characteristics of a method for use in marking non-surgically sterilized cats and dogs, and provided a foundation for ACC&D's venture into identifying and encouraging the development of new methods.

In the interest of eliciting novel ideas for marking cats and dogs, ACC&D, with funding from Dr. Amy Fischer, initiated an InnoCentive Brainstorm Challenge,[5] "Marking methods to identify contracepted/sterilized cats and dogs," early in 2013. Seventy-four solvers submitted a total of 99 solutions, from which a winner and a runner-up were selected in each of two categories: a marking method with potential to be brought to use in the near term, and a marking method of great interest which might not be fully realized until a future time because it requires additional technologic development. (The winner and runner up from the longer-horizon solution category both graciously volunteered their time to participate in the Think Tank.)

Anne Olscher (Animal ID Solutions) at Think Tank

The ACC&D Marking Project Team developed a set of criteria upon which the InnoCentive proposals were judged. A first round of review sorted the proposals based on thoughtfulness, innovation, and practicality. The top proposals were then ranked based on a list of seven more-detailed criteria that were derived by group consensus after each member of the Marking Project Team had ranked the criteria based on their own experience and priorities.

These events, each very valuable in its own right, also served as important steps prior to the Think Tank. Participants in the Think Tank were provided with the InnoCentive criteria as a foundation upon which they could build when brainstorming new ideas and evaluating potential marking methods. Further refinement of the InnoCentive criteria that took place during the Think Tank can be found in this summary under "Marking Methods Criteria," and a spreadsheet with the final criteria and parameters is located in Appendix A. Participants also received copies of the winning and highest contender proposals to review before the Think Tank. A summary of the proposals received in response to the InnoCentive challenge can be found in Appendix B, and copies of the winning and top-contending proposals can be found in Appendix C.

As background for the Think Tank, participants were also provided with the marking method summary prepared by ACC&D (available for download from the ACC&D website) as well as a summary of animal marking methods prepared by the World Society for the Protection of Animals, materials describing freeze branding and types of ear tags, and an overview of options currently available for anesthetizing or sedating animals.

Topics of Discussion

The Goal

To kick off discussion at the Think Tank, facilitator Dorian Simpson reviewed its goals with the panel:

- Identifying marking methods that would be useful in the near term as well as those with potential but which may not be available until further in the future
- Preliminary identification of design parameters for studies to evaluate marking methods
- Preliminary identification of partners who could assist in the development, testing, or deployment of marking techniques

[5] "InnoCentive is the global leader in crowdsourcing innovation problems to the world's smartest people who compete to provide ideas and solutions to important business, social, policy, scientific, and technical challenges." From the InnoCentive website, www.innocentive.com/about-innocentive. Accessed June 14, 2013.

- Building consensus between scientific and animal welfare leaders

It is important to note that ideas discussed during the Think Tank are not expected to be an end point. Rather, ACC&D held the meeting with the hope that the ideas generated could serve as a foundation for further research and initiatives. (Please see recommendations for next steps on page 18 of this Think Tank outcome report.)

Introductory Discussion

Given the diverse background and expertise of participants, the Think Tank began with some preliminary questions and discussion to bring everyone to a common understanding of what ACC&D wishes to achieve and why. This introductory session entailed discussion of three important and relevant topics:

- Free-roaming cat and dog population demographics
- Expectations and requirements for visual identification of a "marked" animal, and the potential value of a hierarchy of solutions
- What marking mechanisms are currently in place, including their pros and cons.

Each of these topics is addressed below.

Population Dynamics

Canine and feline population dynamics, and effective strategies to manage the size of a given population of animals, are important backdrops to the discussion of marking and monitoring. Key considerations:

- Continued attention is required to maintain or reduce population size; periodic concentrated efforts are less successful
- To reduce the size of a canine or feline population, at least 70% of the population in question must be *maintained* as non-reproductive

Gene Pancheri posed the question of what percentage of animals in a population need to be sterilized to have an effect on population size. As one example, if it were possible to sterilize the appropriate number of animals, and if the population was known to turn over in three years, then a long-lasting mark would not be necessary; the approach would be to sterilize the required percentage of animals every three years. This has implications for marking strategy; such a scenario would simply require a mark that lasted long enough so that animals could be counted during an intensive, short-term sterilization campaign, making it possible to determine if the quota of sterilized animals was reached.

Cynthia Mills and Sheilah Robertson reported that current understanding predicts that a sterilization rate of at least 70% of a population must be *maintained* to begin to reduce population size.[6] Michelle Kutzler additionally explained that there are generally insufficient resources to achieve and maintain a 70% sterilization rate in a given population in one campaign. Cynthia Mills added that the every-three-year approach has been tried and it does not work; more continuous action is necessary. There are multiple reasons for this, including reproduction within the community stemming from animals that were not sterilized, as well as immigration of new fertile animals into a given community.

Expectations for Visibility, and the Potential Value of a Hierarchy of Solutions

A question about expectations for visibility led to discussion of exactly what the team meant by the term "visible," as well as the potential for a tiered system of solutions. Key points of discussion and resolution are as follows:

- The mark should be visible by eye and ideally, technology will not be required to read or interpret the mark
- A layered system in which additional complexity is incorporated where greater technology is available could be desirable

[6] ACC&D convened a scientific Think Tank in 2011 to investigate how field studies and computer modeling approaches adopted from wildlife biology might be applied to cat and dog population management programs. The outcomes of the Think Tank are available at the ACC&D website (http://www.acc-d.org/ThinkTanks). This Think Tank led to an ACC&D-led initiative that utilized Vortex Population Viability Analysis (PVA) software to model free-roaming cat population outcomes following multiple different interventions in varied geographies. Findings and resulting population management guidance were presented at ACC&D's 5th International Symposium on Non-Surgical Contraceptive Methods of Pet Population Control in June 2013. More information on Vortex PVA software can be found here: http://www.cbsg.org/our-approach/science-based-tools/vortex.

- A hierarchy of solutions is needed, with basic physical marking plus the potential to add more complexity and collect additional information where need dictates and resources allow

William Perlman asked if the team believed it would be necessary to see the mark at all times, or if it could be visible under certain situations, such as a tattoo visible only when illuminated with a certain wavelength of light. This question yielded various responses, propositions, and insights. Anne Olscher noted that with RFID tags, information about tagged animals could be collected by placing a reader in a portal through which the animals travel. In this scenario, the "mark" or tag would not need to be continuously visible, but only to be read when the animal passed through the portal. Michelle Kutzler thought this could work well with a feeding station. Cynthia Mills pointed out that for population management programs, being able to identify and count the animals visually would be most useful.

Dorian Simpson then asked whether the mark needed to be visible by eye, or if a simple device such as binoculars would be acceptable.

Photo Card Recognition – photo courtesy of & © Evocative Photography

Though it might be acceptable for persons working with a population management program to use a device to augment or in lieu of the human eye, Aileen Walden suggested that in most locales it would add value for the mark to be easily visible and understandable to community residents. Kelly Coladarci pointed out that dependence on technology would be risky in some parts of the world where access to replacement parts is difficult. She added that the simpler the methodology, the greater the probability of adherence. Sheilah Robertson agreed, noting that technological failure could be disastrous in remote areas, and it would be best to focus on methods that are not technology-dependent.

Joyce Briggs suggested a layered system, where more complexity could be used where more resources were available. A more complex system would yield more information about an animal, but the expectation would be that basic data could be gleaned from even the simplest and least expensive form of the marking system.

Evaluation of Marking Methods in Present Use

The introductory session included discussion of positive and negative features of the following identification methods commonly used today: ear tipping and notching, collars, ear tags, and tattoos.

As a starting point, Joyce Briggs suggested discussing and evaluating the aforementioned marking methods currently in use by surgery-based programs, including how well they meet identification needs and their applicability when treatment is non-surgical. Surgery-based programs include TNVR (trap, neuter, vaccinate, return), ABC/AR (animal birth control/anti-rabies), and CNVR (catch, neuter, vaccinate, release) programs.[7] She noted that there are resources available[8,9] but also questioned whether the field would benefit from additional guidance on best practices or recommended standards for existing, commonly used methods.

[7] Though varied in their names and specific strategies and details, there is consistency among these programs in that they include capturing free-roaming animals (via humane trap, net, or direct handling), *surgically* sterilizing the animal, sometimes vaccinating the animals against rabies, deworming the animal, treating basic health issues (eg, ear mites, ticks), and returning the animal to the location in which it was captured. At the time of this report, we are not aware of any program that relies on non-surgical contraceptive/sterilization with the exception of limited field-testing of potential non-surgical options for free-roaming animals.

[8] The Association of Shelter Veterinarians veterinary medical care guidelines for spay-neuter programs. Vet Med Today Special Report. 2008. *J Am Vet Med Assoc*. 233(1): 74-86.

[9] Identification methods for cats and dogs. Guidance for WSPA staff and member societies. Available for download from: http://www.icam-coalition.org/downloads/Identification%20methods%20for%20dogs%20and%20cats.pdf. Accessed June 10, 2013.

Ear Tipping and Notching

Around the globe, ear tipping is frequently used to mark surgically sterilized cats; ear notching is also used to a much lesser extent. In regions with free-roaming dog populations, ear notching is sometimes performed on canines to identify those who have been surgically sterilized. These marking methods have definite strengths: they are permanent, highly visible, low-cost, and, with education, easily understood by the community. They also have potential shortcomings, however. At times the marks may be difficult to differentiate from other types of ear damage. For example, Bruce Earnest and Sheilah Robertson pointed out that in very cold climates, feral cats frequently have frostbitten ears, rendering ear tipping less useful as definitive identification. Also, ear tipping can be seen as disfiguring by the public, and Kelly Coladarci related an experience during a clinic in which a community member became very upset by ear tipping and requested that a cat's ear be surgically repaired. She also noted that ear tipping of dogs can be associated with an increased incidence of fly strike, which is a significant problem in some parts of the world. Ear tipping and notching must be conducted under anesthesia, a difficulty for programs using non-surgical methods that ideally will not otherwise require anesthesia.

Example of Ear Tipping

John Boone additionally pointed out that ear tipping provides only yes/no information about whether a cat has been sterilized, and might not communicate all the information needed or desired for a non-surgical contraceptive or sterilization program.

Collars

For free-roaming and owned dogs, collars are often used as a means of identification. Collars are very easily seen and can communicate information through the use of color or pattern on the collar itself or by attaching tags to the collar. However, collars cannot be used on young animals without supervision since as the animal grows, the size of the collar must be adjusted. There is some concern that animals, especially cats, may be injured if the collar is caught on an object. Also, collars are easily removed, and Kelly Coladarci and John Friar related anecdotes from the field of people removing collars from treated animals or transferring collars from treated to untreated animals. For an animal sterilized via a non-surgical method that leaves no outward sign of treatment, something less easily removed than a collar might be preferred.

Ear Tags

Ear tags have been used to a limited extent in dogs. Ear tags are highly visible and can communicate information through color or numbers printed on the tag. However, tags can be lost, and dogs and cats can self-mutilate trying to remove a tag that irritates the ear.

Example of Ear Tag

Infection following tagging may also be of concern. Additionally, ear tags may not provide a uniform solution since different styles of tag may be needed for different ear types (large vs small, prick vs floppy, etc). As is true for ear tipping, ear tag application may require anesthesia, which is a downside if anesthesia would otherwise not be required in a non-surgical sterilization/contraception campaign.

Tattoos

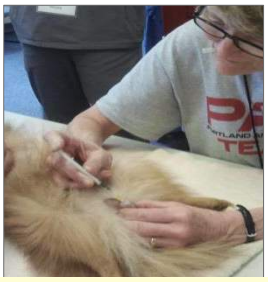
Tattoos have been used to identify cats and dogs for decades. Currently tattoos are used to identify sterilized animals. A "Z" (or sideways "N" for neutered) is tattooed in the groin area of a dog treated with Zeuterin, and green tattoo ink is often placed in the incision line, on either side of the incision line, or in the groin area of female cats and dogs at the time of spay. Tattoos have the advantage of being semi-permanent, low-cost, and capable of incorporating codes to allow identification of individual animals. However, like the previously described marking mechanisms currently in practice, tattoos also present challenges. Tattoos can be difficult to see, depending on the location of the tattoo on the body and on color and type of fur present. Bruce Earnest questioned whether there is a way to increase the

visibility of tattoos through the use of bright or reflective ink. William Perlman reported that some people obtain UV ink tattoos that glow under backlight, but Michelle Kutzler pointed out that this fluorescence would be quenched with exposure to sunlight. Also, application of tattoos can be painful; Sheilah Robertson referenced a study which found that ear tattoos in rabbits are painful[10] and should be conducted with topical anesthetic, which would require restraining the animal and waiting 5-30 minutes for the anesthetic to take effect. Kelly Coladarci suggested that sedation may be sufficient for tattoo application, and that line blocks might be an effective approach to manage localized pain.

With this discussion as background, Joyce Briggs presented two scenarios each for dogs and for cats in which ACC&D feels new marking strategies are needed and around which the Think Tank participants would develop their recommendations.

ACC&D Scenarios of Greatest Need

Dog Scenarios



Non-Surgical Sterilization

For dogs, the two scenarios involved (1) a permanent non-surgical sterilant (such as Zeuterin/EsterilSol, which is injected intratesticularly, or an agent yet to be determined and used for male and/or female dogs), and (2) a long-lasting contraceptive (such as a GnRH vaccine, Suprelorin, or an agent yet to be determined), most likely injectable vs. oral, that could have either a predictable or a variable length of contraception.

The goal was to have a contraceptive duration of 3 years, but it was noted that a one-year duration was more likely to be achievable in the short term.

Both scenarios assumed a government- or NGO (non-governmental organization)-run program targeting a population of loosely owned dogs, likely in the context of a rabies and/or population control program. An additional important consideration was that such programs have varied access to technology.

In the target populations of loosely owned dogs, it was expected that some animals could be handled while others would require capture and sedation. While a veterinarian or veterinary technician/para-veterinarian might be available for some type of fertility control treatments, it was assumed that in some situations trained volunteers with minimal veterinary skills would apply the mark.

The mark would need to be read and recognized by those involved with the program, but there might also be a benefit/need to have it be recognized by members of the general population. It was also important that the marking method and mark be acceptable to the local community and possible future owners.

Cat Scenarios

For cats the two scenarios also concerned (1) a permanent contraceptive delivered via injection (such as the intratesticular injection Zeuterin/EsterilSol or a new product to be determined that might be injected elsewhere), and (2) a long-term contraceptive, of either one-year duration or meeting the goal of 3 to 5 years of duration. It was noted that a laboratory study of GonaCon™ in cats has shown variable response ranging from 1 to 5 years (average of 2.5 years) and another study has shown that GonaCon elicits a shorter and weaker response in males than females.[12] (Michelle Kutzler reported that she has observed the same in dogs and other species using the GnRH vaccine labeled for dogs and formerly available commercially from Pfizer). With such differential responses, a mark that could communicate treatment date would provide helpful

Trapping a feral cat

[10] Keating SCJ, Thomas AA, Flecknell PA, Leach MC. Evaluation of EMLA cream for preventing pain during tattooing of rabbits: changes in physiological, behavioural and facial expression responses. 2012. *PloS ONE*. 7(9):e44437. Doi:10.1371/journal.pone.0044437.

[11] Levy JK, Friary JA, Miller, LA, Tucker SJ, Fagerstone, KA. Long-term fertility control in female cats with GonaCon™, a GnRH immunocontraceptive. 2011. *Theriogenology*. 76(8):1517-1525.

[12] Levy JK, Miller LA, Crawford PC, et al. GnRH immunocontraception of male cats. 2004. *Theriogenology*. 62(6):1116-1130.

information for measuring treatment impact in the field and/or determining when to retreat an animal.

Both scenarios assumed the cats would be feral or at least refractory to handling, requiring that the treatment be administered in the field while the cat is restrained in a trap and ideally not requiring sedation. The option of transporting the cats to a surgical facility for treatment and marking was posed to the group. This was considered much less desirable than treating in the field due to both the stress and costs/resources associated with transport and use of a facility.

Both scenarios assumed animals would be treated and marked as part of a TNR program. Though such programs occur worldwide, initial focus would be on the United States, Europe, or island communities. The mark would likely be read by a trained individual involved in monitoring a cat colony and responsible for determining whether an animal needs to be trapped and treated. As in the dog scenario, the marking method and resulting mark would need to be acceptable to the local community and potential future owners.

The cat scenarios are far more typical in the U.S., while dog scenarios are more applicable internationally.

Marking Method Criteria

The panel was presented with the criteria against which the InnoCentive proposals were evaluated; panel members were asked to further refine the minimal required and ideal parameters for each criterion based on their own experience. A table containing the final criteria can be found in Appendix A.

Visibility

Minimum requirement: The mark must convey the information needed to a) avoid accidentally retreating an animal who was non-surgically sterilized, or b) identify when retreatment would be required for a long-term contraceptive. Additionally, the mark might convey information useful to research programs such as tracking the movement of animals from one location to another. For both of these aims, the more information that could be gained from a distance without handling the animal, the more useful the mark would be. It was agreed that at a minimum, the mark should be readable and yes/no information collected without recapturing the animal, albeit possibly with the aid of a device such as binoculars. The Marking Project Team originally suggested a minimum read distance of 5 feet, but drawing from field experience Aileen Walden and Bruce Earnest agreed that a person could usually approach only to within 12 to 15 feet of an animal. Therefore, the mark would need to be readable from a minimum distance of 12 feet.
Ideal: The mark is visible and readable, without assistance from binoculars or other technology, from a distance of at least 25 feet.

Permanence

Minimum requirement: 3 years or longer.
Ideal: Lifetime of animal for a sterilant. For a long-term contraceptive a non-permanent and/or changeable mark may be required.

Impact on Animal Behavior

Minimum requirement: No impact.
Ideal: No impact.

Time to Administer

Minimum requirement: Less than 10 minutes.
Ideal: 5 seconds.

Training Needed to Administer

Minimum requirement: Little training required.
Ideal: No training required.

Humane Application

Minimum requirement: Humane control of pain with analgesia and minimal chance of infection. John Boone proposed that, analogous to some wildlife scenarios, quick pain might be preferable to a longer, more stressful procedure involving capture and sedation. Kelly Coladarci strongly agreed, noting that the stress of an approach considered more “humane” might contradict a short encounter of pain. She emphasized that an increased knowledge of animal handling will be required, and she suggested local blocks as a way to reduce pain and also reduce animal reactions thereby increasing the safety of the handler. Valerie Benka expressed concern that obvious signs of distress such as vocalizing could reduce the acceptability of the program to people responsible for the treated animal population. The

importance of demonstrating humane treatment of animals to community members was also emphasized.
Ideal: No pain at all. The panel discussed that in addition to being pain-free, ideally any mark should also be considered non-disfiguring. This is important to gaining community acceptance and to avoid interfering with an animal's potential for adoption.

Cost per Application

Minimum requirement: Less than $10.
Ideal: Less than $1. Several panel members noted that in some cases marks might be desirable for owned pets (for example, cat owners might desire a permanent, highly visible way other than a collar to identify their cat if the cat were to become lost). Additionally, some suggested it might be possible to make the mark or tag "cool" such that people would want their pet to have the mark. Joyce Briggs suggested the possibility of funding charitable programs by selling a marking or tracking service to pet owners, analogous to the TOMS shoes One for One® campaign in which for every pair of shoes a customer buys, TOMS donates a pair of shoes to a person in need.

Cost of Device

Discussion of the cost of an application device was deferred, since so many variables contribute to this cost, such as the total number of applications that can be performed per device, and the number of applications that can be performed per device per unit of time (determining how many devices might be needed per site).

Ease of Information Retrieval

Minimum requirement: The mark should be readable without recapture of the animal, and perhaps with minimal assistance from binoculars. It was noted that as cell phone service and sophisticated mobile phones become increasingly ubiquitous globally, cell phone or smart phone applications might be used to detect or identify animals.
Ideal: It was agreed that ideally there should be no dependence on technology to read the mark. For public health and humane population control programs, it would also be important for the mark to be visible to and recognized by community residents. Kelly Coladarci noted the importance of community education since in many areas people are not aware of the connection between spay/neuter programs and animal welfare. Moreover, the community should be informed of whom they can contact to express any concerns. If the community understands the significance and importance of marking an animal, they may be more accepting. If a community does not trust or support a program, members may hide animals to avoid their being treated.

Quantity of Information

Minimum requirement: At a minimum, for a permanent sterilant, a yes/no mark would be sufficient. For a long-term contraceptive, information such as treatment date would be required.
Ideal: In addition to type of treatment and date and location of treatment, other information such as vaccination type and date would be included.

Cost of Device to Retrieve Information From Tag or Mark

Minimum requirement: less than $50.
Ideal: No cost, visual identification sufficient.

The final criteria table can be found in Appendix A.

Overview of Potential Solution Options

As an introduction to the types of marking methods that might be considered as potential solutions, several Think Tank attendees presented overviews of broad solution categories and highlights of highly rated solutions that were submitted in response to the InnoCentive Challenge.

Tagging

John Boone presented an overview of ear tagging. The method is considered simple and quick. A variety of tag types are commercially available, most of which are affixed with plier-like applicators. Ear tags have been used to a limited extent in dogs, with reported outcomes ranging from "great to horrible". The differences in outcomes might be associated with tag type/design and placement, since poor tag placement can predispose a tag to complications (e.g., irritating to the animal, allowing gravity to pull on the tag). Stan Gehrt reported he was

unable to find any published studies about the use of ear tags in cats, while a study of 4 different ear tags in red foxes observed a high loss rate. Several attendees had heard anecdotally of one program that had tried ear tags in cats with poor results, including a large number of infections.

John Boone felt that to date, poor results with a specific tag type usually have led to abandoning the tag rather than systematic experimentation to make improvements. Therefore, he argued, there is room to optimize ear tag design and placement for dogs and cats.

Leg bands used in birds encode a large amount of information based on a system of colors and presence/absence of the band in four positions (top and bottom of right and left legs). It is possible that ear tags could similarly encode information with multiple colors and left vs. right ear placement.

In wildlife biology, ear tagging is done without sedation because a quick procedure with brief pain is considered more humane compared to the increased handling time required to sedate and then tag the animal, and because an animal is at increased risk of predation while recovering from anesthesia.

The winning InnoCentive solution in the short-term category proposed a flexible ear tag applied around the tip or edge of the ear, attached by two small posts and applied with an applicator that incorporated a topical anesthetic and antibiotic. John Boone stated that to his knowledge, all ear tags currently used are rigid; no one has investigated tags made from a flexible material. Sheilah Robertson reported that in Keating et al's study of rabbits, a fast-acting topical anesthetic was very effective at reducing pain associated with tattooing, and this agent might also be useful when applying ear tags. Sheilah Robertson and Kelly Coladarci expressed interest in the potential to manufacture tags embedded with insecticide and antibiotics to help prevent infection and fly strike.

As variations on an ear tag that pierces the ear, the group discussed the potential of magnetic closings or surgical glue to attach a tag to the ear. These ideas were dismissed as impractical because the pressure of a magnetic closing could result in tissue destruction, and surgical glue does not last long enough to be useful.

Physical Markings

Amy Fischer reviewed techniques used to permanently mark the skin or fur, including freeze branding, tattooing, and jet injection technologies.

The second place solution for the InnoCentive prize in the near-horizon category was a simple marking system incorporating freeze branding. Freeze branding is being used as an alternative to hot branding on cows and horses in some areas, and some people have used freeze branding to mark dogs, particularly those in the hunting community, on the flank or ear. A cold metal brand is applied to the skin, damaging the hair follicles such that the hair grows in white. This leaves an easily visible mark on dark, shorthaired animals, though a specific symbol is difficult to read on longhaired animals. For light-haired animals, the brand can be applied for a longer time, resulting in a bald spot similar in appearance to a hot brand. However, the technique requires some skill because the brand must be cooled to a specific temperature and applied for a specific time. If done incorrectly, freeze branding can result in a wound.

Dr. Amy Fischer at Think Tank

Freeze branding is not recommended by the WSPA, and the AVMA[13] suggests that it is painful. However, practitioners report the procedure is well tolerated by animals including dogs. Because of negative connotations associated with hot branding, some renamed the freeze branding technique "whiting". Amy Fischer reported one published study that identified skin tumor development in cattle and sheep after freeze

[13] Welfare Implications of Hot-Iron Branding and Its Alternatives. Backgrounder available for download from the AVMA website (https://www.avma.org/KB/Resources/Backgrounders/Pages/Welfare-Implications-of-Hot-Iron-Branding-and-Its-Alternatives.aspx), accessed July 5, 2013.

branding.[14] Michelle Kutzler noted that since these were papillomas, the viral-based tumors could be spread by flies attracted to the site of the brand.

Example of freeze branding

Freeze branding requires either dry ice or liquid nitrogen, neither of which is easy to obtain in many areas of the world.[15] The panel discussed whether there might be a way to achieve the cold brand without using Sheilah Robertson additionally offered that a product like ethyl chloride spray, which has been used to numb skin with cold prior to vaccinations, could be used as an analgesic prior to freeze branding.

Another proposed InnoCentive solution suggested the use of a multichannel jet injector to inject ink under the skin in a specific pattern, essentially creating a needle-free tattoo. Jet injectors have been used for needle-free vaccines, using high-pressure and high-velocity to deliver liquid under the skin.

Michelle Kutzler expressed concern that exact control of delivery is not possible with jet injectors, precluding a repeatable pattern. Also, she pointed out that jet injectors are indicated for designated vaccine locations, but it is not clear that the technique would work on a location desired for a mark, such as on the cartilage of the ear.

Additionally, Sheilah Robertson pointed out that cats hate the loud noise made by needle-free vaccine applicators. Valerie Benka added that marks made using jet injectors would have the same limitations as traditional tattoos, including being difficult to see under fur.

A Pilot Study Comparing Ear Tagging to Freeze Branding in Dogs

Dr Raffaella Leoci of the Veterinary Medicine program at the University of Bari, Italy, presented via Skype the preliminary results of her pilot study comparing ear tagging to freeze branding in street dogs in Puglia, Italy. Her team studied signs of stress and adverse reactions associated with each method. The researchers were inexperienced in both techniques, so Dr. Leoci also reported on the difficulty and learning curve of each approach.

The researchers evaluated multiple measures of stress, including heart rate, pupil size, and reaction at palpation on the Melbourne Pain Scale. Saliva and blood samples were collected to measure stress hormones, and dogs were videotaped to record external signs of discomfort, pain, or stress associated with the procedures. The results of these assays were not yet available at the time of the Think Tank, but will be presented at the ACC&D Symposium in June 2013.

Multiple indicators (including defecation, clinging with nails, and need for strong restraint) led researchers to

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[14] Yeruham I, Perl S, Nyska A. Skin tumors in cattle and sheep after freeze- or heat-branding. 1996. *J Comp Pathol*. 114(1):101-106.

[15] A personal communication from the Parsemus Foundation relayed information collected in preparation for a study of white-marking:

> white-marking… requires the use of a coolant, usually liquid nitrogen (-196 °C), although a mixture of dry ice and 99% pure denatured alcohol (-67 °C to -77 °C) can used. This has obvious implications for human safety, and the handling and use of such material will be subject to local and/or national legislation and regulations. Organizations in resource-limited settings may not be able to get or afford liquid nitrogen. Availability of dry ice, the alternative coolant, varies widely—it is readily available in supermarkets throughout the United States and Canada, and it also appears to be widely available in India, Indonesia, and South Africa, but it may be more difficult to get in some countries, including in Europe. The number of dry ice distributors per country varies widely, and not all of these countries will have retail outlets:
>
> **Number of dry ice distributors in representative countries with TNR activity:**
> Australia 12
> Brazil 1
> China 2
> Greece 2
> India 26
> Indonesia 8
> Italy 1
> Nigeria 2
> Pakistan 3
> Romania 4
> Singapore 1
> South Africa 13

conclude that the dogs were maximally stressed by initial handling since they were not used to human contact. The dogs were sedated with diazepam (brand name Valium) before application of the ear tag or freeze brand.

Dr Leoci's group studied two types of ear tags, one round and rigid (rototag), and the other rectangular and attached at only one end, so the tag could move freely (swivel tag). They found that the tags were easy to apply with simple instructions. Some but not all dogs appeared to find application of the tag painful, based on abdominal contractions and vocalizations at the time of application.

Roto-tag

Swivel tag

The researchers observed that any part of the tag that rubbed against the skin could cause skin lesions. They did not observe infection or fly strike. They did observe that the dogs were irritated by the round rototags, shaking their heads and scratching them against the wall. Dr Leoci proposed the rototags may have been too large, and the lighter swivel tags better tolerated.

For freeze branding Dr Leoci's group used liquid nitrogen. They found that the dogs did not react to the procedure as if it was painful, but that the technique required skill to obtain a good mark and was time-consuming. The large amount of liquid nitrogen required made it less cost effective. They would like to repeat the procedure using dry ice, which may be less expensive but requires more time to create a mark. She noted that the freeze brand mark is not immediately visible because the hair must grow in, and that the freeze brand conveys less information than an ear tag since the brand is a simple symbol while the ear tag can be different colors and be printed with a number, city name, or other information.

Dr Leoci concluded that neither method was a clear winner, though for a dog population control campaign, ear tags might be preferable due to lower cost, faster application, and greater visibility.

RFID

Gene Pancheri presented an overview of RFID technology, and Anne Olscher brought several examples of RFID tags so the group could observe differences in size, material, and weight. RFID tags can be active, meaning the tag contains its own power source, or passive, meaning the tag receives power from the transmitter that reads the tag. There are tradeoffs among price, size, read distance, and the amount of data that can be obtained from a tag, with larger tags having larger ranges. Also, tags with larger ranges tend to be more expensive. Passive tags are used in many environments including retail and library management, race timing, electronic toll systems, and product tracking.


InnoCentive winner Gene Pancheri at Think Tank

Animal ID tags tend to be passive, low-frequency (120-150 kHz) tags with about a 10 cm range and low data transfer speed. Currently used microchips for dogs and cats are optimized for scanners operating at 125, 128, or 134.2 kHz, and external ear tags used for cattle are read at 134.2 kHz. High-frequency (13.56 MHz) and ultra-high-frequency (900 MHz) passive tags have larger ranges of about 1 meter. A unique ID number is stored on the tag and broadcast when the tag is interrogated by a scanner. That ID can be associated with a database in which information about the animal is stored.

Surface acoustic wave (SAW) RFID technology can increase the range of RFID tags. These tags work in the microwave range and reflect back the incoming signal rather than relying on an integrated circuit. SAW RFID tags can provide a larger range with less power than traditional RFID tags; they can also provide information about temperature and relative location, which might be useful in differentiating individuals when a scanner sends

a signal towards a group of animals. These tags can be read through liquids and might be implantable. Regarding concerns of exposing an animal to a constant source of radiation, implanted tags are low-frequency passive tags that only broadcast when interrogated by a reader, meaning that they do not constantly emit a signal. Active tags do continually emit a signal but would have to be external since they require batteries, which add bulk and can be heavy.

Reese with a Radio Tag

The group discussed the possibility of encoding information (e.g., a date) within the number on the tag to avoid needing to access a database to gain information about an animal. Though it is possible to place a code of interest on some integrated circuit tags, this would require the handler to put the information on the tag before tagging the animal, which could be cumbersome in the field. This would additionally require special equipment and a different reader. Based on her experience, Anne Olscher said she would not recommend trying to recode tags. William Perlman pointed out that if the size of the database is a concern, GPS-based partial databases could be downloaded to a phone or computer so only the animals within a certain geographic range would be included.

Anne Olscher reported that a current focus in RFID research is expanding read ranges by modifying readers while keeping the tags inexpensive. She further noted that once linked to a database, the RFID tag number can track a very large amount of information. As an example, she demonstrated the Horse Welfare Alliance of Canada database, which combines multiple types of identifying information about an individual horse including photos, iris scan image, RFID number, and DNA fingerprint. The database also contains fields for medical information.

Kelly Coladarci and Bruce Earnest noted that United Parcel Service of America, Inc. (UPS) had once been interested in partnering with The Humane Society of the United States (HSUS) to set up a system to track animals removed from puppy mills using a bar code on the animals' collars. Such collaboration might be useful in tracking animals via RFID codes.

Anne Olscher briefly discussed invisible RFID ink tattoos, a technology developed by Somark Innovations and presently used to identify laboratory rodents via tail tattoos. The company announced in January 2007 that it had successfully tested biocompatible RFID ink that could be used to create chipless RFID tag tattoos readable through hair.[16] Six years ago there was discussion of the technology being used commercially to track large mammals, e.g., cattle, in livestock facilities—something with potential applications for cat and dog marking efforts. This has not since come to fruition, however.

Facial Recognition and Retinal Scanning

The group also discussed biometric approaches to identifying animals from a distance, including facial recognition software and retinal scanning. Retinal scanners detect an individual as they walk through a portal and have a 4-foot read range, and biometric passports based on facial recognition and iris scans process travelers very rapidly.

William Perlman explained that facial recognition software relies on bony landmarks, and may be difficult to apply to furred faces. Michelle Kutzler added that animal fur color and thickness can change depending on nutrition, health, season, and other factors. Sheilah Robertson reported that researchers in Glasgow have identified expressions associated with pain in the cat, and these researchers might have data that could provide bony landmarks for cat faces. Bruce Earnest suggested that the Google Glass technology might be used in the future to assist with visual identification of animals in the field. Google Glass is a wearable computer that responds to voice commands. A display mounted on glasses allows the wearer to view computer output without looking down at a cell phone or other mobile device. In theory, with Google Glass or similar technology the wearer could capture an image of an animal, interrogate it

[16] Jones KC. Invisible RFID ink safe for cattle and people, company says. 10 January, 2007. InformationWeekwebsite. http://www.informationweek.com/invisible-rfid-ink-safe-for-cattle-and-p/196802844. Accessed 24 May 2013.

against a database of images of animals in a marking program, and determine if the animal has been treated, all without needing to look away from the animal.

Based on their experience with feral animals, many in the group felt that retinal or iris scanning would be too difficult to carry out on this population, and trying to get the animal to hold its head still and work close to its face could present a danger to the handler(s). Limited resources and/or access to technology could also reduce the value of these marking and identifications, at least in the short-term future.

Other Methods

Dorian Simpson asked the panel to consider other types of solutions that had been proposed by InnoCentive respondents, including collars, hair removal or hair dyes, and flashing LED tags, and determine whether any deserved further discussion. Stan Gehrt recommended that collars not be discarded as an option. Radio collars are used successfully with many species in wildlife research, and though there is a popular perception that collars are not safe for cats, he noted that studies have not supported this. Joyce Briggs referenced a study of collars in owned cats by Lord et al, which found a low rate of injuries caused by collars.[17] Amy Fischer circulated another study of collar safety in pet cats that found fighting and road accidents to be greater hazards to roaming pet cats than collars.[18] Importantly, both studies looked at collar safety and retention in pet cats whose owners can monitor collars for safety and correct fit, a different population than free-roaming or feral cats who may not tolerate handling. Though only a small percentage of collars were lost in the study by Lord et al, collars are not a permanent solution since people can remove collars or switch them between animals.

Additionally, Valerie Benka pointed out that collars are not a good choice for marking sterilized (non-surgically or surgically) juvenile animals. Collars would need to be readjusted to ensure a proper fit as the animal grows. The group discussed the existence of expandable collars and collars with foam inserts that compress as an animal grows.

Other approaches to creating a mark on an animal by manipulating the fur such as bleach, dye, or paint were discussed, but such marks will disappear as the hair grows out so are only useful for short-term (under one year) campaigns. Coloring the teeth was among the more novel suggestions, but the group concluded this would not be highly visible enough to be useful for the ACC&D scenarios. Sheilah Robertson noted that sometimes, in dogs, hair that is shaved for surgery does not grow back. This seems especially to be true of one specific area where an epidural injection is performed, and it is unclear if this is due to the clipping or to the injection of drugs at the location.[19]

Identification of Top Contenders

After discussing the advantages and disadvantages of existing and/or proposed approaches to marking and identifying animals, the group broke into three subgroups. Each subgroup was encouraged to merge learnings up to that point with the expertise of its members and creative, "outside the box" thinking to identify a top short-term and long-term solution for the scenarios described at the beginning of the Think Tank. Ideally one solution would be identified for both dogs and cats, but a group could recommend one for each.

All subgroups arrived at similar conclusions regarding the most promising near-term marking method: a visible ear tag with an optional RFID component.

Group 1 proposed an ear stud with a disk or band that wrapped around the edge of the ear, made from flexible, nonreactive silicone. They proposed color-coding the disk

Example of coding on improved ear marker

[17] Lord LK, Griffin B, Slater MR, Levy JK. Evaluation of collars and microchips for visual and permanent identification of pet cats. 2010. *J Am Vet Med Assoc*. 237:387-394.

[18] Calver MC, Adams G, Clark W, Pollock, KH. Assessing the safety of collars used to attached predation deterrent devices and ID tags to pet cats. 2013. *Animal Welfare*. 22:95-105.

[19] Slow hair regrowth at the site of epidural injections is mentioned in numerous articles and book chapters related to epidural injections, for example Torske KE and Dyson DH. Epidural analgesia and anesthesia. 2000. *Vet Clin North Am Small Anim Pract*. 30(4): 859-874.

and placing a post through its center. The post would be a bright color such as brilliant fluorescent pink, and could incorporate an RFID tag at additional cost, thereby permitting collection of more detailed or individualized information. They proposed using a topical nonsteroidal anti-inflammatory agent and also Tri-Solfen, a local anesthetic and antiseptic, during application.[20]

Think Tank Breakout Session

The group proposed snap-on segments that could be coded to indicate the procedure and the date, and an outreach program to educate the local population, especially children, about the meaning of the colors. The group also suggested that the owner of a pet or loosely owned animal receive a matching stud.

Group 2 also proposed an ear piercing, incorporating into the stud an RFID tag whose frequency was compatible with universal scanners. Placing the RFID tag external to the body would hopefully extend the read range relative to implanted chips. The group proposed using an applicator like an ear piercing gun with topical antibacterial and anti-inflammatory agents, and applying the piercing to cats while the animal is caught in a squeeze trap, rendering anesthesia or sedation unnecessary. This group felt collars were also an option, but preferred ear studs since they would be much lighter to carry in the field than collars and could be used on juvenile animals.

This group proposed using different colors to signify date and region to allow for tracking animal movement. They suggested developing smart traps to work with the RFID and hold unmarked animals but release animals that are already marked. They also considered automated monitoring of cats with detectors located at feeding stations.

Group 3 proposed a flexible ear tag attached with two thin posts, incorporating a color-coding or patterning scheme. They proposed experimentation to determine the optimal material for the tag before adding RFID technology.

This group was open to including new RFID technology, such a different frequencies or SAW RFID technology, though this might require introducing new readers since the newer tags would not be compatible with existing readers. However, since many areas of the world are not currently using RFID tags, introducing readers would be required anyway.

Dorian Simpson, Facilitator (Planning Innovations Group)

In discussing the consensus approach, Michelle Kutzler recommended that the ear tag should be designed to have the smallest possible contact area with the skin since moisture behind the tag would increase irritation, and she noted that cats are prone to ear mites and may scratch out the tag. Bruce Earnest suggested that the stud could be reflective to enhance visibility at night.

In summing up the day, Dorian Simpson noted the high degree of consensus about the best marking solution(s) and suggested that the group was well positioned to move on to identifying partners, initial study design parameters, and information that should be collected from the marking method, including how it might be organized in a database.

[20] Sheila Robertson informed the group about this local anesthetic and antiseptic gel spray currently approved for use in lambs to provide pain relief following mulesing. It (1) includes a mixture of fast-acting anesthetic agents to numb the wound within 1-3 minutes and for several hours, (2) includes a vasoconstrictor to reduce bleeding and perhaps reduce crust formation and attraction of flies, and (3) includes an antiseptic agent to form a moisturizing film over the wound and help prevent infection. http://animalethics.com.au/products/tri-solfen/faq/#other. Accessed June 10, 2013.

Database for Population Management

A database to capture important or desired information about marked animals is critical to a successful population management initiative and carries the added benefit of supporting research about the population dynamics of free-roaming cats and dogs. Participants with database expertise were invited to attend the Think Tank; to further stimulate thinking, a novel and progressive database in use was presented the evening of the first day.

Roni LeDuc and Stephanie Nichols-Young presented a Salesforce database that has been adapted by the Animal Defense League of Arizona to track and manage feral cat colonies in Maricopa County, Arizona. Though Salesforce is designed for commercial use, Roni LeDuc has personalized the fields and worked within the database structure to make it a powerful resource. The result: a database with entries for over 6,000 colonies and 25,000 treated cats. It additionally includes information on caretakers, colonies and spay/neuter clinics, and facilitates assigning trapped feral cats to a clinic with capacity to perform the surgery, as well as tracking trap availability at several depots around the county.

Refinement of Top Contender

On the final day of the Think Tank, the group sought to refine the consensus solution, ear tags with optional RFID posts, which had been reached the previous day.

The panel decided that experiments would be needed to determine:

- Tag design including size, shape, material, color and coding scheme
- Stud size, type, and material
- The application method, including ways to control pain and minimize the chance of infection, and optimal positioning in the ear
- The retention rate and an acceptable rate of failure
- RFID technology and frequency
- The type of scanner that would be used, where or how scanners would be placed, and the range of RFID detection that can be achieved

Think Tank participants

Also needed would be short- and long-term adverse reaction management plans, as well as simple pictorial application instructions that can be understood across a multitude of language and cultures; a reference was made to the instruction manuals created by multi-lingual retailer IKEA.

Stan Gehrt noted that in wildlife studies, both ears are tagged because the rate of tag loss is high. In a review of four tag types in red foxes, he found an average loss rate of 20% per year, with large tags being lost more often than small. In addition to this trade-off between visibility and permanence, he pointed out that there is a trade-off between permanence and damage to the ear if the tag rips out. John Boone asked whether studies had been conducted to optimize the tag based on these outcomes; Stan Gehrt thought not. Valerie Benka inquired about strategies to reduce welfare consequences of the tag, and Stan Gehrt noted that tag design should take into account that the more contact the tag has with the ear, the more potential there is for related damage; however, the farther the tag extends from the ear, the more likely it is to rip out.

John Friar noted that by combining an external mark, such as a collar or ear tag, with an injected microchip, information about the animal could be recovered from the chip even if the collar or tag is lost.

The panel again broke into three subgroups to identify directions for tag and study design, potential partners, and a decision tree to examine the need for existing and/or new marking methods. Recommendations on these three topic areas are listed below.

Recommendations for Ear Tag and Study Design

1. Design tag prototypes. Must consider tag materials and geometry and ability to incorporate RFID. Also must design the applicator and determine how to include antiseptic, analgesic, and insecticidal agents into tag and application process.
    a. Should design multiple prototypes to cover multiple possibilities
        i. One idea is a dome, spreading out and away from the ear to minimize contact with the skin of the ear
    b. Outsource to people who specialize in this type of work
    c. Generate a prospectus with directions such as limited contact with skin
    d. Take advantage of computer-aided design, especially to minimize need to test in animals
2. Fabricate prototypes
3. Controlled testing to select the best 1 or 2 designs for dogs and cats
    a. Application protocols
        i. For cats, apply through a cage. Initial idea is to use ethyl chloride spray to topically anesthetize the ear, have Tri-Solfen on the post, and apply the tag in less than a minute
            1. A new cat cage design may be helpful, with small removable panels or flaps and a "squeeze" mechanism
        ii. For dogs, application thought to be easier, but need to consider different dog ear shape and size
        iii. Ideally, sedation would be unnecessary, but must be considered for handler safety and pain of the animal
    b. Monitor daily
        i. Local reactions at the site of application, such as irritation, inflammation, or infection
        ii. Behavioral reactions such as head shaking or scratching at the ear that might indicate the tag is irritating. Cameras could be used to document animal reactions.
4. Field testing
    a. Managed cat colonies would be a good test group
        i. Owned and well-monitored
        ii. Outdoor exclusive so exposed to environmental challenges such as dirt, fleas, mites, etc
    b. Ongoing street dog programs may be partners for testing in dogs
    c. RFID technology combined with detectors located at feeding stations could facilitate monitoring and recapture of animals

Recommendations Regarding Potential Partners

To assist with product development and delivery

- Corporate
    - Pet ID companies such as HomeAgain® and Avid
    - Pet products companies: Bayer HealthCare (producer of Tri-Solfen® in Australia), Animal Ethics (Tri-Solfen® developer), Purina, Iams, Heinz, Pfizer (now Zoetis), Merial, and Halo Purely for Pets® (co-owned by Ellen Degeneres)
    - American Pet Products Association, Pet Industry Joint Advisory Council, and Pet Industry Distributors Association (PIDA)
    - Ear tag manufacturers
    - Humane animal trap manufacturers
    - RFID technology companies such as Detex
    - Mail/shipping/logistics companies such as UPS, DHL, FedEx
    - Database companies such as IBM, Salesforce, Blackbaud
    - Design agencies such as Ziba, IDO, Frog Design
- Government
    - Public health departments
    - CDC
    - USDA

  - US Military/Department of Defense (may be especially interested after recent death of soldier from rabies acquired from a dog bite in Afghanistan)[21]
- Non-governmental organizations interested in rabies and public health
  - World Health Organization
  - American Medical Association
  - International Medical Association
  - Red Cross
  - Doctors Without Borders
  - Veterinarians Without Borders
  - One World Health
  - American Public Health Association
  - World Organisation for Animal Health
- Universities
  - Design programs (with Masters students – possible thesis projects)
  - Mechanical, biological, and materials engineering
  - Computer modeling
  - Veterinary schools
- Wildlife organizations
  - SOS India
  - Blue Cross India
  - Overseas Citizenship of India
  - Jane Goodall Institute
- Visionary investors
- Animal welfare organizations and key funding agencies
  - PetSmart Charities
  - International Cat Care (formerly FAB, Feline Advisory Bureau)
  - International Companion Animal Management Coalition
  - Alley Cat Allies
  - The Humane Society of the United States/Humane Society International
  - ASPCA
  - Petco Foundation
  - Found Animals Foundation
  - Gates Foundation
  - Jason Debus Heigl Foundation
  - Marchig Animal Welfare Trust
  - Morris Animal Foundation
  - Winn Feline Foundation

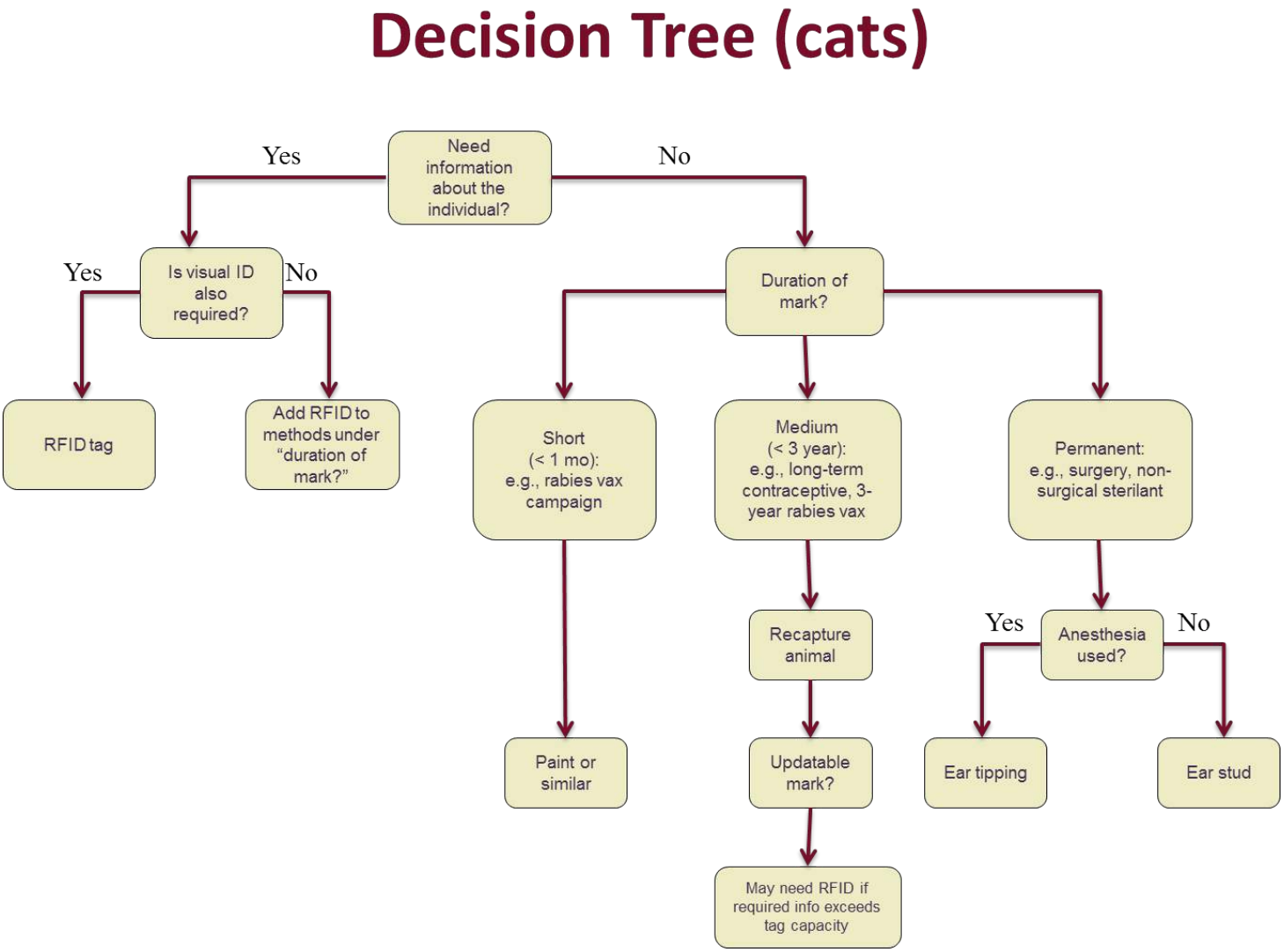
To assist with education and compliance

- Government
  - Education ministries
- Industry
  - International marketing and public relations firms
- Non-governmental organizations
  - Teachers' organizations
  - Women's rights and human rights organizations
  - Children's clubs (Girl Scouts, Girl Guides)
  - International children's and orphans organizations (UNICEF)
- University cultural anthropology, sociology, and education departments

[21] Montgomery N. Confusion, anger surround report of soldier's rabies death. Stars and Stripes website. http://www.stripes.com/news/confusion-anger-surround-report-of-soldier-s-rabies-death-1.166967. Accessed May 24, 2013.

Potential Decision Tree Flowchart - Cat

The following is an example of a decision tree that might be used to determine what type of marking method would be most appropriate to mark a population of cats. Alternatives include existing methods such as ear tipping and new methods, providing visual ID and information ranging from yes/no treated to more complex needs. A separate tree would be needed for dogs, which might include different outcomes depending on ear shape and size. Another tree could be used to determine optimal RFID technology, with important decision points including whether the RFID code should be meaningful without access to a database, whether the RFID tag will be internal or external, and how large the read range must be.



Conclusions and Recommendations of the Panel

The Think Tank panel expressed universal enthusiasm about the strong probability of developing and utilizing a marking method incorporating an optimized ear tag and RFID technology in the field.

Several members stated that the proposed work could have a tremendous impact, facilitating research in tracking, managing, and studying cat and dog populations. Recommended next steps included:

- Identification of experts and key opinion leaders in each category of the recommended potential partners list
- Tailor an approach to each potential partner by industry and what is needed (for example, expertise vs. funding or other support vs. assistance with design or synthesis of prototypes)
- Identify target communities and focus research efforts on best practices regarding education programs and achieving compliance within those communities. As a first step, collect information from ACC&D partners about cultural and physical barriers to compliance in target communities

Several participants expressed that the Think Tank had been very productive, in large part because of the dynamic created by bringing together participants from different fields and with different expertise to meet face-to-face, which could not have been replicated via tele- or video-conference.

Prepared by Tamara Golden, PhD
Golden Bioscience Communications, LLC

Appendix A - Minimal and Ideal Requirements for a Marking Method to Identify Non-Surgically Sterilized Cats and Dogs

Criteria		Minimum	Ideal
Visibility at Moderate Distances		Approx. 12 Ft.	>25 Feet
Permanence		>3 years	Life of animal
Behavioral Impact		None	None
Application	**Time to apply**	<10 min	5 sec
	Training to apply	Little	None
	Humane	Controllable or very brief pain	No pain
	Cost per application	<$10	<$1
	Device cost	Deferred discussion	Deferred discussion
Info Retrieval	**Ease of retrieval**	Visual or simple device	Visual and data capture
	Quantity of information	Treated Y/N	Type of treatment, date, other
	Device cost	<$50	None

Appendix B - Summary of InnoCentive Solution Proposals Received

Total "solutions" proposed: 99[22]

Total individual solvers: 74

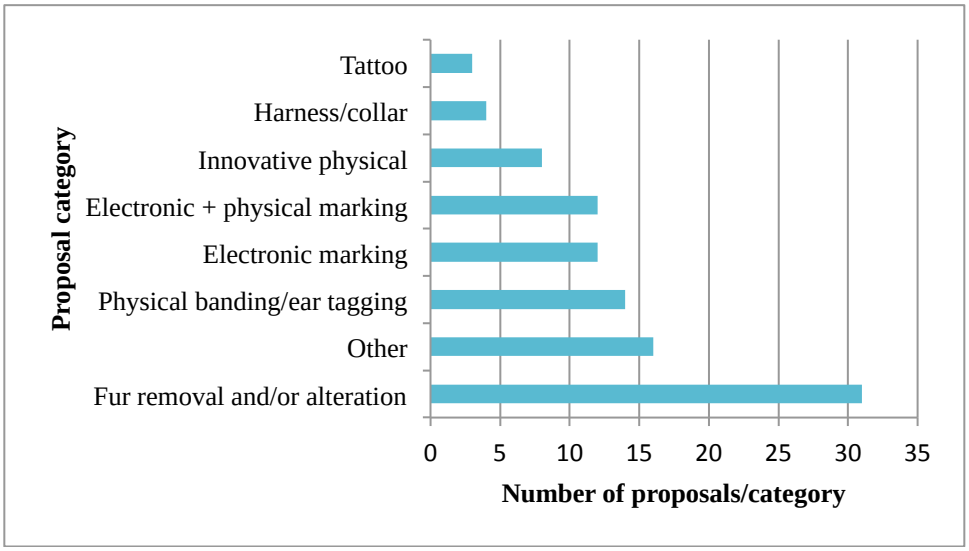


Figure 1: Total solution distribution (by category)

Contenders for InnoCentive award fell into 5 of the 8 categories:

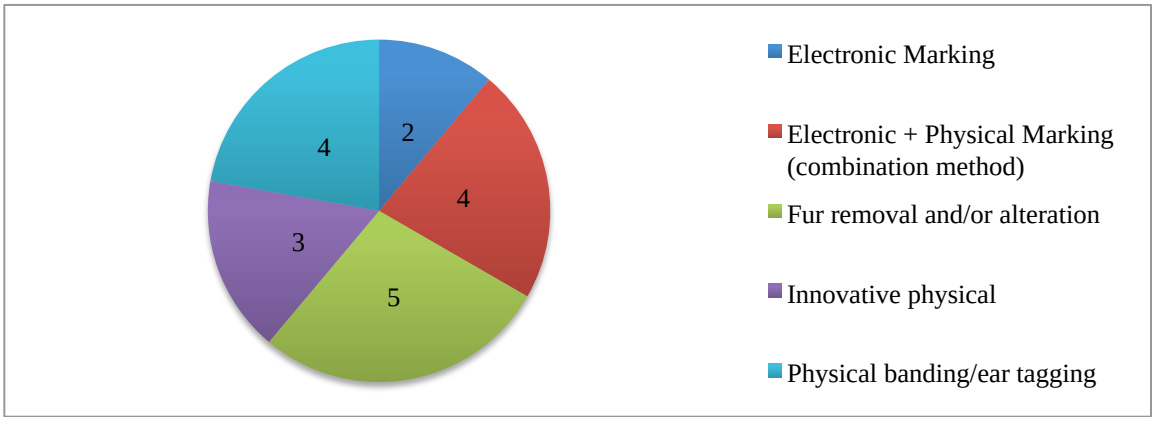


Figure 2: Contender distribution (by category)

[22] Refers to individual "solutions." If a solver proposed multiple distinct solutions, they were counted individually.

Proposals summary

1. **Fur removal and/or alteration**
    a. Dye, bleach, and/or paint the skin and/or hair of the animal's foot, tail, leg, and/or ears. Included some recommendations for types of dye, bleach to use.
    b. Braid tag into long-haired animals.
    c. Colorful hair extension using veterinary glue/barbed hook.
    d. Variations of cold/freeze branding, including methods of encoding information in branding pattern (e.g., matrix barcode or ID code).
    e. Hair electrolysis.
    f. (Laser) hair removal/alteration.
    g. Ink injector in lieu of conventional tattooing.

2. **Other**
    a. Behavioral marker: have animals respond to something in the environment.
    b. Database of nose prints.
    c. Use of cameras to track/ID animals.
    d. Ear tipping/notching.
    e. Euthanasia.
    f. Flat nose piercing.
    g. Olfactory markers.
    h. Use of DNA spray to track animals.
    i. Use of scent dogs to identify fertile cats/dogs.

3. **Physical banding/ear tagging**
    a. Reflective/multi-colored/numbered ear tags.
    b. Use of highly reflective metal in ear tags to improve visibility.
    c. Small/reflective microdermal piercing (potentially removable for purposes of updating info).
    d. Magnetic ear markers (rather than piercing).
    e. Ear tagging/banding with analgesic and antiseptic recommendations.
    f. Metal rings in skin (not limited to ear).
    g. Zip-tie plastic band on leg.
    h. Elastic band on tail.
    i. ID ears with permanent marker.

4. **Electronic marking**
    a. Sound-emitting tag/collar.
    b. RFID tags (multiple variations, sizes, energy sources, and suggestions for range extension).
    c. GPS chip/collar.

5. **Electronic + physical marking (combination approach)**
    a. Flashing light ring attached to ear + reflective plastic lodged inside ear cavity.
    b. Chipless RFID "ink" – provides visible marker and RFID capabilities.
    c. Colored ear tag + microchip, IR diode (blinking light), and/or "IC" magnetic coil.
    d. Fiber optic "hair" glued to animal.
    e. Microchip plus identification vest.
    f. Flashing LED ear tags.

6. **Innovative physical**
    a. Braces.
    b. Contact lenses.
    c. Inject metal into microchip casing; use a metal detector vs. microchip scanner to ID animal.
    d. Inject ink/pigment into eye.
    e. Facial recognition software with animal ID database.
    f. Visible Implant Fluorescent Elastomer tags.
    g. Genetic manipulation to cause animal to glow/fluoresce under UV light.

7. **Harness/collar**
    a. Conventional dog tag.
    b. (Expandable) collar.
    c. Shirt.
    d. Harness.

8. **Tattoo**
    a. Tattoo fur-less areas (inside of ear, nose, or anus).

Appendix C - Winning and Top-Rated InnoCentive Proposals

Short-Term Winner: "Gel Antibiotic Piercing Gun w/Neon Reflective Ear Bands"

1) An ear-piercing device specifically designed to be generously dipped into a gel solution with analgesic, antibiotic and antiseptic properties. Two sponges would be mounted around each end of the piercing device so that after insertion a thick gel would further saturate the area and would continue to treat the site...thus cutting down the risk associated with infection. The device should also punch two holes...one for the post and a second slightly larger hole so that the gel can flow freely through the ear.

2) Tag would clamp on loosely like a "sensormatic tag" used in security detection systems only the "earring/tag" would place a band around the tip of the ear.

3) The material would be made of a Bright Neon Reflective tape that could be color-coded to identify different procedures.

[ACC&D commentary: a simple concept that did not occur to us that could potentially be very useful. Shortcomings sometimes observed with ear tags seem to be related to their rigidity, and leverage is exerted when the animal pulls at the tag, it snags on something, or gravity acts upon it. A flexible, color-coded band (perhaps Kevlar fabric or a light vinyl-coated fabric lattice) that laps the ear tip and is anchored by two small posts is intriguing. I would liken it to the edge banding that is sewed around the outer margins of a pot holder, though it would only lap a short segment of the ear margin, not the whole thing. Certainly this would allow the mark to be placed at the ear tip, making it practicable for flop-eared dogs as well as prick eared dogs and cats. Color coded bands could contain considerably more information than an ear-tip amputation currently does, and the flexibility of the band could very well prevent the leverage effect, and allow the tag to be more readily tolerated by the animal.]

Short-Term Runner-Up: "Freeze Branding Methodology"

This proposal offers a marking scheme, process and tool description that is economically viable and can be implemented in the field by volunteers with minimal training. Freeze branding has been used successfully on livestock for years; it involves using a metal brand that is cooled with liquid nitrogen or dry ice and applied to the skin (hair/fur is shaved first), like a hot brand. When the animal's coat grows back in, the area that was branded grows back white. This effect continues for the life of the animal. Animals with naturally white, short fur may also be branded. The brand is left on the skin longer, disabling the follicles permanently so the fur does not grow back where the brand was applied.

Marking Scheme: Freeze brand bars on one or both haunches of the animal. By limiting the number of bars to 2 or 3 the markings would still be visible and distinguishable even on small animals with long fur (i.e. feral cats). The orientation and number of bars could be used to indicate various pieces of binary or trinary data about the animal, for instance:

- Horizontal bar(s) indicate female
- Vertical bar(s) indicate male
- One bar indicates medical (or other limited duration) contraception
- Two bars indicates surgical (or other permanent) contraception

Other information could be encoded by putting different information on the right and left side of the animal. E.g., the sex and contraception information could be on the right side, and the number of rabies vaccinations could be indicated on the left. Since the vast majority of individuals are immune for life after three rabies vaccines a maximum of 3 bars should be sufficient for this information. Note that the orientation of the bars on the left side in this scenario could still be used to indicate the sex, or could be used to indicate some other piece of binary information.

Tools: Freeze branding of simple bars would require relatively inexpensive tools. It could be done in the field by volunteers with minimal training. The tools required are:

- Disposable razors, or some other means of shaving a patch of skin to apply brand
- A small cooler (even a disposable Styrofoam cooler)
- (Optionally) a contact anesthetic such as Xylocaine
- A branding iron (see below)
- Dry ice
- Insulated gloves for handling the brand (possibly even oven mitts or kitchen hot pads)

The branding iron can be a relatively simple implement because it only needs to make a bar-shaped mark. Any metal working shop or farrier could make such a thing quickly and cheaply. The design I propose:

- Start with a 1/2 inch square steel or iron bar approximately 12 inches long
- Bend 8 inches of the bar into a curve with a radius of about 3 inches, creating a sickle shape with a 4 inch straight handle
- Taper the curved portion of the bar by cutting, grinding or hammering so that the outside edge of the curve goes from 1/2 inch near the handle to 1/4 inch at the tip of the sickle shape

Branding Procedure: Branding would require obtaining a block of dry ice, transported in the cooler with the brand. Once an animal is restrained, the area where the brand is to go would be shaved. To brand an animal, an appropriately sized section of the outside edge of the curve of the brand would be held against the skin. For small animals, a 2-inch section of the narrow part of the curve near the tip would be used. For the largest animals, a 4-inch section of the wider part of the curve near the handle (or even the handle itself) would be used to make a longer, wider mark. The person doing the branding would choose the section of the curve to use to make a proportionally sized mark, depending on the size of the animal.

Comparison Arguments: There are many possible high-tech options for this sort of marking, however these are all expensive and require significant expertise and training to implement and maintain. Even a data collection app on a smart phone requires constant maintenance as new operating system versions are released, and smart phones, though common in many developed countries, are not ubiquitous.

This freeze branding solution is simple and inexpensive to implement virtually anywhere. It requires no special equipment to recognize and understand the markings. This means that the general public can be enlisted to help monitor populations, even in low-tech areas of developing countries. Volunteers could gather data more frequently and consistently and alert staff of significant changes in animal populations that may require intervention. This would allow trained staff to manage more animals in less time.

New high-tech solutions, even relatively simple ones, will require iterative development and testing in trial populations. This process will take months or years, and the entire plan cannot be rolled out everywhere until the technology is proven. Once the development and testing process is completed, devices will need to be manufactured centrally in a small number of facilities (maybe only one). They would then incur the extra expense of shipping, as well as the time and effort for the administration required to transport them across jurisdictional boundaries. Devices (sending units and receivers) will need to be maintained or replaced over time, and problems or failures of devices will delay data collection or result in incomplete or inaccurate data.

The freeze branding solution uses tools and supplies that can be created, purchased, maintained, and replaced locally. The only thing that needs to be delivered to local organizations is instructions. In theory, this solution could be implemented around the world within a week or two. The freeze branding process has been refined and proven with livestock for years. It is simple, effective, and permanent; there is nothing to “wear out” or become obsolete.

High-tech solutions could be used to provide much more information about individual animals, up to and including unique identification of each individual animal. Note that the cost of equipment, skill and training required to implement and maintain these solutions increases proportionally with the amount of information that can be encoded.

The freeze branding solution being proposed here can encode a maximum of 4-5 pieces of binary and possibly trinary information. It is not practical to encode information that would uniquely identify individual animals. It may be possible to increase data points in the dataset by incorporating "dots" into the branding scheme (by using the end of the handle of the brand described above); however, this may be less effective on smaller animals and may lead to misreading of markings on animals with longer coats.

Keep It Simple: Complex, high-tech systems are well suited to highly structured, well-funded organizations (e.g., military). Managing populations of feral animals is usually done by a few dedicated professionals and an ever-changing group of concerned citizen volunteers. This organizational structure does not include the funding, personnel, training or supply chain required to implement a distributed high-tech feral animal tracking system. This freeze branding solution provides most, if not all, of the data required for managing populations of feral animals, and keeps it simple enough to make it practical.

Long-Term Winner: "Extended Range RFID"

Ways to increase RFID range:
1) Place RFIDs externally so that water in the body does not absorb part of the signal. Attachment to the ear would likely be sufficient.

2) Use UHF tags - have a longer range than lower frequency tags.

3) Separate the Reader transmitter from the Reader receiver. When one is identifying pets it is more convenient to have a single hand-held unit that both transmits and receives. That is not necessary in your case. One or more directional transmitters could be placed a few feet in front of the receiver, thus increasing the power delivered to RFID tags while simultaneously decreasing the cross-interference between the Reader transmitter and the Reader receiver. If all of these suggestions are used in tandem, the RFIDs should be able to be read at 20 to 30 meters.

Follow-up: The problem with long range RFID is that the transmitter's power has to be high (operator may need a ham radio license) and the receiver antenna needs to be precisely tuned to the frequency used. Cell phones have neither capability. Cell phones could certainly connect to the reader via, e.g., blue tooth to store or send the collected data. As you may know, there are two main types of RFID tags -- active and passive. Active tags can be read at greater distances but require batteries with limited lifetimes and are an order of magnitude more expensive per tag. I think these are killer issues for your application. Passive tags are cheap -- but they receive their power from the receiver transmitter. As you can imagine the amount of power they receive is small and so their response is very weak. Thus in order to get range you have to take all three of the suggestions I made above. This will not be off the shelf equipment. You will have to work with an RFID company (hopefully on a pro bono basis) to have this designed specifically for you. It will not require an invention -- but it is not something that they currently sell.

Follow-up: SAW RFID tags is an interesting technology whose tags can be read at long distances (20-40 m) with low power (no need for a ham radio license or even a separate transmission antenna). In the past SAW RFIDs would not have had the capacity to contain all the information you would need for the large number of individual animals that you have set forth in the problem statement. However, the technology has come a long way. At this point it could contain not only a unique identifier number, but the number stored on each tag is large enough that other information could be encoded into it via a lookup table in your database. Another interesting feature of SAW RFID is that its temperature and the direction it is

moving can be teased from its signal with the proper software. The other post indicated that it would be difficult to attach to the animal -- but based on my research, it would appear that it could be embedded into a rather small ear tag.

Follow-up: Eugene is onto what is, in my opinion, the most elegant solution. If you are looking into a customized reader solution, and you want something that is intuitive and accessible, I would discuss something like this: http://www.amazon.com/RFID-ME-Android-Powered-Devices/dp/B007KXC1NO. More information here: http://www.mtigroup.com/rfidme/

Follow-up: You will need to find a way to increase broadcast strength so that these devices can be used at a distance, as opposed to a few inches from the subject, who will need to be equipped with passive tags. All this technology exists, but this would put it all in once place and have the potential option of a Bluetooth RFID add-on for a cell phone. Note: You will need to discuss the ability for Bluetooth to broadcast at the power you would need for an effective long-range cell phone RFID reader. Physical limitations may make this difficult or impossible. Where it could get really cool is hooking the cell phone RFID reader into a custom application that utilizes the Google Maps API. This would light up the broadcast region with little pings indicating neutered pets over the geographical area provided by Google.

Envision an animal control van, with a higher-powered reader and antennae, patrolling the streets with a laptop/tablet open on the passenger seat to ping out all of the neutered animals overlaid on the Google Map of the area. If the personnel spots an animal that isn't lit up on the map she knows it is not neutered. In the event that this animal control personnel has to leave the vehicle to patrol she can pull out her cell phone with RFID reader and fire up the app to investigate tighter spots like alleys, and abandoned buildings. This technology could also be used for pet identification, health records, etc.

Follow-up: RFID is in my humble opinion the only reasonable solution. Additionally, new smartphones have NFC feature that is compatible with 13.56 MHz RFID.

Long-Term Runner-Up: “Combined facial and marking recognition”

This solution is the easiest to deploy to the field and may even be self-funding...also, depending on the encoding scheme used, the database will NOT require a lot of storage space. In humans combining facial recognition algorithms with algorithms that recognize skin texture may increase accuracy by 20-25%. A similar method could be used with animal facial recognition ENHANCED with fur texture and markings identification. Facial recognition could be used to identify the breed and dramatically narrow the field of possible animals. Marking patterns could then be used to make a definite match (or not match). The animal is simply photographed (and encoded) at the time of sterilization or contraception. The encoded "dogprint" is stored in a central database along with information about the animal.

Field workers would e-mail photographs of a target animal to a remote [high-speed] server that would process and encode the photograph(s), then compare them to the database. The results of the query would be e-mailed back to the worker in the field. Processing at the server would eliminate the need for an app to be installed the cell phone and provide greatly faster image processing.

The best part about this solution is that it could be self-funding -- the same technology developed here could be used to create a national (or international) pet registry. People would pay to register their animals for a "found pet notification" service. When someone finds a lost animal they simply take a picture with a digital or cell camera and e-mail it to the registry server. The server would then identify the animal and notify the owner and the finder. Other advantages of this approach:

- Non-invasive and almost free (once cost of software development OR licensing is recovered).
- Only equipment needed by a field worker is a cell phone camera, not even an "App".
- The status of the animal, e.g., if the contraception expires, can easily be updated on the server.

- Since the database stores the encoded "dogprint" instead of an actual photograph, database will not take up much storage space even if there are hundreds of thousands of animals registered in it.

ADDITIONAL INNOCENTIVE CONTENDERS

"Microdermal Piercing"

A small microdermal piercing would mark an animal in a relatively noninvasive way [?]; it is easily identifiable by color or reflective facings. Procedure could be done quickly and easily with a punch similar to an ear piercing gun, and jewelry could be applied to almost any area of the body. Another advantage: jewelry could be used in a multitude of ways. Besides simple ID through color or ID at a distance through usage of a reflective facing the option of technology would also be at your disposal. Jewelry could include RFID, bar codes, or radio frequency devices.

ACC&D Comments: Uncertain if microdermal piercings/implants have been tried. Adverse reactions are a potential issue, but piercing seems less likely than conventional ear tags to catch and tear. In humans, healing time is 1-3 months. "Jewelry" on animal might place it at risk.

"Matrix Barcode Identification Marks on Upper Back"

Square-shaped freeze branding or tattoo mark with matrix barcode (e.g., QR code) ID system on upper back (between shoulder blades). Potential variants on this solution:

1) Square matrix barcode freeze branding mark for the animals with short dark fur (white and dark fur creating the mark).

2) Square freeze branding mark or otherwise generated no-fur rectangular area with tattoo gun-generated matrix barcode (as another option, or in combination with #1 for long-haired and light-haired animals).

Further elaboration.

1. *Visibility at moderate distances*: Square or rectangular forms do not normally appear in nature, making them ideal for instant recognition at moderate distances. Positioning mark on upper back (between shoulder blades) would make it visible when animal is resting, sitting, walking, and even running away. Additionally, such positioning offers multiple size options for markings.
2. *Humane application without the need for prior anesthesia*: Both procedures can be made painless, or pain can be reduced by simple spray-on anesthetics and performed without complete anesthesia.
3. *Lifelong permanence (or multi-year duration)*: Both types of markings are life-long.
4. *Minimal interference with normal behavior or relationships with humans*: Upper back, and especially area between shoulder blades, is not typically included in animal-animal interactions, whereas ears, eyes, paws and tail are often included in non-verbal communication where positioning or movements show state of mind (aggression, subjection, etc.). Matrix code system is abstract and hence would be more appealing to humans potentially adopting the animals (vs. letter or number codes).
5. *Capacity to transmit information, including identification of individual animals, if possible*: Matrix code capacity to transmit information is tremendous and depends on design quality. All information could be stored in computational system connected with database of individual matrix codes.
6. *Ease and efficiency of application and recognition*: Recognition of sterilized/contracepted animal would be instantaneous. Individual recognition would be more susceptible to quality of the matrix code design. Initial recognition system could function similar as photo ID method, with individual matrix code connected to the unique ID in the code database, but this system offers ability to create technology for instantaneous recognition similar to existing technology of QR code recognition by smartphones – eliminating human error.
7. *Application*: As existing freeze branding and tattoo gun technology.

8. *Low expense*: No need for specific new technology development (e.g., DNA modification, fluorescent dye development) in initial phase would make it cheap; further software and technology R&D for method sophistication would be possible in future. Some adaptation of tattoo guns might be needed.

ACC&D comments: Relatively comprehensive analysis, but not as thorough as runner-up who proposed freeze branding. Tattooing would presumably require anesthesia, but freeze branding solution has some strengths in terms of visibility, lack of interference with behavior, cost, humaneness, speed, etc. Note that this solver proposes freeze branding on the upper back (runner-up proposed haunches).

"Hair removal via a home electrolysis-style device"

A V-shaped pattern of hair removed from between the shoulder blades would be readily identifiable, while not significantly affecting health or behavior. Electrolysis is long-lasting (according to Wikipedia article on laser hair removal, "The FDA currently allows the term "permanent hair removal" for electrolysis only. Unlike laser epilation, electrolysis can be used to remove 100% of the hair from an area and is effective on hair of all colors..."). Additionally, the location of between the shoulder blades is an area that is unlikely to be damaged by animal fighting. The hairless spot would be noticeably different than hair lost from mange (noticeably cleaner in skin condition and appearance), so natural hair loss would normally not be a large factor. Current home electrolysis options are cheap (~$50, many under $100 per unit), so per-animal cost can be low. Lastly, electrolysis can be used in conjunction with more expensive options; nothing prevents use of RFID tags for more specific information, while electrolysis can be used for initial animal visual ID. Ideal solution would be tagging all animals with the electrolysis, with perhaps 1-10% of animals in the total population tagged with RFID tags for additional information.

Addition: Longer haired animals would require larger patches. This wouldn't necessarily take significantly more time (depending on the equipment, might only take a few extra seconds).

Addition: Article about a patch of needles, supposed to be painless:
http://portal.acs.org/portal/acs/corg/content?_nfpb=true&_pageLabel=PP_ARTICLEMAIN&node_id=222&content_id=CNBP_022754&use_sec=true&sec_url_var=region1&__uuid=

This patch is intended to be used for injections. However, the design could be adapted into an electrolysis device. Using a higher-density patch of needles, you could guarantee that you're definitely getting a vast majority of hair follicles in an area. Using shorter-length needles means: 1. very low chance of blood exposure, so less disease risk than some proposed methods. 2. reusable design, or mass produced so cheaply that cost is not a concern. 3. painless (aren't going deep enough into the skin to trigger pain response). Each needle would act as one of the probes used for electrolysis. Any skin damage (e.g., damage to a non-follicle area of the skin) would heal normally, while the follicles would not be able to regenerate. Lastly, in addition to the above, if you kept micro needles in addition to the probes, you could follow up the electrolysis by injecting the localized area with a substance to prevent future growth of hair, antibiotics to prevent infecting the injection area, etc. Whatever you want to inject really.

http://www.catalogfavorites.com/itemdy00.aspx?T1=K1832&srccode=NXCFC6&utm_source=google&utm_medium=comparison&utm_campaign=datafeed&gclid=CKHepMq9-7UCFahDMgodyH8AeQ.
From what I've gathered, you apply a gel to the area in mind, then it de-hairs the entire area at once.

Here's another system that might work better:
http://www.sharperimage.com/si/view/product/Home-Electrolysis-Roller/200066. It seems to use a roller & gel system as well. Problem: you have to use systems a few times to be effective on a human. I'd imagine it would definitely be more noticeable on a dog than trying to remove the far-spaced hairs of a human (compared to how much hair is on a dog, for example). All systems seem to be painless.

ACC&D comments: It is not clear if this would be painless and/or possible, or if electrolysis would actually permanently remove hair. However, if all pieces fell into place, this seems like a potential option, and the solver deserves credit for doing research.

"Visible Implant Fluorescent Elastomer tags"

Visible Implant Fluorescent Elastomer (VIE) tags consist of two bio-compatible elastomer materials that are injected under the skin as a liquid and cure into a pliable solid. Color elastomer and a curing agent are injected using hand-held syringes or air-powered injectors. The flexible nature of the compound, and its tendency to occupy available space rather than displace and irritate surrounding tissues, means that VIE tags are retained better than rigid internal tags.

Five fluorescent colors (red, yellow, green, orange and pink) and five non-fluorescent colors (black, blue, brown, white and purple) are available. Both fluorescent and non-fluorescent colors are visible under ambient light. The non-fluorescent pigments can be difficult to visualize under darkly pigmented skin, and should be used only in translucent tissue, where detection will occur under bright ambient light. While fluorescent pigments are also visible under ambient light, their detection is greatly enhanced with the use of a fluorescence enhancing technique such as blue or UV light. The combination of different colors and tag locations allows identification of individual animals.

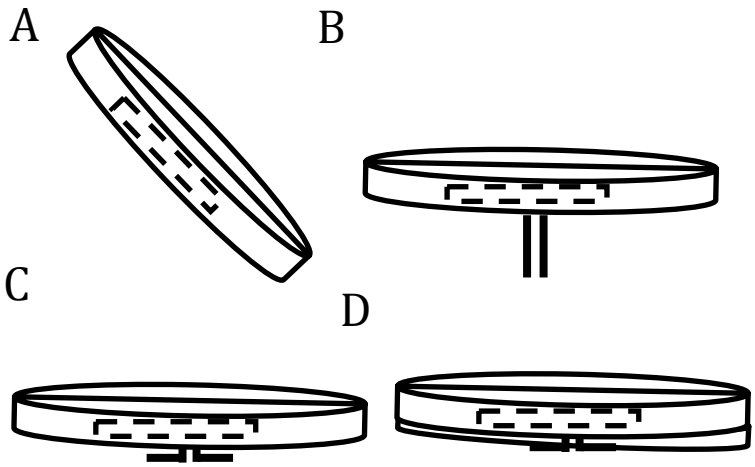
The advantage of the VIE system is that the amount of elastomer material required is small, so that the method can be used in small animals. Moreover, the materials are relatively inexpensive. VIE and VIAlpha materials are available from Northwest Marine Technology Inc. VIE tags are most useful for marking groups of animals, while VIAlpha tags can be used to easily identify individuals.

John Boone follow-up: 1) Has this technique ever been used in mammals? Do cats or dogs have areas where tissue is sufficiently translucent for this technique to be effective, and where fur does not interfere substantially with visibility? 2) What is the approximate distance at which these markers would be clearly visible in normal daylight conditions? 3) It sounds like this injected material would have to be placed where a subcutaneous pocket could be formed (i.e., could not insert into ear cartilage). Is this correct?

ACC&D conclusion: Followed up with producer and method is not possible in dogs and cats, but is innovative and might have potential in some form in the future.

"Teflon based RF transmission embedded ear tag (TBET)"

Teflon embedded microchips (RF transmission or barcoded): button shaped (~ 1 cm diameter; 0.4-0.6 cm thick, weight <50 mg) which can be tagged to the ear.
The Teflon can be color-coded to identify animals which are sterilized (green/blue) vs intact (red), while the microchip embedded within the tag can transmit necessary identification details.
Since the device is circular (button shaped figure below) of ~ 1 cam diameter it can be visually identified from a short distance (few meters). The color-coding of this tag can be used to identify animals which are sterilized (Green/Blue) vs which are intact (Red).



The above tag will have attached pins (made of Teflon) that can easily penetrate the ear by using an applicator, and the pins can be folded over another Teflon disk to permanently anchor the tag to the ear.
Since this is a very minor surgical procedure it will not require general anaesthesia; the procedure can be performed under tranquilization. With experience (considering my own experience in veterinary practice) it should be performed in < 5 minutes. Local analgesic creams may be used for acute pain management.
Since tag is very light (< 50 mg) it should not cause discomfort to animal or interfere with natural behaviour/human interaction. Moreover the tag is likely to have long durability since it is Teflon based.
Note: since ears are in various shapes, while applying the tag care must be taken to ensure that the tag is visible from the front.
It is hard to predict the cost factor, but considering the cost of micro-chip and mass production is these tags, it will be feasible to manage the cost within $10 USD/tag.
ACC&D conclusion: It is nice that this proposal considered the challenge (both the need for visibility and to encode information). However, if a tag and chip are to be used, it seems more economical to inject the chip so it is not lost if the ear tag falls out.

“Marking animals using Jet injectors”

Jet injectors can be used for a fast, permanent, low-cost marking of animals with no pain. They have been used for decades for fast mass vaccination of large populations. Jet injectors’ working principle is based on a high pressure (200-1000bar) and high velocity (400-1200 ft/sec) narrow jet that penetrates the skin in a fraction of a second and injects fluid under the skin, with no pain. Jet penetration depth can be controlled according to application demands. Jet injectors can be used to inject ink pigments under skin (similar to a tattoo). The marking can be done in areas with less hair (below the ears etc.) or in some visible area after permanently removing the hair from this area. By using few different colors it is possible to code information (e.g., sterilization date). Another option is to use UV tattoo ink, and then by using UV spotlight the mark on the animal will glow and can be seen from a longer distance.

The advantages of the suggested method: 1) permanent marking with an option to use color coding; 2) low-cost method; 3) proven reliability; 4) very fast and doesn’t require special training; humane and doesn't cause pain to the animals – no sedation or anesthetizing are needed; 5) visible from distance. Technology overview: http://www.bioject.com/products/technology. Recently a new jet injector was developed at MIT, the injector actuation is electrical, instead of using compressed gas, like in most other commercially available products. This new jet injector allows direct injection into the eye. By this method it might possible to inject biocompatible ink to the animals' eye in order to create a clear mark from a distance. UV ink might also be used to create a distinct mark at the eye – and then by using UV spotlight this mark will glow and can be seen from a distance easily. Links about the new injection method:

http://www.gizmag.com/jet-injection-system-mit/22673/. YouTube movies about the new MIT method: http://www.youtube.com/watch?v=Xx9MJLhNLuk, http://www.youtube.com/watch?v=M09LyLqb5qw, http://www.youtube.com/watch?v=Uq4io4kXFb4.

For tattoos the ink is injected to the dermis layer at depths of 0.4-1.5mm; some jet injectors are designed for intradermal injections (very shallow injections that deposit liquid between the layers of the skin); if ink is injected to a shallow depth of 0.4mm I think it would be possible to create a pattern on the skin.
Cost: Disposable jet injector handpiece units, which last 20,000 injections according to the manufacturer, cost about $55 (see table 2, fig 1): http://www.path.org/publications/files/TS_lshtm_dsji_cost_article.pdf. Multi-use units cost $200-$700. The same jet injector can also be used for injecting the chemicals for castration and contraceptive vaccines in order to reduce costs. **Capabilities**: It is possible to design, based on commercially available injectors, a device with an array of jet injector nozzles, similar to an ink cartridge of an ink jet printer, and in that way any pattern or text can be permanently printed on the skin. If you need to mark a large number of animals the design cost of such device shouldn't be too high. Another alternative is to use Multi-Channel Jet Injector to create similar effect – see the picture at the bottom of the page: http://www.dantonioconsultants.com/prod_ji_human.htm.

Up-eared animals (cats and some dogs) can be marked inside the ear flap, where fur is less and the mark can be seen from a distance. For other animals the fur can be permanently removed (or partly removed) from the marked area. Also, using UV ink can make the mark more easily seen from a distance, even under some fur, when UV spotlight is used to light on the animals (especially effective at night).

I think that jet injectors can have all the advantages of a normal tattoo (permanent, allows to convey information etc.), while solving most of the disadvantages of the tattoos (cause pain- requires heavy sedation, skill required to apply, takes time (and cost) etc.), so if you are not using tattoos because of the above disadvantages - Jet injectors can solve it.