AVMA Guidelines for the Depopulation of Animals: 2019 Edition

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CONTENTS

ABBREVIATIONS

AV	Attending veterinarian
CAS	Controlled atmosphere stunning
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
EEG	Electroencephalography
EPA	Environmental Protection Agency
FAD	Foreign animal disease
HPAI	Highly pathogenic avian influenza
ICS	Incident Command System
LOP	Loss of posture
LORR	Loss of righting reflex
MAK	Modified atmosphere killing
OIE	World Organisation for Animal Health
PCB	Penetrating captive bolt
POD	Panel on Depopulation
POE	Panel on Euthanasia
POHS	Panel on Humane Slaughter
PPE	Personal protective equipment
VSD	Ventilation shutdown

0: Introduction

0.1 Depopulation

The term depopulation refers to the rapid destruction of a population of animals in response to urgent circumstances with as much consideration given to the welfare of the animals as practicable. Urgent circumstances may include emergency situations, such as the need for immediate disease control or a response to natural or human-made disasters. These guidelines are not applicable to precautionary killing. The AVMA Guidelines for the Euthanasia of Animals[1] or the AVMA Guidelines for the Humane Slaughter of Animals[2] should be referred to in circumstances necessitating prophylactic culling.

The challenge facing veterinarians and others tasked with depopulation is to balance aggressive management of and rapid response to an emergency situation with animal welfare concerns surrounding humane destruction. Veterinarians are positioned to offer sound professional judgment as the value of animals' lives and their welfare is weighed against immediate risk to human beings, other populations of animals, or the environment. Although practical limitations may include availability of equipment and skilled expertise, biosecurity, finances or cost, and time, the method of depopulation must balance ethical responsibilities to animal welfare and the well-being of veterinarians and other responders, all while maintaining public trust and confidence. Therefore, the choice of terminal method, the handling of animals, and the disposal of animal carcasses should adhere to strong ethical standards and procedures and to state and federal laws.

When practicable in the emergency situation, as much attention as possible should be shown to the needs and natures of animals that will be terminated. This may involve using techniques from the AVMA Guidelines for the Euthanasia of Animals[1] or the AVMA Guidelines for the Humane Slaughter of Animals,[2] all of which are acceptable as depopulation techniques. However, ensuring the welfare of animals will be one of many important considerations during an actual response to an emergency situation. Therefore, the emergency destruction of animals through depopulation techniques may not guarantee that the deaths the animals face are painless and distress free. However, acceptable depopulation methods must ensure that every effort is taken in the planning and response phases of an emergency to ensure that animals designated for depopulation experience a rapid loss of consciousness or loss of brain function under the prevailing conditions, and that they are handled in a humane manner before and during their depopulation.

0.2 Historical Context

In 1963, the AVMA convened the first POE to provide guidance for veterinarians who perform or oversee the euthanasia of animals. In 2011, the AVMA POE determined there was a need to address and evaluate the methods and agents that veterinarians may encounter when animals are killed under conditions where meeting the POE definition of euthanasia may not be possible. The guidance contained within this document relates to depopulation, the destruction of animals in an emergency situation in as humane a manner as possible.

The content of the AVMA Guidelines for the Depopulation of Animals reflects the AVMA's ongoing commitment to ensure that the treatment of animals during every stage of life, including during emergency situations, is respectful and as humane as possible. An emergency situation such as a natural disaster or disease outbreak may necessitate the rapid termination of animals in large numbers.

The AVMA is committed to inducing humane death in an animal. This means, in accord with the 2013 AVMA Guidelines for the Euthanasia of Animals,[1] that the processes and method be respectful, be conducted with minimal pain and distress to the animal, and be informed by species-specific expertise. When the absence of pain and distress cannot always be achieved, depopulation must still be guided by balancing the ideal and the ethical impulse of minimal pain and distress with the reality of the environment in which depopulation must occur. These Guidelines are part of a triad of documents on humane killing—the other two being the AVMA Guidelines for the Euthanasia of Animals: 2013 Edition[1] and the AVMA Guidelines for the Humane Slaughter of Animals: 2016 Edition.[2]

When significant effort to save animals' lives has been exhausted, it is imperative that animals are destroyed and their carcasses be disposed consonant with high ethical standards. However, exigent circumstances may frustrate adherence to the Animal Welfare Principles[3] or humane methods outlined in the AVMA Guidelines for the Euthanasia of Animals.[1] For example, where the goal is to save as many animals as possible and protect significant public interests by rapidly curtailing the spread of disease, pain and suffering may be unavoidable. The circumstances surrounding depopulation are unusual and will involve extraordinary intervention measures. Given this context, the Animal Welfare Principles[3] and humane handling and depopulation techniques should be employed as is practicable on the basis of the scientific evidence currently available in conjunction with judicious emergency planning, management, and response procedures. The POD is committed to ensuring that no unnecessary pain or distress is inflicted on conscious animals during an emergency situation like depopulation.

The depopulation of animals impacts many stakeholders, including owners, the public, actors in the food supply chain, shelter personnel, wildlife management teams, emergency responders and operators, and animals themselves. Policy makers, the scientific community, and the public share an interest in the best ways possible to plan and respond to emergency situations where depopulation is necessary. Attention to questions about the moral status of animals has meant that veterinarians and others involved in depopulation of animals during emergency situations must demonstrate to the public and each other due diligence when discharging their professional responsibilities.

The POD has worked diligently to identify and apply the best research and empirical information available to promote the humane destruction of the species of animals addressed in this document. Mechanical and physical methods, electric methods, and controlled atmosphere and gas methods are used to bring about unconsciousness through physical disruption, hypoxia, neuronal depression, or epileptiform brain activity in food animals at slaughter. A range of factors, including expanded knowledge about the cognitive capabilities of animals, technological and economic conditions, and social and ethical considerations affecting the sustainability of animal agriculture, the care and management of food animals, and food security, will influence the recommendations in this and future editions of this document. The AVMA encourages its members to utilize their scientific knowledge and practical expertise to protect and promote the health and welfare of all animals.

The Guidelines do not venture into the morality of killing animals during depopulation or of the acceptability of so-called prophylactic culling or precautionary killing. The POD did labor on the acceptability or defensibility of method (ie, when a method is preferred and when it is unconscionable for veterinarians to endorse a particular technique). Here, existing science, consideration of what animals might experience during a crisis situation, personal value commitments of veterinarians, their commitment to professional codes of conduct, and finding the best outcome for animals in an emergency situation helped to guide the choice of method. Urgency and risk to the public, human safety and public health, animal welfare, and environmental factors recommend the use of professional judgment. Triage thinking was discussed in light of availability of resources and best outcomes of all considered to judiciously address a crisis situation. These considerations helped to shape the categories underscored in this chapter (ie, preferred methods, methods permitted in constrained circumstances, and methods that are not recommended).

The POD's focus was on what should happen to animals when depopulation is their ultimate fate. When animals are designated for depopulation, prima facie, they should be treated with respect and handled appropriately, and the depopulation process should limit the harms experienced by these animals as is practicable. When possible, (humane) depopulation methods (including handling of animals) and agents are designed to minimize anxiety, pain, and distress and to bring about rapid loss of consciousness and complete loss of brain function in animals. The POD addressed depopulation of animals used for food production, equids, laboratory animals, companion animals (shelters), aquatics, and zoo animals and wildlife.

The process of termination, as defined here, encompasses the period from which an animal is designated for depopulation on-site until that when it is dead and its carcass is ready for disposal. Biosecure containment plans should be envisioned before execution of a response to handle the volume of carcasses designated for disposal.

While the POD is motivated primarily by the science and ethics of animals' welfare, members of the Panel are also sensitive to adjacent concerns related to depopulation. A partial list of these concerns includes public health and safety; food safety and quality; environmental and economic sustainability; occupational health and impact on operators, caregivers, and local communities; and religious and cultural expectations. These issues, however, are not the main focus of this document. The veterinarian's primary responsibility is doing what is in animals' best interest under emergency circumstances (ie, ensuring the most respectful and humane depopulation process possible).

The AVMA Guidelines for the Euthanasia of Animals: 2013 Edition[1] should be consulted if individual animals are considered for humane termination.

0.3 Current Edition and Members of the Panel

This POD is supported via a Cooperative Agreement with the USDA. The membership of the POD included considerable breadth and depth of expertise in the affected species and environments in which depopulation is performed. These Guidelines represent more than 2 years' worth of deliberation by more than 70 individuals, including veterinarians, animal scientists, and an animal ethicist. In reviewing the literature and formulating their recommendations, members of the POD reached out to other expert colleagues in pertinent fields and also received invaluable input from AVMA members and others during a designated comment period. The scientific integrity and practical utility of these Guidelines are a direct result of AVMA members' input as well as suggestions from others concerned about the welfare of animals when they are designated for depopulation.

Depopulation may employ euthanasia techniques, but not all depopulation methods meet the AVMA criteria for euthanasia. The POD convened and operated similarly to the POE and POHS.

The Chair of the POE and POHS served as Chair for the POD. The range of expertise included veterinarians, nonveterinarians, and experts from animal welfare and animal science, emergency management, disease control, epidemiology, agricultural engineering, and ethics. There were nine Working Groups: poultry, cattle, swine, small ruminants, equids, aquaculture, companion animals, laboratory animals, and zoo and wild animals. Appointments were made by the Animal Welfare Committee, and chairs of working groups made up the Panel. An ethicist was also appointed to the Panel. Two nonvoting invited guests from the USDA and the National Institutes of Health (Office of Laboratory Animal Welfare) also participated on the POD.

In these Guidelines, methods, techniques, and agents used to depopulate animals as humanely as is practicable are discussed. Tables have been included to assist veterinarians in applying their professional judgment. Species-specific information is provided for terrestrial and aquatic species.

The Guidelines acknowledge that the depopulation of animals is a process involving more than what happens to the animal at the time of its death and that veterinary responsibilities associated with depopulation are not limited to the moment or procedure of killing the animal. In addition to delineating appropriate methods and agents for depopulation, the Guidelines recognize the importance of considering and applying good predepopulation and animal-handling practices. Information about confirmation of death has also been included. While some euthanasia methods may be utilized in depopulation, given extenuating circumstances, deviation may be necessary.

More research is sought to examine how emergency situations like zoonoses, pandemics, large-scale feed contamination and natural disasters affect animals, emergency workers, and caregivers of animals and to raise awareness and consider the full range of animal welfare issues during such crisis situations. Interdisciplinary research will enable policy makers, crisis management teams, and other stakeholders to develop effective strategies to address animal welfare concerns in emergency preparation and response plans at local, national, and international levels.

0.4 Statement of Use

The POD has developed these Guidelines for use by members of the veterinary profession who are involved in the rapid destruction of a population of animals in response to urgent circumstances with as much consideration given to the welfare of the animals as practicable. The POD's objective in creating the Guidelines is to provide guidance for veterinarians about options for killing animals in emergency situations.

The POD's main objective in creating the Guidelines is to provide guidance for veterinarians about how to prevent or minimize pain and distress in animals that have been designated for depopulation in accordance with clinical standards of care and local, state, and federal regulatory bodies and to ensure a quick and effective depopulation process that respects animals, human beings, and the environment.

While the AVMA believes the Guidelines contain valuable information that can help improve animals' welfare during depopulation, it is important to understand that public health and safety are priorities and that federal and state regulations must be adhered to in the United States. Depopulation may employ euthanasia or slaughter techniques, but not all depopulation methods meet the AVMA criteria for euthanasia. Because meeting these criteria may not be possible under emergency situations—particularly when large numbers of animals or nontypical risks to human health and safety are part of the picture—separate and discrete guidance is needed.

An emergency situation is characterized by a plethora of complicated problems and risks and can include outbreaks of infectious disease and animal control problems due to a disaster situation and destruction of property. The value placed on animals (eg, the economic and moral value on individual animals like racehorses or poultry) and the strength of the bond between human and animal may vary between different affected parties and deserve careful consideration and sensitivity in an emergency situation. Veterinarians take part in a disaster or emergency response team to offer clinical expertise in disease control, behavioral issues, animal care, and injury management in affected populations of animals. Their role is essential in planning for and responding to emergency situations involving depopulation of animals and can result in important public health outcomes. Planning for preparedness and response is essential to remove barriers that could frustrate a swift and effective depopulation and to ensure that crisis team members have adequate training to respond in an emergency. Crisis or depopulation veterinary infrastructure includes competencies in animal health and welfare, appropriate knowledge of zoonotic diseases, ability to provide crisis standard of care for animals displaced during natural and human-caused disasters, and the capacity to develop strong working relationships with others managing the emergency, such as government agents and health professionals. To respond to depopulation, veterinarians require training tailored to their concerns and needs and must be able to partner well with other responders.

In crisis situations, veterinarians may be members of an emergency response or crisis management team, and they will need to plan and prepare to care for animals alongside other agencies in advance. Participation by veterinarians in coordinated, measured management in response to emergency situations is important as a way to ensure efficient use of resources and manage human capital well. Good coordination between veterinarians, local veterinary medical associations, emergency preparedness and crisis management agencies, and facilities like animal shelters or laboratories and farms would enhance the depopulation and emergency relief efforts. Coordination will help to mitigate unexpected public health consequences, improve biocontainment during depopulation and disposal activities, and anticipate disposal volume issues. More importantly, it will enable the timely deployment of emergency response plans to reduce suffering and deaths of animals.

These Guidelines do not address methods and techniques involved in the termination of animals that will be recirculated into the food supply chain, which falls under the purview of the POHS.

The POD encourages thoughtful flexibility in the use of depopulation methods and judicious deliberation when preparation planning must change in the context of response. Thoughtful integration of animal welfare and husbandry practices within formal policy and planning for emergency response for ethical, psychological, cultural, economic, and ecological reasons are necessitated by our respect for animals and our relationships to them. While it is the responsibility of veterinarians to develop and employ methods of depopulation that minimize animals' suffering and save as many animals' lives as possible, there may be events (eg, the recent outbreak of HPAI) that expand faster than they can be controlled using conventional methods and that outstrip the capacity of state and federal regulatory agencies to apply preferred methods in a timely manner. Using less than ideal methods that result in a quick death for animals and support disease containment may become necessary.

Decisions to implement alternatives that are not recommended must be made on a case-by-case basis, be consistent with strong ethical standards, and occur only with appropriate justification. Further, due consideration must be given to all currently available resources, impact on human victims, and communities and only as a last resort. In all cases, depopulation must comply with applicable state and federal laws. The use of less preferred methods should not become synonymous with standard practice. A public and critical examination of preparation and response plans (including rapid diagnosis, decision and risk communication, and management), biosecurity, depopulation techniques, and facility design should occur in normal or ordinary times before an emergency situation occurs. Doing so will ensure that there is adequate training, equipment, and supporting personnel to manage an emergency situation and that channels for transfer of technology and knowledge during a crisis continue to receive funding so that innovation can occur to anticipate and manage a variety of crisis situations.

Veterinarians experienced in the species of interest should be consulted when choosing a method of depopulation. To avoid unnecessary distress to animals and to prevent or limit human injury before and during depopulation, methods and agents should be selected that maintain calm animals. Attention to species-specific anatomy, physiology, natural history, husbandry, and behavior will assist in understanding how various methods and agents may impact an animal during depopulation and whether or not the costs are acceptable to humans and the environment. Veterinarians performing or overseeing depopulation should assess the potential for species-specific distress secondary to physical discomfort, abnormal social settings, novel physical surroundings, pheromones or odors from previously slaughtered animals, the presence of humans, and other factors. In evaluating depopulation methods, veterinarians should also consider human safety, availability of trained personnel, potential infectious disease concerns, conservation or other animal population objectives, regulatory oversight, availability of proper equipment and facilities, options for carcass disposal, and the potential for secondary toxicity. Human safety is of utmost importance, and appropriate safety equipment, protocols, and expertise must be available before animals are handled. Advance preparation of personnel must include training in the stipulated depopulation methods and assurance of sensitivity to animals and their welfare, including handling and respectful disposal of carcasses. Special attention should be paid to unique species attributes that may affect how animals are handled, stunned, and rendered unconscious and terminated. The public's attachment to or special affinity with certain species should be considered when employing a terminal method, as should public sentiment to the ways in which carcasses will be disposed of. Once an animal has been killed in the course of a depopulation, death must be carefully verified. Depopulation must always be performed in accordance with applicable federal, state, and local laws and regulations.

0.5 Evaluating Depopulation Methods

Depopulation is a process marked by quick and efficient destruction of a complete population of animals. Making ethics a priority and basing decisions regarding the termination of animal lives in disasters or emergencies on supporting reasons and evidence will enhance the professional credibility of veterinarians during these circumstances. Depopulation is unpleasant for all those involved but may be a necessary evil when the priority is to reduce suffering and minimize unnecessary deaths of even larger numbers of animals. Some depopulation methods require physical handling of the animal. The amount of control and the kind of restraint required will be determined not only by the species, breed, and size of animal involved, but also by resources such as numbers of capable personnel, depopulation agents, the level of excitement and prior handling experience of animals, and competence of the personnel performing depopulation. Proper handling is vital to minimize pain and distress in animals and to ensure the safety of the person performing depopulation, other bystanders, and other animals in harm's way.

Selection of the most appropriate method of depopulation in any situation will depend on the species and number of animals involved, available means of animal restraint, skill of personnel, and other considerations such as availability of agents and biosecurity. Personnel who depopulate animals must demonstrate proficiency in the use of the technique in a closely supervised environment. Each facility where depopulation is performed is responsible for appropriately training its personnel. Experience in the humane restraint of the species of animal is critical. Where possible, training should include familiarity with the normal behavior of the species, an appreciation of how behavior affects handling and restraint, and an understanding of the mechanism by which the selected technique induces loss of consciousness and death. When direct contact with animals is possible, death should be verified before disposal of the animals. Personnel must be sufficiently trained to recognize the cessation of vital signs of different animal species.

The POD gave serious consideration to the following criteria in their assessment of the appropriateness of depopulation methods: 1) ability to induce loss of consciousness followed by death with a minimum of pain or distress; 2) time required to induce loss of consciousness and the behavior of the animal during that time; 3) reliability and irreversibility of the methods resulting in death of the animal; 4) safety of personnel; 5) compatibility with the safety of other humans, animals, and the environment; 6) potential psychological or emotional impacts on personnel; 7) ability to maintain equipment in proper working order; 8) legal and religious requirements; 9) sensitivity to public sentiment regarding the destruction of large numbers of animals; and 10) availability of agents and carcass-processing and disposal venues to handle the volume. These Guidelines do not address every contingency. In circumstances that are not clearly covered by these Guidelines, a veterinarian experienced with the species in question should apply professional judgment and knowledge of clinically acceptable techniques in selecting a method of depopulation or euthanasia (if required). Reaching out to colleagues with relevant experience may be necessary. Veterinarians will be working with other members of a crisis management team and in some cases may not have jurisdiction or the capacity to carry out their professional activities. When exercising their professional responsibilities, veterinarians should consider whether 1) the procedure results in the best outcome for the animal; 2) their actions conform to acceptable standards of veterinary practice and are consistent with applicable federal, state, and local regulations; and 3) the choice of depopulation or euthanasia technique is consistent with the veterinarians' professional obligations and adheres to sound ethical grounding.

0.6 Definitions

The decisions about depopulation should be made with consideration of professional, ethical, and technical aspects as well as the availability of infrastructure, equipment, and trained personnel; human and animal welfare; and disposal and environmental outcomes. The methods involved in depopulation will also reflect the severity of the emergency in question, and responsible decisions with regard to depopulation will also include trade-offs. Depopulation methods may not be congruent with euthanasia methods since they involve the mass termination of large populations of animals.

0.6.1 Preferred methods

These methods are given highest priority and should be utilized preferentially when emergency response plans are developed and when circumstances allow reasonable implementation during emergencies. The methods may correspond to those outlined in the AVMA Guidelines for the Euthanasia of Animals[1] or the Guidelines for the Humane Slaughter of Animals[2] but be adjusted for situational considerations.

0.6.2 Permitted in constrained circumstances

These methods are permitted only when the circumstances of the emergency are deemed to constrain the ability to reasonably implement a preferred method. Potential constraints that might result in use of methods in this category include, but are not limited to, constraints on zoonotic disease response time, human safety, depopulation efficiency, deployable resources, equipment, animal access, disruption of infrastructure, and disease transmission risk.

0.6.3 Not recommended

These methods should be considered only when the circumstances preclude the reasonable implementation of any of the preferred methods or those permitted in constrained circumstances and when the risk of doing nothing is deemed likely to have a reasonable chance of resulting in significantly more animal suffering than that associated with the proposed depopulation technique. Examples of such situations include, but are not limited to, structural collapse or compromise of buildings housing animals, large-scale radiologic events, complete inability to safely access animals for a prolonged period of time, or any circumstance that poses a severe threat to human life.

0.7 Stress and Distress, Unconsciousness, and Pain

These Guidelines acknowledge that a humane approach to the depopulation of animals is warranted, justifiable, and expected by society, but may not be actualized in some cases. A preferred goal during the process of depopulation should be to minimize or eliminate anxiety, pain, and distress before loss of consciousness. Therefore, both the induction of unconsciousness and handling before depopulation must be considered. Criteria for determining the humaneness of a particular depopulation method can be established only after the mechanisms of pain, distress, and consciousness are understood in relation to the exigent situation. For a more extensive review of these issues, the reader is directed to the AVMA Guidelines for the Euthanasia of Animals: 2013 Edition.[1]

Depopulation methods produce unconsciousness through four basic mechanisms: 1) physical disruption of brain activity (eg, blunt cranial trauma, PCB, gunshot), 2) hypoxia (eg, controlled low atmospheric pressure for poultry, N_2, Ar, exsanguination), 3) direct depression of neurons necessary for life function (eg, CO_2), or 4) epileptiform brain activity (eg, electric stunning). Because loss of consciousness resulting from these mechanisms can occur at different rates, the suitability of a particular agent or method will depend on the species and whether an animal experiences pain or distress before loss of consciousness.

Distress during depopulation may be created by the method itself or by the conditions under which the method is applied and may manifest behaviorally (eg, overt escape behaviors, approach-avoidance preferences [aversion]) or physiologically (eg, changes in heart rate, sympathetic nervous system activity, hypothalamic-pituitary axis activity). Stress and the resulting responses have been divided into three phases.[4] Eustress results when harmless stimuli initiate adaptive responses that are beneficial to the animal. Neutral stress results when the animal's response to stimuli causes neither harmful nor beneficial effects to the animal. Distress results when an animal's response to stimuli interferes with its well-being and comfort.[5] Although sympathetic nervous system and hypothalamic-pituitary axis activation are well accepted as stress response markers, these systems are activated in response to both physical and psychological stressors and are not necessarily associated with higher-order CNS processing and conscious experience by the animal. Furthermore, use of sympathetic nervous system and hypothalamic-pituitary axis activation to assess distress during application of CAS methods is complicated by continued exposure during the period between loss of consciousness and death.[1]

Ideally, depopulation methods result in rapid loss of consciousness and the associated loss of brain function. The perception of pain is defined as a conscious experience[6] and requires nerve impulses from peripheral nociceptors to reach a functioning conscious cerebral cortex and the associated subcortical brain structures. The International Association for the Study of Pain describes pain as "an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage. Activity induced in the nociceptor and nociceptive pathways by a noxious stimulus is not pain, which is always a psychological state, even though we may well appreciate that pain most often has a proximate physical cause."[7] Pain is therefore subjective in the sense that individuals can differ in their perceptions of pain intensity as well as in their physical and behavioral responses to it.

Distress during administration of CO, CO_2, and the inert gases N_2 and Ar has been evaluated by use of behavioral assessment and aversion testing and reviewed in the context of euthanasia.[1] It is important to understand that aversion is a measure of preference, and while aversion does not necessarily imply that an experience is painful, forcing animals into aversive situations creates distress. The conditions of exposure used for aversion studies, however, may differ from those used for depopulation. Agents identified as being less aversive in some species (eg, Ar in pigs[8] or N_2 gas mixtures) can still produce overt signs of behavioral distress (eg, open-mouth breathing) for extended periods of time before loss of consciousness under certain conditions of administration (eg, gradual displacement).[9] In rodents, Ar and N_2 have been shown to be strongly aversive and should be avoided.

Unconsciousness, defined as loss of individual awareness, occurs when the brain's ability to integrate information is blocked or disrupted. In animals, loss of consciousness is functionally defined by LORR, also referred to as LOP.[6,10,11] This definition is quite useful because it is an easily observable, integrated whole-animal response. Although any physical movement occurring during anesthesia, euthanasia, slaughter, or depopulation is often interpreted as evidence of consciousness, cross-species data from the anesthesia literature suggest that both memory formation and awareness are abolished early in the overall process relative to loss of reflex muscle activity.[6] Thus, vocalization and nonpurposeful movement observed after LORR or LOP with properly applied CAS methods are not necessarily signs of conscious perception by the animal. While generalized seizures may be observed following effective CAS methods, these generally follow loss of consciousness; indeed, anesthesia, coma, and generalized seizures all represent a loss of consciousness where both arousal and awareness in humans are low or absent.[12] Loss of consciousness should always precede loss of muscle movement.

Although measurements of brain electric function have been used to quantify the unconscious state, EEG data cannot provide definitive answers as to onset of unconsciousness even when state-of-the-art equipment is employed. At some level between behavioral unresponsiveness and the induction of a flat EEG (indicating the cessation of the brain's electric activity and brain death), consciousness vanishes. However, current EEG-based brain function monitors are limited in their ability to directly indicate unconsciousness, especially around the transition point.[13,14] Also, it is not always clear which EEG patterns are indicators of activation by stress or pain.[15] Reduction in α-to-delta brain wave ratios coincides with LOP in chickens,[16,17] reinforcing the usefulness of LOP or LORR as an easily observable proxy for loss of animal consciousness.

Physical methods that destroy or render nonfunctional the brain regions responsible for cortical integration (eg, gunshot, captive bolt, cerebral induction of epileptiform activity in the brain [eg, electric stunning], blunt force cranial trauma, and maceration) produce instantaneous unconsciousness. When physical methods directly destroy the brain, signs of unconsciousness include immediate collapse (LORR or LOP) and a several-second period of tetanic spasm, followed by slow hind limb movements of increasing frequency[18–20] in cattle; however, there is species variability in this response. The corneal reflex will also be absent. Signs of effective electric stunning that induces both epileptiform activity in the brain and cardiac arrest are LORR, loss of menace reflex and moving object tracking, extension of the limbs, opisthotonos, downward rotation of the eyeballs, and tonic spasm changing to clonic spasm, with eventual muscle flaccidity.[20,21] Many physical methods are inexpensive, humane, and painless, if performed properly, and leave no drug residues in the carcass. Furthermore, animals presumably experience less fear and anxiety with methods that require little preparatory handling. However, physical methods usually require a more direct association of the operator with the animals, which can be offensive to, and upsetting for, the operator. Physical methods must be skillfully executed to ensure a quick and humane death because failure to do so can cause significant stress, distress, and pain. Physical disruption methods are usually followed by exsanguination to ensure death. Exsanguination is also a method of inducing hypoxia, albeit indirectly.

Controlled atmosphere stunning methods also depress the cerebral cortical neural system, producing loss of consciousness accompanied by LORR or LOP. Purposeful escape behaviors should not be observed during the transition to unconsciousness. Depending on the speed of onset of unconsciousness, signs associated with release of conscious inhibition of motor activity (such as vocalization or uncoordinated muscle contraction) may be observed at LORR or LOP. Signs of an effective stun when the animal is in deep levels of anesthesia include LORR or LOP, loss of eye blink (menace reflex) and corneal reflex, and muscle flaccidity.[22] As with physical disruption methods, CAS methods are usually followed by exsanguination to ensure death.

Decapitation and cervical dislocation are physical methods of depopulation that require separate comment. The interpretation of brain electric activity, which can persist for up to 30 seconds following these methods,[23–25] has been controversial.[26] As indicated previously, EEG methods cannot provide definitive answers as to the exact onset of unconsciousness. Other studies[24,25,27–29] indicate such activity does not imply the ability to perceive pain and conclude that loss of consciousness develops rapidly.

In summary, the cerebral cortex or equivalent structures and associated subcortical structures must be functional for pain to be perceived. If the cerebral cortex is nonfunctional because of physical disruption, hypoxia, generalized epileptic seizure, or neuronal depression, pain cannot be experienced. Motor activities occurring following LORR or LOP, although potentially distressing to observers, are not perceived by an unconscious animal as pain or distress. Reflexive kicking in unconscious animals may be mistaken for conscious activity and can occur even after decapitation, as neurologic circuits involved with walking are located in the spinal cord.[30] Given that we are limited to applying slaughter methods based on these four basic mechanisms, efforts should be directed toward educating individuals involved in the slaughter process, achieving technical proficiency, and refining the application of existing methods, including handling conditions before slaughter.

0.8 Animal Behavioral Considerations

One of the major aspects of these Guidelines is to minimize animal distress, including negative affective or experientially based states such as fear, aversion, anxiety, and apprehension, during the depopulation process once a decision has been made to depopulate. They are also meant to anticipate human welfare and safety concerns regarding the repeated termination of animals' lives on a large scale and likely with a great degree of urgency. Veterinarians and other employees conducting depopulation should familiarize themselves with predepopulation protocols and be attentive to species and individual variability to mitigate distress in both food animals and human handlers. The method for inducing unconsciousness and the handling and restraint methods associated with it must be evaluated as an entire system.[31] Physical methods require more handling and restraint of individual animals, compared with CAS, but they induce instantaneous unconsciousness. Controlled atmosphere stunning does not induce instantaneous unconsciousness, but possible distress during handling may be reduced. There may be a trade-off between possible distress during a longer time to induce unconsciousness and the benefits of reduced handling of individual animals.

The method choice might be determined by the purpose of depopulation (eg, for disease control purposes, or to save the greatest number possible). Depending on the method, animals may have to be handled and restrained during the process of termination. Measures should be adopted to minimize distress and suffering before loss of consciousness. As best as possible, acceptable husbandry and proper handling techniques should be maintained until the animals are terminated. For the sake of the animal, depopulation should occur efficiently, consonant with humane standards of care principles and with minimal stress. Operational procedures should be adapted to the premises and should consider animal welfare and husbandry aspects in conjunction with the aesthetics of the method of depopulation, availability of trained personnel who are competent to execute the destruction, presence of adequate agents to perform the depopulation, cost of the method, safety of the personnel carrying out the procedure, biosecurity, and the environment.

0.9 Human Behavioral Considerations

A number of disasters (eg, Hurricane Katrina, Hurricane Rita, Hurricane Harvey, wildfires) have disclosed gaps in planning when it comes to dealing with the welfare of companion animals and animals in the wild, zoos, or aquariums, and provisions regarding animal welfare have not been well considered within the evacuation plans for their human caregivers. This lack of proper planning and trained individuals can result in significant loss of animal life and suffering and psychological distress to both animals and their owners. Prior planning, sensible compensatory leave allowances, overtime pay, and recognition of dedication will alleviate some of the stress of the recovery period, minimize burnout, and facilitate staff retention. In addition to an increased work load, the psychological impact of a disaster associated with animal suffering and loss of animal life, combined with feelings of a limited ability to do anything about it, may manifest. Stress counseling is most effective when it has been incorporated as part of regular disaster preparedness efforts. The cyclic nature of emergencies and cross-relation of all four phases confirms that planning does not end with the publication of a plan. Disaster preparedness is a continual effort in which the phases of the cycle of emergency management are constantly being anticipated, reviewed, and improved.

In crisis situations, human considerations should not be considered independently from animal welfare ones. Sufficient planning for the evacuation of animals together with their owners is necessary as an integral part of emergency management to reduce animal suffering and loss of life and limit the scope of depopulation. Emergency management plans should consist of properly trained and well-equipped individuals to respond to the link between humans and animals and address the role of veterinarians in promoting animal welfare during times of catastrophe. Emergency preparedness is essential for the veterinary profession as part of its obligations to animals and humans. Clear outcomes should be delineated regarding mitigation, preparedness, response and emergency relief, and recovery in an emergency situation and the potential impact of depopulation on the veterinary community and others performing the depopulation. Considering the human dimension associated with depopulation, such as whether veterinarians have sufficient training and education in the area, is important.

People (caregivers and owners, for example) are strongly connected to their animals and animals in general, and depopulation efforts should be sensitive to this. The mass destruction of flocks and herds of animals that belong to farmers of livestock, for example, can exert a heavy emotional and financial cost. Those making the decision to depopulate must be mindful of the emotional impact of the procedure on owners of the animals, laboratory technicians, conservation managers, emergency response personnel, veterinarians, and the community at large. Anticipatory measures, such as a rigorous animal care emergency plan with a view to human welfare and safety, should be considered by all facilities that house animals. An effective depopulation plan should include a priority system of which animals to depopulate first or save or spare, training for members in the case of such a contingency, well-designed communication methods, and clear provisions for animals and staff.

Depopulation is a joint responsibility, and thus the emergency response to destroy large groups of animals is not solely the domain of veterinarians or veterinary agencies. Rather, it is a shared responsibility that may involve government agencies, communities, businesses, professions, and individuals. Benefits and burdens of decisions related to emergency response involving depopulation should be distributed equitably among members of society impacted by the crisis, and it is important to have a fair process and transparency in decision-making between all the relevant parties. Consideration of the human element of emergency management and depopulation of animals should be a significant concern if not paramount to any procedure carried out to respond to a state of emergency if the effort is to occur relatively unimpeded. Effective biosecurity measures and new technologies that have the potential to improve the efficiency and effectiveness of the process should be considered if they can limit the number of animals that need to be depopulated, protect human health and safety, and bolster humane performance of depopulation procedures.

Typically, when responding to a regulatory disease, an official veterinarian will lead operational activities and will have the authority to appoint the personnel with the required training and competencies to respond to the emergency. It is also the role of the lead veterinarian to ensure adherence to mandated animal welfare and biosecurity standards, federal and state laws, and professional codes of conduct.

Depending on the magnitude or scale of the emergency, veterinarians may be organized into specialist response teams and deployed to work on an affected area. Response plans should follow preparation plans unless the situation requires modification. Plans should deal with animal welfare considerations and normal animal husbandry practices, personnel safety, biosecurity, and available resources and how to communicate risks to the public (and through mass or social media to ensure balanced reporting of the depopulation). Due consideration should also be given to potential psychological impacts on veterinarians, personnel performing the depopulation, the community, and caregivers and owners of animals. Negative environmental impacts from the depopulation and carcass disposal should also be identified.

To minimize public distress, justification for the mass destruction of animals should be communicated in a transparent and honest way. Every effort must be made to share the welfare-protection measures undertaken. The respect of the profession will depend on how the public and other interested parties perceive the ways in which animal welfare is safeguarded owing to a well-executed depopulation plan. A successful depopulation can galvanize community support for the effort and keep the morale of those performing the depopulation up. It should also include targeted public education and options for the public to incorporate improved biosecurity measures as is practicable and as part of a sensible surveillance and monitoring component to minimize the effects of depopulation on people, animals, and the environment.

Emergency veterinarians and those participating in depopulation as part of specialist teams may be asked to communicate the nature of depopulation to the public and offer their expertise. They may also be asked to provide an ethical accounting and monitoring of animals' welfare at different facilities to the public in a transparent fashion. Veterinarians are encouraged to increase their awareness of euthanasia and depopulation methods and to enhance understanding of the science behind the methods currently employed with a view toward crisis standards of care. All those impacted by an emergency involving depopulation should be encouraged to understand the diversity of public concerns and trending societal values related to normal animal husbandry and when depopulation of animals must be pursued.

The depopulation of animals is a learned skill that requires training, respect, and self-awareness. Personnel performing depopulation must be technically proficient. Periodic professional continuing education on the latest methods, techniques, and materials available for both euthanasia and depopulation is highly encouraged. Personnel must also possess a temperament that does not lead to callousness and abuse. Self-awareness when it comes to mass destruction of animals will help to mitigate compassion fatigue and callousness.

Killing of animals by personnel involved in depopulation can substantially impact psychological well-being.[32] Appropriate oversight of the psychological well-being of these individuals is paramount to mitigate guilt, distress, sadness, fatigue, alienation, anxiety, and behaviors that lack consideration of others or may lead to harming themselves, animals, or other people. People may have individual differences in how they psychologically react to the job of killing animals.[33] It is difficult to care about animals when they have to be killed. This is called the caring-killing paradox.[34]

Involvement by local veterinary organizations may be helpful during a depopulation effort to ensure adequate volunteers in the future and as a way to pull expertise together to limit animal and human suffering and to find effective ways to provide emotional support to impacted veterinarians and other depopulation personnel and the public in general, especially if there is any underestimation of the toll of killing healthy animals.

Veterinarians and others who are regularly exposed to the depopulation process should also be monitored for emotional burnout, psychological distress, or compassion fatigue and be encouraged to seek appropriate psychological counseling.[35] Depopulation may result in fear, anxiety, helplessness, anger, frustration, a sense of defeat, and distrust.

Those involved in the depopulation process may be torn between serving the best interest of animals, the human client (individual), personal professional interests, and societal concern to safeguard the welfare of animals. Some may also disagree with the decision to depopulate animals in the first place or resist certain methods in the presence of empirical or ethical disagreement. Others may experience guilt from being implicated in the deaths of so many animals. More studies both on the impact of depopulation on the personnel performing the procedure and on attitudes among the general public and veterinary community toward depopulation of different species of animals will go a long way in promoting healthier and more respectful human-animal relationships.

0.10 Managing Public Information and Access

The purpose of depopulation and why it must be done should be articulated transparently and judiciously to the public and to owners of animals that will be destroyed. Doing so will help to engender public support for a difficult decision and is an important aspect of *right procedure*. The successful communication of the reasons for killing animals in large numbers is the responsibility of the public information officer, ensuring correct and consistent messages. Rules of confidentiality and regulating media and social media should also be articulated carefully. While public trust and support will likely be bolstered by greater transparency regarding the defensibility of method, for example, all members of the public may not desire to witness the events associated with depopulation of animals.

Managing information will very likely be a significant challenge. It is of paramount importance that reliable and trusted sources of information be put into place as quickly as possible, as delays lead to speculation. The individual or group in charge of public information will vary with the event and authority. The event given impact (local, state or regional, national, or international) will determine the access.

0.11 Environmental Considerations and Disposal

The disposal of carcasses in large numbers can present a potential public health and environmental risk. A depopulation plan should consider the effective management of carcasses to reduce potential risks to humans, livestock, and adjacent environment. Thus, a depopulation plan must be informed by disposal. All state and federal laws need to be followed during carcass disposal, and coordination may involve state officials and government agencies like the Department of Natural Resources and the APHIS.

0.12 Veterinary Ethics and Depopulation

Depopulation involves making ethical decisions within the context of an emergency situation. An emergency situation that involves depopulation is thus not an ordinary situation. The hard decisions that need to be made during this extraordinary situation should be based on sound ethical grounding or standards. Ethical reasoning cannot be suspended or ignored, and it is important that preparation planning and response planning for emergency situations occur within normal times (ie, when there is no urgency) and be guided by commonly shared moral values.[36] Developing a framework for ethical decision-making before an emergency is essential. Having a framework for ethical decision-making is essential for effective and humane depopulation, since veterinarians will be challenged to be sensitive to a plurality of views about the ethical value and killing of animals,[37] and to address ethical problems and situations that affect not only animals, but also the environment and a variety of human agents and their value systems.

Depopulation, as a method of containment for effective emergency or disaster management and response, should account for human well-being, animals and their welfare, and the importance of specific human-animal bonds and relationships. Careful attention to animal issues will be critical in addressing evacuation, containment, depopulation, recovery, and disposal and to maintain public trust. Sound animal welfare standards and guidelines (see AVMA Animal Welfare Principles[3]) will provide valuable frameworks for planning for animals in emergency contexts and ensure that ethical commitments are upheld. Restoring both public confidence and security and economic stability after an emergency also constitutes important elements of effective emergency management and successful depopulation.

Before an emergency occurs, planning, training, simulation, risk management, and coordination will be crucial to ensure animal and human welfare issues are addressed in a response. However, emergency situations can be punctuated by failures in mass or electronic communication and disruptions in accessibility to resources or to the affected disaster or catastrophic sites. A state of emergency is also characterized by surprise, shock, and unpredictability and is undesired by those impacted. Some emergencies involving the depopulation of animals can be more localized and can be addressed by means of local resources. However, some are more global in scope and require interagency cooperation (including international partners) and state and federal intervention (eg, the 2015 H5N1 HPAI outbreak).

A central component of veterinary ethics in a crisis situation is determining which animals we ought to care about and how we ought to care about them. Deliberation about these considerations in a crisis involving depopulation will inevitably fall to a multidisciplinary team.[38] Such a team may be composed of members of the public, members of animal-related industries, scientists, veterinarians, and members of government agencies. These members will likely vary in their priorities, interests, and views about the moral and economic value of animals. Preferences for certain biological group membership (eg, whether a species or individuals are considered nuisances or pests) and disagreement about whether to consider animals' interests for their own sake or indirectly in an emergency situation could initially frustrate a crisis management process. For instance, depopulation of species with a charismatic appeal can create public objections regardless of the methods used, whereas the welfare standards applied to animals commonly accepted as pests (eg, rodents or insects) may not elicit much public scrutiny. In the wake of divergent views of which animals should matter and how we ought to consider their interests, a general commitment to animal welfare (eg, that we should be mindful of their capacities, feelings, and functions) can be a common starting point for ethical and practical deliberation. When adjudicating depopulation and disposal techniques and, more generally, policies and actions regarding treatment of animals in a crisis situation, thoughtful consideration should be given to different social, cultural, and emotional human-animal relationships as well as to the competing ethical and economic reasons placed on why different individual animals and animal species should be either saved or destroyed.

Depopulation guidelines should be developed before an emergency occurs to help veterinarians and their partners decide how to administer the best possible veterinary care in conjunction with high professional standards of veterinary ethics. Coordination ahead of time with other crisis team members will likely result in respect and a good outcome.

Proper planning and preparation are important ethical duties that should occur beforehand and must be carried out by the veterinary community and others tasked with responding to the emergency with a high degree of professionalism. Here, veterinarians and their partners must prepare and deliberate over how they would give the best care possible under the worst possible conditions (ie, delineate crisis standards-of-care procedures) to different parties affected by an emergency situation.

An emergency situation involving depopulation may involve judicious application of public-health decision-making that tends to stress duties to populations rather than individuals, with quick containment or resolution, and keeping in mind scarce resources such as time, human ability, funds, and veterinary medical supplies. Strong ethical grounding is essential in guiding crisis management and depopulation procedures through commonly shared ethical principles like fairness; stewardship of limited resources, including human capacity; respect for the interests of human and animal beings who have a stake in the decision; and consequentialist considerations like producing the most good and doing the least harm.

During an emergency situation involving the destruction of large numbers of animals, hard decisions must be made. Alongside a nexus of actors and agencies tasked with bringing about the best outcome for all those affected, veterinarians may face planning that is complicated by conflicts of duties, scarcity of resources, limited and evolving information, uncertainty, emotional distress, differences in ethical values and priorities, and high levels of risk to multiple stakeholders.[39]

Not every contingency can be anticipated ahead of time, and ethical values or issues may not be the only factors considered when the relevant authority decides how best to ameliorate an emergency situation involving depopulation. There is also no perfect formula or recipe when dealing with depopulation. That said, the following ethical considerations can help veterinarians and others during an emergency that may entail depopulation (the discussion that follows is adapted from Campbell and Hare[40]).[36,41,42] An alternative framework may be found in Mepham.[43]

The soundness of the ethical decision-making during an emergency situation involving depopulation begins with what the veterinarians are obliged professionally to do. Veterinarians are obliged professionally to protect or promote animal welfare and health.[3] This may be relatively straightforward to perform in normal times. However, during an emergency situation (eg, pandemic, natural disaster, or biosecurity breach) involving depopulation, living up to one's veterinarian-client-patient relationship or the compendium of Animal Welfare Principles[3] can become challenging given the complexities associated with the emergency situation. The priorities of reducing suffering or saving lives during an emergency situation, while the cornerstones of a moral compass, can be complicated by conflicts of duties to animals, the public, clients, the profession, and themselves and by differing conceptions of harm, divergent notions of risk, competing ethical frameworks and priorities, how the collective good is conceived,[44] and opposing conceptions or emphases regarding the value of animals' lives and their welfare.[45] Veterinarians should consider the plurality of views regarding animal welfare and the human-animal relationship (eg, some animals are regarded as family members while others are only valued instrumentally) when depopulating animals in a variety of contexts.

The soundness of the ethical decision-making regarding depopulation can be bolstered through a number of steps. During the first step of ethical deliberation, *problem-seeing*, veterinarians and others should come together to locate or identify the ethical dimensions of the situation—that is, to distinguish the ethical issues from empirical, economic, or political ones, delineating substantive from procedural ethical challenges and concerns in the process. While there may be overlap, ethical issues should be distinguished from animal welfare and care aspects (eg, that focus specially on medical, species, or biological knowledge) of the situation and from logistic, environmental, and regulatory issues, for example. Problem-seeing also invites veterinarians and others to begin reflecting on their personal ethical values or commitments and to distinguish them from the values of the organizations or constituents that they represent.

The second step of *identifying all relevant parties* who will be involved in or who are affected or implicated by the emergency and the decision to depopulate is vital to ensure that none of the morally relevant individuals and groups (which may include animals targeted for depopulation or those intended to be saved, human victims, emergency responders and veterinarians, farms, labs and shelters, and the environment or wild species) are left out from consideration. This step can uncover the relationships between the different parties and the strength afforded to the interests of the different impacted parties. This step will also help in identifying the decision-makers who are or ought to be involved in deliberating about depopulation or other emergency responses as well as highlight both real and potential conflicts of interest for these decision-makers.

The third step involves *considering the context* of the emergency or depopulation, which includes gathering pertinent information to aid in decision-making. Veterinarians' expertise in discerning *clinically related issues* will be important in moving forward with the decision to depopulate. The diagnosis of the situation may involve reducing suffering of infected or compromised animals or identifying which animals should be saved. The goals of depopulation or any intervention will come into focus, as will probabilities associated with success, identification of risks, and contingencies in case of therapeutic failure. During both preparation and response planning for an emergency, veterinarians will be essential in delineating the *crisis standards of care* (ie, a clinical benchmark of acceptable-quality clinical care) during both the preparation and response phases of a depopulation. The standards should reflect the consensus of opinion on clinical matters and be guided by evidence-based clinical processes and operations. Consistent crisis standards of care should 1) reflect strong ethical underpinnings and avoid violating ethical norms; 2) outline triage protocols and ensure consistency of implementation between crisis management teams; 3) promote consideration and integration of different value perspectives; 4) enhance engagement with community members and effective risk communication and real-time information sharing (as much as possible) with affected populations; 5) maximize autonomous choices of human victims and members of a crisis management team (of which veterinarians are members) regarding allocation of scarce resources such as talent, time, energy, and money; 6) pay particular attention to vulnerable populations; 7) have clear indicators of success and what is not tolerable as well as 8) make transparent lines of accountability. Clinically related issues intersect with those involving *quality of life/death issues* when veterinarians are asked to consider which lives to save or how suffering might be reduced. For example, veterinarians may raise the following important considerations: What are the prospects for the animals for a return to normal life if some animals are spared depopulation (which might be an option in the case of disease outbreak and vaccination)? How well will animals tolerate a proposed intervention that minimizes the number of animals slated for depopulation? What physical and mental harms are the animals likely to experience in the event of therapeutic failure? What physical and mental deficits are the animals likely to experience if treatment succeeds? How will the quality of life of animals involved in depopulation affect their caregivers and the communities or ecosystems to which they belong (in the case of wild animals, for example)?

Besides clinical issues, considering other *stakeholders' preferences and interests* will be key in ensuring that contextual matters are addressed in a measured way. Thus, it is important to consult other potential sources of information. For example, nonclinical considerations could include whether owners and caregivers or affected members of the public or depopulation operators have been informed of benefits and risks associated with the depopulation method or alternative solutions. Do they understand what is at stake, and can they give consent for the depopulation or alternative responses?

The next step involves *formulating response plans and generating a set of alternative remedies*. A number of basic questions may be asked to assist in the evaluation of the decision-making alternatives of the crisis management or depopulation response team. These questions include whether the action respects the rights of both animal and human beings with an interest in the decision (rights-based approach); will generate more good than harm (consequentialist approach); reflects good conduct and professionalism (virtues approach); treats the relevant parties justly and humanely, including recognizing that they have interests in the first place (justice approach); and promotes the interests of the entire community (people, animals, the environment, and other affected parties; common good view).[43]

Deliberation during this stage may involve a decision to forgo depopulation altogether or choosing between depopulation methods. Here, veterinarians can help response teams evaluate the merits of the means or alternatives recommended to achieve the goals of either reducing suffering or saving lives. This step includes determining whether the crisis response team has the best available data regarding how a disease outbreak is spreading, determining the effectiveness of an intervention like a vaccine, or determining whether animals in a compromised situation can be rehomed or rehabilitated. It may also include investigating the circumstances surrounding disasters like flooding, fires, or earthquakes on the welfare of stranded animals.

Identifying the values or ethical bases embedded in both preparation and response planning to an emergency is an important next step in ethical decision-making. Making values (ie, ideas that guide action) explicit and clear can help with the justification process when there are conflicts of duties or interests and when priorities between values or outcomes must be made. Identifying ethical principles and values and making them public is particularly important in emergency situations to gain public support and to ensure that the impacts of response (be it depopulation or not) on animals, human agents such as clients, and the public at large are as thoroughly thought through as is practicable.

Here, ideally, the relevant ethical principles and values should be articulated publically or made as transparent as possible. These principles may reflect whether, for example, consequences, rights, or virtues of character are motivating various responses.

Generally, ethical decisions are informed by common principles or values that can be distinguished as either substantive or procedural in nature. *Substantive principles* express philosophical and normative commitments that emphasize "consequences, constraints or conduct."[46] *Procedural principles* reflect the decision-making mechanisms that are connected to the way in which we deliberate. Briefly, the emphasis on consequences can highlight a) utilitarian thinking, which seeks to produce either the least amount of suffering or the greatest overall or aggregate good for all considered (in effect, save the greatest number); b) Pareto optimality, which seeks to ensure that at least no one is made worse off when achieving the best outcome; c) the "save all who can be saved" principle[36]; or d) the minimax principle, which necessitates that decision-makers figure out the maximum possible cost under each course of action and choose the minimum of those possible costs. Consequentialist thinking aims to produce the most good or to do the least harm and turns on concerns regarding well-being. The focus of this approach is future impacts of an action, for all those who may be affected by it. Decisions regarding consequences can be viewed as concerning well-being. Concerns regarding well-being can be based on efforts to either ensure nonmaleficence (eg, to refrain from doing harm to animals, caregivers, or members of the general public) or promote beneficence (eg, to do good for others either by benefitting them directly or preventing or removing harms that will ultimately impact them).

The emphasis on constraints like justice, duties, and rights highlights nonconsequentialist reasons for acting[47] and emphasizes the intentions and motivations behind actions, including duties that exist before the situation such as obligations to respect the autonomy of caregivers and emergency operators or respect for fairness (eg, Are we treating some animals merely as a means to an end? Are we respecting morally significant rights and entitlements of human agents impacted by the emergency and decision to depopulate? Do we have fair procedures to decide which and how many animals are destroyed? Are the depopulation outcomes consistent with public conceptions of justice?). An emphasis on constraints could also be influenced by fidelity, namely, whether the decision to depopulate is faithful to institutional and professional roles of veterinarian (eg, whether it reflects the trust relationships that veterinarians and others have with the community and perhaps as expressed through the Oath or veterinarian-client-patient-relationship).

The emphasis on conduct highlights virtues of character and attempts to discern qualities (virtues and vices) that motivate the human agents in the situation[46] (eg, whether the veterinarians are behaving in a manner that is laudable [ie, commensurate with professional expectations specified by their organization's code of professional conduct]), despite extenuating circumstances brought on by the emergency. For example, are they behaving with integrity according to professional codes of conduct, or have they been honest with clients whose animals must be depopulated?

Deliberating about depopulation according to *right procedure* (ie, by soliciting input during normal times from relevant stakeholders) as part of preparation or response planning or communicating risks and preparing the public or animal caregivers for worst-case scenarios is an important part of ethics discourse. Ethical decision-making is at the core of determining our obligations to animals during disaster or crisis situations and is essential for judicious preparation, policies, response, and recovery.[48,49] A depopulation plan and its execution require adherence to commonly shared ethical principles. Further, when possible, broad public discussion of the allocation of limited resources in emergencies should be a vital component of disaster preparation in a democratic society and should not to be overlooked.[36] Broad public engagement is critical to resolve a crisis situation quickly and efficiently and to ensure that the best care is available to those who need it the most, while balancing equitably the needs of the community against that of the individual. Veterinarians who are part of a crisis response team will benefit from having the support of an informed public that is aware of necessary procedures to address the calamity and from making the desired outcome transparent.

It is important that the ethical basis of depopulation preparation and response be public to meet public expectations of transparency, consistency, proportionality, and accountability, especially during emergency situations. These procedural matters can guide the development of consistent crisis standards-of-care protocols and shape integrated and ongoing community and crisis team engagement; enhance education and communication regarding risks, uncertainty, and science-informed or evidence-based processes between stakeholders and crisis team responders; provide the public with assurances regarding legal authority and involvement by government actors at various levels; highlight clear indicators of success; and delineate lines of responsibility and professional limitations. Here, it is important to identify who will request or need ethical information (eg, decision-makers of incident command teams, emergency management committees, local emergency management command centers [including police, fire, and emergency medical services], public health agencies, clinicians [eg, veterinarians, physicians, nurses, and social workers], consumer and citizen advocacy groups, and local faith-based organizations).

Whether weighing and weighting harms and benefits or considering constraints such as rights and entitlements or considering right professional conduct, veterinarians should keep in mind the relevance of their ethical decision-making for courts of law, professional bodies, and members of the public. It is important to consult legal and professional rules as decisions are being made on the best course of action or choice of depopulation method.

Depopulation, not unlike having to perform numerous euthanasia procedures, can result in lasting emotional distress.[50] A poorly executed depopulation can lead to harms to patients, clients, nonveterinary staff, veterinarians, emergency operators, and related crisis personnel and to the profession. Seeking out others who can be sounding boards can be beneficial to veterinarians assisting with depopulation. *Discussing the matter with others*, such as experts in the areas of emergency management or professional colleagues, can also guide professional decisions during emergencies. Sharing experiences related to managing outbreaks and developing a statement to address the need for thoughtful, critical, and flexible thinking in application of depopulation techniques can also improve welfare outcomes and the justification and accountability of one's decision-making in a crisis situation. Discussing values (ie, the guiding principles that respected others consider to be the most important ones in mitigating health and welfare issues during a crisis [and which can reflect a lifetime's worth of experience]) can enhance one's moral compass during an emergency situation. Also, asking how someone in the field that one admires would behave in this situation can help to give some perspective on how to conduct one's self in emergency situations involving depopulation. Learning from colleagues who have knowledge on how to effectively respond to a disaster or disease outbreak, including depopulation, will enable veterinarians and others who must carry out such an initiative in a crisis situation to deliver appropriate care to and anticipate the needs of both animals and human beings impacted by the process to depopulate animals.

0.13 References

1. AVMA. AVMA guidelines for the euthanasia of animals: 2013 edition. Available at: www.avma.org/KB/Policies/Documents/euthanasia.pdf. Accessed Feb 7, 2019.
2. AVMA. AVMA guidelines for the humane slaughter of animals: 2016 edition. Available at: www.avma.org/KB/Resources/Reference/AnimalWelfare/Documents/Humane-Slaughter-Guidelines.pdf. Accessed Feb 7, 2019.
3. AVMA. Principles of veterinary medical ethics of the AVMA. Available at: https://www.avma.org/KB/Policies/Pages/Principles-of-Veterinary-Medical-Ethics-of-the-AVMA.aspx. Accessed Feb 16, 2019.
4. Selye H. Stress and the general adaptation syndrome. *Br Med J* 1950;1:1383–1392.
5. DeGrazia D. The ethics of animal research: what are the prospects for agreement? *Camb Q Healthc Ethics* 1999;8:23–34.
6. McMillan FD. Comfort as the primary goal in veterinary medical practice. *J Am Vet Med Assoc* 1998;212:1370–1374.
7. Antognini JF, Barter L, Carstens E. Overview: movement as an index of anesthetic depth in humans and experimental animals. *Comp Med* 2005;55:413–418.
8. Raj ABM, Gregory NG. Welfare implications of the gas stunning of pigs 1. Determination of aversion to the initial inhalation of carbon dioxide or argon. *Anim Welf* 1995;4:273–280.
9. Alkire MT, Hudetz AG, Tononi G. Consciousness and anesthesia. *Science* 2008;322:876–880.
10. Webster AB, Collett SR. A mobile modified-atmosphere killing system for small-flock depopulation. *J Appl Poult Res* 2012;21:131–144.
11. Hendrickx JF, Eger EI II, Sonner JM, et al. Is synergy the rule? A review of anesthetic interactions producing hypnosis and immobility. *Anesth Analg* 2008;107:494–506.
12. Zeller W, Mettler D, Schatzmann U. Untersuchungen zur Betäubung des Schlachtgeflügels mit Kohlendioxid. *Fleischwirtschaft* 1988;68:1308–1312.
13. International Association for the Study of Pain. Pain terms. Available at: www.iasp-pain.org/AM/Template.cfm?Section=Pain_Definitions&Template=/CM/HTMLDisplay.cfm&ContentID=1728#Pain. Accessed Feb 7, 2011.
14. Cavanna AE, Shah S, Eddy CM, et al. Consciousness: a neurological perspective. *Behav Neurol* 2011;24:107–116.
15. Alkire MT, Hudetz AG, Tononi G. Consciousness and anesthesia. *Science* 2008;322:876–880.
16. Mashour GA, Orser BA, Avidan MS. Intraoperative awareness—from neurobiology to clinical practice. *Anesthesiology* 2011;114:1218–1233.
17. Hawkins P, Playle L, Golledge H, et al. Newcastle consensus meeting on carbon dioxide euthanasia of laboratory animals. 9 August 2006. Available at: www.nc3rs.org.uk/sites/default/files/documents/Events/First%20Newcastle%20consensus%20meeting%20report.pdf. Accessed Feb 7, 2019.
18. McKeegan DE, Sparks NH, Sandilands V, et al. Physiological responses of laying hens during whole-house killing with carbon dioxide. *Br Poult Sci* 2011;52:645–657.
19. Benson ER, Alphin RL, Rankin MK, et al. Evaluation of EEG based determination of unconsciousness vs. loss of posture in broilers. *Res Vet Sci* 2012;93:960–964.
20. Finnie JW. Neuropathologic changes produced by non-penetrating percussive captive bolt stunning of cattle. *N Z Vet J* 1995;43:183–185.
21. Gregory NG, Lee JL, Widdicombe JP. Depth of concussion in cattle shot by penetrating captive bolt. *Meat Sci* 2007;77:499–503.
22. Vogel KD, Badtram G, Claus JR, et al. Head-only followed by cardiac arrest electrical stunning is an effective alternative to head-only electrical stunning in pigs. *J Anim Sci* 2011;89:1412–1418.
23. Grandin T. Improving livestock poultry and fish welfare slaughter plants with auditing programs. In: Grandin T, ed. *Improving animal welfare: a practical approach.* Wallingford, England: CABI Publishing, 2010;160–185.
24. Cartner SC, Barlow SC, Ness TJ. Loss of cortical function in mice after decapitation, cervical dislocation, potassium chloride injection, and CO_2 inhalation. *Comp Med* 2007;57:570–573.
25. Vanderwolf CH, Buzak DP, Cain RK, et al. Neocortical and hippocampal electrical activity following decapitation in the rat. *Brain Res* 1988;451:340–344.
26. Mikeska JA, Klemm WR. EEG evaluation of humaneness of asphyxia and decapitation euthanasia of the laboratory rat. *Lab Anim Sci* 1975;25:175–179.
27. Bates G. Humane issues surrounding decapitation reconsidered. *J Am Vet Med Assoc* 2010;237:1024–1026.
28. Holson RR. Euthanasia by decapitation: evidence that this technique produces prompt, painless unconsciousness in laboratory rodents. *Neurotoxicol Teratol* 1992;14:253–257.
29. Derr RF. Pain perception in decapitated rat brain. *Life Sci* 1991;49:1399–1402.
30. van Rijn CM, Krijnen H, Menting-Hermeling S, et al. Decapitation in rats: latency to unconsciousness and the 'wave of death.' *PLoS One* 2011;6:e16514.
31. Grillner S. Human locomotion circuits conform. *Science* 2011;334:912–913.
32. Grandin T. Making slaughterhouses more humane for cattle, pigs, and sheep. *Annu Rev Anim Biosci* 2013;1:491–512.
33. Woods J, Shearer JK, Hill J. Recommended on-farm euthanasia practices. In: Grandin T, ed. *Improving animal welfare: a practical approach.* Wallingford, England: CABI Publishing, 2010;194–195.
34. Grandin T. Behavior of slaughter plant and auction employees towards animals. *Anthrozoos* 1988;1:205–213.
35. Meyer RE, Morrow WEM. Euthanasia. In: Rollin BE, Benson GJ, eds. *Improving the well-being of farm animals: maximizing welfare and minimizing pain and suffering.* Ames, Iowa: Blackwell, 2004;351–362.
36. Zack N. The ethics of disaster planning: preparation vs response. *Philos Manag* 2009;8:55–66.
37. Meijboom FL, Stassen EN, eds. *The end of animal life: a start for ethical debate. Ethical and societal considerations*

on killing animals. Wageningen, Netherlands: Wageningen Academic Publishers, 2016.
38. Murray G, McCutcheon S. Model framework and principles of emergency management. *Rev Sci Tech* 1999;18:15–18.
39. Tannenbaum J. Veterinary medical ethics: a focus of conflicting interests. *J Soc Issues* 1993;49:143–156.
40. Campbell CS, Hare JM. Ethical literacy in gerontology programs. *Gerontol Geriatr Educ* 1997;17(4):3–16.
41. Croney CC, Anthony R. Engaging science in a climate of values: tools for animal scientists tasked with addressing ethical problems. *J Anim Sci* 2010:88(suppl 13):E75–E81.
42. Morgan C. A guide to moral decision making for veterinarians. *Newsl Soc Vet Med Ethics* 2006;12(1):3–4.
43. Mepham B. Morality, morbidity and mortality: an ethical analysis of culling nonhuman animals. In: Meijboom FL, Stassen EN, eds. *The end of animal life: a start for ethical debate. Ethical and societal considerations on killing animals*. Wageningen, Netherlands: Wageningen Academic Publishers, 2016;341–362.
44. Anthony R. Taming the unruly side of ethics: overcoming challenges of a bottom-up approach to ethics in the areas of food policy and climate change. *J Agric Environ Ethics* 2012:25:813–841.
45. Allen H, Taylor A. Evolution of US foot-and-mouth disease response strategy. *Disaster Prev Manag* 2014:23;19–39.
46. Thompson PB. *From field to fork: food ethics for everyone*. New York: Oxford University Press, 2015.
47. Beauchamp TL, Childress JF. *Principles of biomedical ethics*. 7th ed. New York: Oxford University Press, 2013.
48. Rollin BE. Ethics and euthanasia. *Can Vet J* 2009;50:1081–1086.
49. Nussbaum MC, Chan JCW, Lau JYF, et al. *The ethics and politics of compassion and capabilities*. Hong Kong: Faculty of Law, The University of Hong Kong, 2007.
50. Rollin BE. Euthanasia, moral stress and chronic illness in veterinary medicine. *Vet Clin North Am Small Anim Pract* 2011;41:651–659.

1: Companion Animals

1.1 General Considerations

1.1.1 Included species and settings

Companion animals for this section will include the following: cats, dogs, ferrets, potbellied pigs, rabbits, and small rodents commonly kept as pets (chinchillas, gerbils, guinea pigs, hamsters, mice, and rats). Aquatic, avian, and exotic animals that are kept as companion animals will be considered in other sections of this document.

Companion animals for which depopulation may be considered may be encountered in several environments, including individually owned animals; breeding animals (from dams, sires, and single litters to colonies of breeding animals); populations of animals maintained in animal control facilities, shelters, rescues, sanctuaries, and pet shops; animals maintained in research laboratories; animals maintained in veterinary facilities, boarding facilities, or quarantine stations; animals maintained at working animal training facilities (eg, dogs intended for military, law enforcement, security, or service); Greyhounds maintained on racetrack grounds and training facilities; and free-roaming, unowned, abandoned, or feral companion animals that may be present in virtually any terrestrial ecosystem.

Institutions such as well-managed research laboratories, animal control facilities, quarantine facilities, and animal shelters generally have depopulation protocols within their emergency and disaster preparedness plans owing to governmental or institutional regulations. Other facilities that house groups of companion animals such as training or boarding facilities, breeding operations, and private shelters or sanctuaries tend to be less rigidly regulated and are less likely to have emergency depopulation procedures in place.

1.2 Events Necessitating Depopulation

Emergency events that may necessitate the consideration of depopulation of companion animals may include the widespread loss of essential survival resources during natural disasters such as earthquakes or floods; non-natural disasters such as incidents involving terrorism, bioterrorism, conventional or nuclear attack or accidents, or toxic chemical spills; contamination of food and water supplies; zoonotic or pandemic disease that threatens public health and the food supply; and contagious veterinary disease in a single locality or species. Public perceptions, political and legal interventions, logistic difficulties, and compliance issues are likely to complicate depopulation efforts directed at companion animals, as was seen with the euthanasia of an Ebola virus victim's pet dog in Spain in 2014.[1]

1.3 Depopulation Methods

In the majority of cases of depopulation involving companion animals, the number of animals involved will be much smaller than in situations involving depopulation of other types of animals (eg, swine, poultry), which should allow for the employment of standard euthanasia measures. Whenever possible, standard euthanasia methods as outlined in the current AVMA Guidelines for the Euthanasia of Animals[2] must be utilized. Methods described in the following that do not fit the AVMA criteria for euthanasia should be considered only when exigent circumstances prevent the implementation of standard euthanasia methods (eg, unavailability of euthanasia solutions) and should not be considered to be acceptable for routine or nonexigent circumstances. Additionally, some methods that are permitted within the AVMA depopulation criteria may be aesthetically objectionable to handlers, observers, and the public (eg, close-range gunshot or decapitation of pet animals), so the choice of depopulation method should be made with due consideration for potential media and public response that may occur. With all methods, determination that death has occurred must be made before disposal of the remains, and proper disposal methods should be employed to conform to local, state, and federal laws and to minimize hazards to scavengers and the environment due to chemical residues in tissues.

1.3.1 Inhalant methods

Inhalants include inhalant anesthetics (enflurane, halothane, isoflurane, methoxyflurane, sevoflurane, nitrous oxide, chloroform, and ether), carbon dioxide, carbon monoxide and inert gases. Inhalant anesthetics are best utilized as the first step in a two-step method in which the secondary method (eg, physical method) induces death once the animal is unconscious. Because of the relative safety of modern inhalant anesthetic agents, their use as sole agents for euthanasia is generally impractical for depopulation because of the large amounts of inhalant required and prolonged time before death occurs.[3] The order of preference for inhalant agents is isoflurane, halothane, sevoflurane, enflurane, methoxyflurane, and desflurane, with or without N_2O. Nitrous oxide when used alone can cause distress due to hypoxia before loss of consciousness, but it may be used in combination with other inhalant anesthetics to speed onset of anesthesia and lower the amount of the other anesthetic required. Carbon dioxide, carbon monoxide, and inert gases require specialized equipment or facilities to properly administer these inhalants without causing undue distress to animals and hazards to human personnel. Therefore, the use of these agents should be limited to rare instances when appropriate facilities as outlined in the AVMA Guidelines for the Euthanasia of Animals[2] are immediately available for use in depopulation of companion animals. The extreme flammability of ether and the toxicity and carcinogenicity risks of chloroform to personnel performing depopulation make these agents less desirable as inhalant methods; therefore, their use is generally discouraged, as safer alternatives should be pursued.

Because of the potential for recovery following insufficient inhalant exposure, care must be taken to ensure death has occurred before disposal of animal remains.[2] Tissue residues may persist for days, so proper disposal of remains is required.[4] Inhalant agents can be hazardous to personnel, and procedures must be in place to minimize animal worker exposure to anesthetic vapors.[5] Inhalants take longer to induce anesthesia and death in neonates, so a secondary method may be required.[6] Some inhalant anesthetics have the potential for diversion and abuse by personnel.

1.3.2 Noninhalant chemical methods—injectable agents

As outlined in the AVMA Guidelines for the Euthanasia of Animals,[2] IV or IP injection of barbiturate-based euthanasia solutions is the preferred method of euthanasia for all companion species. Alternative routes of administration (eg, intrarenal, intrahepatic) to awake animals generally require greater animal restraint, operator skill, and time, so they are less desirable in depopulation situations where expediency is essential and trained personnel may be scarce. Where available, IV administration of embutramide-based euthanasia solutions is also acceptable; owing to pain on injection and the potential for dysphoria upon induction of unconsciousness, routes other than IV are not recommended for embutramide-based compounds.[2] Injectable anesthetics may be used as a sole method of euthanasia via overdose. Both euthanasia solutions and injectable anesthetics may be used as part of two-step euthanasia whereupon the injections are titrated until unconsciousness occurs, then a secondary method (eg, IV potassium chloride, neuromuscular blocking agent, bilateral thoracotomy, or another physical method) is employed. This two-step method can be useful in situations where supplies of euthanasia solution or injectable anesthetics are limited.

Intravenous potassium chloride causes significant pain upon injection so is recommended only in animals that are unconscious.[2] Saturated and concentrated solutions of magnesium sulfate injected via IV or intracardiac routes caused rapid death in dogs when administered without prior sedation.[9] Reported effects of solutions with concentrations $\leq 50\%$ included involuntary urination, slight muscular tremors, tachycardia and tachypnea, vocalization (2 of 30 dogs), and involuntary defecation (5 of 30 dogs). Intravenous or IC injection of solutions with concentrations $> 60\%$ caused more intense muscle tremors resulting in jerking of limbs. Because of these adverse effects, companion animals should be unconscious before administration of concentrated magnesium salt solutions.

Neuromuscular blocking agents induce flaccid paralysis with no loss of consciousness or pain sensation. Death is due to asphyxia from paralysis of respiratory muscles, which is likely to result in considerable distress before loss of consciousness

Opioids in supratherapeutic dosages cause profound CNS depression leading to respiratory arrest and death. Ultrapotent opioids (etorphine hydrochloride and carfentanil citrate) are 3,000 to 10,000 times as potent as morphine sulfate and have been used for immobilization and euthanasia of wildlife, particularly megafauna.[10] Although highly effective, these agents have a very high risk to human personnel, as less than one drop on broken skin or mucous membranes or accidentally injected may result in death within minutes if appropriate treatment is not obtained. These drugs require special licensing and should be handled only by experienced operators with appropriate reversal agents at hand.

The enteral or parenteral use of quaternary ammonium compounds, solvents (eg, acetone, carbon tetrachloride), formaldehyde, phenols, or similar compounds is never acceptable for depopulation situations. There is no research describing efficacy, dosing, mechanism of action, onset of action, or adverse effects of the use of these compounds to induce death. Many are corrosive and likely to cause pain upon injection. Some (eg, formaldehyde) have significant human health and carcinogenicity concerns.[11]

1.3.3 Noninhalant chemical methods—oral agents

Oral administration of sedative drugs can aid in reducing patient stress, allowing appropriate restraint, and minimizing personnel distress during depopulation. A variety of drugs, including benzodiazepines, barbiturates, opioids, injectable anesthetic agents (eg, ketamine, tiletamine-zolazepam), and phenothiazines, are available that can be used orally to provide sedation. Drugs may be delivered directly to the animal or may be placed in food—the latter method is very useful when dealing with aggressive, fearful, or feral animals.

The oral route can be extremely useful for administration of sedatives before handling or depopulation purposes. However, there are several drawbacks to the oral route as a means of delivering a lethal dose of any agent, including lack of reliable, established lethal dosages for most toxic agents and animal species; lack of assurance that a lethal dose will be ingested by the target animal; species and individual variability in bioavailability, absorption rates, and response to a given dose of an agent; difficulty of administration, including risk of aspiration, if the animal does not willingly consume the agent; potential for agent loss due to vomiting or regurgitation (in species capable of these functions); variability of the latent period between ingestion and death; and potential for recovery in animals exposed to sublethal doses. Additionally, for baited agents intended for free-roaming animals, accidental exposure of nontarget species to the bait or poisoned carcasses and the environmental fate of unconsumed bait are of concern. Also in consideration with lethal oral agents are the severity and duration of clinical signs before death (ie, degree of pain and suffering), the potential health and psychological hazards to human personnel who may witness distress in dying animals, and the negative public perception of animals being deliberately poisoned. Because of these drawbacks, orally administered agents are generally inappropriate for use as depopulation methods in companion animals.

1.3.4 Physical methods

Many physical methods of depopulation can be highly effective and humane when performed properly by adequately trained personnel. However, many physical methods involve techniques that may be stressful to those overseeing and performing the technique, and these methods may be objectionable to those who may not be fully informed on the merits and risks of these methods (eg, general public, media). Therefore, the decision to use physical methods to depopulate companion animals should be made only in extreme cases where alternative methods (ie, inhalants, noninhalants) are unavailable or in limited supply. Whenever possible, physical methods that may cause significant distress to onlookers should be performed out of sight of the public.

Close-range gunshot or captive bolt, as described in the AVMA Guidelines for the Euthanasia of Animals,[2] may be used provided adequately trained personnel are available, appropriate safety measures can be implemented, and equipment is well maintained. Death is due to immediate disruption of brain matter. Utilization of gunshot requires personnel highly versed in gun safety, caliber selection, and targeting characteristics of the species in question. Whenever practicable, sedation or anesthesia is preferred to minimize stress and to provide restraint for proper anatomic application of the method.[12] Hazards from ricochet or skull fragmentation following a gunshot need to be considered.

Distance gunshot may be required in situations where direct contact with animals to be depopulated is not possible (eg, feral animals). Distance gunshots generally target the largest body mass with death due to exsanguination.[13] There is significant risk to unintended targets if improper caliber is used or ammunition misses its intended mark.

Maceration utilizes specialized machinery to instantaneously fragment chicks less than 72 hours old. Death is due to immediate disruption of brain tissue. This process would be feasible only for neonates that fall within the size limitations of the equipment (generally < 75 g [2.6 oz]), and limited equipment availability precludes its use in most companion animal depopulation scenarios.

Manual cervical dislocation is an acceptable method of euthanasia in small animals < 200 g (7.1 oz).[2] Commercial tools are available to aid in cervical dislocation for rabbits up to 3 kg (6.6 lb). Cervical dislocation requires that those performing the method be highly proficient. Done properly, the method appears to induce rapid loss of consciousness; sedation of animals not accustomed to being handled is recommended. The procedure can be aesthetically unpleasant and can cause stress to those performing the method.

Decapitation results in death from suppression of brain activity due to hypoxia from loss of cerebral blood flow. Guillotines must be adequately maintained to ensure efficient action and appropriately sized to the species being depopulated. Animals should be sedated or unconscious to properly restrain and position the patient. Lack of appropriate equipment availability will greatly limit the use of this method in depopulation situations.

Electrocution is considered humane if applied to unconscious animals, but it requires specialized equipment, personnel familiar with equipment, and proper placement of electrodes and is aesthetically objectionable owing to violent muscle contractions.[2] It also may not be effective at inducing death in small animals (< 5 kg [11 lb]) and has the potential to be a serious hazard to personnel.

Asphyxia, including drowning, entails death via oxygen deprivation by interference with respiration through mechanical obstruction of airways or environmental oxygen depletion. In awake animals, asphyxia would be highly distressing in the several minutes that it would take for unconsciousness to occur.[14]

1.4 Implementation With Prioritization

1.4.1 Preferred methods

Injection of euthanasia solution is the most preferred method of depopulation and should have highest priority when formulating response plans that involve emergency depopulation. Euthanasia solutions have known dosing requirements, predictable and rapid onset of action, relative ease of administration, and general acceptance by the public. If euthanasia solutions are in short supply, titration of the dose to achieve unconsciousness followed by a secondary method to induce death (eg, physical method or IV potassium chloride) may be considered to extend the availability of the euthanasia solution. Injectable anesthetic overdoses are acceptable alternative depopulation methods, as are two-step methods involving injectable anesthesia followed by IV administration of concentrated potassium or magnesium solutions, neuromuscular blocking agents, or physical methods. Inhalant anesthetics administered via chamber may be used for small mammals and some other species < 7 kg (15.4 lb); cost and difficulty in administration generally will exclude their use in larger animals.[2] Signs of distress may be apparent owing to the aversive nature of most of these agents; whenever possible, the least aversive agent available should be used. Once unconsciousness ensues, a secondary method to induce death may be performed, or the animal may be left in the chamber until death has occurred. Breath holding may prolong onset of action of inhalant agents. In situations where appropriate equipment and personnel as outlined in the AVMA Guidelines for the Euthanasia of Animals[2] are available, CO and CO_2 may also be used for depopulation.

Other physical methods that could be considered as second steps following anesthesia in two-step methods include exsanguination, hypothermia, asphyxia (eg, bilateral thoracotomy, drowning), decapitation, and cervical dislocation. A surgical plane of anesthesia should be maintained before and during administration of the secondary physical method until death has been confirmed.

1.4.2 Permitted in constrained circumstances

These methods should be considered only when the emergency circumstances constrain the ability to reasonably implement a preferred method. Potential situations that might result in use of methods in this category include, but are not limited to, constraints on human safety, depopulation efficiency, deployable resources, equipment, animal access, disruption of infrastructure, disease transmission risk, and zoonotic disease risk. Many of these methods, while administering as humane a death to the animals as possible, may be considered unaesthetic to those performing the procedures as well as the media and public, so alternative methods should be carefully considered.

In cases of shortage of euthanasia or injectable anesthetic agents, solutions that have exceeded their expiration dates, compounded formulations, or non-pharmaceutical grade injectable euthanasia agents or anesthetics may be utilized for emergency depopulation purposes. Alternative routes such as intrahepatic or intrarenal injection may be considered only if they can be performed with efficiency and minimal distress to awake animals.

Intravenous injection of > 60% magnesium sulfate solution may be considered for use in dogs in extreme situations where other injectable agents are not available or are in short supply. Prior sedation is highly recommended.

The injectable anesthetic agents α-chloralose and urethane (ethyl carbamate) are not likely to be readily available outside of research facilities, where they may be used if necessary. Lack of availability and potential health risks to personnel (eg, urethane) make them not recommended outside these settings.

Decapitation requires specialized equipment and is unlikely to be feasible in most depopulation situations. However, if species- and size-appropriate equipment is available, these methods may be utilized. From an equipment and practical standpoint, decapitation would not be appropriate for individuals > 20 kg (44 lb), and sedation must be used to aid in restraint.

1.4.3 Not recommended

These methods are generally not recommended and may be considered last resorts to be utilized only in situations when circumstances preclude the reasonable implementation of any of the preferred methods or those allowed in constrained circumstances *and* when doing nothing is deemed to have a reasonable chance of resulting in significant animal suffering.

Injection of a neuromuscular blocking agent may be utilized only if it can be followed by a secondary measure (eg, captive bolt, close-range gunshot) within 50 seconds of immobilization.

Ultrapotent opioids are highly effective at causing death, but they pose extreme hazards to personnel because of their high potency. Special licensing requirements and difficulty in obtaining the agents in an emergent basis would further limit their ability to be used for depopulation of companion animals. These agents may be best reserved for darting of feral animals; if death has not occurred within minutes of immobilization, a secondary method should be employed.

Nitrous oxide when used alone may cause distress due to hypoxia before loss of consciousness and is unlikely to cause death. It may be considered for use in dire circumstances, with a secondary method after unconsciousness occurs.

Distance gunshot may be the only means of dealing with free-roaming, uncatchable animals. Strong consideration must be given to the potential risks to unintended targets should the shooter miss or ricochet occur. Carcasses should be retrieved to ensure that the kill has occurred, to provide samples for appropriate testing (eg, rabies), and to limit lead exposure to scavenging animals.

Maceration requires highly specialized equipment and is feasible only for very small animals (eg, neonates) that weigh < 75 g.

Cervical dislocation may be considered for non-anesthetized rabbits and small rodents provided personnel highly proficient in the method are available; ideally, animals should be accustomed to handling or sedated to minimize stress during application of the method.

Electrocution requires specialized equipment and proficiently trained personnel, and it poses risks to operators. Additionally, it is aesthetically unpleasant to those involved in implementing the method. Ideally, animals should be sedated or anesthetized during application of the method for restraint and to minimize stress.

1.5 Special Considerations

1.5.1 Dangerous animals

Companion animals that cannot be safely handled should be sedated by means of drug delivered orally (eg, baited food, liquid sedatives squirted into mouth) or parenterally (eg, darts, pole syringes) before application of the euthanasia method. These animals should be minimally handled, and then only by trained personnel and with the knowledge that even sedated or anesthetized animals may be able to inflict serious bites and scratches. Distance gunshot might be considered as a last resort for dangerous animals, but only if no other feasible methods are available.

1.5.2 Diseased animals, animals exposed to hazardous agents

1.5.2.1 Hazards to humans

Companion animals that may harbor serious zoonotic disease (eg, rabies) or that have been exposed to hazardous compounds (eg, chemical spill, radiation disaster) can pose a hazard to humans with which they come into contact. Ideally, such animals should be isolated from the public and other animals, and they should be handled only by personnel wearing appropriate PPE and trained in appropriate handling techniques. The depopulation method selected should take into account any requirements for postmortem analysis (eg, preserving intact brain tissue for rabies testing).

1.5.2.2 Hazards to animals

Outbreaks of highly infectious, fatal diseases (eg, parvoviral enteritis) that may spread within a group situation (eg, shelter, kennel) may necessitate depopulation to relieve suffering and control disease spread. In most cases, depopulation should be reserved as a last resort in those situations where morbidity and mortality are uncommonly severe.[15]

1.5.3 Fetal or neonatal animals

Scientific data show that mammalian fetuses are in a state of unconsciousness during pregnancy and birth and thereby do not suffer while dying in utero upon death of the dam. Ovariohysterectomy of pregnant animals involves ligation of uterine blood vessels and will result in fetal death; however, due to the resistance of altricial neonates (cats, dogs, mice, rats) to hypoxia, the uterus should not be opened for at least an hour following uterine removal in late pregnancy.[2] The disposition of neonatal animals should take into account the degree of development of that species at birth (ie, altricial vs precocial) and the potential of such neonates to experience distress.

1.5.4 Feral or free-roaming populations of dogs or cats

Free-roaming companion animals, especially feral animals, pose similar challenges to those of wildlife when it comes to depopulation, namely, determination of the population size, containment, mobility of animals, possibility of reinhabitation, and difficulty in attaining complete eradication of the population. As with wildlife, depopulation of free-roaming companion animals may be limited to attaining a reduction in population rather than complete eradication.

Depopulation of free-roaming or feral companion animals may include multiple methods, such as sedating remotely by means of darts or baited food or catching in live traps. Kill traps should be avoided whenever possible to avoid unnecessary deaths in nontarget animals. Animals that are unable to be sedated remotely or caught may need to be killed via gunshot from a distance, provided skilled shooters are available and a thorough assessment of risks to nontarget animals and humans has been performed. The method of depopulation chosen should take into account preservation of appropriate samples for any required analysis (eg, preservation of brain tissue for rabies testing)

1.6 References

1. Ebola and dogs: WSAVA calls for testing not automatic euthanasia. *Vet Rec* 2014;175:361.
2. AVMA. AVMA guidelines for the euthanasia of animals: 2013 edition. Available at: www.avma.org/KB/Policies/Pages/Euthanasia-Guidelines.aspx. Accessed Jul 2, 2013.
3. Golledge HDR. Response to Roustan et al. 'Evaluating methods of mouse euthanasia on the oocyte quality: cervical dislocation versus isoflurane inhalation': animal welfare concerns regarding the aversiveness of isoflurane and its inability to cause rapid death. *Lab Anim* 2012;46:358–360.
4. Lockwood G. Theoretical context-sensitive elimination times for inhalational anaesthetics. *Br J Anaesth* 2010;104:648–655.
5. Occupational Safety and Health Administration. Anesthetic gases: guidelines for workplace exposures. Available at: www.osha.gov/dts/osta/anestheticgases/index.html#A. Accessed Dec 11, 2016.
6. Flecknell PA, Roughan JV, Hedenqvist P. Induction of anaesthesia with sevoflurane and isoflurane in the rabbit. *Lab Anim* 1999;33:41–46.
7. Lord R. Use of ethanol for euthanasia of mice. *Aust Vet J* 1989;66:268.
8. Allen-Worthington K, Bric AK, Marx JO, et al. Intraperitoneal injection of ethanol for the euthanasia of laboratory mice (*Mus musculus*) and rats (*Rattus norvegicus*). *J Am Assoc Lab Anim Sci* 2015;54:769–778.
9. Aranez JB, Caday LB. Magnesium sulfate for euthanasia in dogs. *J Am Vet Med Assoc* 1958;133:213.
10. KuKanich B, Papich M. Opioid analgesic drugs. In: Riviere J, Papich M, eds. *Veterinary pharmacology and therapeutics*. 9th ed. Ames, Iowa: Wiley-Blackwell, 2009;301–336.
11. Agency for Toxic Substances and Disease Registry. Toxicological profile for formaldehyde. July 1999. Available at: www.atsdr.cdc.gov/toxprofiles/tp111.pdf. Accessed Dec 11, 2016.
12. Dennis MB, Dong WK, Weisbrod KA, et al. Use of captive bolt as a method of euthanasia in larger laboratory animal species. *Lab Anim Sci* 1988;38:459–462.
13. Longair JA, Finley GG, Laniel MA, et al. Guidelines for the euthanasia of domestic animals by firearms. *Can Vet J* 1991;32:724–726.
14. Merck MD, Miller MM. Asphyxia. In: *Veterinary forensics: animal cruelty investigations*. 2nd ed. Ames, Iowa: Wiley-Blackwell, 2013;169–184.
15. Association of Shelter Veterinarians. Position statement: depopulation. Last reviewed: January 2014. Available at: www.sheltervet.org/assets/docs/position-statements/depopulation.pdf. Accessed Nov 25, 2016.

2: Laboratory Animals

2.1 General Considerations

Animal species used in biomedical research are found in many settings. These range from government laboratories (military, such as the US Army Medical Research Institute for Infectious Diseases, and nonmilitary, such as the NIH and the FDA) to research laboratories in public and private universities, colleges, hospitals, pharmaceutical and product research companies, contract research organizations, laboratory animal breeders, importers, and dealers. The numbers of animals in these institutions may be quite high, particularly with regard to rodents, such as mice and rats.

A complete depopulation of the animals in these various institutions, other than laboratory rodent breeders, has probably never occurred for disease, in part because most of the animals are purposely bred for research, are of high and sometimes irreplaceable value, and are housed in locations that minimize the possibility of disease entry or spread. Depopulation may be more likely to be considered in situations where the animals cannot be maintained or cared for owing to widespread disruption of utilities (eg, electric, gas, water) or natural or human-caused disasters or in situations where personnel are prevented from caring for the animals because of the aforementioned disasters; pandemic disease outbreaks with resulting morbidity, mortality, or quarantine; or social unrest subsequent to the same disasters or socioeconomic disruption. Depopulation is an emergency situation that is considered only in situations where death of the animals in question would likely occur but over a prolonged period of time. While distasteful to veterinarians, depopulation is the most humane response to extraordinary circumstances. Research institutions that are required to follow the Guide for the Care and Use of Laboratory Animals (Guide) "must" have emergency plans.[1] However, history has shown that the typical research institution will not depopulate as a default in the face of a threatening, emerging, or unfolding severe situation, but will prepare, harden, and resist the known and anticipated effects of emergency scenarios (eg, severe weather, hurricane, workforce outage) and then act to recover from any event, including prioritizing the preservation of surviving animal populations. Experience shows that where this approach has failed, the situation will be rapid, of overwhelming scale, and unpredictable with respect to degree of consequence. The predilection of favoring a course of salvage of survivors over depopulation is driven by the unique attributes and high value of many research models and is facilitated by containment within structures engineered to resist the most likely natural and manmade impacts.

Research institutions where animal models are used are required by statute (AWAR §2.33) and policy[2] to have a designated AV by title. The AV by statutory and regulatory authority is responsible for all aspects of animal welfare and the care and disposition of animals used in research, including euthanasia and depopulation.[3] As such, all recommendations herein in deviating away from standard practice (those designated as allowed in constrained circumstances) are accomplished under the authority and responsibility of the AV. For example, anesthetic and euthanasia agents that have exceeded their expiration date may be judged by the AV as effective and used in emergency situations. In addition, while IP injection of 70% ethanol is considered acceptable with conditions by the AVMA Guidelines for the Euthanasia of Animals[4] for mice only, the AV might judge it to be appropriate in an emergency situation for other small mammals (< 0.22 kg [0.49 lb]; see 1: Companion Animals). Use of compounded or nonpharmaceutical-grade injectable anesthetics or euthanasia agents may also be justified for depopulation.

Beyond this context, research entities that follow the Guide must have disaster plans that deal with potential threats to their animal colonies.[1] A component of these plans may involve ranking animals by value and importance in research programs so that the least valuable or most easily replaced animals are euthanized first and the most valuable (eg, nonhuman primates), rarest (eg, captive endangered species), or most difficult to replace (eg, humanized mouse models on experiment) are euthanized last. Institutions should outline ways in which these decisions may be made as needed without the need for communication with investigators or upper administration when such communication may be interrupted.

In all but a few extreme cases, the depopulation of laboratory animals on a wide scale can be accomplished using, and sometimes adapting to or adjusting, the methods of the Guidelines for the Euthanasia of Animals[4] and the Guidelines for the Humane Slaughter of Animals[5] as well as methods described in other sections of these Guidelines for the Depopulation of Animals.[4,5] The attributes that make depopulation in a research setting unique as a process, compared with euthanasia and slaughter, are the range of species, large numbers of animals, and time constraints. Whatever the breadth of phyla and magnitude of the census, depopulation plans will be accomplished best if they rely upon the use of approved agents and methods that have been demonstrated to be effective and are commonly in use by the facility staff. In some instances, there may be impediments to using the standard euthanasia techniques, such as insufficient quantities of drugs, gases, equipment, and trained personnel. While impediments may contribute to the emergency situation, depopulation methods that require a lengthy time for full effectiveness (eg, deliberately depriving a census of drinking water as the means of depopulation) are unacceptable. Such methods may confound salvage and may occur of their own volition as a facility fails.

For laboratory animals, methods listed as unacceptable in the AVMA Guidelines for the Euthanasia of Animals[4] remain unacceptable for depopulation, even in emergency situations. However, if the AV determines that an unacceptable method is more appropriate than the alternative, their decision applies. A practical example in a laboratory environment might be the availability of urethane or chloralose. While these agents are unacceptable methods in the Guidelines for the Euthanasia of Animals,[4] they might be appropriate for euthanasia or anesthesia followed by a secondary method in an emergency situation.

2.2 Implementation of Depopulation Methods

2.2.1 Small laboratory and wild-caught rodents

2.2.1.1 Preferred methods

Any method considered acceptable or acceptable with conditions in the AVMA Guidelines for the Euthanasia of Animals.[4]

2.2.1.2 Permitted in constrained circumstances

When rapid depopulation of large rodent colonies is necessary, institutions will probably be unable to adhere to the acceptable methods or acceptable with conditions methods described in the AVMA Guidelines for the Euthanasia of Animals.[4] When time to depopulate is restricted, such as in an impending natural disaster, or euthanasia resources do not meet inventory needs, the AV may use professional discretion in forgoing some of the conditions imposed in the AVMA Guidelines for the Euthanasia of Animals.[4]

The most common method of euthanasia in the laboratory setting is overdose with an inhalant agent, such as carbon dioxide or isoflurane. For mass depopulation, it is justifiable to combine cages of rodents, preferably without overcrowding or fighting, immediately before gas exposure. Ideally, animals should not exceed a confluent monolayer in the chamber; however, extreme circumstances may necessitate overcrowding. Time exposed to unfamiliar animals should be as short as possible to minimize stress and fighting. When using carbon dioxide for mass depopulation during an emergency, a prefilled chamber of carbon dioxide has several advantages over the recommended slow-flow chamber filling for euthanasia. Use of prefilled chambers will decrease the time to unconsciousness, which is especially important if combining unfamiliar animals; decrease the time required to depopulate; and conserve the supply of gas, enabling depopulation of a larger number of animals. To further shorten the time to depopulate and conserve resources, it may be prudent to utilize the gas to induce unconsciousness and follow with a physical method of euthanasia, such as cervical dislocation, decapitation, or bilateral thoracotomy.

Use of compounded or nonpharmaceutical-grade injectable anesthetics and euthanasia agents is justified for depopulation. In addition an AV may make a professional judgment about the use of agents that have exceeded their product expiration date. If the AV determines the expired product to perform in the expected manner, he may direct its use for depopulation. To facilitate drug administration to a large number of animals in a timely manner, needles and syringes may be reused until dulling is noted (ie, increased resistance to penetrating the skin). The use of a needle with a larger than typical gauge may help speed the process, especially if viscous euthanasia solutions are in use. In research institutions, 70% ethanol may be readily available. Its use (ie, IP injection) in mice could conserve agents that have a more universal application. Injection of 0.5 mL of 70% ethanol IP in mice (< 35 g [1.2 oz]) results in death in 2 to 4 minutes.[6]

2.2.1.3 Not recommended

Not applicable.

2.2.2 Laboratory dogs, cats, ferrets, and rabbits

2.2.2.1 Preferred methods

Injectable anesthetic overdose or injectable euthanasia solutions are the preferred methods of euthanasia. Consideration must be given to the number and type of animals to be euthanized and the available drug inventory. Utilizing a two-step method of euthanasia (eg, anesthesia followed by a physical or adjunctive method of euthanasia, such as bilateral thoracotomy, exsanguination, or IV or intracardiac injection of potassium chloride or magnesium sulfate) will enable more conservative use of drug resources.

2.2.2.2 Permitted in constrained circumstances

In emergency situations, if the number of animals exceeds the institution's inventory of anesthetic or euthanasia drugs and the AV determines the effectiveness, use of compounded or nonpharmaceutical-grade, expired anesthetic or euthanasia agents may be justified for euthanasia.

2.2.2.3 Not recommended

Not applicable.

2.2.3 Sheep, goats, and swine

2.2.3.1 Preferred methods

Depending on the specific setting, depopulation of these larger species can be accomplished using techniques described in the Guidelines for the Euthanasia of Animals,[4] in the Guidelines for the Humane Slaughter of Animals,[5] or in other relevant sections of this document (chapters 4 and 5). For small populations that are in most biomedical research settings, it is recommended that these animals undergo induction of anesthesia with an injectable agent, followed by a physical or adjunctive method of euthanasia.

2.2.3.2 Permitted in constrained circumstances

In emergency situations, if the number of animals exceeds the institution's inventory of anesthetic and euthanasia drugs and the AV determines the effectiveness, use of compounded or nonpharmaceutical-grade, expired anesthetic and euthanasia agents may be justified for euthanasia.

2.2.3.3 Not recommended

Not applicable.

2.2.4 Nonhuman primates

2.2.4.1 Preferred methods

The depopulation of nonhuman primates in a research setting differs from that of zoos and exhibitions by the prospect of greater numbers and density of nonhuman primates at a site. In addition, housing systems are often available at research settings that promote safe and expedient handling. Populations may range in head count, depending upon the institution, from a few to several thousand. The primary method of euthanasia involves injection of euthanasia agent or anesthetic agent followed by a physical method or another injectable agent such as potassium chloride.

With large populations, there is the risk of exhausting the supply of euthanasia and anesthetic agents, which would hinder the ability to depopulate the entire population of a large number of potentially dangerous animals. These realities dictate that at locations that may have a substantial census (eg, primate centers, import facilities), emergency planning should include evaluations of customary drug inventories in light of the maximum census, identification of any shortfall scenarios, and interventions to address that exigency. Agreements with local or regional peers might enable sharing of resources, but this should be done with advance planning involving appropriate regulatory and law enforcement authorities (eg, Drug Enforcement Agency).

2.2.4.2 Permitted in constrained circumstances

In emergency situations, if the number of animals exceeds the institution's inventory of anesthetic and euthanasia drugs, and the AV determines the effectiveness, use of compounded or nonpharmaceutical-grade, expired anesthetic and euthanasia agents may be justified for euthanasia. In certain situations, gunshot may be appropriate for great apes or where euthanasia drug stockpiles are committed elsewhere, or under an extreme acutely life-threatening situation such as an inescapable and uncontrolled fire. Gunshot may also be appropriate where animals are maintained outdoors, for example, in corrals. In the event that gunshot is believed to be the most appropriate method, it is recommended that law enforcement personnel or other trained firearm operators be employed. The appropriate firearm and projectile and the optimal anatomic target and angle have not been identified for monkeys and lesser apes, which would ensure penetration, destruction of the brain, and retention of the projectile within the target. Therefore, because of the close quarters and constrained spaces of indoor facilities, even if the animal is restrained by a squeeze apparatus, gunshot should not be used for confined monkeys and lesser apes, owing to the risk of the bullet's emergence from the contralateral side of the head and thus endangerment of personnel.

2.2.4.3 Not recommended

Not applicable.

2.2.5 Aquatic vertebrates

2.2.5.1 Preferred methods

Any method considered acceptable or acceptable with conditions in the AVMA Guidelines for the Euthanasia of Animals[4] or the AVMA Guidelines for the Humane Slaughter of Animals.[5]

As is the case with depopulation in general, preplanning, including established standard operating procedures based on projections of the scale of the event, resources required, and well-written, realistic disaster plans, will be critical to an effective outcome. In some cases, immersion in anesthetizing agents must be accomplished at an unprecedented level and in a minimum of time. Where immersion agents are to be used and there is a mixed census of aquatics with varying sensitivity to the effects of the chemical or drug, it is recommended that a solution concentration be predetermined for universal use. Regardless of the size of the aquatic enterprise, for diminutive tropical finfish common to research (eg, zebrafish, medaka) and the pet trade, emergency plans should include provisions for the use of rapid chilling as described in the Guidelines for the Euthanasia of Animals[4] on a large scale and high-throughput basis. It bears reiterating that, whether for euthanasia or for purposes of depopulation, this method is inappropriate for temperate, cool, or cold-water–tolerant finfish that can survive at 4°C and below and for most fish larger than 3.8 cm in length (please refer to the Guidelines for the Euthanasia of Animals[4] and chapter 8: Aquatic Animals [Aquaculture] of this document). While ordinarily not considered acceptable for euthanasia, the following methods of the Guidelines for the Humane Slaughter of Animals[5] may have utility under emergency conditions for the depopulation of conscious research fish, providing they are of sufficient size to enable proficient handling and are delivered by trained, experienced, skillful operators: pithing, blunt force to the head followed by decapitation and pithing or exsanguination by cutting the gill arches for large fish, and gill spiking.[5]

2.2.5.2 Permitted in constrained circumstances

While rapid chilling may be applied humanely to larger, non–cold-adapted fish in combination with a secondary method, under times of extreme time limitation, for depopulation it may need to be accepted that secondary methods may not be possible. Likewise, finfish and amphibians under conditions that reliably result in euthanasia, such as immersion or rapid chilling, may be left unattended under urgent constraints.

2.2.5.3 Not recommended

Not applicable.

2.2.6 Avian and poultry

Please refer to chapter 6 as the primary reference for poultry. The following is supplementary information for research settings. Any methods that are acceptable or acceptable with conditions in the AVMA Guidelines for the Euthanasia of Animals[4] and any techniques covered in the AVMA Guidelines for the Humane Slaughter of Animals[5] are considered preferred methods of depopulation.

2.2.6.1 Preferred methods

The use of inhaled or injectable agents is preferred for the euthanasia or depopulation of most avian species found in biomedical research institutions. Consideration must be given to the number and type of animals to be euthanized and the available drug or gas inventory. Utilizing a two-step method of euthanasia (eg, anesthesia followed by a physical or adjunctive method of euthanasia, such as bilateral thoracotomy, exsanguination, or IV or intracardiac injection of potassium chloride or magnesium sulfate) will enable more conservative use of drug resources.

2.2.6.2 Permitted in constrained circumstances

In emergency situations, if the number of animals exceeds the institution's inventory of anesthetic and euthanasia drugs and the AV determines the effectiveness, use of compounded or nonpharmaceutical-grade, expired anesthetic and euthanasia agents may be justified for depopulation.

2.2.6.3 Not recommended

Not applicable.

Methods considered unacceptable in the AVMA Guidelines for the Euthanasia of Animals[4] (thoracic compression) remain unacceptable for depopulation, even in emergency situations.

2.3 Special Considerations

2.3.1 Dangerous animals

In research facilities, intractable animals may be present. These include animals that are dangerous because of their size or strength (eg, nonhuman primate species, farm animals), those that are venomous or poisonous, or both. In every case, human safety should be the first consideration. Means of restraining agitated or escaped animals, such as nets, catch poles, snake hooks, or darting apparatus, should be readily present in the facility. Facilities should also have bite- or puncture-resistant gloves, face protection, and other personal safety equipment readily available. Euthanasia should be accomplished following species-specific guidelines.

2.3.2 Animals exposed to biological, chemical, or radiation hazardous agents

Animals in research facilities may be deliberately administered infectious, toxic, or radioactive agents that could pose a hazard to humans. Exposure of laboratory staff, handlers, or first responders to such agents might occur if precautions are not taken. Maintaining human health should be a priority, and PPE should be donned and doffed following standard procedures for the animals and agents present in the facility. As part of disaster management, special consideration should be given to animals infected with zoonotic agents, their location, and means of euthanizing them. For animals harboring Animal Biosafety Level 3 or 4 agents, consider methods of euthanasia that would not require entering the housing rooms or biosafety laboratories. The disposal of animals of these varying types of hazards, their waste, and disposition of their enclosures should also be considered during response and recovery.

2.3.3 Fetal or neonatal animals

Neonatal animals, especially altricial young, are resistant to many agents successfully used with adult animals. The methods considered as acceptable and acceptable with conditions by the AVMA Guidelines for the Euthanasia of Animals[4] apply in a depopulation scenario. Precocial young should be euthanized as adults of the same species. Altricial young, such as mice and rats, are most efficiently euthanized with physical methods, including hypothermia (< 7 days of age), decapitation, and cervical dislocation. High concentrations of inhalant anesthetics may also be used. Utilizing a two-step method of euthanasia (eg, anesthesia followed by a physical or adjunctive method of euthanasia, such as bilateral thoracotomy, exsanguination, or IV or intracardiac injection of potassium chloride or magnesium sulfate) will enable more conservative use of drug resources. In emergency situations, if the number of animals exceeds the institution's inventory of anesthetic and euthanasia drugs and the AV determines the effectiveness, use of compounded or nonpharmaceutical-grade, expired anesthetic or euthanasia agents or 70% ethanol injected IP (in small nonaltricial animals [< 0.22 kg]) may be justified for depopulation. Animals in utero will be euthanized when the dam is euthanized without ever gaining consciousness and no further manipulation is necessary.[7]

2.3.4 Embryonated poultry eggs

Depopulation of chicken eggs before hatching is sometimes necessary. A review[8] of studies evaluating the spontaneous EEG activity of a chicken embryo's brain indicates that there is no detectable EEG activity before day 13 or 14 (60% to 67% incubation, considering chickens hatch at 21 days of incubation) but that at day 15 (70% incubation), EEG activity begins to be detected, and at day 17 (80% incubation), the EEG activity becomes more sustained with increases in amplitude.[8] By day 18 (86% incubation) the EEG activity has resolved into slow and fast wave patterns that mature by day 19 or 20 (90% to 95% incubation) into two distinct forms seen during sleep after hatching. In addition, a sleep-like state persists until after hatching, with the developing embryo exhibiting an EEG pattern that cannot be differentiated from patterns present in REM sleep. On the basis of these observations it is considered that the chick is not capable of exhibiting any cerebral state that resembles awareness before hatching.[8] It is unlikely that all species of poultry have the same development patterns and physiologic characteristics as chickens. However, in constrained situations, embryonated eggs may be depopulated by cooling at 40°F for 4 hours, or freezing (see 6: Poultry).

2.3.5 Endangered animals

Members of endangered species should not require any special consideration in the laboratory environment other than consideration of methods suitable to the species. A euthanasia priority list by species should be created, with animals that would be difficult to replace euthanized last (see 2.1: General Considerations).

2.4 References

1. Garber J, Barbee R, Bielitzki J, et al. *Guide for the care and use of laboratory animals*. Washington, DC: National Academies Press, 2011.
2. Garber J, Barbee R, Bielitzki J, et al. *Guide for the care and use of laboratory animals*. Washington, DC: National Academies Press, 2011;14.
3. Garber J, Barbee R, Bielitzki J, et al. *Guide for the care and use of laboratory animals*. Washington, DC: National Academies Press, 2011;35.
4. AVMA. AVMA guidelines for the euthanasia of animals: 2013 edition. Available at: www.avma.org/KB/Policies/Documents/euthanasia.pdf. Accessed Feb 7, 2019.
5. AVMA. AVMA guidelines for the humane slaughter of animals: 2016 edition. Available at: www.avma.org/KB/Resources/Reference/AnimalWelfare/Documents/Humane-Slaughter-Guidelines.pdf. Accessed Feb 7, 2019.
6. Lord R. Use of ethanol for euthanasia of mice. *Aust Vet J* 1989;66:268.
7. Mellor DJ, Diesch TJ, Gunn AJ, et al. The importance of 'awareness' for understanding fetal pain. *Brain Res Brain Res Rev* 2005;49:455–471.
8. Mellor DJ, Diesch TJ. Birth and hatching: key events in the onset of awareness in the lamb and chick. *N Z Vet J* 2007;55:51–60.

3: Bovine

3.1 General Considerations

The dairy,[1] beef,[2] and bison[3] industries are represented to some degree in all 50 states and play a significant role in the US economy. The setting in which these various bovids are found varies on the basis of type and location within the nation, with most dairy animals in barns or small paddocks or pastures, the majority of beef cow-calf and bison herds on small to large pastures or open range, and the majority of beef feeder cattle confined to pens or small pastures. This variability in setting can add additional complexity with regard to access to animals and confinement capabilities in urgent or emergency situations.

A popular nationally coordinated resource called Beef Quality Assurance provides guidance[4,5] for proper management techniques, including euthanasia, carcass disposal, and emergency action planning. Resources are available for those involved in the dairy, stocker, cow-calf, livestock transportation, and feedlot industries and can be accessed at www.bqa.org/. Cattle operations participating in the Beef Quality Assurance program should have a written euthanasia action plan, which describes the euthanasia methods used by production phases and types for their premises. Cattle operations and other livestock operations that do not participate in Beef Quality Assurance programs may have an alternate written plan or should be able to verbally explain their plans for euthanasia, carcass disposal, and emergency response.

3.2 Events Necessitating Depopulation

Fortunately, animal health incidents that require the use of depopulation methods to eradicate or prevent disease, protect public health, or maintain a secure food supply are rare. Every animal health situation involving depopulation as part of the response is unique and should be evaluated individually to determine optimal response methods.

3.2.1 Infection or exposure to high-consequence diseases or reportable diseases

The USDA APHIS has identified important FADs and pests that, if introduced to the United States, could result in significant negative impacts to animal and sometimes human health, our nation's secure food supply, and the economy. These important FADs and pests are termed "high consequence." A list of high-consequence diseases can be found on the Center for Food Security and Public Health website.[6] Additional information from USDA APHIS Veterinary Services on high-consequence FADs and pests can be found on the USDA APHIS website.[7]

In the event of an FAD, the USDA APHIS would be involved with the response and recovery activities, and their focus would be on accomplishing the following goals:

> "1) detect, control, and contain the FAD in animals as quickly as possible; 2) eradicate the FAD using strategies that seek to stabilize animal agriculture, the food supply, the economy, and to protect public health and the environment; and 3) provide science- and risk-based approaches and systems to facilitate continuity of business for non-infected animals and non-contaminated animal products."[8]

The USDA High Consequence Livestock Pathogen list includes some crossover with the CDC's Category A, B, and C Bioterrorism Agent List.[9] A decision to depopulate cattle or other large ruminant livestock infected or exposed to high-consequence diseases may be made by state and federal animal health officials to eradicate the disease of concern. Depopulation related to infection with foot and mouth disease, rinderpest, contagious pleuropneumonia, or other diseases as determined by the US Secretary of Agriculture to be a threat to agriculture as outlined in the US Federal Code of Regulations (9 CFR 53)[10] will have primary oversight by the USDA.

The United States maintains a draft of the National List of Reportable Animal Diseases Framework.[11] The reportable diseases are determined by the USDA Veterinary Services, which serves as the national veterinary authority. The United States uses guidance from the OIE to identify notifiable diseases and conditions. A list of reportable disease can be on the OIE website.[12]

Regulatory diseases include diseases for which USDA Veterinary Services has an eradication or control program. United States Department of Agriculture Veterinary Services programs applicable to domestic cattle and alternative large ruminant livestock include the National Tuberculosis Eradication Program, National Brucellosis Eradication Program, cattle fever tick program, and bovine spongiform encephalopathy surveillance program.

Notifiable diseases and conditions include incidents related to emergency diseases, emerging diseases, and regulatory diseases. Emergency incidents include FADs, exotic vectors, and high-priority diseases. Emerging diseases include discovery of new pathogens or strains, novel presentation of previously identified pathogens, or identification of a new location for a recognized pathogen. In some circumstances, infection with a reportable disease may require depopulation of affected animals to reduce the risk of further spread.

3.2.2 Agroterrorism

Agroterrorism may be defined "as the deliberate introduction of an animal or plant disease with the goal of generating fear, causing economic losses, and/or undermining social stability."[13] Lists of potential agroterrism pathogens by species[14,15] may be found on the Center for Food Security and Public Health website along with an overview of potential bioterrorism diseases' effects on humans and animals.[16]

It is critical that those involved with bovine depopulation resulting from suspected or confirmed agroterrorism be aware of routes of transmission[17] and adhere to biosecurity protocols for the disease of concern.

3.2.3 Zoonotic diseases

Diseases such as anthrax (*Bacillus anthracis*),[18,19] melioidosis (*Burkholderia pseudomallei*),[20] Q fever (*Coxiella burnettii*), brucellosis (*Brucella abortus*), tuberculosis (*Mycobacterium bovis*),[21] and vesicular stomatitis (vesicular stomatitis virus Indiana subtype 1, New Jersey subtype, and Indiana subtypes 2 and 3)[22] are examples of zoonotic diseases that can be spread between cattle and humans.[23] Potential infection or exposure of cattle to zoonotic diseases may precipitate a decision to depopulate, as several diseases would result in products derived from these animals being unfit for human consumption. When a decision has been made to depopulate bovines infected with or exposed to a zoonotic disease, the chosen depopulation method requires careful consideration and planning to reduce the risk of disease transmission to humans, and those involved with depopulation activities should fully understand routes of disease exposure for the zoonotic disease of concern. In addition, the time to complete depopulation procedures is likely to be extended owing to enhanced biosecurity protocols.

3.2.4 Intoxications and adulterations

Intoxications and adulterations may render an animal unfit for human consumption because of compromised human food safety and confidence in a wholesome product. Examples include consumption of feed adulterants such as accidental inclusion of pesticides in rations as well as ingestion of most proteins derived from mammals (exceptions include some pure porcine or equine ingredients). Cattle that have been administered drugs prohibited for extralabel use, such as chloramphenicol, clenbuterol, diethylstilbestrol, dimetridazole, ipronidazole, other nitroimidazoles, furazolidone, or nitrofurazone, should be considered for depopulation. Foreign objects such as buckshot, birdshot, broken needles, or materials related to long-range darting could be considered adulterants but would rarely affect a group of cattle. Infrequently, groups of cattle are moved using shotguns; this practice is strongly discouraged by industry and can result in the inclusion of buckshot or birdshot, making the animal unfit for human consumption. It is also unlikely for groups of cattle to become candidates for depopulation because of foreign matter present in their body such as broken needles or materials related to long-range darting since these occurrences are rare and typically affect an individual animal, not a group of animals. Environmental or systemic exposure to hazardous materials including pesticides, fungicides, herbicides, pentachlorophenol, polychlorinated biphenyls, or heavy metals may require the destruction of affected or exposed cattle. Ingestion of sufficient amounts of feed containing mycotoxins such as vomitoxin, zearalenone, or aflatoxins may also result in residues that render the animal unfit for human consumption.[24]

When depopulation is considered because of intoxicants or adulterants, careful consideration should be given to carcass disposal since some options may result in negative environmental effects owing to the type of intoxicant or adulterant. In cases where known exposure to adulterants or intoxicants has occurred but the animals do not demonstrate clinical signs of illness or suffering, are not a threat to human health, and are not likely to negatively affect the environment, then depopulation may not need to occur immediately. In some circumstances, the intoxicant or adulterant may be metabolized over time so that the animal is no longer a candidate for depopulation. Depending on the type of adulterant, typical rendering temperatures may reduce or eliminate the intoxicant or adulterant. In cases where a slower speed of depopulation is not a priority, emphasis on selection of the most humane depopulation method possible is warranted. Cooperation and communication with knowledgeable authorities regarding compliance with local, state, and regional carcass disposal regulations are important components of selection of depopulation methods.

3.2.5 Radiologic or nuclear accidents and incidents

According to the World Nuclear Association, there are an estimated 100 nuclear reactors in the United States.[25] Statistics associated with radiologic accidents and incidents have been collected since 1945; only 56 incidents totaling 354 human casualties (42 deaths and 312 injuries) were recorded for the United States,[26] making this type of exposure very unlikely. Although a radiologic emergency in the United States would be very uncommon, radiation exposure originating from a nuclear power plant incident, accidents involving nuclear or radioactive materials or weapons, or terrorism could result in affected cattle populations becoming a candidate for depopulation. A decision to depopulate exposed cattle may be made if necessary to alleviate suffering of animals that demonstrate signs of sickness owing to exposure or if there is an inability to provide animal husbandry, including appropriate feed and water and maintenance of a healthy environment. Such a decision also may be made because of perceived or real public health safety concerns.

Selection of depopulation techniques, development of cleaning and disinfection protocols, and methods of waste and carcass disposal management associated with depopulation activities should be carefully coordinated with knowledgeable environmental regulatory authorities. In addition, individuals involved with depopulation associated with radiation may be affected by unique types of psychological stress.[27]

3.2.6 Natural disasters

Natural disasters affecting domestic cattle or alternative large ruminant livestock may result in a decision to depopulate. Scenarios where animals are known or suspected to be contaminated (eg, by exposure to flood waters) may cause them to be restricted from entering the human food supply and may result in depopulation. Decisions to depopulate potentially contaminated animals may occur even if no clinical signs of illness are demonstrated, owing to public perception that the animal protein may not be wholesome or because of risk aversion. In other cases where natural disasters have affected cattle or alternative large ruminant livestock population health or well-being, depopulation may be employed to prevent or end suffering. Natural disasters may affect livestock by causing traumatic injuries or disease resulting from exposure to toxins such as smoke or chemicals. In other cases, depopulation may be necessary because basic care and feeding cannot be provided owing to a lack of access to the animals or resources. The USDA APHIS Veterinary Services has summarized animal health hazards of concern during natural disasters on its website.[28]

Additional information and resources regarding natural disasters and animals may be reviewed here: www.prep4agthreats.org/Natural-Disasters/index.php.[29]

3.3 Planning for Depopulation

An optimal depopulation method is a method that minimizes potential risks to human health and safety and is expected to result in rapid loss of consciousness and death while causing the least amount of pain and distress possible to the animal. Depopulation plans will be unique to each animal health event and for each premises. Development and exercise of detailed response plans before their use is extremely beneficial to an actual response involving depopulation activities. A comprehensive, but flexible, depopulation plan before carrying out those activities is ideal. Relevant local, state, and federal authorities as well as industry stakeholders should be included in communication and decision-making as appropriate. Key personnel will need to be identified, and safety and hazard communication should be planned for. A list of federal and state contacts and resources may be accessed here: www.prep4agthreats.org/federal-and-state-contacts.php.[30] The chosen depopulation method should not conflict with any postmortem examination (ie, necropsy) or specimen submissions.

A needs assessment for personnel and resources should be included in the planning phase. Since most depopulation scenarios are time sensitive, the need for a comprehensive plan must be balanced with a timely decision for depopulation. Methods that require the least number of steps to meet objectives are preferred (ie, one-step killing methods). Secondary or adjunct methods should always be available and planned for in case the primary method is not successful. Consideration for human health and safety, expected timeline of depopulation, available resources, potential human physical and psychological impacts, public perception and acceptance, demographics of cattle or alternative large ruminant livestock population to be depopulated, animal environment and available facilities, biological risk management, documentation of the depopulation plan and associated activities, provisions for appraisal and indemnity, sample collection and testing, and carcass removal and disposal methods should be included.

Finally, logistics must be considered for any potential depopulation event involving large numbers of animals. For example, large feedlots may contain over 100,000 head of cattle. When compared with smaller species, such as pigs or poultry, there are much greater disposal problems. In some parts of the United States there are several 50,000- to 100,000-herd feedlots in close proximity to each other. Burial of 100,000 cattle at one time would create monumental disposal problems and possible groundwater contamination. Composting or rendering this number of cattle in a timely fashion would be not be feasible. Euthanizing 50,000 to 100,000 head of cattle could be accomplished over time, but there are few viable solutions for disposal. If a highly infectious disease of great economic concern such as foot-and-mouth disease affects one or more large feedlots, vaccination must seriously be considered as an alternative to euthanizing the entire cattle herd in a 50,000- to 100,000-herd feedlot.

3.3.1 Human health and safety

Protection of human health and safety is a principal consideration when planning for and participating in depopulation activities and associated tasks such as disposal, biosecurity, and cleaning and disinfection procedures. Potential physical, environmental, and psychological hazards should be clearly communicated to personnel involved in depopulation activities. Effective communication and adherence to health and safety protocols are particularly important for zoonotic diseases. Depopulation activities requiring the use of PPE will require personnel training before initiation of depopulation. In addition, human health and safety should be primary concerns when considering the potential depopulation method in light of animal temperament and degree of stress, size, available handling facilities, ability to properly restrain animals when necessary, and personnel experience in handling cattle or alternative large ruminant livestock. Site-specific safety, security, and environmental factors should also be evaluated for risks to human health and safety and may be a factor in planning for depopulation. Debris, flooding, and damaged or hazardous facilities may present significant risks to human health and safety, and proposed depopulation plans may need to be modified or aborted to safeguard human health and safety. The US Department of Labor Occupational Safety and Health Administration[31] has developed a series of emergency preparedness and response documents[32] as well as safety and health topics[33] that may be relevant to depopulation. Further information on cleaning and disinfection procedures,[34] human health and safety,[35,36] PPE,[37,38] and biosecurity[39] is available online.

3.3.2 Timeline for depopulation

The expected time to carry out proposed depopulation methods should be considered in the context of the overall timeline for completion of objectives related to the response. Though the decision to depopulate cattle or alternative large ruminant livestock implies that animal destruction should occur quickly, timelines for depopulation may vary. Some reasons for depopulation of cattle or alternative large ruminant livestock necessitate that depopulation occur as rapidly as possible while other reasons may be less urgent.

3.3.3 Available resources

The selection of a depopulation method must consider available human and physical resources. It is important to accurately estimate and plan for the number and type of human, operational, and logistical resources needed to meet objectives associated with various depopulation methods.

Personnel training and experience as well as their existing level of expertise are important considerations to conduct depopulation procedures as humanely and efficiently as possible. Additionally, inadequate preparation and training for technical aspects of livestock depopulation have been shown to contribute to psychological stress among responders. Availability and procurement of needed equipment is an important component of planning and execution. If the depopulation incident will be managed with the ICS, personnel should have a minimum level of training and awareness. Additional information about the Federal Emergency Management Agency's Independent Study program can be found on their website.[40]

This study program includes the following National Incident Management System–compliant courses:

- IS-100.b (ICS 100) Introduction to Incident Command System.
- IS-200.b (ICS 200) ICS for Single Resources and Initial Action Incidents.
- IS-700.a. National Incident Management System (NIMS), An Introduction.

Relevant emergency management agencies should be identified and contacted as appropriate. Contact information for emergency management agencies and offices can be found on the Federal Emergency Management Agency website.[41]

In the event that the depopulation scenario involves an FAD, the USDA APHIS has developed a partial listing of FAD stakeholders that lists relevant federal, state, tribal, international, academia, industry, and other organizations that would be involved in an FAD event. The list, though obviously targeting FADs, may also be useful for other scenarios and can be found on the USDA APHIS website.[42]

3.3.4 Potential human physical and psychological impacts

Depopulation activities usually require a baseline level of physical fitness and emotional resiliency. Direct and indirect involvement with depopulation activities can result in significant negative psychological impacts. The negative effects of bovine depopulation procedures on human psychological health have been well documented.[43–46] Potential physical and psychological impacts related to depopulation activities should be considered when depopulation activities are planned. The use of experienced, skilled depopulation personnel to lead efforts may improve overall animal welfare as well as decrease human stress. The application of psychological first-aid when appropriate may be beneficial.[47] A psychological first-aid field guide training module for first responders is available.[48]

A tip sheet called "Tips for Disaster Responders: Preventing and Managing Stress" is available.[49]

A suite of mental health and wellness resources is available from the Johns Hopkins Center for Public Health Preparedness.[50]

Some depopulation methods may require a higher level of human strength, endurance, and cardiovascular fitness to be conducted successfully, compared with other depopulation methods. It is important to recognize potential negative effects that participation and association with depopulation activities may cause among those involved as well as producers and other stakeholders. Personnel involved in depopulation activities should consider physical and mental fitness abilities and limitations before participating in activities. Potential or known medical, mental, or physical limitations should be disclosed to appropriate authorities before participation in activities that may be affected by limitations. The affidavit[51] used by the National Disaster Medical System to report and assess physical and medical fitness of health-care members of Disaster Medical Assistance Team employees utilized for disaster responses has application to veterinarians and other personnel involved in depopulation responses and may provide useful guidance regarding potential medical and fitness requirements.

3.3.5 Public perception and acceptance

Public perception should also be taken into account when depopulation methods for cattle and alternative large ruminant livestock are considered. This is especially important if the depopulation activities are likely to be widespread or take place in areas where the public may witness depopulation events.

Efforts should be made to shield depopulation activities from being easily observed by the public. When appropriate, especially for large-scale depopulation events, the use of law enforcement to protect boundaries and maintain public safety is advisable. When possible, trained communicators such as designated public information officers should be tasked with leading communication with the media and general public. Best practices for developing appropriate message content for animal emergencies have been developed by the National Alliance of State Animal and Agricultural Emergency Programs.[52] If depopulation events involve animals other than those described herein, species groups should work together to present a unified message. The USDA APHIS has developed communications and messaging fact sheets that may be relevant for some depopulation scenarios.[53]

The use of extension resources may also be useful to provide messaging to the public. For example, the Extension Disaster Education Network is a multistate collaborative effort designed to link extension professionals across a multitude of disciplines to provide educational messages and accurate information.[54]

3.3.6 Demographics of cattle or alternative large ruminant livestock populations

The number, production type, and size of cattle or alternative large ruminant livestock on an operation will greatly influence the depopulation method. The depopulation method should account for size and production type as well as premises that have multiple species that are slated for depopulation. The number of animals to be depopulated can significantly impact the selected type of depopulation method. For example, the use of injectable barbiturates might be feasible for depopulation of smaller herds or groups of cattle or alternative large ruminant livestock but would not be reasonable for larger groups of animals.

3.3.7 Animal environment and available facilities

Location of premises and environment are key factors in selection of depopulation methods. Thorough evaluation of availability and suitability of needed facilities and equipment for the proposed depopulation method is a critical planning step and should be completed before selection of a depopulation method. A means of humanely and safely providing adequate animal restraint to protect human and animal safety is critical. Selection of depopulation methods must be compatible with the existing animal environment and working conditions. A secure area for staging human resources and necessary equipment is important to address logistic and operational resources needed to carry out depopulation efforts efficiently. If the premises or depopulation site cannot accommodate the proposed depopulation methods without compromising site security or human health and safety, then an alternative method area should be selected. Care should also be taken to select a staging area that will remain away from the general public. The method's compatibility with the animal environment, existing facility, and infrastructure situation's requirements and purpose is critical in selection of methods (eg, musk oxen are not considered fully domesticated, and a captive bolt should be used when animals can be adequately restrained; conversely, gunshot should be used when musk oxen cannot be restrained). For example, many cattle and bison feedyards have alley and chute facilities available where individual cattle or pens can be worked through relatively quickly. Some small feedlots may not have adequate alley and chute facilities, and cattle may be difficult to work effectively. Large feedlots will have too many cattle present to be able to work all cattle in the lot quickly.

Compared with domestic cattle facilities, bison and some other large ruminant facilities must be fortified to handle the size and temperament of the animals. Bison-handling equipment must have larger and taller dimensions (crowd tubs may need to be more than 7 feet tall to retain bison) than would be typical for domestic cattle and must be designed to withstand more rugged use. Fencing is also required to be fortified, often with an exterior and interior fence constructed of more rugged material than would be typical for commercial cow-calf operations. Modified bison-handling facilities have been successfully used to handle musk oxen. Alternative livestock with a long history of domestication such as musk oxen and water buffalo may be managed in facilities that are similar to cattle provided their body size and horn structure are accounted for as appropriate.

3.3.8 Biological risk management

If animals are slated for depopulation because they have been exposed or infected with the disease of concern, biosecurity efforts, must focus primarily on biocontainment to decrease the risk of disease spread from an infected or presumed-infected premises. Adherence by disposal personnel to prescribed biosecurity protocols including cleaning, disinfection, and decontamination procedures is critical to halt disease spread.[55] In situations where a regulatory disease is present, strict biosecurity and decontamination procedures are likely to be in place for workers assigned to depopulation and disposal activities as well as the premises when those activities are completed. In addition to handling animals in a biosecure manner, depopulation personnel may need to consider animal products such as milk, animal bedding and feed, PPE, and equipment and materials associated with depopulation activities. The USDA APHIS has collaborated with the Center for Food Security and Public Health to develop biological risk management resources as part of the Foreign Animal Disease Preparedness and Response Plan. These resources include guidelines, tactical topics, and biosecurity concepts related to general concepts, operational measures, premises bioexclusion, cleaning and disinfection, and PPE as well as maintaining biosecure areas for both infected and uninfected premises.[56,57]

3.3.9 Sample collection and testing

Events that require depopulation may include a significant component of diagnostic and surveillance testing as part of the response and recovery efforts. Thus, depopulation methods may impact the successful collection and submission of samples following death for diagnostic testing. Consultation with diagnosticians or others potentially involved with sample collection, submission, and testing of animals following death should occur so that, it possible, depopulation methods do not hinder or prevent the collection and submission of useful tissue or other samples.

3.3.10 Carcass removal, storage, and disposal methods

Depopulation personnel may not be directly assigned to disposal activities associated with animal depopulation. However, waste disposal is a critical component of response efforts following depopulation. Decisions regarding carcass disposal must be carefully coordinated with local, state, and federal authorities to ensure that the selected depopulation method does not prevent the use of available disposal options. Carcass disposal activities will be based on effective and efficient containment, consideration of environmental factors, likelihood of acceptance by stakeholders and the general public, and financial cost. Guidance regarding EPA regulations for carcass disposal can be found in 40CFR243.200-1(a).

Carcass removal plans should include movement of the deceased animal to a site away from depopulation activities. For example, depopulation methods that include plans to destroy cattle in a chute will require extensive planning for removal of carcasses from the chute. In some cases, depopulation may be conducted at a rate that exceeds the capacity of disposal activities. Care should be taken to plan for the temporary storage of carcasses in a safe and biosecure manner before disposal in the event that disposal activities cannot be completed shortly after animal death. The USDA APHIS has developed a carcass management overview[58] that includes type of mortality, who has primary carcass management responsibility, who confers legal authority, how it fits with the National Response Plan, and relevant entities that assistance may be provided by. A figure depicting a tiered response method is available on the USDA APHIS website.[59] The USDA APHIS has collaborated with the Center for Food Security and Public Health to develop comprehensive guidelines for disposal of carcasses and other waste materials associated with mass depopulation as part of the Foreign Animal Disease Preparedness and Response Plan. In addition to the guidelines, other resources include an accompanying disposal standard operating procedure and the EPA Disaster Debris Disposal Guidance.[60]

3.4 Implementation With Prioritization of Depopulation Methods

The AVMA defines depopulation as the rapid destruction of a population of animals in response to urgent circumstances with as much consideration given to the welfare of the animals as practicable. Depopulation methods should be designed to result in either rapid death or insensibility that persists until the time of death. Loss of consciousness should be accomplished by methods that minimize anxiety, pain, distress, or suffering in animals. Depopulation may not meet the requirements of euthanasia owing to situational constraints. An optimal depopulation technique for large numbers of cattle or alternative large ruminant livestock should result in rapid and efficient destruction using the most practical humane method. Whenever possible, AVMA Guidelines regarding preferred euthanasia methods should be utilized. Confirming insensibility and death is a critical component of the depopulation plan.

3.4.1 Preferred methods

The AVMA POE[61] has previously designated three primary methods as acceptable for bovine euthanasia: gunshot, PCB, and IV administration of a lethal dose of barbiturate or barbiturate acid derivative. Depending on the depopulation scenario, the use of a euthanasia method designated as acceptable may be a practical depopulation method. In addition to the methods recommended by the POE, the POD has included humane slaughter with the use of commercial or private processing plants as a preferred depopulation method.

3.4.1.1 Commercial or private processing

In some cases, it may be possible to depopulate cattle or other large ruminants using commercial or private processing facilities. This may be a particularly feasible option if the reason for depopulation does not present a human food-safety concern, animals are fit for transport, and transport of the animals is not likely to spread disease or cause welfare concerns. If depopulation using a slaughter plant is feasible, the disposition of the carcass must be carefully considered. Processing facilities may be extremely reluctant to process animals that may represent a food safety risk or that require special carcass disposition.

Plants may be categorized as Food Safety and Inspection Service inspected, state inspected, custom exempt, or retail exempt. The use of mobile slaughter or processing units may be an option, particularly for smaller numbers or when transport to slaughter is not practical or humane. Whenever possible, it is important to include packing plants in emergency response preparedness activities to gain important perspective and facilitate collaboration when appropriate. It is important to determine the types of animals that a packing plant can process. Facilities may be able to process only certain types of cattle such as young calves or fed cattle (cattle typically < 30 months of age). Nontraditional large ruminants such as bison and other alternative large ruminant livestock may require special accommodations that typical plants cannot provide.

Federally inspected plants have oversight from the USDA Food Safety and Inspection Service through the Federal Meat Inspection Act and are often modern plants that may be capable of humanely and efficiently processing cattle at more than 300 head/h. If practical, the use of commercial or private processing for the humane slaughter of cattle or other large ruminants that must be depopulated is a preferred depopulation method. More information regarding humane slaughter can be found in the AVMA Guidelines for the Humane Slaughter of Animals: 2016 Edition.[62]

3.4.1.2 Firearm

It is important to consider the range, conditions, and specific targets when performing firearm depopulation. Ricochet and overpenetration must be taken into account to prevent injury to personnel or unintended animal targets. The marksman and firearm caliber must be appropriate for the situation.[63,64] Marksmen must be familiar with bovine anatomy and make appropriate ballistics choices for the target, whether it be thoracic organs or the head or spine. This is true for both long- and short-range use of firearms.

3.4.1.3 PCB—alternative shot placement

The use of a PCB may be effective for some depopulation scenarios. Penetrating captive bolt as outlined in the AVMA Guidelines for the Euthanasia of Animals[61] is considered a preferred method with appropriate consideration for the size and age of the animal. However, even with modern facilities designed specifically for the production type of cattle slated for depopulation, the use of PCB may not occur rapidly enough to meet depopulation goals outlined by leadership.

The AVMA POHS[62] has previously suggested a minimum bolt velocity of 55 m/s for steers and 70 m/s for bulls for stunning, which can be used for guidance. Maintenance of PCB and associated equipment is critical for successful use, particularly when the equipment will be used repetitively. It is important to regularly check the PCB and to clean and maintain it as needed during depopulation activities. One recommendation suggests "resting" a PCB periodically, perhaps following every 20 shots.[65]

Current euthanasia recommendations encourage the use of a secondary step to ensure death occurs.[63] Implementation of a secondary step following the use of a PCB may greatly increase the time required to complete depopulation activities.[66] It may be useful to work in pairs when using a PCB for euthanasia, with one person tasked with operating the PCB while another ascertains death and uses an adjunct method as necessary. Some types of PCB may be suitable for euthanasia of bovines and alternative large livestock as a stand-alone method.[67,68]

A straightforward frontal approach for PCB has been described, which suggests that using the midline at the level of the base of the ears is a reliable and simple method to ascertain the optimal point of entry for a PCB when a frontal approach is used.[69] The use of a frontal point of entry to target the brainstem with a PCB may add additional stress to the animal being euthanized since it requires the handler to position themselves in front of the animal. If the animal is not well restrained or sedated, it may also result in injury to the human operator who is placed directly in front of the animal. Personnel carrying out the euthanasia may benefit from facility modifications that would place the shooter slightly above the animal to obtain an improved shot. This orientation is common at packing plants. Personnel moving cattle through the chute system should maintain awareness of when firearms are being used and remove themselves from the area before the gun is fired. This can slow cattle movement significantly but may prevent human death or injury caused by ricochets or misses. In some cases, a shot directed from just behind the animal's head may be effective and cause less stress for the animal as well as decrease the likelihood of human injury. This point of entry, sometimes termed a poll shot, is not an uncommon point of entry for feedyard and dairy personnel. The shot is directed from just behind the poll and aimed toward the base of the tongue.[70] An older study determined that a poll-stun was not as effective as a frontal approach, but given the anecdotally reported success among producers as well as veterinarians, the approach should be reevaluated. Similar to the frontal shot, speed and accuracy may be improved if the shooter is elevated slightly above the animal. This approach may facilitate more rapid depopulation since it does not require workers who are typically handling cattle behind the animal in the chute to alter their positions.

3.4.1.4 Injectable agents

The use of injectable methods such as barbiturates, barbiturate derivatives, or their combinations is not typically feasible for large numbers of cattle or other large ruminant livestock. The pharmaceuticals require extensive record keeping and supervision.[71] The IV technique typically used for chemical euthanasia requires training and experience as well as adequate restraint. Additionally, the use of these chemical agents limits carcass disposal options, and potential environmental and wildlife risks must be considered.[72] When these or other factors do not preclude their use, guidance as outlined in the AVMA Guidelines for the Euthanasia of Animals[61] may be utilized.

3.4.2 Permitted in constrained circumstances

Use of compounded or nonpharmaceutical-grade injectable anesthetics and euthanasia agents is justified for depopulation. In addition, the veterinarian may make a professional judgment about the use of agents that have exceeded their product expiration date.

3.4.2.1 PCB with sedation

Feedback from feedlot veterinarians and managers regarding the effectiveness of PCB as a depopulation method for cattle restrained in a chute or sedated in a chute and then allowed to exit before onset of sedation and euthanasia is not favorable.[73] In one study, a 13.6-kg (29.9-lb) PCB that utilized compressed air was successfully used as a one-step method to euthanize cattle between 227 and 500 kg (500 and 1,100 lb). However, the weight and size of the PCB used in the study will likely present considerable challenges in efficiently depopulating large numbers of cattle. In addition, though described as portable, the equipment is set up to be used chuteside, which would require considerable labor and time to remove cattle from the chute following death. Sedation with xylazine hydrochloride before the use of a PCB may facilitate efficiency if administered orally and has been used anecdotally in individual animals at dosages similar to what would be given IM. This may be more effective in confined operations where animals consume delivered rations. After a period of feed withdrawal, a sufficient amount of xylazine hydrochloride likely to provide heavy sedation could be combined with the normal ration under a veterinarian's supervision and delivered to the animals via a method that all animals are likely to be able to eat at once. Following observation of signs of sedation, animals could be depopulated with a PCB. This method does not necessarily meet the criteria for extralabel drug use as laid out in the AMDUCA of 1994[74] but may be considered appropriate for emergency use.

For animals that do not consume the ration or do not demonstrate profound signs of sedation, a dart gun or pole syringe may be utilized to administer sedation IM. Alternatively, animals in the pen that did not consume feed or demonstrate signs of adequate sedation may be processed through the facility's chute system, sedated in the chute, and immediately released in a quiet area following administration of sedation. Once signs of sedation are noted, the animal can be euthanized.

3.4.2.2 Electrocution

It is unlikely electrocution could be used as a depopulation method for cattle and other large ruminants. The currently available technology makes bovine electrocution an unwieldly option for depopulation because of risks to human safety and animal welfare. Current USDA recommendations suggest sedating animals before electrocution, which will require a workforce that is capable of administering sedatives and evaluating their effectiveness. In addition, the time required to sedate animals will negatively impact the depopulation rate. In the event that electrocution is deemed a feasible depopulation method, the AVMA Guidelines for the Euthanasia of Animals[61] and AVMA Guidelines for the Humane Slaughter of Animals[62] should be consulted for guidance.

3.4.3 Not recommended

The use of oral toxins to deliver a lethal dose of any agent is not currently recommended. In a Delphi survey exploring the use of toxic agents for depopulation of feedlots, veterinarians and managers expressed concerns regarding animal welfare, potential lack of effectiveness, human health risk, carcass disposal, and lack of sufficient toxin supply.[73] Other drawbacks include lack of reliable, established lethal dosages for many toxic agents; lack of assurance that a lethal dose will be consumed; species and individual variability in bioavailability, absorption rates, and response to a given dose of an agent; variability of latent period between ingestion and death; potential relay toxicities involving nontarget animals; environmental impact; and potential for recovery in animals exposed to sublethal doses. Additionally, for baited toxic agents intended for use on cattle and other large ruminants not confined to smaller pens, accidental exposure of nontarget species to the bait and the environmental fate of unconsumed bait are of concern. The severity and duration of animal suffering before death and potential human health and safety hazards make oral toxins an unsuitable option for depopulation. The use of oral toxins such as cyanide and nitrite as depopulation methods should be considered only when no other depopulation method can be reasonably expected to succeed.

3.5 Special Considerations

3.5.1 Special-needs animals

Some populations slated for depopulation may have atypical animals that will not be a fit for the intended depopulation method. For example, one or more animals may be moribund or nonambulatory (eg, because of injury or perhaps related to the reason for depopulation). Very young calves may be difficult to move and handle. If at all possible, animals that have special needs that may hinder the success of the planned depopulation activities should be euthanized in place with the most practical humane method possible. The specific circumstances will vary between depopulation events. Thus, no specific recommendation is made for depopulation method, except to use the most practical and humane method possible.

3.5.2 Dangerous animals

It is important that only knowledgeable, qualified individuals handle cattle and other larger ruminants, which are capable of posing a human safety risk. Bulls and alternative large ruminant livestock such as bison can be particularly dangerous to handle and restrain, and depopulation activities involving them may pose a significant risk to human safety. If one or more animals are deemed too dangerous for the planned depopulation method to be safely used, an alternate plan that uses the most practical humane depopulation method possible should be chosen.

3.5.3 Confirmation of death

Whenever human safety can be reasonably ascertained, depopulation plans should include a protocol for confirmation of insensibility and death. For depopulation methods that are likely to require more than one step and for which the secondary step is meant to be completed on insensible animals, determination of insensibility is critical. In some cases, such as with the use of some captive bolts, insensibility may be evident, but cardiac function may persist for several minutes.[75] American Veterinary Medical Association[61,62] and AABP[76] guidelines should be consulted for guidance in confirming death.

3.6 References

1. USDA National Agricultural Statistics Service. Table 23. Miscellaneous livestock and animal specialties—inventory and sales: 2012 and 2007. In: *2012 census of agriculture*. Washington, DC: National Agricultural Statistics Service, 2014;398–399. Available at: www.nass.usda.gov/Publications/AgCensus/2012/Full_Report/Volume_1,_Chapter_1_US/usv1.pdf. Accessed Feb 11, 2019.
2. BEEF *magazine 2007 National stocker survey: national overview and detailed summary*. New York: Penton Media Publication, 2008.
3. Hansen R. Bison profile. Updated June 2012. Available at: www.agmrc.org/commodities-products/livestock/bison-profile. Accessed Feb 10, 2019.
4. Beef Quality Assurance website. Available at: www.bqa.org. Accessed Feb 10, 2019.
5. Beef Quality Assurance. Supplemental guidelines 2014. Available at: www.bqa.org/Media/BQA/Docs/supplemental_guidelines_2014.pdf. Accessed Feb 10, 2019.
6. Center for Food Security and Public Health. High consequence livestock pathogens and toxins. May 1, 2005. Available at: www.cfsph.iastate.edu/pdf/high-consequence-livestock-pathogens-and-toxins. Accessed Feb 10, 2019.
7. APHIS Veterinary Services. Factsheet: high-consequence foreign animal diseases and pests. July 2013. Available at: www.aphis.usda.gov/publications/animal_health/2013/fs_hc_diseases.pdf. Accessed Feb 10, 2019.
8. Roth JA, Stumbaugh A, Spickler AR, et al. NAHEMS guidelines: vaccination for contagious diseases. 10-2014. Available at: lib.dr.iastate.edu/cgi/viewcontent.cgi?article=1001&context=vmpm_reports. Accessed Mar 12, 2019.
9. CDC. Emergency preparedness and response. Bioterrorism Agents/Diseases, A to Z. Available at: emergency.cdc.gov/agent/agentlist.asp. Accessed Feb 10, 2019.
10. Electronic Code of Federal Regulations. Title 9: animals and animal products. Part 53—foot-and-mouth disease, pleuropneumonia, rinderpest, and certain other communicable diseases of livestock or poultry. Available at: www.ecfr.gov/cgi-bin/text-idx?SID=4adf0f038b7984fcd80b4eaad3cbe588&mc=true&node=pt9.1.53&rgn=div5. Accessed Nov 1, 2016.
11. USDA APHIS. US national list of reportable animal diseases (NLRAD) framework. September 2016. Available at: www.aphis.usda.gov/animal_health/downloads/us-national-list-of-reportable-animal-diseases-framework.pdf. Accessed Feb 11, 2019.
12. Center for Food Security and Public Health. Diseases Reportable to the OIE. Available at: www.cfsph.iastate.edu/pdf/diseases-reportable-to-oie. Accessed Feb 10, 2019.
13. Monke J. Congressional Research Service report for Congress. Agroterrorism: threat and preparedness. Available at: fas.org/sgp/crs/terror/RL32521.pdf. Accessed Feb 21, 2019.
14. Center for Food Security and Public Health. Agroterrorism pathogens by species. May 1, 2005. Available at: www.cfsph.iastate.edu/pdf/agroterrorism-pathogens-by-species. Accessed Feb 10, 2019.
15. Center for Food Security and Public Health. Transmission routes of potential bioterrorism agents. May 1, 2005. Available at: www.cfsph.iastate.edu/pdf/transmission-routes-of-potential-bioterrorism-agents. Accessed Feb 10, 2019.
16. Center for Food Security and Public Health. Human disease from potential bioterrorism agents. Available at: www.cfsph.iastate.edu/WallChartReferences/. Accessed Feb 10, 2019.
17. Center for Food Security and Public Health. Bovine disease exposure routes. Available at: www.cfsph.iastate.edu/Infection_Control/Routes/English/DiseaseBRMBovine.pdf. Accessed Feb 10, 2019.
18. OIE. Anthrax. Available at: http://www.oie.int/en/animal-health-in-the-world/animal-diseases/Anthrax/. Accessed Feb 19, 2019.
19. Center for Food Security and Public Health. Anthrax. March 2007. Available at: www.cfsph.iastate.edu/Factsheets/pdfs/anthrax.pdf. Accessed Nov 6, 2016.
20. Center for Food Security and Public Health. Melioidosis. January 2016. Available at: www.cfsph.iastate.edu/Factsheets/pdfs/melioidosis.pdf. Accessed Feb 10, 2019.
21. Center for Food Security and Public Health. Bovine tuberculosis. July 2009. Available at: www.cfsph.iastate.edu/Factsheets/pdfs/bovine_tuberculosis.pdf. Accessed Feb 10, 2019.
22. Center for Food Security and Public Health. Vesicular stomatitis. January 2016. Available at: www.cfsph.iastate.edu/Factsheets/pdfs/vesicular_stomatitis.pdf. Accessed Feb 10, 2019.
23. Center for Food Security and Public Health. Technical factsheets. Available at: www.cfsph.iastate.edu/DiseaseInfo/factsheets.php. Accessed Feb 10, 2019.
24. Food Animal Residue Avoidance Databank. Prohibited and restricted drugs in food animals. Available at: www.farad.org/prohibited-and-restricted-drugs.html Accessed Feb 10, 2019.
25. World Nuclear Association. Nuclear Power in the USA. December 2016. Available at: www.world-nuclear.org/information-library/country-profiles/countries-t-z/usa-nuclear-power.aspx. Accessed Dec 14, 2016.
26. Johnston WR. Statistical summary of radiological accidents and other incidents causing radiation casualties. November 2011. Available at: www.johnstonsarchive.net/nuclear/radevents/radeventdata.html. Accessed Dec 14, 2016.
27. CDC. Psychological first aid in radiation disasters. Available at: www.orau.gov/rsb/pfaird/01-introduction.html. Accessed Mar 29, 2019.
28. Johnson R, Muller M. Animal health hazards of concern during natural disasters. February 2002. Available at: www.aphis.usda.gov/animal_health/emergingissues/downloads/hazards.PDF. Accessed February 11, 2019.
29. All Hazards. Natural disasters. Available at: www.prep4agthreats.org/Natural-Disasters/index.php. Accessed Dec 14, 2016.
30. All Hazards. Federal and state contacts and resources. Available at: www.prep4agthreats.org/federal-and-state-contacts.php. Accessed Dec 14, 2016
31. US Department of Labor Bureau of Labor Statistics. Occupational employment statistics. Available at: www.bls.gov/oes/current/oes119013.htm. Accessed Feb 11, 2019.
32. US Department of Labor Occupational Safety and Health Administration. Emergency preparedness and response. Available at: www.osha.gov/SLTC/emergencypreparedness/. Accessed Dec 14, 2016.

33. US Department of Labor. Occupational Safety and Health Administration. Safety and health topics. Available at: www.osha.gov/SLTC/index.html. Accessed Dec 14, 2016.
34. Dvorak G, Bickett-Weddle D, DeVoe S, et al. FAD PReP/NAHEMS guidelines: cleaning and disinfection. July 2014. Available at: www.aphis.usda.gov/animal_health/emergency_management/downloads/nahems_guidelines/cleaning_disfection.pdf. Accessed Feb 10, 2019.
35. Leedom Larson K, Mogan JP, Allen H, et al. FAD PReP/NAHEMS guidelines: health and safety. December 2018. Available at: www.aphis.usda.gov/animal_health/emergency_management/downloads/nahems_guidelines/fadprep-nahems-guidelines-health-safety.pdf. Accessed Mar 29, 2019.
36. CDC National Institute for Occupational Safety and Health. Emergency preparedness and response. November 2016. Available at: www.cdc.gov/niosh/topics/emergency.html. Accessed Feb 19, 2019.
37. Mogan JP, Brown GB, Wormley E. FAD PReP/NAHEMS guidelines: personal protective equipment (PPE). April 2011. Available at: www.aphis.usda.gov/animal_health/emergency_management/downloads/nahems_guidelines/fadprep_nahems_guidelines_ppe_final_april2011.pdf. Accessed Feb 11, 2019.
38. Center for Food Security and Public Health. Personal protective equipment: safety while wearing PPE. Available at: www.cfsph.iastate.edu/Emergency-Response/Just-in-Time/04-PPE-Safety_HANDOUT.pdf. Accessed Mar 27, 2019.
39. Mogan JP, Allen H, Bretz K. FAD PReP/NAHEMS guidelines: biosecurity. June 2016. Available at: www.aphis.usda.gov/animal_health/emergency_management/downloads/nahems_guidelines/fadprep_nahems_guidelines_biosecurity.pdf. Accessed Mar 27, 2019.
40. Federal Emergency Management Agency. IS-10.A: animals in disasters: awareness and preparedness. Available at: training.fema.gov/is/courseoverview.aspx?code=IS-10.a. Accessed Feb 10, 2019.
41. Federal Emergency Management Agency. Emergency management agencies. Available at: www.fema.gov/emergency-management-agencies. Accessed Feb 10, 2019.
42. USDA. A partial listing of FAD stakeholders. FAD PReP manual 5-0. www.aphis.usda.gov/animal_health/emergency_management/downloads/documents_manuals/fad_stakeholders_par_list.pdf. Accessed Mar 12, 2019.
43. Hibi J, Kurosawa A, Watanabe T, et al. Post-traumatic stress disorder in participants of foot-and-mouth disease epidemic control in Miyazaki, Japan, in 2010. *J Vet Med Sci* 2015;77:953–959.
44. Mort M, Convery I, Baxter J, et al. Psychosocial effects of the 2001 UK foot and mouth disease epidemic in a rural population: qualitative diary based study. *BMJ* 2005;331:1234.
45. Olff M, Koeter MWJ, Van Haaften EH, et al. Impact of a foot and mouth disease crisis on post-traumatic stress symptoms in farmers. *Br J Psychiatry* 2005;186:165–166.
46. Whiting TL, Marion CR. Perpetration-induced traumatic stress—a risk for veterinarians involved in destruction of healthy animals. *Can Vet J* 2011;52:794–796.
47. Nusbaum KE, Wenzel JG, Everly GS Jr. Psychologic first aid and veterinarians in rural communities undergoing livestock depopulation. *J Am Vet Med Assoc* 2007;231:692–694.
48. Brymer M, Jacobs A, Layne C, et al. Psychological first aid: field operations guide. 2nd Edition. Available at: www.ptsd.va.gov/professional/treat/type/PFA/PFA_V2.pdf. Accessed Feb 10, 2019.
49. Substance Abuse and Mental Health Services Administration (SAMHSA). Tips for disaster responders: preventing and managing stress. HHS Publication No. SMA-14-4873. 2014. Available at: store.samhsa.gov/system/files/sma14-4873.pdf. Accessed Feb 11, 2019.
50. Johns Hopkins Center for Public Health Preparedness. Mental Health Preparedness. Available at: www.jhsph.edu/research/centers-and-institutes/johns-hopkins-center-for-public-health-preparedness/training/online/mental-health-trainings.html. Accessed Nov 10, 2016.
51. Assistant Secretary for Preparedness and Response, Office of Preparedness and Emergency Operations, National Disaster Medical System. Affidavit for physical and medical fitness for duty. Available at: www.dmatca4.org/pages/forms/NDMSPhysicalMedicalFitnessAffidavit.pdf. Accessed Feb 10, 2019.
52. National Alliance of State Animal and Agricultural Emergency Programs. Preparedness and community outreach best practices. June 2012. Available at: www.cfsph.iastate.edu/Emergency-Response/bpwg/commprep-whitpaper6-23-12.pdf. Accessed Feb 11, 2019.
53. USDA APHIS. Outbreak response tools. Updated August 2015. Available at: www.aphis.usda.gov/aphis/ourfocus/animalhealth/emergency-management/ct_fadprep_outbreak_response_tools. Accessed Dec 15, 2016.
54. Extension Disaster Education Network. Available at: eden.lsu.edu/Pages/default.aspx. Accessed Feb 11, 2019.
55. Animal Decontamination Best Practices Working Group of the National Alliance of State Animal and Agricultural Emergency Programs. Animal decontamination: current issues and challenges. December 2010. Available at: www.cfsph.iastate.edu/Emergency-Response/bpwg/animal.decon.whitepaper8feb2011.pdf. Accessed Feb 10, 2019.
56. Dewell R, Bickett-Weddle D, Mogan J, et al. *FAD PReP/NAHEMS guidelines: mass depopulation and euthanasia*. Ames, Iowa, and Washington, DC: Center for Food Security and Public Health and USDA, 2011.
57. Dewell R, Bickett-Weddle D, Mogan J, et al. FAD PReP/NAHEMS guidelines: mass depopulation and euthanasia. Available at: www.cfsph.iastate.edu/pdf/fad-prep-nahems-guidelines-mass-depopulation-and-euthanasia. Accessed Feb 10, 2019.
58. USDA APHIS. Carcass management. Available at: www.aphis.usda.gov/emergency_response/downloads/hazard/Carcass%20management%20table.pdf. Accessed Feb 10, 2019.
59. USDA APHIS. Carcass removal scenario using NIMS tiered response principle—Stafford Act incidents. Available at: www.aphis.usda.gov/emergency_response/downloads/hazard/Carcass%20Mgt%20Tiered%20Response.pdf. Accessed Feb 10, 2019.
60. USDA APHIS. Emergency management tools—disposal guidance. Available at: www.aphis.usda.gov/aphis/ourfocus/emergencyresponse/sa_tools_and_training/ct_aphis_role_emergency_tools_disposal_guidance. Accessed Feb 10, 2019.
61. AVMA. AVMA guidelines for the euthanasia of animals: 2013 edition. Available at: www.avma.org/KB/Policies/Documents/euthanasia.pdf. Accessed Feb 7, 2019.
62. AVMA. AVMA guidelines for the humane slaughter of animals: 2016 edition. Available at: www.avma.org/KB/Resources/Reference/AnimalWelfare/Documents/Humane-Slaughter-Guidelines.pdf. Accessed Feb 7, 2019.
63. Shearer JK. Euthanasia of cattle: indications and practical considerations, in *Proceedings*. North Am Vet Conf Large Anim 2005;19:28–29.
64. Thomson DU, Wileman BW, Rezac DJ, et al. Computed tomographic evaluation to determine efficacy of euthanasia of yearling feedlot cattle by use of various firearm-ammunition combinations. *Am J Vet Res* 2013;74:1385–1391.
65. Atkinson AS. Stunning: mechanical stunning. In: Dikeman M, Devine C, eds. *Encyclopedia of meat sciences*. 2nd ed. New York: Academic Press Inc, 2014;413–417.
66. Derscheid RJ, Dewell RD, Dewell GA, et al. Validation of a portable pneumatic captive bolt device as a one-step method of euthanasia for use in depopulation of feedlot cattle. *J Am Vet Med Assoc* 2016;248:96–104.
67. Appelt M, Sperry J. Stunning and killing cattle humanely and reliably in emergency situations—a comparison between a stunning-only and a stunning and pithing protocol. *Can Vet J* 2007;48:529–534.
68. Gilliam JN, Shearer JK, Bahr RJ, et al. Evaluation of brainstem

disruption following penetrating captive-bolt shot in isolated cattle heads: comparison of traditional and alternative shot-placement landmarks. *Anim Welf* 2016;25:347–353.
69. Dewell RD, Dewell GA, Bear DA, et al. Description and justification of a consistent technique for euthanasia of bovines using firearm and penetrating captive bolt. *Bovine Pract* 2016;50:190–195.
70. Daly CC. Recent developments in captive bolt stunning. In: Ewebank R, ed. *Humane slaughter of animals for food*. Potters Bar, England: Universities Federation for Animal Welfare, 1987;15–20.
71. Thurmon JC. Euthanasia of food animals. *Vet Clin North Am Food Anim Pract* 1986;2:743–756.
72. Griffin D. Feedlot euthanasia and necropsy. *Vet Clin North Am Food Anim Pract* 2015;31:465–482.
73. McReynolds SW, Sanderson MW. Feasibility of depopulation of a large feedlot during a foot-and-mouth disease outbreak. *J Am Vet Med Assoc* 2014;244:291–298.
74. US FDA. Animal Medicinal Drug Use Clarification Act of 1994 (AMDUCA). Available at: www.fda.gov/AnimalVeterinary/GuidanceComplianceEnforcement/ActsRulesRegulations/ucm085377.htm. Accessed Mar 5, 2019.
75. Dewell RD, Moran LE, Kleinhenz KE, et al. Assessment and comparison of electrocardiographic and clinical cardiac evidence of death following use of a penetrating captive bolt in bovines. *Bovine Pract* 2015;49:32–36.
76. American Association of Bovine Practitioners. AABP practical euthanasia of cattle. Available at: www.aabp.org/resources/AABP_Guidelines/Practical_Euthanasia_of_Cattle-September_2013.pdf. Accessed Feb 10, 2019.

4: Swine

4.1 General Considerations

4.1.1 Swine production

Swine production has changed dramatically since the late 1970s, when farrow to finish was the predominant type of swine operation and the greater number of operations had less than 100 head. The movement between production phases occurred on one site, and external movements included taking swine to market and bringing breeding swine onto the farm. In the 1990s, the industry started to change the model of production. Today, the majority of swine are produced from two- and three-site farms, and the distances that swine travel for production purposes have increased.

According to the USDA's Farms, Land in Farms, and Livestock Operations summary, the number of US swine operations in 2010 totaled 69,100. As of March 1, 2016, the USDA's National Agricultural Statistics Service reported the US swine inventory was 67.6 million head. There is a greater number of farms that raise less than 1,000 head; however, they make up only 5% of the total pig inventory. Ninety percent of the US inventory are raised on farms with > 2,000 head. The number of head on a swine farm can vary from 1 to 2 head to > 5,000 head of swine. The type of rearing environment varies; however, most swine are reared indoors in modern facilities with controlled environments. In general, these facilities house anywhere from 1,250 to 2,400 head, and there can be multiple barns per farm. There are farms that raise swine outdoors or with access to outdoor facilities, and in some cases, swine can be raised in gable barns, sheds, or lean-tos, but these farms make up the minority of the total inventory. According to the USDA APHIS, the feral swine population is currently estimated to exceed more than 6 million swine. The majority of this population is free-ranging; however, there are some farms that raise captive feral swine primarily for hunting.

Indoor housing, outdoor housing, and free-ranging feral swine pose unique challenges when depopulation is needed. Larger farms using indoor housing pose a challenge owing to the number of swine on the site. In the case of swine or feral swine raised outdoors, there can be challenges related to herding swine to a location where depopulation can occur. Free-ranging feral swine cannot be effectively herded, so there is a need for individuals competent in managing wild and feral swine for carrying out activities related to depopulation.

4.1.2 Workforce

In the swine industry, the workforce varies by farm size and specificity of worker responsibilities. Larger farms can have a highly structured workforce with a higher level of specificity in worker roles, as compared with an independent commercial or backyard farm where the owner and employees take on a broader range of responsibilities. Larger farms generally have more access to workers who can be deployed for depopulation purposes, compared with smaller farms. Workforce training available to pork producers includes The Pork Quality Assurance Plus Program (PQA Plus), which is an educational program that allows for certification in 10 good production practices addressing pork safety, animal well-being, worker safety, environmental stewardship, and public health. Swine farms may also have internal training specific to their site's production procedures. The Transportation Quality Assurance Program (TQA) is a certification program for swine transporters, producers, and animal handlers to increase knowledge of how to appropriately handle, move, and transport swine.

On modern swine farms, there is a higher probability of having employees who are skilled in moving livestock, humane euthanasia methods, and carcass disposal. Specific to on-farm euthanasia, recommendations[1] for producers have been developed by the National Pork Board and the American Association of Swine Veterinarians. These recommendations do not specifically address depopulation; however, swine farms may have written emergency response plans that address depopulation and carcass disposal.

In many states, swine veterinarians and producers may have attended state or federal emergency response training exercises that help inform and guide producers in the development of an emergency response plan for depopulation and carcass disposal. When depopulation is being considered, it is important to understand the capabilities of the available workforce and what each farm has in the form of plans, personnel, resources, capacity, and training to carry out the depopulation plan.

Swine farms participating in the PQA Plus Program should have a written euthanasia action plan, which describes the euthanasia methods used by production phase for that premises. Farms that are not participating in the PQA Plus Program may or may not have a written euthanasia plan; however, they should be able to verbally communicate the methods that are used on farm and the equipment used to carry out euthanasia and carcass disposal.

4.1.3 Marketing considerations

The goal of swine production is to provide a wholesome, safe, high-quality food for consumers. Because there is little flexibility in the current marketing channel, any eventuality that reduces or eliminates the marketability of swine could have a negative impact on animal welfare in a very short period of time. This puts a high level of importance on the speed at which a decision can be made for swine that cannot be moved or marketed because of regulatory issues, natural and manmade disasters, food safety, and other public health issues.

4.2 Events Necessitating Depopulation

There are certain incidents where the rapid destruction of a population of swine must occur in response to urgent circumstances with as much consideration given to the welfare of the swine as practicable. Each incident will have specific circumstances that affect the methods used for depopulation.

4.2.1 Regulatory diseases

Regulatory diseases represent one of the most likely incidents in which depopulation is used by state and federal animal health officials as the first line of defense to quickly eradicate the disease by preventing further disease replication in infected, exposed, or at-risk swine. Stop movements, if implemented as a disease control measure, can also result in the need for depopulation of swine on noninfected farms in disease control areas because swine cannot be moved.

4.2.2 Nonregulatory (highly pathogenic) diseases

The presence of a highly pathogenic nonregulated swine production disease represents a scenario in which depopulation may be required as an ancillary effort to support herd health stabilization. In this circumstance, depopulation of infected and susceptible swine is needed to prevent further replication of the agent while efforts are taken to stabilize herd health and clean the environment so further losses are mitigated.

4.2.3 Emerging swine production diseases

The emergence of a swine production disease into the US swine herd represents a scenario in which depopulation may be required in an effort to prevent the disease from spreading from the index case or early cases to the rest of the national herd. In this case, the disease is not regulated, and producers may elect to rapidly depopulate the herd at their own expense to protect the broader industry as a whole.

4.2.4 Zoonotic diseases

Evidence of a zoonotic disease in swine represents a scenario in which depopulation may be required because of real or perceived public health threats or food safety issues, such that swine can no longer be moved or marketed. It is important to note that zoonotic diseases may complicate or increase the burden of accomplishing depopulation owing to the level of personal protection required to prevent human exposure (ie, general public, farm workers, and those working to do the depopulation).

4.2.5 Intoxications and adulterations

Known adulterations of live swine (eg, oral exposure to dioxin or melamine) may result in a scenario in which movement or marketing is prevented owing to real or perceived effects on food safety, resulting in swine that cannot be processed for food. In most cases, the urgency may not require depopulation. The level of urgency may change depending upon knowledge of an immediate or impending danger to swine welfare from the toxicant exposure (eg, kidney failure), which may warrant depopulation. In either case, it is important that a disposal plan be developed and approved by the competent environmental authority to protect environmental health.

4.2.6 Radiologic exposures

A radiologic emergency, such as a nuclear power plant incident, could present a scenario in which depopulation is needed to prevent or relieve animal suffering and protect worker and public health. It is anticipated that an incident requiring this level of response would prevent producers from feeding and caring for their swine and responders from carrying out complex processes for depopulation and immediate actions pertaining to carcass disposal. In this situation, it is important that a disposal plan be developed and approved by state environmental authorities, and it should be recognized that there may be a significant delay in carcass removal and disposal from the farm.

4.2.7 Natural disasters

In most cases, the response to natural disasters on a farm occurs after the incident (eg, tornado, hurricane) and would not require the use of depopulation. There may be incidents in which swine cannot be removed from harm's way (eg, flooding, fire) that would require depopulation to prevent or relieve animal suffering. In other cases, farms may be damaged to an extent that is hazardous for workers to enter buildings. Farms may also remain intact but be isolated owing to the disaster (eg, power loss, road closure), with basic services, including animal care and feeding, unable to be restored in time to prevent animal suffering.

4.3 Planning for Depopulation

Developing a depopulation plan before carrying out those activities is important. Ideally a plan should be developed and tested before an incident requiring depopulation. Even if preplanning has not been accomplished before an incident, it is in the best interest of those being tasked with depopulation not to rush to implementation at the expense of the planning phase. The following should be considered when a plan is being developed.

4.3.1 Time constraints

The justification and need to undertake depopulation are closely tied to the urgency of the situation. Methods used for depopulation should be evaluated on the basis of their ability to achieve the necessary throughput to accomplish work within the allotted time frame.

The competent authority should be able to pro-

vide justification and a timeline for depopulation to occur. In most cases, justification for depopulation is related to an emergency situation in which a regulatory disease is present in the US swine herd.
Other situations that may warrant depopulation are those in which there is an immediate or impending danger to swine or human welfare that cannot be mitigated by removing animals from harm's way to mitigate the immediate or impending threat.

4.3.2 Worker safety

Worker health and safety should be a primary consideration when depopulation, disposal, and decontamination procedures are considered. An individual should be designated to address and ensure worker health and safety during all phases of the depopulation process.

4.3.3 Ownership

The ownership of the animals throughout the depopulation process should be documented to ensure appropriate indemnification if approved by state or federal officials.

4.3.4 Indemnity

The need for regulatory oversight and approval before depopulation must be factored into any plan where there is an appraisal and indemnity process to offset the financial losses to owners.

4.3.5 Public perception

Public perception should also be considered in the decision about the appropriate method for depopulation, although this should not take precedence over animal welfare considerations.

4.3.6 Number of swine

The number of swine present on a farm influences the method used for depopulation. In cases where there are large numbers of swine, methods of depopulation where throughput can be increased are preferable.

4.3.7 Size of pigs

The size of the pigs to be depopulated can help determine the method that best fits the urgency of the situation. Swine can vary in size from 1 lb (0.5 kg) for neonates to over 600 lb (272.7 kg) for mature breeding stock. The average slaughter weight for market swine is 290 lb (131.8 kg) at 7 months of age. In most wean-to-finish farms, market swine that are weaned and placed together will be of similar size, with weights ranging from 15 to 310 lb (6.8 to 140.9 kg). More disparity in size occurs on sow farms and farrow-to-wean farms where there will be a combination breeding stock of varying sizes (280 to 600 lb [127.3 to 272.7 kg]) and suckling pigs under 20 lb (9.1 kg) of body weight. Specific to farms that are farrow to finish, there will be larger variation in weights. In some cases, multiple methods may be required to take into account the differences in animal sizes.

4.3.8 Animal environment

Farms with indoor facilities can pose challenges because of difficulties in accessing carcasses if swine are depopulated inside a building, which can result in a need for manual removal of carcasses, increasing the time required to empty the barn. It is preferable for swine to be moved to the area where the method for depopulation can be applied and the carcasses can be easily managed for removal. The ease of handling will be dependent upon the quality of the facilities, ability to use people adept at moving swine, and previous handler interactions. Moving swine may not be possible if swine are unable to walk because of disease or other health conditions. The configuration of indoor swine-housing facilities must be considered, as they can significantly complicate removal of carcasses.

Farms raising swine outdoors will vary in the ease with which swine can be centralized and penned for ready access. The ease of handling will be dependent upon the quality of the facilities, terrain, ability to use people adept at moving swine, and previous handler interactions. A best-case scenario would allow for the herding of the swine into a small area where they can be loaded for transport and depopulated. A second option would be to depopulate swine after relocation to a more confined area where ease of access to both the live animals and the carcasses can be ensured. In some cases, farms may be limited to fencing only, and it may not be possible to move swine to a more centralized area.

By definition, wild and feral swine are roaming free, which greatly complicates efforts to accomplish depopulation. In these situations, it is imperative that individuals competent in managing wild and feral swine are retained and used for planning and carrying out activities related to depopulation.

4.3.9 Availability of personnel and equipment for depopulation

The availability of trained and competent personnel and purpose-designed, well-maintained equipment should always be considered when the method of depopulation is decided.

4.3.10 Staging

Locations for staging human resources and equipment should be designated and communicated to personnel.

4.3.11 Animal handling

Plans should identify the location for depopulation, the route to that location from the area the animals are housed, and who is responsible for gaining access and moving the pigs. Consideration should be given to moving pigs to pens closer to egress points to save on the distance that a carcass needs to move to be extracted from the barn.

4.3.12 Depopulation

Plans should identify the type of restraint needed and the application of the methods chosen for depopulation. Depopulating swine in the conveyance that will take the carcass to the disposal location is most efficient.

4.3.13 Carcass removal

Plans should identify the methods for carcass removal from the housing environment and how carcasses are transitioned to the conveyance moving carcasses to disposal. It is important to factor in the number of conveyances and number of personnel that will be needed to ensure that carcasses can be removed in a timely manner to prevent long-term piling of carcasses, which can lead to adverse environmental conditions.

4.3.14 Disposal method

The carcass disposal options available need to be factored in as methods used for depopulation are being considered. It is important to ensure that if chemical and physical methods (eg, gunshot) that leave residues in the carcass are being considered that an approved method of disposal is available. If not, then other methods should be explored.

4.3.14.1 Operator and observer impact

The impact of conducting depopulation procedures on observers, operators, and producers should not be underestimated. Significant post-traumatic stress is reported following depopulations of large numbers of pigs and other animal species, especially when the animals are in apparent good health. Appropriate social services and mental health support resources should be identified, and this information should be disseminated to all of those participating in the depopulation exercise. Daily debriefing may assist with averting development of post-traumatic stress disorder.

4.3.14.2 Decontamination considerations

In situations where a regulatory disease is present, the competent veterinary authority may dictate biosecurity and decontamination procedures for workers assigned to depopulation and disposal activities as well as the premises when those activities are completed.

4.4 Planning for Carcass Disposal in Urgent Circumstances

Developing a carcass disposal plan for urgent circumstances before carrying out those activities is important. Ideally, plans should be developed and tested before an incident requiring carcass disposal. Even if preplanning has not occurred before depopulation, it is in the best interest of those being tasked with carcass disposal not to rush to implementation at the expense of the planning phase. Planning must factor in the ability to get the necessary equipment, skilled personnel, and regulatory permissions in place to carry out disposal in the specified timelines.

Carcass disposal is generally a regulated process. The competent authority in charge of carcass disposal regulations may vary by jurisdiction and by situation. In situations where the disposal of carcasses is necessary over and above what is legally allowed, it is imperative that the competent authority be contacted to approve carcass disposal plans. In some instances, the authority may have resources to aid producers in planning and siting for carcass disposal in emergency situations. Producers are encouraged to have on-site carcass disposal plans in place along with the appropriate contracts to ensure that the actions can be carried out.

The primary consideration for carcass disposal is staging resources for ease of access and loading and removal of carcasses. It is important that once the methods are selected that individuals are tasked immediately with arranging the acquisition and staging of adequate equipment and human resources to ensure that transportation is not the rate-limiting step in carcasses disposal.

If carcasses are being removed manually from the housing environment, then considerations should be given to transitioning the carcass directly to a mechanized conveyance for transportation to the point of final disposition. This approach will help provide efficiencies, with workers only having to handle the carcass once it is picked up. If the carcass cannot be transitioned into a mechanized conveyance, then piling the carcasses in an area outside the barn where they can be easily accessed for removal and disposal is preferable.

4.5 Implementation With Prioritization

Methods for depopulation are used when the rapid destruction of a population of pigs must occur in response to urgent circumstances. Various physical, chemical, and inhalant methods may be used for depopulation provided the method can be applied by competent personnel in the time frame allotted. Not all methods will induce death in a manner that is consistent with euthanasia. Regardless, the welfare of swine must be considered when methods are selected, such that the most humane method of depopulation is used whenever possible.

4.5.1 Preferred methods

4.5.1.1 Physical methods

All physical methods considered acceptable or acceptable with conditions outlined in the AVMA Guidelines for the Euthanasia of Animals[2] (eg, gunshot, PCB, and nonpenetrating captive bolt) or techniques covered by the AVMA Guidelines for the Humane Slaughter of Animals[3] for a given species are considered preferred methods with appropriate consideration for the size and age of the animal. In addition, the following physical methods not outlined in the euthanasia guidelines are considered preferred.

Gunshot—For nursery, growing, finishing, and mature pigs, a gunshot to the head can be used for depopulation if done correctly. However, gunshot is not appropriate for depopulation of suckling pigs. The practicality of using gunshot decreases as the number of swine to be depopulated increases. Ideally, the pig should be outdoors and on soil to reduce the chance of ricochet. Gunshot should not be used for depopulation if human safety cannot be assured, the size of the gun and ammunition cannot ensure the effectiveness of the technique, or users are not trained in firearm safety.

Nonpenetrating captive bolt—For suckling and nursery pigs, a nonpenetrating captive bolt can be used for depopulation. A nonpenetrating captive bolt is not appropriate for grower, finisher, or mature pigs. The practicality of using a captive bolt decreases when time is a factor and the number of swine to be depopulated increases. A nonpenetrating captive bolt should not be used if the force achieved is not effective for the weight of the pig being depopulated. Captive bolts should not be considered for depopulation if the pigs cannot be properly restrained and the captive bolt cannot be properly applied or human safety cannot be assured.

PCB—For nursery, growing, and mature pigs, a PCB can be used for depopulation provided the pigs are appropriately restrained and the captive bolt can be properly and safely applied. The practicality of using a captive bolt decreases when time is a factor and as the number of swine to be depopulated increases. Captive bolts should not be used for depopulation if the bolt length and cartridge combinations are not appropriate to the size and age of the pig being depopulated. Captive bolts should not be considered for depopulation if the pigs cannot be properly restrained and the captive bolt cannot be properly applied or human safety cannot be assured.

Electrocution—Electrocution can be used for depopulation for pigs over 10 lb (4.5 kg).[2] If head-only electrocution is selected for depopulation, a secondary method is needed such as head-to-heart electrocution, across-the-chest electrocution, or exsanguination. In some cases, equipment for electrocution may be present on a site; however, it is usually designed to euthanize one pig at a time. Specialized equipment and trained individuals are needed to safely depopulate large numbers of pigs. Electrocution should not be used for depopulation if human safety cannot be ensured and if adequate amperage and voltage cannot be achieved for the age of the pig to render the brain insensible and initiate cardiac fibrillation and death. Head-only electrocution should not be used if a secondary method cannot be applied within 15 seconds of initial stunning of the pig.

Manual blunt force trauma—Blunt force trauma is effective only for sucking and young pigs where the frontal bones are not fully developed, leaving the brain susceptible to blunt, high-velocity impact. This method may not be practical for the depopulation of large numbers of swine. Blunt force trauma should not be used for depopulation if the blow cannot be administered accurately or workers cannot apply sufficient force to effectively euthanize larger piglets.

Movement to slaughter—Transport to processing plants with routine use of stunning and kill methods should be used for grower or adult pig depopulation, whenever possible. Processing plants are purpose built to handle humane killing of large numbers of pigs on a daily basis. This method may be recommended provided that certain circumstances are met, including the following:

- A competent authority grants permission to transport pigs to a processing plant.
- The processor is willing to conduct emergency slaughter.
- The pigs being killed do not pose a public safety risk (from exposure to live animals, carcasses, or animal products).
- The pigs are mobile with minimal outward signs of disease.
- Animal movement during transit poses minimal risk to other animals.
- Swine pass pre- and postmortem inspection at the plant.

4.5.1.2 Inhaled methods

Carbon dioxide—Carbon dioxide is a practical means for depopulation provided certain criteria are met to address the numbers and size of pigs and overall throughput. Some farms use carbon dioxide as their primary method of euthanasia for suckling or nursery pigs (up to 70 lb [154 kg]). Limitations of using carbon dioxide equipment found on farm for depopulation are available gas volume, container volume, and size of pigs. Construction of chambers will need to occur to accomplish depopulation by CO_2 inhalation for large numbers of pigs. Proper construction of the chambers is important to ensure safety of the workers, adequate footing for the pigs, and achievement of a lethal CO_2 concentration.[4] A description of a method, assembly of the materials, and a time-motion simulation of throughput is available at www.ncagr.gov/oep/MassDepop.htm. In properly constructed chambers, a CO_2 displacement rate of 20% of the container volume/min for 5 minutes will results in unconsciousness within 2 minutes and death within 10 minutes, which according to Meyer et al[5] would improve animal welfare during emergency depopulation by eliminating the need for individual animal handling and restraint. Methods described would also be expected to reduce physical demands on animal workers and veterinarians engaged in depopulation.[4] Inadequate flow rates can result in lack of death or can result in the pig's suffocating before it becomes anesthetized or loses sensibility.

4.5.1.3 Noninhaled methods

Anesthetic overdose can be used for depopulation but is not practical for the depopulation of large numbers of swine. Overdose should not be used for depopulation if IV administration cannot be achieved, drugs cannot be stored and used under the supervision of a person registered with the US Drug Enforcement Administration, or carcasses cannot be disposed of appropriately.

4.5.2 Permitted in constrained circumstances

Use of compounded or nonpharmaceutical-grade injectable anesthetics and euthanasia agents is justified for depopulation. In addition, the veterinarian may make a professional judgment about the use of agents that have exceeded their product expiration date.

4.5.2.2 VSD plus

Circumstances that have resulted in VSD of modern swine facilities have resulted in the complete or partial depopulation of pigs housed in affected facilities. When ventilation systems fail, "pigs may suffer distress or death by what is commonly called 'suffocation' implying lack of oxygen or excessive CO_2."[6] In realistic terms, death may result from any combination of excessive temperature, CO_2, or toxic gases from slurry or manure below the barn.[6] The most compelling reason to use VSD when all other methods have been ruled out is that, when done properly, it may provide a quicker death, potentially eliminating the chance for the animals to die over a longer period of time from distressing and devastating disease.

Ventilation shutdown involves closing up the house, shutting inlets, and turning off the fans. Body heat from the herd raises the temperature in the house until animals die from hyperthermia. Numerous variables may make the time to death of 100% of animals in the barn subject to a range of times. The age and size of the barn; the insulation of the barn; the ventilation system; the ability to adequately seal fans, louvres, doors, and windows; and the number and size of animals in the barn can make achieving temperature goals problematic. The POD recommends that VSD only be used in facilities with the capability to adequately increase air temperature to a level that causes the generation of latent heat that results in a > 95% death rate in < 1 hour. The goal of any depopulation is 100% mortality, and this remains true for VSD. To achieve this goal, additional heat sources or the addition of CO_2 may be needed. In the United Kingdom, a case study[7] involving swine that experienced a ventilation failure event showed that 100% mortality was not achieved within that particular barn design, even after 16 hours. Failure to achieve 100% mortality in depopulation is unacceptable. Future research may provide additional information to inform decision-making surrounding VSD.

4.5.2.3 Sodium nitrite

High doses of sodium nitrite have been used in various bait forms for the control of feral swine through the induction of methemoglobinemia when an adequate amount of bait is ingested. Sodium nitrite baits have been tested in domestic and feral swine and are efficacious provided pigs consume a toxic dose in a short period of time.[8] A report published by the Institute of Medical and Veterinary Science[9] suggests that sodium nitrite intoxication is an acceptable method of humanely killing feral swine that can be achieved with 3 hours of ingestion of a toxic dose. Sodium nitrite could be used for depopulation provided there is an adequate supply of sodium nitrite available in a form that ensures ingestion at a level that results in a toxic dose and death within an acceptable time frame. Conditions that would limit ingestion through free feeding by pigs (eg, disease) may not present an ideal situation for the use of sodium nitrite for depopulation, especially if the reason for depopulation is to stop disease replication.

4.5.3 Not recommended

Not applicable.

4.5.4 Confirming insensibility and death

Regardless of the depopulation method used, it is important that every effort be taken to confirm insensibility and death provided it does not cause a risk to human health or safety.

4.6 Special Considerations

4.6.1 Dangerous animals

Adult pigs can be dangerous to handle because of their size and temperament and should be moved only by qualified individuals. Feral swine should be considered dangerous, and depopulation should be conducted only by qualified individuals under the approval and supervision of the state agencies responsible for these populations.

4.6.2 Nonambulatory swine

In some cases, groups of swine may be nonambulatory (eg, because of illness or injury). If possible, these pigs should be euthanized according to best industry practices before they are removed from the housing environment.

4.6.3 Fetal pigs

In certain situations, induction of sow abortions may be necessary to prevent future overcrowding in the event that swine cannot move due to disease control measures. Fetal abortions may also be needed to prevent infection of future litters by providing a break in production, allowing for cleaning and disinfection of the environment as well as herd stabilization.

4.7 References

1. American Association of Swine Veterinarians. On-farm euthanasia of swine: recommendations for the producer. 2008.

Available at: porkcdn.s3.amazonaws.com/sites/all/files/documents/Factsheets/Well-Being/FINAL%20-%20EuthanasiabookletSINGLES.pdf. Accessed Feb 11, 2019.
2. AVMA. AVMA guidelines for the euthanasia of animals: 2013 edition. Available at: www.avma.org/KB/Policies/Documents/euthanasia.pdf. Accessed Feb 7, 2019.
3. AVMA. AVMA guidelines for the humane slaughter of animals: 2016 edition. Available at: www.avma.org/KB/Resources/Reference/AnimalWelfare/Documents/Humane-Slaughter-Guidelines.pdf. Accessed Feb 7, 2019.
4. Meyer RE, Morrow WE, Stikeleather LF, et al. Evaluation of carbon dioxide administration for on-site mass depopulation of swine in response to animal health emergencies. *J Am Vet Med Assoc* 2014;244:924–933.
5. Meyer RE, Whitley JT, Morrow WEM, et al. Effect of physical and inhaled euthanasia methods on hormonal measures of stress in pigs. *J Swine Health Prod* 2013;21:261–269.
6. Bird N. Ventilation failure alarms: 2 case studies. Available at: www.dicam.co.uk/download/research/Case_Study_2_ventilation_failure_incidents.pdf. Accessed Mar 26, 2019.
7. Smith P, Crabtree H, Bird N. *Perfecting the pig environment*. Nottingham, England: Nottingham University Press, 2009.
8. Shapiro L, Eason C, Bunt C, et al. Efficacy of encapsulated sodium nitrite as a new tool for feral pig management. *J Pest Sci* 2016;89:489–495.
9. The Institute of Medical and Veterinary Science. Assessing the humaneness and efficacy of a new feral pig bait in domestic pigs: report for the Australian Government Department of the Environment, Water, Heritage and the Arts. March 2010. Available at: www.environment.gov.au/system/files/resources/091b0583-f35c-40b3-a530-f2e0c307a20c/files/pigs-imvs-report.pdf. Accessed Feb 11, 2019.

5: Small Ruminants, Cervids, and Camelids

5.1 General Considerations

5.1.1 Settings in which species are commonly found

The settings in which these species are commonly found during depopulation events vary somewhat on the basis of the species and the geographic location in the United States. In most cases, sheep, goats, and camelids will be located in farm flock or herd situations. On most of these premises, the animals will be confined in a pasture or paddock-type area with access to a shelter to get out of the weather. In some cases, particularly some dairy goat operations, the animals may be confined to a barn with minimal to no outside access. For farm flock or herd situations, there are often available working facilities, or in cases where these are not readily available, they can be easily constructed for use during depopulation efforts. Commercially available portable small ruminant working facilities are available from a variety of suppliers and can easily be assembled, disinfected if necessary, and moved when the depopulation is completed.

One slight variation of the farm flock or herd setting would include the addition of a private petting zoo or agricultural educational interactive site. These are most commonly encountered when the operation is marketing a niche product or experience for sale. Examples would include petting zoos located on private farms, on-farm storefronts or shops marketing niche-produced products (eg, cheese, wool, or milk), on-farm educational exhibits (eg, birthing barn exhibits or farm tours), or interactive animal experiences (eg, camel rides or "be a farmer for a day" experiences). In terms of depopulation efforts, these facilities can often be managed like farm flock or herd settings, with specific consideration placed on potential public safety and media relations issues.

In the western portions of the United States, there are a significant number of range-based sheep and goat operations. These animals are grazed on large parcels of land with minimal to no fencing. In many cases, these animals are located in areas without easily accessible working and restraint facilities. The operations commonly use public grazing allotments and are present on land controlled by the US Forestry Service or Bureau of Land Management. Owing to the lack of facilities, more extensive dispersal of the animals, and potential for public interaction with the animals or the depopulation efforts (on public grazing grounds), these positions pose some unique challenges for depopulation that need to be considered in the development of emergency preparedness plans or depopulation standard operating procedures.

Captive cervids (white-tailed deer, elk, and others) are found in two predominant settings in the United States. In some cases, these facilities are licensed and inspected by the USDA under the Chronic Wasting Disease Program plans. Breeding facilities and farms are often similar to farm flock or herd situations with the addition of taller fencing (in most cases 8 to 10 feet tall). Many of these facilities will include working facilities appropriate for the species. When present, these working facilities can and should be used for depopulation efforts. However, some captive cervid operations are run as fenced hunting-type preserves. These operations are high fenced and vary in size from several hundred acres to several thousand acres. In most cases, these preserves include rough terrain that may limit visibility and areas that include sparse to dense forest or underbrush. These types of facilities often do not provide as much flexibility with working facilities or their ability to easily confine animals in a smaller paddock.

5.2 Events Necessitating Depopulation

There are a variety of potential situations that would lead to a decision to perform depopulation of small ruminants, cervids, or camelids. These situations can be largely divided into cases where the depopulation events are resulting from, or necessary for, disease control efforts, biosecurity, or human safety. Alternatively, depopulation events could be related to efforts to minimize animal suffering in the absence of disease. Several examples of each type of situation are provided to demonstrate general principles; however, these examples are provided only as case studies and are not intended to represent a comprehensive list of potential scenarios.

5.2.1 Infectious disease

In the development of depopulation plans focused on infectious disease concerns, the type of disease and desired outcomes of the depopulation efforts need to be fully considered. Federally regulated diseases are of critical concern, in particular diseases that would be considered foreign to the United States. In these situations, there will be significant involvement of animal health regulatory entities (both state and federal), and the ultimate decision-making capacity will fall under the emergency management incident command infrastructure. Specific consideration for the role of the depopulation method related to control of infectious materials, zoonotic risk, rapid elimination, and limited carcass disposal options should all discussed. Many of these situations will result in the need for a rapid and aggressive response that may limit the time available for assembling resources and logistics. In some cases, depopulation methods discussed as preferred in this document may not be feasible or appropriate in light of these considerations. Species-specific examples of this type of situation would include tuberculosis, brucellosis, scrapie, chronic wasting disease, foot-and-mouth disease, peste des petite ruminants, goat pox, or Rift Valley fever.

In infectious disease situations, the zoonotic potential of the agent should be considered when the depopulation plan is developed. When weighing the different methods for depopulation, it is prudent to consider the potential routes of transmission for the zoonotic agents and the associated risk of transmission induced by the depopulation method. For instance, if a given method results in a significant risk for aerosol generation of infectious material, either this risk needs to be appropriately mitigated or the method needs to be excluded from consideration.

5.2.2 Depopulation to alleviate immediate or rapidly foreseeable animal suffering

In some cases, depopulation may be employed as a means of eliminating the significant and impending risk of uncontrollable animal suffering. In depopulation scenarios, a significant factor to consider is the number of animals involved. While smaller animal numbers may allow for evacuation or individual animal treatment, larger populations of animals may preclude these types of options and necessitate depopulation as a means of limiting animal suffering. While a variety of scenarios are possible under this category, they can broadly be divided into those associated with local or regional disasters and those that are not disaster related. Examples of disaster-related events could include flooding, earthquakes, hurricanes, tornados, and blizzards. Those situations, and similar ones, may result in an inability to provide adequate food or water to sustain health, an inability to access the animals for provision of care, or trauma associated with physical injury during the disaster event. Alternatively, these natural disasters may result in unexpected exposure or consumption of a toxin that will result in significant animal suffering in the foreseeable future (eg, consumption of salinized water). Disaster-related events often pose unique challenges that may not be present in the other depopulation scenarios. Absence of or inconsistent electrical power, damaged infrastructure (eg, roads, equipment, buildings), and massive human casualties that limit resources may all impact the decision-making process for depopulation method.

Examples of nondisaster-related events would include large-scale predation damage in small ruminant operations, fire or smoke exposure, or extreme cases of livestock hoarding. Predator damage in large flocks or herds should not be underestimated and can result in significant and prolonged animal suffering. Likewise, smoke inhalation from a barn fire may not result in immediate death but can be associated with irreversible lung damage that needs to be alleviated.

5.2.3 Radiologic exposure

Exposure of animals to radioisotopes results in a unique scenario for depopulation efforts. The most likely means of exposure for small ruminants, cervids, and camelids would be through radiologic release by nuclear power plants located upwind of the premises. In these cases, the potential inability to provide routine care and food for the animals is coupled with an inability to transport the animals out of the affected zone owing to radiologic contamination. In some cases, these situations might even preclude humans entering the area to accomplish depopulation because of human health risk.

5.3 Depopulation Methods

Approved euthanasia methods should always be considered as potential options in depopulation efforts; however, in some cases, these methods may not be feasible owing to circumstances or risk. From an animal welfare perspective, use of approved methods would be preferred when feasible because of their intent to eliminate animal suffering. When a need exists to depopulate a limited number of animals that can be easily caught and restrained, these methods should be considered as the highest-priority options.

5.3.1 Challenges and constraints to standard euthanasia in emergency situations

Unfortunately, in many depopulation scenarios, the situation or safety considerations prevent the use of standard euthanasia methodologies. Scenarios where the animals are not easily contained in a small area for restraint pose a significant challenge. As outlined in the potential settings where small ruminants, cervids, or camelids might be found, the extensively managed range animals or hunting preserve–type settings are problematic. In addition to making it difficult to get in close proximity to these animals, the rough terrain and ability of the animals to find cover where they can hide from view make depopulation more challenging. In cases where there is a reasonable means of safely moving the animals to a location where confinement and restraint are feasible, this should be evaluated with appropriate consideration of any potential unnecessary stress that this may place on the animals. The decision to depopulate animals from a distance should be considered only in cases where reasonable efforts to develop an alternate plan have been exhausted. The ability to safely achieve close proximity (within 3 feet) with the animal during the depopulation is likely to decrease the risk of unexpected and unnecessary animal suffering and provides more technical methods for use; however, this depopulation decision needs to be balanced with issues such as animal suffering and human safety.

5.4 Implementation With Prioritization

5.4.1 Preferred methods

These methods are given highest priority and should be utilized preferentially when emergency response plans are developed and when circumstances allow reasonable implementation during emergencies.

5.4.1.1 Physical methods

All physical methods considered acceptable or acceptable with conditions outlined in the AVMA Guidelines for the Euthanasia of Animals[1] (eg, gunshot, PCB, and nonpenetrating captive bolt) or techniques covered by the AVMA Guidelines for the Humane Slaughter of Animals[2] for a given species are considered preferred methods with appropriate consideration for the size and age of the animal. In addition, the following physical methods not outlined in the euthanasia guidelines are considered preferred.

PCB for use in camelids—In such cases, the bolt should be of sufficient length to penetrate the skull to the depth of the brainstem. The appropriate site for bolt placement is the crown of the head on midline directed at the caudal jaw without significant lateral, rostral, or caudal angulation.[3]

5.4.1.2 Inhaled methods

Use of carbon dioxide by volume displacement with concentrations of 10% to 30% has been demonstrated to not be aversive to small ruminants under the age of 2 months and is considered a preferred method.

5.4.1.3 Noninhaled methods

In situations where carcass disposal does not pose a significant environmental risk, the use of injectable barbiturates as outlined in the Guidelines for the Euthanasia of Animals[1] is considered a preferred method. However, in cases where disposal plans are uncertain or pose environmental risk, this method would be considered lower priority.

5.4.2 Permitted in constrained circumstances

These methods are allowed only when the circumstances of the emergency are deemed to constrain the ability to reasonably implement a preferred method. Potential constraints that might result in use of methods in this category include, but are not limited to, constraints on human safety, depopulation efficiency, deployable resources, equipment, animal access, disruption of infrastructure, disease transmission risk, and zoonotic disease risk.

When captive cervids or extensively housed range small ruminants cannot be confined and restrained, the use of longer-range gunshot is acceptable. Reasonable consideration and efforts to utilize a preferred method should be evaluated before this approach is implemented. In addition, the marksmanship skill of the shooter should be considered, and efforts to maximize the potential for effective shot placement should be made (please refer to appendix B). In cases where it is feasible to identify and utilize highly skilled marksmen (ie, USDA, APHIS, Wildlife Services marksmen or military- or law enforcement–trained sharpshooters), this should be done. In cases where the marksman is highly skilled and has the appropriate required equipment and the animals are located < 50 yards from the shooter, the use of a head or proximal cervical shot as outlined by other sources should be considered. In cases where these criteria are not met, the shooters should be instructed to place the shot in such a manner as to maximize trauma to the critical mass (eg, heart and lungs). The shooters should be prepared to make an additional shot if necessary.

5.4.2.1 Expired injectable agents

Use of compounded or nonpharmaceutical-grade injectable anesthetics and euthanasia agents is justified for depopulation. In addition, the veterinarian may make a professional judgment about the use of agents that have exceeded their product expiration date.

5.4.3 Not recommended

Gunshot at a distance of > 3 feet is not recommended with confined or restrained small ruminants, cervids, or camelids.

5.5 Special Considerations

5.5.1 Diagnostic sample collection

In cases where depopulation is being performed owing to the risk of a transmissible spongiform encephalopathy such as chronic wasting disease or scrapie, there may be the need to collect diagnostic samples from the brain for testing. In such cases, the selection of method should involve consideration of the required diagnostic samples.

5.5.2 Dangerous animals

During depopulation, animals often become disoriented, excited, and unpredictable. The presence of unfamiliar people, increased numbers of people, use of PPE, and unusual or loud noises (eg, gunshots) exacerbate the situation. When possible, individuals with prior experience working with the species to be depopulated should be prioritized in team selection. Additional considerations should include the potential psychological and emotional impact of having owners and caretakers involved in euthanizing large numbers of their own animals. Sexually intact males of all species (ie, sheep, goats, cervids, and camelids), especially those in rut, pose the highest risk of injury to personnel.

5.5.3 Diseased animals

When a zoonotic risk exists, the depopulation plan should include consideration of appropriate PPE and critical control points to minimize disease transmission risk.

5.5.4 Consideration of predator control animals (dogs, llamas, donkeys)

In many cases, small ruminants will be housed with livestock guard animals. These animals are trained to protect their charges from danger, and potential guard species include dogs, donkeys, and, in some cases, llamas. These guardian animals become highly bonded to the livestock, and their presence needs to be considered before implementation of any depopulation efforts. At minimum, efforts should be made to catch and remove the guardian species from the immediate area before depopulation of the animals is initiated. This minimizes stress on the guardian animal and eliminates any potential human danger originating from the guardian protecting its charges. In depopulation efforts associated with infectious disease incidents, the risk of transmission of the disease by the guardian animal (via direct or indirect means) should be considered, and in some cases, it may be appropriate to require depopulation of the livestock guard animal. In such cases, the guardian should be the first animal depopulated.

5.6 Handling Considerations

When handling camelids, it is important to remember that there is minimal boney support for the rostral muzzle. Placing physical pressure (either with the hand or an inappropriately fitted halter) will result in nasal collapse and induce unnecessary stress for the animal. Appropriately fitted halters will have the noseband placed slightly below the eyes.

White-tailed deer do not handle like other domesticated ruminants. In many cases, they have much larger flight zones and do not move through narrow alleyways like other ruminants. They often are best handled in completely enclosed boxes that are kept dark to minimize their stress. Working boxes should be designed to allow the animals to turn around and should allow isolation of a single animal if necessary. Some states own portable deer-handling facilities that might be used in emergency situations.

5.6.1 Drop chutes

Many white-tailed deer operations will have and utilize drop chutes. These chutes have a floor that is designed to drop out from under the deer after it runs into the chute, resulting in the deer's being suspended in air and minimizing their ability to struggle. To minimize stress for the deer in the chute, every attempt should be made to accomplish the depopulation method in under 30 seconds.

Portable small ruminant corrals, alleyways, and chutes are available from a variety of manufacturers. These are relatively light, can be disassembled and carried in a pickup truck, and allow for easy handling of large groups of animals. This equipment can be readily deployed to the field and can be disinfected if necessary.

In rare cases, the use of sedatives or anesthesia delivered via a dart gun might be considered before the depopulation method is applied. The perceived benefit should be weighed against the risk of incomplete sedation and increased stress induced by this method.

5.7 References

1. AVMA. AVMA guidelines for the euthanasia of animals: 2013 edition. Available at: www.avma.org/KB/Policies/Documents/euthanasia.pdf. Accessed Feb 7, 2019.
2. AVMA. AVMA guidelines for the humane slaughter of animals: 2016 edition. Available at: www.avma.org/KB/Resources/Reference/AnimalWelfare/Documents/Humane-Slaughter-Guidelines.pdf. Accessed Feb 7, 2019.
3. Gibson TJ, Whitehead C, Taylor R, et al. Pathophysiology of penetrating captive bolt stunning in alpacas (*Vicugna pacos*). *Meat Sci* 2015;100:227–231.

6: Poultry

6.1 General Considerations

6.1.1 Background: poultry production in the United States

In its April 2015 report of Poultry Production in the United States, the USDA's National Agricultural Statistics Service[1] placed the "combined value of production from broilers, eggs, turkey, and the value from sales of chickens in 2014 at $48.3 billion, up 9% from $44.4 billion in 2013. Of the combined total, 68% was from broilers, 21% from eggs, 11% from turkeys, and less than 1% from chickens (excluding broilers)."[2]

Broiler production (on the basis of numbers of birds produced) is concentrated in several southern states, with Georgia, Alabama, Arkansas, North Carolina, and Mississippi accounting for over 50% of national production. Minnesota, North Carolina, Arkansas, Indiana, Missouri, and Virginia lead the nation in turkey production. Egg production is somewhat more widely dispersed geographically, with Iowa, Ohio, Pennsylvania, Indiana, Texas, Georgia, and California combining to produce 55% of the nation's eggs, but Arkansas, Alabama, Florida, Michigan, Minnesota, Nebraska, and North Carolina also have significant layer industries.[2] The National Agricultural Statistics Service numbers do not differentiate between types of egg production, however, so it should be pointed out that the figure cited here includes broiler breeder eggs, turkey hatching eggs, and table eggs. The different styles of housing in these industries—conventional battery-type cages, single-floor cage-free housing, multitier cage-free aviaries, and free-range and pasture production—present their own unique challenges in depopulation efforts.

Most commercial poultry production now takes place in single-story covered barns with no access to the outdoors, so depopulation and disposal (often in-house composting) can occur inside.

It's difficult to obtain accurate and up-to-date numbers on urban and backyard poultry in the United States because there are no national registration requirements for small flocks. Registration requirements for poultry are state specific. In recent years, consumers have become more concerned about the source of their food, and this has contributed to the trend of raising more backyard poultry. Even cities from Portland, Ore, to Portland, Me, have revised ordinances to allow residents to keep small flocks.[2] It's not an exaggeration to say that every town and city across the country probably has a poultry population. The most critical small flocks to depopulate in a disease outbreak would be those located near large commercial poultry facilities. The USDA National Animal Health Monitoring System surveyed backyard and small production flocks located in a 1-mile (1.6-km) radius around 349 large commercial poultry operations in 18 major poultry states in 2004.[2] Fifty-five percent of these operations had 1 to 5 backyard flocks within that radius. Six percent had 6 to 19 flocks within the same distance. Sixty-two percent of the birds in these flocks were chickens, but the remainder comprised a variety of species, including birds as large as turkeys and geese. Eighty-one percent of the flocks were mixed species. Ninety-two percent of the flocks had fewer than 100 birds, and 59% had fewer than 20.[2]

6.1.2 Challenges and constraints to standard euthanasia in emergency situations

The priority in FAD emergencies is the ability to stop the spread of the pathogen. Following the 2014–2015 HPAI outbreak, the USDA and industry stakeholders agreed that one of the most critical problems was that the delay in depopulating infected poultry exacerbated the amount of virus ultimately shed and released into the environment. For this reason, the goal should be for all poultry at the impacted facility to be depopulated within 24 to 48 hours after a presumptive positive classification. This time to depopulation needs to be balanced against the procedures and resources available, time to implementation, animal welfare, and disease spread. It can be a challenge to meet the goal response time since deployable assets, including equipment, personnel, and supplies, need to be rapidly mobilized and transported to the site or sites.

Zoonotic disease agents create additional concerns, which include the possible exposure of emergency workers and farmers to the disease agent; disposal issues surrounding the disposition of contaminated carcasses, bedding, and manure; and the concomitant heightened concern around quickly depopulating the affected poultry. Internationally, HPAI, in particular H5N1 and H7N9, has resulted in bird-to-human transmission, demonstrating zoonotic characteristics and resulting in human mortality. For example, strains of H7N9 have resulted in over 450 documented human infections with a 30% fatality rate since early 2013.[3] Fortunately, the HPAI serotype in the 2014–2015 outbreak in the United States did not show any zoonotic characteristics; however, future serotypes may have this capacity. In such cases, public health concerns for farmers and workers then take on paramount importance and further highlight the need to quickly reduce virus amplification and spread.

Fighting birds (encountered by task force personnel in the 2003 exotic Newcastle disease outbreak in California), valuable or rare heritage breeds of poultry, fertilized eggs, and escaped birds also present their own set of challenges. Structural failures, such as those due to excessive snow loads, can result in birds that are able to escape the confinement of the facility, necessitating catching the birds during difficult conditions to maintain biosecurity. Moreover, illegal fighting birds are not included in any registry, and the value of the birds exceeds any likely indemnification. During the 2001 foot-and-mouth disease outbreak in the United Kingdom, heritage and valuable breeds of cattle, sheep, goats, and pigs were depopulated equally with common breeds, resulting in loss of herd diversity. Similar conditions exist for poultry, where historic or valuable breeds represent part of the genetic diversity and also pose challenges for indemnification. Owners of these types of birds can sometimes be uncooperative and hostile, especially with fighting birds and rare breeds, and emergency personnel need to possess an appropriate skill set to handle such situations.

6.1.3 Settings where species are commonly found

6.1.3.1 Floor-reared, confined poultry, including aviary-style housing (broilers, broiler breeders, meat turkeys, breeder turkeys, layers, layer breeders, and ducks)

Floor-reared poultry are defined as poultry raised for meat, hatching egg, and table egg production that are primarily housed inside barns (confined) and on the ground (vs in cages).

The majority of birds raised in the United States are raised in this type of housing. There are multiple variations in the housing design of barns in this category, but the common theme would be that the birds roam freely within the barn (or within sections of the barn) from end to end and side to side.

The size of the farm, both in the number of buildings and the number of birds, varies widely. Typically, a farm will have a limited number of access points and could potentially have designated driveways for so-called clean and dirty traffic. It is important to understand the biosecurity and movement patterns of each farm at the beginning of the depopulation planning process. Some farms may have additional sheds on the facility that may be utilized to stage necessary equipment and supplies. Typically, barns will have an anteroom or entryway attached to each barn that houses the computer system and water treatment system and has a small amount of supplies. This space would likely not be adequate to store additional materials associated with the depopulation process.

Ventilation design can vary from completely enclosed, tunnel-ventilated facilities (most commonly found in the broiler-producing states) to naturally ventilated facilities (typically found in meat turkey and duck production, especially in the upper Midwest). Tunnel ventilation systems would have a concentration of fans on one end of the barn and air inlets and cool cells on the opposite end. Naturally ventilated facilities would typically have open sidewalls covered by wire. A curtain is then used to control the amount of air allowed to enter and exit the barn primarily in warm weather conditions. There are additional ventilation styles that would comprise a series of small doors distributed down the length of a barn that could be opened (similar to a curtain system) as needed to control the barn temperature. Barns may also have minimum ventilation vents that are utilized to bring smaller amounts of air into the barn during the colder months of the year. These vents would typically be located at the junction of the barn's sidewall and ceiling.

Many modern barns utilize a computerized barn controller to automatically adjust the barn conditions to maintain the optimal environment for the birds at any given age. These controllers are typically connected to the barn's heating, cooling, and ventilation equipment.

The tightness of a barn's ventilation system is important to evaluate during selection of the appropriate depopulation protocol. Regardless of the ventilation type, an assessment of the barn's condition should be done to identify any air leaks when CO_2 or VSD is being considered. A plan for amending the controller settings should be determined and implemented to facilitate the selected depopulation protocol.

Heating systems used for young birds are typically a brooder stove system (infrared or radiant heat) potentially supplemented by forced air heaters. Equipment used for older birds could vary from forced-air-only systems to radiant heat only. Heating capacity (BTU/square foot) of the barn will vary on the basis of the age of the bird the building was designed to house. There will typically be greater heating capacity in houses designed for younger birds. In broilers, typically one end of the house would be used to begin growing, or brooding, the young birds, and thus this end would have higher heating capacity. Ducks are more tolerant of cooler temperatures, and as a result, the houses generally have less heating capacity.

The heating capacity of a facility will vary on the basis of not only the number of heaters in the barn but also the size and number of birds. Consideration should be given to the amount of body heat generated by the birds. Standard approximations are available in the industry to calculate this number for each situation, as it will vary with time of year, type of bird, and size of bird. Also, stove efficiency decreases with the age of the stove and should also be taken into consideration when the potential British thermal units a barn could produce is calculated.

Feed and water systems are typically mounted to the ceiling via a series of pulleys and winches. Feeding systems within barns would typically comprise multiple (2 to 5) feeding lines running the length of the barn. Feed would be conveyed from the feed bin outside the house to the hopper inside the house and down the feed line by use of an auger. Feed would then be deposited into the feed pans. In broiler breeders and layers, the feeding system is more likely to be an open trough system in which feed is conveyed with a chain. For ducks, feeders are often larger barrel-type feeders that are on the floor. Sizes of these barrels vary; however, the largest feeders can hold up to a ton of feed.

Water systems can vary from closed drinking systems (ie, nipple drinkers) to open drinking systems such as bell drinkers or troughs. Drinker systems will be mounted on pulleys from the ceiling such that they, too, are able to be retracted toward the ceiling out of the way. A barn will have roughly twice the number of drinking lines as it does feed lines. In some duck housing using litter, the nipple drinker lines are over a pit area (in essence a combination litter and pit floor).

Feed and water equipment should be raised out of the way for all depopulation methods to facilitate barn setup, depopulation, and cleaning and disinfection activities as well as to facilitate the easy and safe movement of people, birds, and equipment. This should be done in a timely manner to minimize bird stress related to the overall time birds are left off feed and water.

Various depths of bedding materials could cover the floor of the barn. Most common would be wood shavings, but oat hulls, rice hulls, sunflower hulls, straw, and miscanthus grass could also be utilized. Young turkeys and breeders will typically be placed on clean, new bedding upon placement. Older meat turkeys and broilers would more likely be raised on a mixture of new and old bedding or potentially all reused bedding. The condition (amount of moisture in the bedding) of the bedding can be variable based on management and density, which will determine its moisture-holding capacity. The frequency of litter change out is often regional and can also impact condition and moisture content.

For ducks, some, including breeder ducks, are raised on litter, but many are raised on wire or some other flooring that allows the water and feces to drop through into a pit. These pits are routinely scraped, putting the liquid manure into holding ponds.

For ducks, the raised flooring allows for more cubic feet of air space in the barn, both above and below the ducks. This will make it almost impossible to seal off a part of a raised-floor barn. In cases where the litter is already moisture laden, contingency plans will be needed for how to perform depopulation activities such as for stuck equipment or to determine how well other equipment can be engaged once water is applied.

6.1.3.2 Egg-producing birds (broiler or turkey breeders, layers in production)

Barns used to house birds while in egg production (broiler or turkey breeders, egg layers) will have a unique barn setup and additional equipment. The equipment may include nest boxes, egg belts, manure belts, and ramps or walkways used by the birds to access the nest area for example. Broiler breeder barns would typically have an elevated, slatted area where the birds access feed and water. Barns may be connected by a hallway to convey eggs and personnel.

Breeder barns provide a significant challenge owing to the number of obstacles present in the barn. All efforts should be made to herd and confine the birds on the floor (off the slatted area) to facilitate rapid application of CO_2 or foam. Aviary-style housing provides additional challenges to the ability to keep birds from taking advantage of the vertical space and enrichments present (nest boxes and perches).

6.2 Floor-Reared, Confined Poultry, Including Aviary-Style Housing

As commercial egg production increases, cage-free production or aviary-style housing will become more common. Aviary-style barns have rows of equipment that run the length of the barns. This equipment contains nest boxes, feeders, waterers, open wire floors, and perches. There is typically a manure belt that runs between each layer of the equipment and a scratch area between rows. This style of barn can vary widely in layout and design, with some systems equipped with doors on the rows of equipment that can be closed to contain the birds and others in which birds are unrestricted. Depending on the equipment details and the ability to confine birds, an aviary may be depopulated as a floor population or may need to be depopulated like a cage system.

Birds will tend to use the vertical space and nest boxes to move away from disturbances. Accessing birds in the equipment can be difficult. Reducing light intensity or working with red headlamps can make birds more docile in these systems. Larger barns have multiple stories separated by a wooden floor. Because of the high bird density in these systems, there is significant body heat production.

6.2.1 Depopulation methods for floor-reared, confined poultry

6.2.1.1 Preferred methods

Preferred methods include water-based foam generators, water-based foam nozzles, whole-house gassing, partial-house gassing, containerized gassing, cervical dislocation, mechanically assisted cervical dislocation, and captive bolt gun.

6.2.1.2 Permitted in constrained circumstances

Methods permitted in constrained circumstances include gunshot, VSD plus, controlled demolition, exsanguination, and decapitation.

6.2.1.3 Not recommended

The use of VSD alone is not recommended.

6.3 Cage-Housed Poultry

The vast majority of poultry that are housed in cages are table egg laying hens. These may be pullets from 0 to 18 weeks of age or sexually mature hens from 18 to over 100 weeks of age. Around the world, an increasing number of broilers are being raised in cage or colony systems, but very few are housed this way in the United States. A cage house typically holds several rows of cage batteries running the length of the house with several levels of cages stacked on top of one another in each battery. Within each level, cages usually are constructed with a partition along the midline of the row forming the back of the cage and the cage fronts facing the aisles on each side. Some colony cages do not have the central partition, so the individual cage spans the width of the level and opens onto both aisles. The cages themselves may be sized variably to hold < 10 birds in small cages to several dozen birds in colony cages. The smaller cage designs generally are open spaces with no interior structures. Colony cage designs may be enriched with features such as perches, nesting areas, and scratch areas. Cage floors are constructed of wire mesh or plastic lattice to allow manure to fall away from the birds. In older systems, the manure falls to the floor or to a lower level below the cages and accumulates. Modern houses generally have manure belts installed under the cages that are used to remove the manure from the house every 2 to 3 days. Modern cage houses are constructed with solid walls and are well insulated to provide a better and more controlled environment for flocks with improved energy efficiency. The tight structure of such houses makes control or alteration of the interior environment easier when a whole-house depopulation method is used. Older houses in warmer climates may have open sides with curtains that can be raised to cover the openings and may rely completely or partially on natural ventilation. These houses can be difficult to seal up to the extent necessary to allow a depopulation method that requires control of the atmosphere and environment inside the house to be effective.

Cage houses usually are sited at least in pairs, but commercial egg farms are often multihouse complexes connected in-line by a cross-conveyor used to remove eggs to a processing or storage facility. These complexes can house very large numbers of birds (hundreds of thousands to millions of birds in flocks of multiple ages). Cage houses have different capacities, but modern structures are usually large, holding over 100,000 birds and as many as 500,000 in very large houses.

For purposes of depopulation, cage houses offer the advantage of fixing the location of birds within the living space, thus allowing easy access to any that must be caught. Birds can be removed from cages and killed independently of others, allowing for an individualized experience in which the well-being of each bird can be addressed. Depopulation decision-making needs to balance between depopulation in-cage with subsequent carcass removal versus removing the birds from cages and then depopulating. Emergency situations such as the occurrence of an FAD requiring depopulation within a short time frame, occurrence of a zoonotic disease making it imperative to restrict human exposure, or structural damage making it dangerous for people to enter the house would make individual bird handling unfeasible.

Whole-house methods are not effective in open-sided or damaged houses that cannot be sealed adequately. If entry into the house or catching of birds from cages cannot be done, depopulation of such houses may require a method demanded by the extremity of the circumstances, such as quarantining the location and letting the flock die of disease, as distasteful as this might be.

6.3.1 Depopulation methods for cage-housed poultry

6.3.1.1 Preferred methods

Preferred methods include whole-house gassing, partial-house gassing, and containerized gassing.

6.3.1.2 Permitted in constrained circumstances

Methods permitted in constrained circumstances include compressed air foam, cervical dislocation, mechanically assisted cervical dislocation, captive bolt gun, VSD plus, and decapitation.

6.3.1.3 Not recommended

Not-recommended methods include water-based foam generators, water-based foam nozzles, gunshot, and VSD alone.

6.4 Outdoor-Access Poultry (Including Free-Range Broilers, Ducks, Turkeys, or Layer Hens)

While confined, cage-type housing systems account for the vast majority of commercial poultry raised in the United States, there has been an increasing demand for birds or products from birds that are provided some form of outdoor access. "Free-range" and "pasture-raised" labels for eggs and broiler or turkey meat have become more common in the marketplace in recent years. Depending on the climatic zone, most farms that allow birds to have some degree of outdoor access generally enclose the birds in a building at night to minimize the chances of predation or for protection from adverse weather. Some farms in more temperate parts of the country, however, only provide perimeter fencing and open-sided structures for shade but do not enclose, and do not have the ability to enclose, birds at night. Farms that do not have the option to enclose birds in a structure certainly will present the most challenges in the event that depopulation is required in a disease outbreak.

Several voluntary animal welfare certification programs now have specific standards for free-range and pasture access. These include the American Humane Association Humane Heartland Program, Humane Farm Animal Care, Animal Welfare Approved, and the Global Animal Partnership program. In addition, the USDA National Organic Program has recently published proposed rules that would add new requirements for outdoor access for poultry. The increasing demand for private-label animal welfare certifications for various poultry products and the growth of the organic segment of this industry will undoubtedly continue, assuring that birds raised with outdoor access will be of significant concern in future scenarios requiring depopulation.

Poultry operations that allow outdoor access while also being able to confine birds in buildings would, in the case of an event requiring depopulation, fall into the "floor-reared broilers, turkey, duck, or layer hens" category of this document.

For poultry operations without the ability to enclose birds in buildings, gathering and confining birds before depopulation will be more time-consuming and subject to other challenges related to weather and terrain. This will require the use of temporary fencing or netting, and in all likelihood, additional personnel would be needed when compared with a similarly sized operation of cage or floor-reared birds. The recommended methods will be based on species. For free-range turkeys, once confinement is accomplished, captive bolt gun or mechanically assisted cervical dislocation would be the acceptable method of choice. In the case of younger turkeys, broiler or layer chickens and ducks, containerized gassing, mechanically assisted cervical dislocation, or cervical dislocation could be employed. As is the case with cage systems, the foam depopulation methods would probably not be feasible in outdoor-access operations.

6.4.1 Depopulation methods for outdoor-access poultry

6.4.1.1 Preferred methods

Preferred methods include captive bolt gun, cervical dislocation, mechanically assisted cervical dislocation, and containerized gassing.

6.4.1.2 Permitted in constrained circumstances

Methods permitted in constrained circumstances include water-based foam generators, water-based foam nozzles, partial-house gassing, gunshot via firearm or pellet gun, exsanguination, controlled demolition, decapitation, and cervical dislocation.

6.4.1.3 Not recommended

Not-recommended methods include whole-house gassing and VSD alone.

6.5 Ratites

Ratites (eg, ostriches, emus, and rheas) are raised in a variety of husbandry and housing styles in the United States, which usually offer a combination of indoor barns and outdoor access. Ratites produce red meat that is similar to beef or venison, and the hide is used for fine leather products.[2]

6.5.1 Depopulation methods for ratites

6.5.1.1 Preferred methods

All methods contained in the AVMA Guidelines for the Euthanasia of Animals[4] or the AVMA Guidelines for the Human Slaughter of Animals[5] are considered preferred.

Preferred methods include mechanically assisted cervical dislocation, captive bolt gun, ingested or injected agent, and gunshot.

6.5.1.2 Permitted in constrained circumstances

Methods permitted in constrained circumstances include exsanguination (after stunning or sedation), controlled demolition, whole-house gassing, partial-house gassing, containerized gassing, water-based foam generators, compressed air foam, VSD plus, cervical dislocation, and decapitation.

6.5.1.3 Not recommended

Water-based foam nozzles and VSD alone are not recommended methods.

6.6 Companion, Lifestyle, or High-Value Birds

Companion, lifestyle, or high-value birds deserve a separate category owing to their unique status as pets, companions, and members of the family. The likelihood of an event catastrophic enough to require the depopulation of these types of birds would undoubtedly be exceedingly rare. Despite this, emergency planners should ensure that responders are highly trained and empathetic individuals who possess the necessary interpersonal skills to carry out what would prove to be an extremely distasteful, heart-wrenching, and onerous task.

6.6.1 Depopulation methods for companion, lifestyle, or high-value birds

6.6.1.1 Preferred methods

Preferred methods include captive bolt gun, containerized gassing, ingested or injected agent, and cervical dislocation.

6.6.1.2 Permitted in constrained circumstances

Methods that are permitted in constrained circumstances include water-based foam generators, water-based foam nozzles, compressed air foam, decapitation, and gunshot.

6.6.1.3 Not recommended

Not-recommended methods include VSD alone, controlled demolition, exsanguination, and whole-house gassing.

6.7 Fertilized Eggs, Embryos, or Neonates

Bird embryos that have attained > 80% incubation should be euthanized by methods similar to those used in avian neonates. Eggs at < 80% incubation may be destroyed by prolonged exposure (> 20 minutes) to CO_2, cooling (< 4°C for 4 hours), or freezing. Anesthesia can be used before euthanasia and is most easily accomplished with exposure to inhaled anesthetics via entry into the air cell at the large end of the egg. Egg addling can also be used to destroy the viability of embryos.[4]

6.7.1 Preferred methods

Preferred methods include containerized gassing, cooling, freezing, and maceration.

6.7.2 Permitted in constrained circumstances

Not applicable.

6.7.3 Not recommended

Not applicable.

6.8 Foreseeable Emergency Events That Might Require Depopulation

The HPAI outbreak in the United States in 2014–2015 was the most catastrophic and expensive animal disease that the United States had experienced to date. Highly pathogenic avian influenza viruses were detected in commercial and backyard poultry flocks, wild birds, or captive wild birds in 21 states. Nine states had infections in commercial poultry, with 211 premises affected. Eleven states had infections in backyard flocks, with 21 premises affected. Efforts to control the disease resulted in the depopulation of 7.5 million turkeys and 42.1 million egg layer and pullet chickens, with devastating effects on those businesses and at a total economic impact of $3.3 billion.[2] The nation's emergency response capacity was taxed to the limit by the need to depopulate quickly to contain the spread of the virus. Equipment and trained personnel capacity were quickly overwhelmed, leading to further spread of the disease and prolongation of the outbreak. Caged layer operations proved to be one of the most difficult situations to manage, with the difficulty of removing either live birds or decaying carcasses from the cages and the size of the facilities all making timely depopulation nearly impossible.

Undoubtedly, the 2014–2015 HPAI outbreak was a catastrophic event, but it highlighted gaps in US emergency response plans, particularly in the area of depopulation capacity, procedures, and protocols. Methods used in past outbreaks (eg, employing carbon dioxide gas and high-density foam), while effective, was too slow and inadequate to meet the objectives of disease containment. The outbreak also highlighted the need for additional response capability in terms of depopulation strategies, equipment, and trained personnel.

Other emergency events requiring depopulation, although perhaps dwarfed by the scale of the HPAI outbreak, still present their own unique challenges. These include barn collapses due to structural failure or heavy snowfall or wind; power outages; barn fires; weather calamities, such as a tornado, flood, or hurricane; terrorist attacks; or toxin or poisoning events.

6.9 Depopulation Methods

Methods employed in past disease outbreaks include carbon dioxide gas introduced into the whole houses or in containers such as large trash receptacles, dumpsters, or carts for laying hens; carbon monoxide, argon, or nitrogen; water-based foam for floor birds such as broilers or turkeys; IV injection of injectable euthanasia agents or inhaled anesthetics for small numbers of birds; cervical dislocation, captive bolt, or decapitation; and, rarely, gunshot.

Ventilation shutdown has been a topic of much discussion since the 2014–2015 HPAI outbreak owing to the inability of emergency disease responders to quickly (within 24 hours) depopulate massive numbers of poultry, especially laying hens, and is discussed in more detail in another section of this document. The decision tree for selecting VSD as a depopulation method is contained in a USDA document.[6] The policy justifies the selection of VSD when "[o]ther depopulation methods are not available, or will not be available in a timely manner; AND the amplification of the virus on the premises poses a significant threat for further transmission and ongoing spread of HPAI" and goes on to delineate several other conditions that must be met.

6.9.1 Water-based foam

There are two primary methods of water-based foam depopulation systems available—generator-based systems (such as the National Veterinary Stockpile Kifco Avi-Guard units) and nozzle-based systems (such as the Spumifer handheld nozzles). Foam depopulation is a rolling process in which birds at one end of the barn are treated first, with birds reaching brain death relatively quickly, while the workers progress through the rest of the barn. Either type of foam depopulation system can typically be adapted to conventional, floor-reared birds. Foam depopulation requires large amounts of water; however, it may be possible to use existing on-farm capacity to fill temporary storage tanks (eg, well or pond), such as the collapsible water tanks used by fire departments, to reduce the amount of water transport required.

Water-based foam was developed for use with floor-reared poultry, including broilers, turkeys, and ducks. Foam generator systems use medium-expansion-rate water-powered generators that operate at expansion ratios of 35:1 to 120:1. Expansion rate impacts water and foam usage. The current systems use a two-part arrangement in which a cart with an operator and two foam generators is pulled through the barn via a semirigid hose and retraction apparatus. The equipment is well matched to the typical sizes expected for broiler barns, but can be used with planning in larger facilities. Nozzles have improved flexibility, allowing them to be used in situations where generator-equipped carts cannot be effectively used. Nozzle-based systems typically use air-aspirating nozzles to combine sufficient air, foam concentrate, and water to achieve satisfactory depopulation. Nozzle-based systems operate at lower expansion rates, resulting in increased water and foam usage. Many foam generator carts also include a foam nozzle, allowing foam to be distributed more efficiently through the barn. Nozzle and generator cart systems have been used with a variety of species.[7–10] When evaluated individually, the time to brain death is approximately 63 seconds for broilers, 190 seconds for turkeys, and 283 seconds for ducks. Foam depopulation is a rolling process in which birds at one end of the barn are treated first, and then the process moves through the facility, with birds reaching brain death relatively quickly, even though foam may still be being applied across the remainder of the facility. When circumstances and logistics permit, water-based foam is a depopulation method that is allowed in constrained circumstances . As with any method, follow-up evaluation for birds that survive the process is necessary. Personnel should not leave the site until the foam has dissipated enough to evaluate for complete success (or have an appointee who is equipped to achieve a 100% mortality rate using another method on an individual-bird basis).

Cage systems do not lend themselves to a water-based foam depopulation method because the foam drains through the open bottom and sides of the cages. Water-based foam characteristics either allow penetration into the cage and drain through the floor or prevent penetration into the cage. High-density compressed air foam can be injected into cages and accumulate well enough to suffocate birds, but it is difficult to achieve high mortality rates for all birds in the cage. Each cage will have to be individually injected with foam, taking time and requiring operators to work throughout the entire house. A foam generator and an adequate supply of foam solution would be necessary. Field-scale compressed air foam equipment is not currently available.

Water sources for poultry could vary, including municipal, well, and surface water. If foam depopulation is the preferred method for a given situation, some farms will not have enough water available to support foam depopulation. In particular, most farms will not have wells with the capacity to directly support foam depopulation. It may be possible to use existing on-farm well capacity to fill temporary storage tanks to reduce the amount of water transport required. Thus, additional water sources should be identified in the disaster planning stages to ensure timely access to large volumes of water if it were to become required. Some of these additional water sources may require special permitting processes and additional agreements that should be negotiated and arranged for in the planning process as much as possible ahead of an outbreak. Water sources should be located to allow rapid refill while minimizing the number of transport vehicles being potentially contaminated.

Whenever practical, birds should be penned to reduce the amount of area to be treated during depopulation. Cost and logistic complexity are often proportional to the area treated.

6.9.2 Containerized gassing and whole-house gassing or partial-house gassing

Various gases or gas mixtures have been used for depopulation of entire poultry flocks or killing limited number of poultry or various livestock species in other circumstances. Carbon monoxide was tried as a whole-house method during an HPAI outbreak in Holland.[11] Hydrogen cyanide has also been tested in Europe.[12] Carbon dioxide has been used widely in containerized and whole-house methods for depopulating poultry flocks. In situations where it is possible to maintain gas concentrations at a high level, an inert gas such as nitrogen or argon, or a mixture of nitrogen and argon with 20% to 30% carbon dioxide, also can be effective.

Carbon monoxide is lethal at low concentrations and so would require a smaller supply than other gases. However, its lethality makes it dangerous for humans to work with, and it is explosive at higher concentrations, requiring a large exclusion zone around a house in a whole-house gassing situation. The low target concentration (ie, 1.5%), can make gas distribution around a house problematic, resulting in surviving birds. Hydrogen cyanide is also poisonous, requiring great precautions to be used safely. In reality, neither carbon monoxide nor hydrogen cyanide is likely to be suitable for depopulation, and they would not be deployed in light of better alternatives.

At sufficient concentrations, CO_2 will kill poultry by hypercapnic hypoxia. The fact that it kills effectively over a wide range of concentrations makes it suitable for containerized and partial- or whole-house gassing methods, including scenarios, such as with older houses, in which it is difficult to seal up the living space of a flock sufficiently to achieve a high gas concentration. Carbon dioxide is detected by poultry, and at concentrations of 40% to 50% or more, it can excite trigeminal nerve endings, resulting in nociception and the potential for aversion from discomfort.[13] On the other hand, chickens have been shown to voluntarily enter concentrations of carbon dioxide 60% or higher to obtain a modest food reward.[14–17] Carbon dioxide can be transported in liquid form, allowing large effective volumes to be delivered to a depopulation site.

Inert gases, such as nitrogen and argon, are not detected by poultry and do not elicit direct aversive responses. Chickens can learn to avoid locations where oxygen levels are low,[18] but loss of consciousness in most depopulation scenarios would likely precede aversion. Inert gases, and mixtures of these gases with carbon dioxide, can be used to displace air so that the residual oxygen in the atmosphere is too low to support life (ie, $< 5\%$). These gases or gas mixtures can be effective with containerized gassing methods or in partial- or whole-house situations where the building can be adequately sealed. They may have an advantage for dealing with waterfowl, compared with carbon dioxide.

6.9.3 Containerized gassing

Containerized gas depopulation methods such as the use of MAK carts with carbon dioxide can humanely induce unconsciousness within 30 seconds of a bird being removed from a cage and death within minutes. However, routine spent hen removal from a large cage-style house can take a crew of 8 to 10 people several days, and to operate faster would require a larger work force. Work flow and efficient removal of the bird from a cage house can be difficult when increasing the work force. During fast-moving disease outbreaks, death due to disease may be faster than practical depopulation and removal rates from caged scenarios.

All containerized gassing methods require catching and handling of live birds to place them into the container or into the module, which then is placed into the container. This has drawbacks when large numbers of birds must be depopulated in a short period time or when the birds carry a potentially zoonotic disease to which handlers would be exposed. The container must be sufficiently airtight to hold an adequate concentration of gas for long enough to ensure the death of birds placed inside, yet be appropriately vented to allow air to be forced out when the gas is injected. The container can be precharged before loading or charged with gas after the birds have been loaded. Owing to the limited volume of the container, a containerized gassing method can be more sparing of gas relative to whole-house gassing. Likewise, the small volume allows the target gas concentration to be reached quickly so that the birds' experience of the modified atmosphere is not prolonged. The small volume also minimizes the likelihood of uneven distribution of gas throughout the chamber, and the gas injection system can be designed to achieve good gas mixing.

Virtually any sealable container could be used for containerized gassing, from something as simple as a trash can with a lid to purpose-built units with automated gas delivery systems. The container size and number need to be appropriate for the flock size and equipment available to handle the containers. Tarp-lined dumpsters or leak-proof commodity trucks with hoses from CO_2 tanks have been used as well.

Containerized gas methods designed to kill poultry in transport modules were used in disease outbreaks in the United States[19] and the United Kingdom.[12] In the US outbreak, a metal chamber open at the bottom was lowered over the module after it had been removed from the house. Carbon dioxide was delivered from a 50-lb CO_2 cylinder through an injection port in the chamber. The cylinder was left to run until the gas stopped. A target concentration of 50% CO_2 was reached in one minute, and movement of birds ceased by 1 minute 45 seconds. A typical commercial broiler farm needed 6 chambers to keep up with the rate of catching. A variation of this technique was to wrap the module in plastic and introduce CO_2 through a small hole. Wrapping required quick work to avoid overheating the birds. The system used in the United Kingdom used a metal container into which the transport module was placed through a door, which was closed to seal the chamber. A gas mixture (80% argon, 20% carbon dioxide) was injected to achieve a residual oxygen concentration of 5%. Fill time to the target concentration was 4 minutes. The procedure was to wait until the sound of bird movement stopped, then check for and kill survivors.

The MAK cart was developed for routine depopulation of spent laying hens housed in cages.[20] The cart is rolled along the aisle of a layer house to the location where hens are to be caught. The chamber of the cart is prefilled with carbon dioxide from a gas supply carried on the cart, and hens are placed into the cart directly after being removed from their cages. Carbon dioxide concentration is maintained in the cart by manual injection on the basis of the operator's observation of bird behavior. Windows into the cart allow the birds to be seen. Birds lose consciousness in 30 to 60 seconds in a properly operated cart but, manual operation of the gas system allows for operator error. The system is efficient with gas, with just over 13 lb of carbon dioxide needed to kill 1,000 hens. A crew of 12 can kill 30,000 hens in 8 hours. The rate of carbon dioxide delivery into the carts is typically high enough to cause cylinders to become so chilled that the liquid carbon dioxide remaining in the cylinder cannot vaporize fast enough to maintain an adequate flow. When this happens, cylinders must be changed out before they are empty.

A MAK trailer was designed for the purpose of depopulating small flocks of poultry.[21] A USDA National Animal Health Monitoring System report[2] notes that more than 90% of small or backyard flocks have fewer than 100 birds. The chamber of the MAK trailer was sized large enough to be able to kill an entire small flock in most cases. It is possible to operate the trailer with carbon dioxide, inert gases, or gas mixtures. Carbon dioxide and nitrogen were tested. Gas injection was controlled automatically. With carbon dioxide, the cart was prefilled and the concentration maintained at 50% during loading. Time to unconsciousness averaged about 20 seconds after birds were placed in the chamber. The number of birds that could be loaded varied with bird size (ie, from 595 X 3.0-lb [1.4 kg] broilers to 79 X 15.6-lb [7.1-kg] turkeys, requiring 26.9 to 10.8 lb of carbon dioxide/load, respectively). Cylinder chilling was observed when loads of birds were killed in close succession. This would not be a problem with single loads, which is the scenario for which the MAK trailer was designed. With nitrogen, birds were loaded in batches, (ie, a batch was a single layer of birds), and the gas was injected after a batch was loaded. Time to unconsciousness averaged just over 4 minutes after the beginning of nitrogen injection. The time to the end of wing flapping convulsions + 30 seconds for each batch was approximately 5 to 7 minutes (the kill cycle). A full load for the size of bird tested, 8.6-lb (3.9-kg) broilers, was two batches. Residual oxygen concentration achieved was ≤ 3%. About 200 cubic feet of nitrogen was required to kill a load of birds.

In conclusion, containerized gassing can provide a rapid, humane death for poultry. It does involve catching and handling of live birds, but not more severe than normal catching before live haul to slaughter. Since the birds are exposed to the modified atmosphere shortly after catch, stress is minimized. In addition to the use of carbon dioxide, containerized gas methods also can use inert gases such as nitrogen or argon or mixtures of nitrogen and argon and carbon dioxide, which may be more effective with some waterfowl than carbon dioxide alone. Containerized gassing also lends itself to depopulation of small flocks and backyard flocks. When time, circumstances, and logistics permit, containerized gassing is a preferred method for depopulation.

6.9.4 Whole-house gassing

The principles for whole-house gassing are essentially the same as for containerized gassing except that the container is the entire interior volume of the house constituting or open to the living space of a flock. Whole-house gassing allows birds to be killed in their own living space without the stress of handling. Any disease is contained within the house until the pathogen can be dealt with. Relatively few people are required to depopulate the flock, and depopulation is accomplished with minimal exposure to birds. The primary gas used for whole-house gassing is carbon dioxide, but carbon monoxide and hydrogen cyanide have been tried in disease outbreaks around the world. Carbon dioxide is relatively safe to use and will kill poultry at concentrations as low as 30% if given enough time.[22]

The house must be relatively gastight, and inlets, fans, and doors must be sealed sufficiently to hold adequate concentrations of carbon dioxide throughout the living space of the birds but vented sufficiently above the birds to allow air to be forced out when the gas is injected. Inadequate sealing of a house will result in the waste of CO_2 or pockets of surviving birds adjacent to unsealed areas. Distribution of gas within a facility is nontrivial and requires the use of a specially designed manifold to provide the proper gas distribution through the facility. Improper gas distribution can result in structural damage to the facility because of flash freezing but can be mitigated by the loosening of belts, draining of some water lines, and placement of manifolds away from sensitive structures and placement of foam board as an insulation barrier to protect against freezing. In houses with multiple rooms, the ventilation in one room may counter attempts to seal an adjacent room if depopulation were to proceed on a room-by-room basis. The amount of carbon dioxide needed to depopulate a house of caged poultry varies with house design and permeability.

Reports in the literature indicate a range of 336 to 2,031 lb of CO_2/1,000 birds in a variety of confinement housing systems. Whole-house gassing can be relatively inefficient in the use of gas because of the space that must be filled that is not occupied by birds. A rule of thumb is that it requires about 1 house volume of carbon dioxide injected into a house to reach 50% to 60% concentration. A field estimate for the amount of liquid carbon dioxide required is as follows:

$$W_{ICO2} = \frac{V}{8.7}$$

where W_{ICO2} = the weight of liquid CO_2 in pounds and V = volume of the barn in cubic feet.

A large modern cage layer house with an internal volume of 500,000 cubic feet would require roughly 25 to 30 tons of CO_2 or two 20-ton tanker loads of CO_2 to depopulate a barn.

The time required to administer carbon dioxide to kill a flock depends on a variety of factors, such as the house size, the target concentration of the gas, the health status of the birds, and the mechanism of gas delivery. Field studies report a range of time from 5 to 60 minutes to achieve concentrations of carbon dioxide from 40% to 65%.[11,23–25] When liquid carbon dioxide is injected into a house at a high rate, temperatures in the vicinity of the injection site can become very low (eg, –23°C,[25] –85°C[24]); however, these studies also show that birds lost consciousness before being chilled, and there was no evidence of antemortem freezing. Foam boards or other insulating materials can be positioned around the manifolds to limit areas of localized cold temperatures for the impact on both the birds and the equipment.

Emergency depopulation of a multihouse complex by whole-house gassing would require logistic planning and a fleet of 4 to 6 tankers rotating from resupply site to complex beginning with the infected house and working out to adjacent barns. A 20-barn complex would take 5 to 6 days to depopulate assuming 4 tankers, 2 crews, and 8 gassing units were mobilized. The limiting factor may be emptying the barns and disposal of the birds in a way to control disease spread, as the described scenario would require composting or burial of 3,000,000 birds in 6 to 7 days.

Gas mixtures that incorporate an inert gas such as nitrogen with carbon dioxide, which require greater displacement of the resident atmosphere within the house than is necessary with carbon dioxide alone, would need even greater volumes injected into the house to achieve the concentration necessary to kill birds.

Whole-house gassing should be conducted according to strict standard operating procedures to protect the safety of people who might be exposed to modified atmospheres. For the safety of the depopulation team, it would be advisable for one or more individuals to be equipped with breathing apparatus to operate in a dangerous atmosphere.

In conclusion, whole-house gassing can provide poultry with a humane death. Whole-house gassing allows flocks to be killed in their own living space with no disturbance from people. Involving minimal labor and minimal exposure of humans to the flock, whole-house gassing can be implemented fairly quickly, stopping further production of pathogens, and if necessary in a large disease outbreak, killed flocks can be left in place while the depopulation effort moves to deal with other flocks. The amount of gas needed to depopulate large commercial poultry houses may require preexisting supply contracts and logistic coordination with multiple CO_2 providers if a disease outbreak were to hit multiple farms or even a single farm with multiple houses. When circumstances and logistics permit, whole-house gassing is a preferred method for depopulation.

6.9.5 Partial-house gassing

Many old poultry houses and those in warm climates have open designs that do not lend themselves to whole-house gassing because they cannot feasibly be sealed to hold adequate concentrations of gas. Partial-house gassing methods involve assembly of a chamber in the house within which a flock can be gassed in one or more groups. The chamber can be constructed of panels or other material to form walls over which a plastic sheet is later pulled or may merely comprise plastic sheets that are anchored to the floor and can be pulled over the birds. The chamber generally is set up in an area cleared of birds, and the birds are driven into it when ready. This method works best with types of birds that can be driven, such as turkeys. Like whole-house gassing, partial-house gassing kills birds in their own living space.

Partial-house gassing requires a team of people to work in the living space of the birds, potentially exposing them to any pathogen the birds carry. It also requires materials to construct the chamber. With appropriate organization and drivable birds, the procedure can be conducted fairly quickly. For instance, Kingston et al[19] used a team of seven people to set up a ground panel enclosure inside a house to depopulate commercial turkeys. Once the chamber is closed, gas can be delivered quickly. Kingston et al[19] took 5 to 6 minutes to reach carbon dioxide concentrations of 48% to 58%. Bird movement ceased in 6 to 7 minutes. Estimates of gas use were not reported, but it is likely that partial-house gassing methods would be intermediate between containerized and whole-house gassing, depending on the degree of volume reduction from the whole house relative to that attained with containerized gassing.

As with whole-house gassing, partial-house gassing should be conducted according to strict standard operating procedures to protect the safety of people who might be exposed to modified atmospheres. For the safety of the depopulation team, it would be advisable for one or more individuals to be equipped with breathing apparatus to operate in a dangerous atmosphere.

The same methodology as used for partial-house gassing might work for sizable flocks of outdoor-housed free-range poultry provided they can be driven.

In conclusion, partial-house gassing can provide a rapid, humane death for poultry. The method is more labor-intensive than whole-house gassing and requires the depopulation crew to work in the living space of the flock and to interact directly with the birds. Unless the birds are sick, this level of interaction with the birds would be less stressful than catching. Partial-house gassing lends itself better to species of poultry that can be driven, such as turkeys. If birds are already sick, partial-house gassing would be problematic if the flock cannot be driven into the location set up to hold the modified atmosphere. If the partial house is sufficiently airtight, other gases than carbon dioxide might also be effective in providing a humane death. Partial-house gassing requires a flock to be housed on the floor. For reasons of time, personnel exposure to birds, depopulation crew size, and resource availability, other nongas methods of depopulation, such as the use of foam, may be more feasible. Nonetheless, if time, circumstances, and logistics are favorable, partial-house gassing is a preferred method for depopulation.

6.9.6 Physical methods

Physical methods of depopulation, including captive bolt gun, mechanically assisted cervical dislocation, and cervical dislocation, can be preferred methods or methods allowed in constrained circumstances depending on the situation. All physical methods require extensive manual handling of the poultry, increasing labor requirements, time, and human and animal stress and raising welfare concerns. Physical methods, however, can be more flexible and adaptable to specific situations because they are applied on an individual animal rather than whole flock. Physical methods may need to be adapted to the specific avian species under consideration and are most appropriate when there are limited numbers of birds to depopulate.

Animals should be caught with a minimum of effort and restrained if possible. If necessary, animals should be carried with two hands.

The use of firearms is generally discouraged for most commercial poultry owing to the number and size of the birds in question. Properly performed depopulation by gunshot causes immediate insensibility and death, with the projectile penetrating the brain resulting in immediate death. While all depopulation methods require skilled personnel, the use of firearms raises the concerns to a higher level. Only skilled firearms operators should be involved in the process. Firearms may be one of the few physical methods available for large ratites. Air rifles or pistols using BBs or pellets may be necessary to depopulate starlings and other nuisance birds that have gained access to the facility during disease response activity.

Captive bolt guns are purpose-built devices designed to cause immediate loss of consciousness and death in appropriate species. Captive bolt guns retain the bolt within the unit (ie, captive), avoiding ricochet or overpenetration. Purpose-built captive bolt guns are available for commercial broilers, layers, and turkeys. The purpose-built captive bolt guns use concussive force to render the animal unconscious and should not break the skin under proper use.

Cervical dislocation is the luxation of the cervical vertebrae without primary crushing of the vertebrae and spinal cord. Properly implemented, cervical dislocation causes rapid loss of consciousness. Cervical dislocation can be appropriate for smaller birds, immature rats, mice, and rabbits, but is not appropriate for large animals or birds.

Mechanically assisted cervical dislocation aims to achieve the same effect as cervical dislocation; however, it uses mechanical devices that increase the mechanical advantage to make it easier to effectively kill the birds. Mechanically assisted cervical dislocation devices use long lever arms, coupled with short and narrow contact at the neck, to increase the effective force on the neck.

When buildings containing birds have been declared unsafe to enter, options for depopulation may be extremely limited. However, the same ethical criteria apply and may justify steps taken to hasten death such as controlled demolition of the building.

6.9.7 VSD

Ventilation shutdown alone as a depopulation method is a last resort and must only be considered when all other options have been thoughtfully considered and ruled out. A primary goal in the case of an outbreak of HPAI (or other highly contagious pathogen) is to stop the spread of the virus as quickly as possible to reduce further bird suffering and economic losses and, in the case of a zoonotic agent, minimize the threat to human health. However, the most compelling reason to use VSD when all other methods have been ruled out is that, when done properly, it provides a quicker death, hence eliminating the chance for the birds to die over a longer period of time from distressing and devastating disease.

Ventilation shutdown as a whole-house depopulation method was employed sporadically in the 2015 large-scale HPAI outbreak in the United States and in the smaller outbreak in Indiana in January 2016. Both of these disease outbreaks resulted in situations where resources had become depleted and personnel were not available to depopulate a house in sufficient time to prevent further widespread dissemination of the virus to adjacent farms. Ventilation shutdown is also a method that may be a necessary alternative for the initial response, or to limit exposure, to a highly zoonotic strain of avian influenza.

Ventilation shutdown involves closing up the house, shutting inlets, and turning off the fans. Body heat from the flock raises the temperature in the house until birds die from hyperthermia, but numerous variables can make the time to death of 100% of birds in the house subject to widely divergent time frames. The age and size of the house; the ventilation system; the ability to adequately seal fans, louvres, doors, and windows; and the number of birds in the house can all make the achievement of temperature goals problematic (outlined later in this chapter). Cage houses, which hold a large biomass in the living space, may lend themselves more readily to VSD than other housing types containing lower biomass per unit volume. Ventilation shutdown has the advantage of quickly stopping production of disease virus and containing the pathogen within the house until it can be neutralized. It also requires little labor and minimal human exposure to birds.

The USDA has published two documents pertaining to VSD. The first, HPAI Outbreak 2014–2015: Ventilation Shutdown Evidence and Policy,[6] describes the rationale for supporting a revised depopulation policy for HPAI, setting a goal for poultry to be depopulated within 24 hours of a presumptive positive classification, on the basis of the current case definition. This document also contains a decision tree for selecting VSD as a depopulation method. The second document, HPAI Response Guidance: Using Ventilation Shutdown to Control HPAI,[26] contains specifications for carrying out VSD, including general guidance, length and temperature of heating, and humidity and bird density. The USDA Response Guide states that "VSD is the last option that will be considered when selecting a depopulation method."

The Evidence and Policy statement delineates six requirements for using VSD for HPAI:

1. Other methods are not available or will not be available in a timely manner.
2. The amplification of the virus on the premises poses a significant threat for further transmission and ongoing spread of HPAI.
3. The questions in the Ventilation Shutdown Evidence and Policy document have been reviewed and discussed by APHIS officials, state or tribal officials, and the incident management team.
4. Incident management team approval.
5. State officials' approval.
6. National Incident Coordinator approval.

The Response Guide states that the temperature of the house must be raised to 104°F or higher as quickly as possible and preferably within 30 minutes, maintaining a temperature of between 104°F and 110°F for a minimum of three hours. Recent research conducted at North Carolina State University[27] and the USDA Response Guidance indicate that VSD alone may not achieve this outcome and that supplemental heat may be needed to achieve this standard. While the USDA guidelines do not recommend the addition of supplemental CO_2, the North Carolina State University research demonstrates that VSD with the addition of supplemental heat, CO_2, and heat plus CO_2 were equally beneficial in decreasing time to 100% mortality. Ventilation shutdown with the addition of heat ensures the temperature standard is met. The obvious goal is a 100% mortality rate in as short a time as possible.[14]

Future research may provide additional information to inform decision-making surrounding VSD. Until then, the following categorizations will apply in these Guidelines:

1. Ventilation shutdown plus heat, VSD plus CO_2, and VSD plus heat and CO_2 applied in a manner that will produce a 100% mortality rate meets the classification category permitted in constrained circumstances.
2. Ventilation shutdown alone is categorized as not recommended.

6.10 References

1. USDA National Agricultural Statistics Service. USDA poultry production data: May 2015. Available at: www.usda.gov/sites/default/files/documents/nass-poultry-stats-factsheet.pdf. Accessed Feb 20, 2019.
2. National Animal Health Monitoring System. Poultry '04. Part 1: reference of health and management of backyard/small production flocks in the United States, 2004. Available at: www.aphis.usda.gov/animal_health/nahms/poultry/downloads/poultry04/Poultry04_dr_PartI.pdf. Accessed Feb 12, 2019.
3. Green JL. Update on the highly-pathogenic avian influenza outbreak of 2014-2015. July 20, 2015. Available at: fas.org/sgp/crs/misc/R44114.pdf. Accessed Feb 12, 2019.
4. AVMA. AVMA guidelines for the euthanasia of animals: 2013 edition. Available at: www.avma.org/KB/Policies/Pages/Euthanasia-Guidelines.aspx. Accessed Jul 2, 2013.
5. AVMA. AVMA guidelines for the humane slaughter of animals: 2016 edition. Available at: www.avma.org/KB/Resources/Reference/AnimalWelfare/Documents/Humane-Slaughter-Guidelines.pdf. Accessed Feb 7, 2019.
6. USDA. HPAI outbreak 2014–2015: ventilation shutdown evidence & policy. September 18, 2015. Available at: www.aphis.usda.gov/animal_health/emergency_management/downloads/hpai/ventilationshutdownpolicy.pdf. Accessed Jan 30, 2019.
7. Rankin MK, Alphin RL, Benson ER, et al. Comparison of water-based foam and carbon dioxide gas emergency depopulation methods of turkeys. *Poult Sci* 2013;92:3144–3148.
8. Caputo MP, Benson ER, Pritchett EM, et al. Comparison of water-based foam and carbon dioxide gas mass emergency depopulation of White Pekin Ducks. *Poult Sci* 2012;91:3057–3064.
9. Benson ER, Alphin RL, Dawson MD, et al. Use of water-based foam to depopulate ducks and other species. *Poult Sci* 2009;88:904–910.
10. Benson ER1, Alphin RL, Rankin MK, et al. Mass emergency water-based foam depopulation of poultry. *Avian Dis* 2012;56(suppl 4):891–896.
11. Gerritzen MA, Lambooij E, Stegeman JA, et al. Slaughter of poultry during the epidemic of avian influenza in the Netherlands in 2003. *Vet Rec* 2006;159:39–42.
12. Raj M, O'Callaghan M, Thompson K, et al. Large scale killing of poultry species on farm during outbreaks of diseases: evaluation and development of a humane containerised gas killing system. *Worlds Poult Sci J* 2008;64:227–244.
13. McKeegan DEF, Smith FS, Demmers TGM, et al. Behavioural correlates of olfactory and trigeminal gaseous stimulation in chickens, *Gallus domesticus*. *Physiol Behav* 2005;84:761–768.
14. Webster AB, Fletcher DL. Assessment of the aversion of hens to different gas atmospheres using an approach-avoidance test. *Appl Anim Behav Sci* 2004;88:275–287.
15. McKeegan DEF, McIntyre J, Demmers TGM, et al. Behavioural responses of broiler chickens during acute exposure to gaseous stimulation. *Appl Anim Behav Sci* 2006;99:271–286.
16. McKeegan DEF, McIntyre J, Demmers TGM, et al. Physiological and behavioural responses of broilers to controlled atmosphere stunning: implications for welfare. *Anim Welf* 2007;16:409–426.
17. Sandilands V, Raj ABM, Baker L, et al. Aversion of chickens to various lethal gas mixtures. *Anim Welf* 2011;20:253–262.
18. Mohan Raj AB, Gregory NG. Preferential feeding behaviour of hens in different gaseous atmospheres. *Br Poult Sci* 1991;32:57–65.
19. Kingston SK, Dussault CA, Zaidlicz RS, et al. Evaluation of two methods for mass euthanasia of poultry in disease outbreaks. *J Am Vet Med Assoc* 2005;227:730–738.
20. Webster AB, Fletcher DL, Savage SI. Humane on-farm killing of spent hens. *J Appl Poult Res* 1996;5:191–200.
21. Webster AB, Collett SR. A mobile modified-atmosphere killing system for small-flock depopulation. *J Appl Poult Res* 2012;21:131–144.
22. Gerritzen MA, Lambooij B, Reimert H, et al. On-farm euthanasia of broiler chickens: effects of different gas mixtures on behavior and brain activity. *Poult Sci* 2004;83:1294–1301.
23. Kloeze H. Disease response preparation focussing on humane depopulation with carbon dioxide, in *Proceedings*. Annu Conf Ont Vet Med Assoc 2008;281–283.
24. Sparks NHC, Sandilands V, Raj ABM, et al. Use of liquid carbon dioxide for whole-house gassing of poultry and implications for the welfare of the birds. *Vet Rec* 2010;167:403–407.
25. Turner PV, Kloeze H, Dam A, et al. Mass depopulation of laying hens in whole barns with liquid carbon dioxide: evaluation of welfare impact. *Poult Sci* 2012;91:1558–1568.
26. USDA. HPAI response guidance. Using ventilation shutdown to control HPAI. January 15, 2016. Available at: minnesotaturkey.com/wp-content/uploads/2015/03/USDA-NEW-Using-VSD-1.15.2016_V2.pdf. Accessed Feb 12, 2019.
27. Anderson K, Livingston K, Shah S, et al. *Evaluating hen behavior and physiological stressors during VSD for the development of humane methodologies for mass depopulation during a disease outbreak. Final report*. Project BRU007: March 30, 2017. Tucker, Ga: US Poultry and Egg Association, 2017.

7: Equids

7.1 General Considerations

7.1.1 Settings of equids

There are over 7 million horses in the United States, according to recent estimates by the American Horse Council,[1] and this number does not include all equid species (eg, horses, mules, donkeys, ponies, miniature horses, zebra hybrids) or situations in which equids are living (eg, unowned animals).

Depopulation may be encountered in several environments for equids, including individually owned animals; breeding animals; populations of animals maintained in animal control facilities, shelters, rescues, and sanctuaries; animals maintained for research purposes; animals maintained in veterinary facilities, boarding facilities, or quarantine stations; animals maintained at working animal training facilities (eg, military, law enforcement, security, or service); equids maintained on racetrack grounds and training facilities; and free-roaming, unowned, abandoned or feral animals. While a large number of equids in the United States live in urban or suburban units (private and public stables), others may be confined in small to extensive pastures. In the unique case of the United States' Bureau of Land Management Wild Horse Program, over 70,000 horses are roaming on open rangeland.[2]

Institutions such as well-managed research laboratories, animal control facilities, quarantine facilities, and animal shelters may have depopulation protocols within their emergency and disaster preparedness plans owing to governmental or institutional regulations. Other facilities that house equids such as training or boarding facilities, breeding operations, and private shelters or sanctuaries are less likely to have emergency depopulation procedures in place.

7.2 Events Necessitating Depopulation

Emergency events that may necessitate the consideration of depopulation of equids include widespread loss of essential survival resources during natural disasters such as earthquakes or floods; nonnatural disasters such as incidents involving terrorism, bioterrorism, conventional or nuclear attack or accidents, or toxic chemical spills; contamination of food and water supplies; zoonotic or pandemic disease that threatens public health and the food supply; and contagious veterinary disease in a single locality or species.

7.3 Depopulation Methods

Challenges and constraints will vary with location; number of equids; available resources (eg, trained or experienced personnel, medical supplies); facilities; nature of the causative agent (eg, disease, injuries, chemical or radiation exposure, starvation); legal and regional constraints; permission and cooperation from owners, trainers, and managers; potential danger to the public; the time needed and allowed for planning; and, lastly, but of utmost importance, the anticipated public reaction.

In many cases of depopulation involving equids, the number of animals involved will be smaller than in situations involving depopulation of other types of animals (eg, swine, poultry), which should allow for the employment of standard euthanasia or slaughter methods. Whenever possible, standard euthanasia or slaughter methods as outlined in the current AVMA Guidelines for the Euthanasia of Animals[3] or AVMA Guidelines for the Humane Slaughter of Animals[4] must be utilized. Methods described in the following that do not fit the AVMA criteria for euthanasia or slaughter should be considered only when exigent circumstances prevent the implementation of standard euthanasia or slaughter methods and should not be considered to be acceptable for routine or nonexigent circumstances.

Some methods that are acceptable within the AVMA criteria may be aesthetically objectionable to handlers, observers, and the public (eg, long-range gunshot or exsanguination), so the choice of depopulation method should be made with due consideration for potential media and public response that may occur. With all methods, determination that death has occurred must be made before disposal of the remains. Proper disposal methods should be employed to conform to state and federal laws and to minimize hazards to scavengers and the environment due to chemical residues in tissues.

7.3.1 Human safety and restraint

Equids are large, athletic animals that are prone to flight responses. Caution should be used when these animals are handled, and care should be taken to ensure appropriate low-stress handling as much as possible. When equids are killed, consideration should be given to the unpredictability of a falling or thrashing equid to ensure safety of personnel.

7.3.2 Noninhalant chemical methods—injectables

As outlined in the AVMA Guidelines for the Euthanasia of Animals,[3] IV injection of barbiturate-based euthanasia solutions is the preferred method of euthanasia for equids. Injectable anesthetics may be used as part of two-step euthanasia whereupon the injections are titrated until unconsciousness occurs, then a secondary method (eg, IV potassium chloride) is employed. This two-step method can be useful in situations where supplies of euthanasia solution or injectable anesthetics are limited.

7.3.3 Physical methods

Physical methods of depopulation can be highly effective and humane when performed properly by adequately trained personnel. Close-range gunshot or captive bolt, as described in the AVMA Guidelines for the Euthanasia of Animals,[3] may be used provided adequately trained personnel are available, appropriate safety measures can be implemented, and equipment is well maintained. Death is due to immediate disruption of brain matter. Utilization of gunshot requires personnel highly versed in gun safety, caliber selection, and marksmanship.

Distance gunshot may be required in situations where direct contact with animals to be depopulated is not possible (eg, free-roaming or feral animals). Distance gunshots generally target the largest body mass with death due to exsanguination. There is significant risk to unintended targets if an improper caliber is used or ammunition misses its intended mark.

Exsanguination via the rectum, under general anesthesia, may be useful in situations where animals are trapped and moving them will induce significant suffering.

7.4 Implementation With Prioritization

7.4.1 Preferred methods

Injection of euthanasia solution is a primary depopulation method and should have high priority when response plans are formulated that involve emergency depopulation. Euthanasia solutions have known dosing requirements, predictable and rapid onset of action, relative ease of administration, and general acceptance by the public. If euthanasia solutions are in short supply, titration of the dose to achieve unconsciousness followed by a secondary method to induce death (eg, IV potassium chloride) may be considered to extend the availability of the euthanasia solution. Injectable anesthetic overdoses are acceptable alternative depopulation methods, as are two-step methods involving injectable anesthesia followed by IV administration of concentrated potassium or magnesium solutions.

Close-range gunshot and PCB as described in the AVMA Guidelines for the Euthanasia of Animals[3] and Guidelines for the Humane Slaughter of Animals[4] are also considered preferred depopulation methods.

7.4.2 Permitted in constrained circumstances

These methods should be considered only when the emergency circumstances constrain the ability to reasonably implement a preferred method.

Solutions that have exceeded their expiration dates, compounded formulations, or nonpharmaceutical-grade injectable euthanasia and anesthetics may be utilized for emergency depopulation purposes in cases where there is a shortage of euthanasia and injectable anesthetic agents. Alternative routes such as intrahepatic or intrarenal injection may be considered only if they can be performed with efficiency and minimal distress to awake animals.

Gunshot at a distance utilizing a scoped rifle handled by an experienced marksman may be used for emergency depopulation. A .30 caliber or greater rifle should be used with an expanding-type bullet targeted at the heart and lung region. Rifle shots are best managed with a rifle rest in these situations. Shots > 100 yards should be avoided when possible to avoid missed shots or wounded equids. Head or neck shots should be avoided at anything other than close range.

Shotguns (.410, 20/16/12 gauge) using slugs, buckshot, or turkey, duck, or goose loads may be effective at short distances (3 m or less).

Large-caliber pistols (.45 caliber, .357 Magnum, .41 Magnum, .44 Magnum) may be used with solid-point bullets.

Exsanguination via the rectum (ie, cutting the aortic bifurcation) under anesthesia may be useful with trapped equids.

7.4.3 Not recommended

The use of choral hydrate or IV injection of > 60% magnesium sulfate solution should be considered only in extreme situations. Associated adverse effects can be severe and aesthetically objectionable with use of these methods. Prior sedation is highly recommended to reduce distress experienced by the animals and support personnel safety.

The use of oral toxins to deliver a lethal dose of any agent is not currently recommended. Drawbacks include lack of reliable, established lethal dosages for many toxic agents; lack of assurance that a lethal dose will be consumed; species and individual variability in bioavailability, absorption rates, and response to a given dose of an agent; variability of the latent period between ingestion and death; potential relay toxicities involving nontarget animals; environmental impact; and potential for recovery in animals exposed to sublethal doses. The severity and duration of animal suffering before death and potential human health and safety hazards make oral toxins an unsuitable option for depopulation.

7.5 Special Considerations

7.5.1 Dangerous animals

Equids may become disoriented, excited, and unpredictable during a depopulation event. The presence of unfamiliar people, increased numbers of people, use of PPE (eg, hazmat suits), and unusual or loud noises (eg, gunshots) exacerbate the situation. Intact males may pose an especially high risk of injury to personnel.

7.6 Carcass Management

Carcass disposal is generally a regulated process, and regulations may vary by jurisdiction and by situation. The use of chemical agents limits carcass disposal options, and potential environmental and wildlife risks must be considered.

References appear on the next page.

7.7 References

1. American Horse Council. Economic impact of the United States horse industry. Available at: www.horsecouncil.org/economics/. Accessed Feb 12, 2019.
2. Bureau of Land Management. Wild horse and burro advisory board transcript. October 18, 2017. Available at: www.blm.gov/sites/blm.gov/files/wildhorse_2017AdvisoryBoard_transcripts.pdf. Accessed Feb 12, 2019.
3. AVMA. AVMA guidelines for the euthanasia of animals: 2013 edition. Available at: www.avma.org/KB/Policies/Documents/euthanasia.pdf. Accessed Feb 7, 2019.
4. AVMA. AVMA guidelines for the humane slaughter of animals: 2016 edition. Available at: www.avma.org/KB/Resources/Reference/AnimalWelfare/Documents/Humane-Slaughter-Guidelines.pdf. Accessed Feb 7, 2019.

8: Aquatic Animals (Aquaculture)

8.1 General Considerations

8.1.1 Aquaculture production in the United States

The settings in which aquacultured species are commonly found in the United States vary widely depending on the species cultured, the environment or aquatic system being utilized, the number of captive animals managed, the end use of the aquatic animal, and the geographic location. For instance, coldwater species (eg, trout, salmon) may be cultured in freshwater raceways with flowing water, aquaculture tanks with recirculating water, or cages in the freshwater or marine environment. Warm- and cool-water species of fish (eg, catfish, tilapia, striped bass, carp, goldfish, baitfish) may be grown in freshwater ponds, aquaculture tanks with recirculating water, or cages in the freshwater or estuarine environment. New emerging aquaculture species (eg, flounder, cobia, barramundi, sea bass, grouper, pompano) may be found cultured in any of the previously mentioned combination of systems and environments. Likewise, cultured aquatic invertebrates (eg, shrimp, crayfish) may be maintained in a variety of freshwater and marine systems such as ponds or tanks. Depopulation recommendations for zebrafish and other populations of laboratory fishes can be found in chapter 2 on laboratory animals. Also, it should be noted that these recommendations pertain to only captive animals, as depopulation of free-ranging aquatic species is considered infeasible.

One obvious difference between the aquatic animals and their terrestrial counterparts is the inclusion of water as part of the decision-making process. Consequently, euthanasia, slaughter, or depopulation decisions need to consider not only the species being terminated but also other organisms (eg, plant and animal) in the water, dilution and inactivation of chemical agents, and discharge of large volumes of potentially toxic or contaminated water.

8.2 Events Necessitating Depopulation

There are a number of potential situations that could result in a decision to depopulate a captive population of aquatic animals. Depopulation of captive aquatic animals may be necessary for disease control, for alleviating animal suffering, for biosafety and human safety issues, or any combination of these. Additionally, depopulation may be necessary for food safety issues or elimination of undesirable species. The method of depopulation should also take into consideration the containment of infectious materials, the zoonotic risk of the pathogen involved, and carcass disposal options. On the basis of these considerations, the type of depopulation chosen may be a preferred method, a method allowable in constrained circumstances, or a method that is not recommended. Examples of particular situations follow to demonstrate general scenarios, but are not intended to represent a comprehensive list of all potential rationales for depopulation.

8.2.1 Depopulation for disease control efforts

For depopulation for disease control, the specific disease and pathogen, the host and environmental survival of the pathogen, and the desired end use of the population need to be considered. Some infections (eg, external pathogens or parasites) may allow the aquatic animal to be processed for human consumption, and in these situations, the aquatic animal should be managed by recommended humane slaughter techniques. In contrast, aquatic animals with other types of infections (eg, disseminated systemic infections or diseases affecting edible portions of the aquatic animal) may not be processed for human consumption, and thus depopulation methods should be considered. In some situations, elimination of the host is sufficient to eradicate the pathogen, while in other situations, eradication of the pathogen may not be possible because of the pathogen's capability for prolonged survival in the environment or facility or reservoir and intermediate hosts. As in terrestrial animals, there are infectious pathogens that have high consequences not only to animal health but also to trade status. Federally regulated diseases, especially those considered foreign to the United States, are of particular concern. In these situations, there will be significant involvement of state and federal animal health regulatory agencies, and the decision-making process and final decision may ultimately be the responsibility of those agencies. Some specific examples of infectious diseases for which depopulation may be considered for disease control would include infectious salmon anemia and spring viremia of carp (both of which are considered an FAD in the United States), furunculosis, francisellosis, streptococcosis, and mycobacteriosis.

8.2.2 Depopulation to alleviate animal suffering

Depopulation of aquatic animals may also be considered as a means of eliminating the imminent risk of animal suffering. Situations where animal suffering may occur are infectious or parasitic diseases in which treatments are not approved, are unavailable, or are cost prohibitive; unmitigable suboptimal, toxic, or contaminated water in the aquaculture system or environment; and disaster-related events such as flooding where a lack of access to buildings prevents adequate provision of animal care or electric outages where pumps for filtering and recirculating water are inoperable.

8.2.3 Depopulation for food safety

Depopulation may be considered when populations of aquatic animals have been exposed to potential toxins, both for the health of the aquatic animal and because of food safety concerns. Two recent events of this type include situations where fish were unknowingly provided feeds contaminated with dioxin (circa 1997)[1–3] or melamine (circa 2007).[4,5] Each compound fed to the aquatic animals made the resulting food product unfit for human consumption or alternative markets. Another situation where depopulation may be considered is when an infectious disease makes the aquatic product unwholesome for human consumption, as is the case for both mycobacteriosis and streptococcosis (eg, *Streptococcus iniae*), or when a parasitic disease such as a digenean trematode or nematode infection in the muscle makes the aquatic product unwholesome for human consumption.

8.2.4 Depopulation for biosafety and human safety

In certain disease situations, the zoonotic potential of a particular pathogen (eg, mycobacteriosis and streptococcosis) may warrant the destruction of a captive population. In these cases, the potential routes of transmission (ie, aerosol, hematogenous, or waterborne) and the associated risk presented by a particular depopulation method should be taken into account. For such disease agents, the risk associated with the depopulation method needs to be mitigated if possible, or the method of depopulation needs to be excluded from consideration.

8.3 Depopulation Methods

Approved euthanasia[6] or slaughter[7] methods for aquatic animals should always be considered as a primary option in decisions regarding depopulation, especially in cases where there is a manageable number of animals, as these methods are generally considered more humane than depopulation options. However, the use of approved euthanasia or slaughter methods may not be feasible owing to the number of animals involved, the particular disease or food safety situation, human safety considerations, the availability of equipment and materials, the urgency of the required action, or the imminent risk of animal suffering.

8.4 Implementation With Prioritization

8.4.1 Preferred methods

These methods are given highest priority and should be utilized preferentially depopulation plans are developed and when circumstances allow reasonable implementation during an emergency situation. All methods listed in the 2013 AVMA Guidelines for the Euthanasia of Animals[6] as acceptable or acceptable with conditions for both finfish and aquatic invertebrates are considered preferred methods for depopulation. Appropriate consideration should be given to the species, type of aquaculture system and environment, number of animals involved, life stage of the animal, size of the animal, human safety, availability of equipment and material, facility discharge, and disposition of the carcass. These methods include immersion agents (eg, benzocaine, carbon dioxide ethanol, eugenol and its derivatives, isoflurane and sevoflurane, quinaldine sulfate, 2-phenoxyethanol, and tricaine methanesulfonate), injectable agents (eg, pentobarbital, ketamine, ketamine-metomidate, and propofol), and physical methods (eg, decapitation, cervical transection, manually applied blunt force trauma to the head, captive bolt needle, maceration, and rapid chilling). Acceptable methods outlined in the AVMA Guidelines for the Humane Slaughter of Animals: 2016 Edition[7] are also considered preferred methods, including electrocution where the electric current should be sufficient to cause immediate unconsciousness (ie, stunning) and death of the fish.

8.4.2 Permitted in constrained circumstances

These methods are allowed only when circumstances are considered constrained enough to affect the ability to reasonably implement a preferred method. Potential constraints that might result in use of methods in this category include, but are not limited to, the number of animals involved, timeliness and efficiency of preferred methods, limitations on human safety, lack of equipment or resources, and disease transmission or zoonotic disease risk. These methods include prolonged exposure to uncontrolled administration of CO_2 or the utilization of dry ice as a source of CO_2; hypothermal shock (ice or ice slurry) for temperate, cool, and cold-water species of fish and medium- to large-bodied fish; decapitation and cervical transection as a primary method; and exposure to toxic compounds (eg, chlorine and rotenone) that cause immediate death.

8.4.3 Not recommended

These methods should be employed only when the circumstances preclude the reasonable implementation of any of the methods in the preferred or allowed in constrained circumstances categories and when the risk of doing nothing has a reasonable likelihood of resulting in significant animal suffering. Examples of such situations include, but are not limited to, inability to safely access animals for a prolonged period of time; loss of infrastructure (ie, electrical power) where lack of filtration, water circulation, and temperature will result in progressively deteriorating water quality; and any circumstance that poses a severe threat to animal or human life. These methods include caustic and toxic chemicals that cause rapid but not immediate death (ie, calcium oxide or quick lime and formalin) and removal from the water (ie, dewatering), which results in anoxia and desiccation.

8.5 Aquatic Invertebrates

Development of guidelines for the depopulation of aquatic invertebrates is problematic. The species scope is exceptionally broad and varied, and the available data for safe, effective, and humane killing en masse are limited. This lack of available information makes evaluation of the humaneness of a particular depopulation method difficult. Though the indications for depopulation of captive aquatic invertebrates are probably uncommon, they may include response to emergencies, such as the control of catastrophic infectious diseases or exigent situations caused by natural disasters. There are probably more examples of depopulation of aquatic invertebrates associated with efforts to control invasive species, such as zebra mussels (*Dreissena polymorpha*), but these are beyond the scope of this document. As with finfish, consideration and efforts to utilize preferred methods should be fully evaluated before implementation of depopulation techniques that are less humane. As described in the 2013 AVMA Guidelines for the Euthanasia of Animals,[6] these preferred methods include immersion in noninhaled agents such as magnesium salts, clove oil or eugenol, and ethanol. If at all possible, these methods of depopulation for aquatic invertebrates should include a second step, such as chemical exposure (eg, formalin, alcohol), physical methods (eg, maceration, destruction of brain or major ganglia), or environmental methods (eg, burial, freezing).

8.6 References

1. Fiedler H, Cooper K, Bergek S, et al. PCDD, PCDF, and PCB in farm-raised catfish from Southeast United States—concentrations, sources, and CYP1A induction. *Chemosphere* 1998;37:1645–1656.
2. Hayward DG, Nortrup D, Gardner A, et al. Elevated TCDD in chicken eggs and farm-raised catfish fed a diet with ball clay from a southern United States mine. *Environ Res* 1999;81:248–256.
3. Rappe C, Bergek S, Fiedler H, et al. PCDD and PCDF contamination in catfish feed from Arkansas, USA. *Chemosphere* 1998;36:2705–2720.
4. Burns K. Events leading to the major recall of pet foods. *J Am Vet Med Assoc* 2007;230:1600–1620.
5. Reimschuessel R, Gieseker CM, Miller RA, et al. Evaluation of the renal effects of experimental feeding of melamine and cyanuric acid to fish and pigs. *Am J Vet Res* 2008;69:1217–1228.
6. AVMA. AVMA guidelines for the euthanasia of animals: 2013 edition. Available at: www.avma.org/KB/Policies/Documents/euthanasia.pdf. Accessed Feb 7, 2019.
7. AVMA. AVMA guidelines for the humane slaughter of animals: 2016 edition. Available at: www.avma.org/KB/Resources/Reference/AnimalWelfare/Documents/Humane-Slaughter-Guidelines.pdf. Accessed Feb 7, 2019.

9: Free-Ranging Wildlife

9.1 General Considerations

Free-ranging wildlife inhabit a variety of settings. In addition to the anatomic, physiologic, and behavioral considerations discussed in earlier sections concerned with domestic animals, multiple other factors must be considered when depopulation of free-ranging wildlife is attempted. Access to these animal populations may be limited due to terrain and habitat, proximity of human occupancy, and lack of habituation to human presence. As with domestic animals, decisions to depopulate are based on values and objectives of decision-makers and the public. These values and objectives are the basis for determining when there are compelling reasons to terminate wildlife lives in an expedited manner. Reasons to terminate wildlife may include infectious disease that poses a risk to the wildlife species or other species or risk to human safety or the environment (including other wildlife species that are threatened or endangered) is occurring or imminent. Unlike domestic animals that are contained in settings where humans are completely responsible for their welfare, it is much less likely that depopulation of free-ranging wildlife will be justified owing to catastrophes, as these are considered natural events affecting natural populations. Wildlife depopulation objectives are also unlikely to be achieved within short periods of time.

Regardless of the justification, the absence of confinement and the frequent inability to identify all individuals present practical constraints for applying depopulation methods to free-ranging wildlife and may justify methods that are unacceptable under other more controlled circumstances. In addition, the practical challenges of working with wildlife often require that more than one method be employed to achieve objectives. Visual barriers should be established where feasible to minimize the potential to disconcert members of the public who are not familiar with the procedures and why they are being done, or where observers would be emotionally distressed for any reason. Perceived or real public perception should be a major consideration in planning and execution of wildlife depopulation.

Free-ranging wildlife, and thus their depopulation, may be governed by multiple legal entities. Many states have legal authority over some free-ranging wildlife species, but other species may be regulated by federal or international law, such as the Migratory Bird Treaty Act. Furthermore, federal, state, local, and tribal laws may not coincide. Consequently, all borders must be considered as a part of depopulation programs, as populations of free-ranging wildlife do not recognize such boundaries, and jurisdictional regulations may differ significantly. In addition, method-specific legislation may need to be considered, such as jurisdictions where firearm regulations exist.

9.1.1 Environmental considerations

Disposal of carcasses can pose substantial concerns for depopulation of free-ranging wildlife. Use of injectable agents, lead-based ammunition, and certain toxicants poses a risk of secondary toxicity to nontarget species in cases of inappropriate carcass disposal. Large numbers of decomposing carcasses may also pose environmental hazards, such as ground water contamination with excess nitrates.

9.1.2 Population considerations

Depopulation of free-ranging wildlife has a less certain outcome than depopulation of wild or domestic animals in confined settings where all individuals can be identified. The size of a free-ranging wildlife population is often uncertain, and many terrains provide hiding locations that prevent identification of all individuals. Thus, it can be unclear how many animals need to be removed to achieve depopulation. Free-ranging wildlife population boundaries are often poorly delineated. As a consequence, individuals from neighboring populations may immigrate into and repopulate a location, potentially undermining the reasons for depopulation. Achieving the depopulation goal of 100% mortality is challenging because of these practical, spatial, and temporal considerations. Personnel need to use depopulation methods that do not promote dispersal of animals when dispersal would undermine program objectives.

9.1.3 Preparation

Lack of preparation cannot be used as a justification for use of less optimal or less humane methods of depopulation. Organizations and individuals need to anticipate and prepare for emergencies as well as prioritize options and responses in advance. This includes addressing training, equipment, legal permissions, supervision and oversight of activities, and emergency response structure and plans.

9.1.4 Wildlife capture

Assessments of methods to depopulate wildlife must consider how animals will be captured. Capture may entail methods that result in death (shooting or body-gripping traps) or a live capture that subsequently requires administration of a method that results in death. Multiple factors in choosing capture method must be considered, including capture that results in immediate or rapid death versus the level of stress associated with live capture before death, escape of potentially injured or infectious animals, the importance of recapture of escaped animals to meet depopulation goals, humaneness of capture, logistics, and personnel expertise and other resource availability.

9.2 Birds

9.2.1 General considerations

There are over 9,000 species of birds in the taxonomic class Aves, representing orders such as passeriformes (songbirds), anseriformes (waterfowl), galliformes (grouse, turkeys) and accipitriformes (hawks, eagles). While all birds have some characteristics in common such as feathers and a unique respiratory system, they have a broad range of anatomic, physiologic, and ecological adaptations. Many species flock in large numbers, while others are mostly solitary. Laws protecting birds may need to be addressed before wild birds are handled or depopulated. Endangered and threatened species are protected by the Endangered Species Act and may be regulated by the CITES. Almost all wild bird species in the United States are covered by the Migratory Bird Treaty Act and are regulated by the US Fish and Wildlife Service, state wildlife agencies, or other regulatory authorities. Urban birds may also be subject to county, city, and municipality regulations.

9.2.2 Events necessitating depopulation

Free-ranging birds are highly unlikely to require depopulation in an emergency situation to protect human or domestic animal health. While wild birds may serve as reservoirs for some pathogens impacting humans or domestic animals, depopulation is not considered an appropriate tool for controlling a wildlife reservoir, as effectiveness of disease containment and eradication in wild bird populations is largely untested. Local depopulation may be attempted as a control mechanism in a wild bird disease epidemic to prevent pathogen spread. Such a depopulation event requires significant planning and preparedness, including plans for carcass removal and disposal as well as addressing potential adverse environmental effects. Tools used to reduce populations during an outbreak need to consider the risks of inadvertent bird dispersal and spread of the infectious agent.

9.2.3 Implementation of depopulation techniques

9.2.3.1 Methods of capture

Capture of birds will vary depending on habitat and species' natural history. Knowledge of target species' natural biology is important in planning an approach to trapping and capture. Trained personnel are required to ensure humane trapping and safety for birds and people. It is very often challenging to capture more than a representative part of the population.

Direct capture—The use of nets over bait may be useful in capturing birds. Prebaiting is typically required to maximize efficacy of capture techniques. Drop nets, cannon nets, rocket nets, and walk-in traps may be used. In aquatic settings, swim-in contraptions such as funnel traps may be used for waterfowl.[1,2]

Sedation—Many species can be sedated with α-chloralose for live capture. Capture rates of 80% to 86% of targeted populations have been recorded.[3] α-Chloralose comes in a powder or pill form that is formulated with appropriate bait for the target species. As immobilization typically occurs 30 to 90 minutes after ingestion, the plan must ensure that the birds will remain accessible when they become sedated.

Dispersal of a chemically restrained animal triggered by the sympathetic nervous system (fight or flight) should be avoided. Ambient temperature should be considered owing to birds' loss of thermoregulatory capacity when sedated. If sedated birds are to be held or transported before depopulation, adequate holding should be available to prevent death from overcrowding of immobilized animals.

The effective dose for α-chloralose ranges from 15 to 180 mg/kg (6.8 to 81.8 mg/lb), depending on the species.[3] While low mortality rates are seen at recommended dosages, α-chloralose has a relatively narrow safety margin in birds, and individuals may easily receive a lethal dose depending on the species, the percentage of the α-chloralose in the bait, and the amount of bait consumed by the bird. Prebaiting is required,[4] and birds should be treated over dry land, as α-chloralose will dissolve and not be ingested in an aquatic setting. Aquatic settings also present a risk of drowning for immobilized birds.

9.2.3.2 Preferred methods

Inhaled agents—These include inhaled anesthetics, CO_2, and the inert gases nitrogen and argon.

Use of inhaled agents to terminate life requires that birds first be captured. Inhaled agents may not be appropriate for diving birds with a high tolerance for anoxia, unless given at high concentrations at an extended exposure time or with a secondary method.

Physical methods—Individual birds can be euthanized with physical methods according to the AVMA Guidelines for the Euthanasia of Animals.[5] These methods include cervical dislocation, decapitation, exsanguination, and blunt force trauma. If performed correctly by skilled personnel, these methods result in rapid death, avoid toxic residues in carcasses, and can be conducted with readily available equipment. These methods may be aesthetically displeasing, require training to meet expectations of proficiency, and may be difficult to employ in larger or very fractious birds.

Injectable agents—The method employs an overdose of an injectable anesthetic (IV or IM), barbiturates, or T-61. Noninhaled agents are rapidly acting and aesthetically acceptable, with easy administration in most birds; however, using these agents requires personnel with significant training and skill, is time-consuming, and may cause significant stress, as each individual bird must be handled for depopulation. Additionally, IV administration may difficult in small birds. This method is not realistic for rapid depopulation of large flocks of birds.

9.2.3.3 Permitted in constrained circumstances

Expired injectable or inhalant anesthetic agents—In cases of limited availability of anesthetic agents, the use of expired anesthetic agents may be considered.

Surfactants—Surfactants can be sprayed by helicopter at night to humanely kill flocks of birds. These agents must be used when temperatures are below 10°C or 50°F and preferably under conditions with precipitation.[6] Surfactants are advantageous to kill large numbers of birds quickly. Their use requires specific meteorologic conditions and special equipment and skills and may present hazards to nontarget animals.

9.2.3.4 Not recommended

Oral agents—Starlicide with the active ingredient DRC 1339 (3-chloro-4-methyl benzenamine HCl) is a toxicant delivered in bait or feed appropriate to targeted species. It has substantial variation in toxicity among species, with LD_{50} ranging from 1 to 10 mg/kg (0.45 to 4.5 mg/lb) to 100 to 1,000 mg/kg (45.5 to 454.5 mg/lb). Death may be delayed for 1 to 3 days, which potentially allows birds to disperse or die in public view.[7] DRC 1339 is easily delivered in bait and carries minimal secondary risk to predators other than owls. Typically, birds must be prebaited and conditioned to baited areas, and careful bait selection and monitoring of the application is important to prevent consumption by nontarget species. If delivered correctly, starlicide can achieve local depopulation.

Gunshot—Gunshot is a capture method that results in death. Shooting birds in flight should be used only under rare circumstances where the justification is overwhelmingly compelling, owing to the challenges of humane death. Additionally, gunshots used with free-ranging birds will more likely result in dispersal than depopulation. Shooting birds sleeping at night roosts has been found to be effective for depopulation. If shooting must occur, personnel must be trained and proficient in the appropriate use of firearms for birds and must follow local firearm regulations.

9.3 Bats

9.3.1 General considerations

Bats are mammals in the order Chiroptera. Many of the 45 bat species native to the United States are considered vulnerable, with other species threatened or endangered. Federally, only bats listed in the Endangered Species Act are afforded protection. Laws regulating bats vary by state; thus, either the US Fish and Wildlife Service or state wildlife officials may need to be contacted before depopulation is considered.

9.3.2 Events necessitating depopulation

Bats are highly unlikely to require depopulation, as they do not pose a substantive risk for introduction of infectious agents to large populations of humans or domestic animals in the United States.[8] Bats may carry some zoonotic diseases, such as rabies and histoplasmosis; however, it is highly unlikely that a colony of insectivorous bats will have enough contact with humans or domestic animals to cause a public health emergency.[8,9]

While some bat species often roost in buildings and other structures, it is generally recommended not to disturb the colony if the bats do not come into contact with humans and are not harming the property. If bats are deemed a hazard to humans, domestic animals, or property, humane exclusion is usually the most effective action. Humane exclusion does not require euthanasia or trapping.[10] Recommendations for conducting humane exclusions can be found from reputable sources such as Bat Conservation International and National Wildlife Control Operators Association Bat Standards.[10]

9.3.3 Implementation of depopulation techniques

9.3.3.1 Methods of capture

Capture of bats is limited to direct capture methods, using mist nets, traps built for bats, or gloved hands and a box. Individuals capturing bats should wear appropriate PPE such as gloves and a properly fitted respirator capable of filtering particulates (N-100 or similar rating) in areas that are prone to *Histoplasma capsulatum*, the fungus that causes histoplasmosis.

Picking up a bat—A bat found in a building or a downed bat can be picked up with leather gloves. A single wild bat can also be captured with a small cardboard or plastic box that is used to cover the bat. Slide a thin piece of cardboard or paperboard between the surface and the box to trap the bat inside and secure the box with a lid that is taped down.

Mist nets—Mist nets can be set up to trap wild bats. However, mist nets are recommended only to survey and capture individual bats for biological research. Mist nets are not appropriate for excluding bats from buildings. Bat mist nests should be monitored so that caught bats can be quickly handled to minimize injury and pain.

Trapping—If bats in a building must be trapped, a trap can be fashioned by making a cage from 1/4-inch hardware cloth lined with window screen. Cut a hole in the top of the cage to fit a piece of polyvinyl chloride pipe. Insert the polyvinyl chloride into the cage. Place the pipe vertically above the cage or at an angle leading down to the cage so that bats drop in. The bats will not be able to climb up the pipe, as they cannot grip the smooth surface.[11]

9.3.3.2 Preferred methods

Overdose of inhalant anesthetic agents—Halothane and isoflurane are recommended by Lollar.[12] With high concentrations and prolonged exposure, these and other inhaled anesthetic agents produce rapid anesthesia and death, with minimal apparent distress. Using a cotton ball soaked in anesthetic placed into a small tube, syringe case, or airtight container or bag as an induction chamber will minimize handling and distress to the bats. Death is usually achieved in 1 to 2 hours and must be confirmed before removal from the inhalant agent.

9.3.3.3 Permitted in constrained circumstances

Injectable agents—Overdoses of the injectable anesthetics xylazine or sodium pentobarbital (euthanasia solution) may be used to terminate bats. Bats should first be sedated.[13] Lollar[12] recommends sedating bats using acepromazine and butorphanol tartrate. Xylazine overdose may then be given SC or sodium pentobarbital may be administered into the peritoneal cavity. Place the bat in a dark, contained area until death is confirmed.

Expired injectable anesthetic agents—In cases of limited availability of injectable agents, the use of expired anesthetic agents may be considered.

9.3.3.4 Not recommended

Physical methods—No physical methods are acceptable for euthanizing bats, and such methods should be avoided where possible during depopulation events. Of note, torpid, unconscious bats may wake during attempted freezing; thus, freezing should be avoided where possible.[12]

Gunshot—Shooting is not an appropriate method for killing microchiroptera. Shooting small bats weighing 5 to 15 g (0.2 to 0.5 oz) and flying in erratic patterns would be difficult.

Pesticides, baits, and fumigants—These should not be used on bats. None are approved for killing or capturing bats.

9.4 Carnivores

9.4.1 General considerations

Carnivores are mammalian predators with teeth used for the capture and killing of prey animals and the tearing and slicing of animal flesh.[14] In North America, carnivores vary in size from the 57-g (2.0-oz) least weasel (*Mustela nivalis*) to the 950-kg (2,090-lb) grizzly bear (*Ursos arctos*[14]). Carnivores are categorized into groups based on size, which correlates with behavioral and habitat needs. Large carnivores, such as bears (*Ursus* spp), wolves (*Canis lupus*), mountain lions (*Puma concolor*), and coyotes (*Canis latrans*), require large areas for their home range. Mesocarnivores (carnivorous animals whose diet consists of 50% to 60% meat) typically weigh < 15 kg (33 lb)[15] and include raccoons (*Procyon lotor*), striped skunks (*Mephtis mephitis*), dogs (*Canis domesticus*), and house cats (*Felis catus*).

Carnivores may conflict with human interests in a variety of ways, including by predation on humans, domestic animals, or rare species; by acting as vectors of zoonotic and other diseases; and by causing damage to agriculture and structures. As apex predators, large carnivores are relatively rare in the habitat and thus are unlikely to have significant enough public and animal health impacts to require mass depopulation. Where depopulation is required, management strategies for killing dozens of large carnivores in a large geographic area would likely be very similar to those for conducting a large number of individual hunting or euthanasia events. Mesocarnivores pose the greatest risk of disease transmission and other negative impacts to human interests and are more likely candidates for depopulation than are larger and smaller species, although depopulation of mesocarnivores is likely to be challenging to achieve.

9.4.2 Events necessitating depopulation

Depopulation of these carnivores may be justified during disease outbreaks to prevent the spread of the infection to naïve populations or to protect threatened or endangered species.

Those seeking to initiate depopulation of a carnivore species confront many challenges. Perhaps the most significant is the size and complexity of the landscapes in which carnivores may reside. Carnivores' use of various landscapes means that traps must frequently be used, increasing the risk of injury and death to nontarget animals.

The high mobility of carnivores requires control efforts to be performed quickly and over a large area to ensure that the targeted carnivores are in fact removed.

9.4.3 Implementation of depopulation techniques

9.4.3.1 Methods of capture

Trapping—Trapping involves the use of devices capable of capturing animals without the direct presence of humans. Devices are broadly categorized as live restraining traps (including cage or box traps, footholds, encapsulated-foot traps, and cable-restraints[16]) and lethal traps (body-gripping–style traps, such as double- and single-bar striking traps and snares[2,17]). Trapping of carnivores is heavily regulated, and trappers must adhere to regulations and best practices.[18,19] Careful selection of and modification or adjustment of traps by adequately trained, experienced personnel can substantially reduce injuries and nontarget captures to improve efficiency and humaneness.[2,20,21] Trapping poses minimal environmental risks, as it does not introduce toxins. Trapping is more efficient than hunting for small to medium carnivores. Traps must be checked regularly, requiring a significant personnel time investment or financial investment in remote sensing technology (eg, TrapSmart system[a]), and some devices may pose significant injury risks to users and nontarget animals. New technology is being developed that allows for traps that capture, kill, and then reset (eg, Goodnature traps[b]).

9.4.3.2 Preferred methods

Gunshot is a commonly used, effective method for humanely killing carnivores and is the preferred method for removing large carnivores from open landscapes. Shooting may be used in a variety of ways, including aerial hunting, hunting over bait, hunting with thermal imaging or spotlighting, hunting with dogs, and calling. Nontarget take is extremely rare with shooting, and appropriate shot placement results in minimal animal suffering. Potential disadvantages to gunshot include difficulty in accessing animals in rough terrains and the need for sufficient space to ensure human and nontarget species safety. Additionally, this may be an extremely time- and personnel-intensive method, requiring highly trained, skilled personnel to carry out correctly. Poor shot placement may result in further animal suffering, as wounded animals may flee and be difficult to locate. Adverse weather conditions may also contribute to poor shooting success, thus delaying or preventing completion of a successful depopulation effort.

9.4.3.3 Permitted in constrained circumstances

Sodium cyanide (M-44)—Sodium cyanide is a powder that is readily absorbed through mucosal membranes. The toxicant is placed in a spring-loaded ejector that, when pulled, discharges the powder.[22] Sodium cyanide, M-44 (EPA 56228-15), is registered for use on coyotes, foxes (*Vulpes vulpes*), and feral dogs (*C domesticus*). These substances are highly regulated and may generally be used only by agents of the USDA APHIS Wildlife Services, with some exceptions in the Western United States. The M-44 device is highly selective, efficient, and effective to target wild canids because the device takes advantage of natural canine biting and pulling behavior that is required to expose the animal to the bait. Most coyotes that trigger the device die within 31 yards.[22] Hooke et al[23] found that wild dogs exposed fully to the toxic powder experienced cerebral hypoxia in 156 seconds. Connolly et al[24] found that coyotes died on average within 127 seconds of pulling the ejector.

The M-44 device must be used with care, as exposed nontarget animals and humans may be injured or killed by this toxicant. Additionally, partial doses may cause injury to target animals and prolong suffering, possibly cause death, or allow recovery from nonlethal doses. Though not registered for use against all carnivores, sodium cyanide may be considered appropriate for emergency use.

Fumigants—Ignitable gas cartridges contain carbon and sodium nitrate that, when ignited, emit carbon monoxide gas.[25,26] These cartridges are used to kill denning carnivores, such as coyotes, red foxes, and skunks. The EPA-registered product 56228-62 may be used for coyotes, red foxes, and skunks. The EPA-registered product 10551-1 may be used for skunks. Both are general-use pesticides and do not require a pesticide license to use. These fumigants are easy to use and do not produce secondary toxicosis to nontarget species. They work best when the soil is moist to reduce the amount of toxic gas that escapes into the surrounding soil. Though not registered for use against all carnivores, ignitable gas cartridges may be considered appropriate for emergency use if the EPA grants an exemption to the restrictions on the label.

Ignitable cartridge use is labor-intensive. Burrows must be located and treated individually. Burrows must also be secured to ensure as much gas as possible remains inside. Care must be taken to avoid smothering the burning cartridge with soil, as this will reduce the amount of toxic gas emitted. Many products have use restrictions that hinder their use in areas with human structures. Care must be taken to avoid treating dens of nontarget animals. Fire safety is essential, as ignitable cartridges may cause fires. Time to death may be prolonged, with adult coyotes requiring 17 to 48 minutes and pups 4 to 14 minutes.[25] Time to death is reduced with higher concentrations of carbon monoxide gas.

Aluminum phosphide is a solid fumigant that, when exposed to moisture, releases toxic phosphine gas. The precise mechanism by which the fumigant kills is not clear, but there is evidence that phosphine gas is cardiotoxic.[27] It is registered under various EPA numbers (eg, 72959-4, 72959-5) and is a restricted-use product because of its potential for causing toxicosis. Though it is not registered for use against carnivores, aluminum phosphide may be considered appropriate for emergency use.

Aluminum phosphide carries lower fire risks than ignitable cartridges and, when used properly, is safe for applicators.[28] It is also heavier than air.[29] Other challenges of fumigants mentioned here also apply to aluminum phosphide.

Overall, fumigants are less efficient than toxicants but more efficient than trapping and shooting. They should be considered in situations where burrowing carnivores need to be controlled but traps and shooting would be too costly.

9.4.3.4 Not recommended

Sodium flouroacetate (compound 1080)—This compound is a toxicant formulated with bait that is capable of killing carnivores. It is highly toxic, efficient, and relatively inexpensive. Sodium flouroacetate is not presently registered by the EPA for control of carnivores except for livestock protection collars. Secondary toxicity to nontarget animals is a significant concern when using these baits. Sodium flouroacetate is not a first choice for control of carnivores in need of depopulation, owing to the number of collars needed and because a substantial proportion of the carnivores must have contact with the collars to meet depopulation objectives. However, this product may be considered if there are no other viable alternatives.

9.5 Marine Mammals

9.5.1 General considerations

Marine mammals include pinnipeds (seals and sea lions), odontocetes (dolphins and whales), mysticetes (baleen whales), sirenians (manatees and dugongs), sea otters (members of the family Mustelidae), and polar bears (members of the family Ursidae). For the purposes of this section, methods applicable to sea otters and polar bears will be found in the carnivore section of this document. The remaining marine mammal taxa share anatomic and physiologic adaptations for living in aquatic environments. Many of these species are threatened or endangered. Laws applicable to marine mammals in the United States that may need to be addressed before handling or terminating marine mammals include the CITES, the Marine Mammal Protection Act, and the Endangered Species Act. United States regulatory agencies that may have a role in enforcing these and other laws include the National Marine Fisheries Service (National Oceanic and Atmospheric Administration, Department of Commerce), US Fish and Wildlife Service (Department of the Interior), and state wildlife and fisheries agencies.

9.5.2 Events necessitating depopulation

Free-ranging marine mammals are highly unlikely to require depopulation because they are unlikely to be a substantive risk for introduction of infectious agents to humans or domestic animals. There are also unlikely to be environmental justifications for depopulating free-ranging marine mammal populations; it is anticipated that rehabilitation or individual euthanasia methods would be applied to marine mammals exposed to environmental hazards such as oil spills. In addition, many populations are threatened or endangered, and further reductions in populations are unlikely to be justified. Other than commercial harvesting methods, there are no established methods for large scale killing of marine mammals. Even in instances where multiple marine mammals are stranded and termination of life is required as a humane measure, animals can generally be managed as individuals.

Methods of euthanasia applied to marine mammals are generally limited by the animal's large size, tolerance for anoxia (as an adaptation for prolonged periods underwater without respiration), and disposal concerns, including avoiding cases of secondary toxicosis where drug residues may be present. Furthermore, the difficulty of accessing and appropriately administering large volumes of medications, and risks to personnel from animal movement and rough surf, present substantive challenges. Public perception of depopulation of marine mammals is unlikely to be favorable, and selection of depopulation methods may need to account for these perceptions.[30]

9.5.3 Implementation of depopulation techniques

9.5.3.1 Methods of capture

Capture of marine mammals in open waters is challenging, whereas capture in shallow inland waters can be more practical when trained personnel are available. Animals that are stranded do not require capture, but hazards to humans such as strong surf and currents may be present. Capture methods are limited to direct capture and firearms.

Direct capture—This method is limited to use of nets unless animals are beached or contained in small natural areas. Use of nets requires specialized equipment and skilled personnel. Capture with nets can be difficult to accomplish and can pose significant safety risks to personnel.

Gunshot—Gunshot is a method of capture that ideally results in rapid death. Gunshot may not always result in rapid marine mammal deaths because it can be difficult to apply under field conditions owing to uncertainty or inability to target vital anatomy. Additionally, firearm-specific regulations and risks to personnel and public observers must be considered. Gunshot is not recommended for cetaceans greater than approximately 7 m in total length.[31]

9.5.3.2 Preferred methods

Noninhaled anesthetic agents—Overdoses of injectable anesthetics may be used to terminate the lives of marine mammals.[5,32–35] These agents can be administered IV or, in some cases, IM, or they can be administered via the blowhole (mucocutaneously).[34] Injectable anesthetics act readily and are generally aesthetically acceptable, and administration can be straightforward.

In some cases, however, injectable anesthetic agents can be difficult to administer effectively. Normal anatomy and physiology, along with disease states (eg, hypovolemic shock), provide limited access to peripheral veins in many marine mammals. Fat layers may hinder access for IM injections, and accessing fluke or caudal peduncle veins can be hazardous in large animals. Availability of resources may be significantly limited, as large volumes of drugs are required to euthanize even one marine mammal. Potassium chloride and succinylcholine are examples of injectable adjunctive methods that can decrease the amount of euthanasia agent required.[32,36] Other considerations include environmental contamination by carcasses and secondary toxicity to nontarget species, possible aesthetically displeasing and potentially unsafe excitation phases of anesthesia, and the possibility of injury to personnel by unrestrained animals or exposure to agents.

When trained personnel, sufficient agent, safe conditions, and safe disposal are available, injectable agents can be effective for euthanasia of marine mammals. The deep IM administration of midazolam, acepromazine, and xylazine, followed by intracardiac saturated KCl, resulted in acceptable euthanasia of mysticetes, with relatively low cost and minimal risk of relay toxicosis, although safe disposal of xylazine IM injection sites would be prudent.[35] Drug delivery well away from the flukes resulted in reduced risk to personnel. Stepwise administration of anxiolytic, sedative, analgesic, and anesthetic drugs, by decreasing responsiveness, further reduced personnel risk leading up to intracardiac needle insertion. Midazolam could be omitted if controlled drugs are unavailable. Appropriately sized needles are required for intracardiac injection. Logistic constraints and limited agent availability can present challenges for use of injectable agents when multiple marine mammals are stranded.

Physical methods—These methods include gunshot, manually applied blunt force trauma, and implosive decerebration.[5,36–44] Physical methods have the advantage of inducing rapid death while avoiding toxic residues in carcasses. These methods can generally be conducted with readily available equipment.

Each of the physical methods requires an accurate understanding of anatomic landmarks, trained personnel with appropriate levels of technical expertise, and safe use of equipment. Tissue destruction can hinder postmortem investigations. Improperly applied, gunshot and implosion can escalate rather than alleviate suffering. Blunt force trauma is limited to use on small juvenile marine mammals. Gunshot and implosive decerebration require compliance with regulations and attention to safety for other animals, personnel, and the public. These methods are often aesthetically displeasing.

9.5.3.3 Permitted in constrained circumstances

Expired injectable anesthetic agents—In cases of limited availability of injectable agents, the use of expired anesthetic agents may be considered.

9.5.3.4 Not recommended

Inhaled agents—Use of inhaled agents alone to terminate life is generally not practical to for marine mammals, owing to the large amounts of agent required and these species' ability to voluntarily withhold inhalation for prolonged periods.

Exsanguination—Exsanguination is best reserved as an adjunctive depopulation method, but there may be rare, unusual circumstances where exsanguination may offer the best option for depopulation of large numbers of beached animals. It is generally aesthetically displeasing and creates a large amount of organic debris for disposal.

Methods of euthanasia are generally most applicable for terminating the lives of marine mammals. In extreme unforeseen circumstances, if depopulation of cetaceans in open water were required, strategies that could be attempted include commercial whaling methods employing penthrite grenade harpoons, which have been developed to induce rapid loss of consciousness and rapid death.[45] Another strategy that can be considered is to herd marine mammals into shallower confined water, where capture can be followed by chemical or physical methods of euthanasia or humane killing. The former strategy would require deployment of industrial-scale whaling vessels available in only a few nations (eg, Norway, Iceland, Japan; subsistence-level whaling as conducted by Inupiat whalers in northern Alaska would not scale up readily) or repurposing of military vessels. Political and practical obstacles would be considerable. Herding attempts could employ Oikami pipes (a Japanese dolphin-herding technique), spraying by fire hoses, playback of alarm tones or killer whale sounds, and boat engine noise, although these methods have proven inconsistent in cetacean rescue operations.[46]

9.6 Rodents

9.6.1 General considerations

Rodents are mammals characterized by paired incisors and are the most abundant and widely dispersed group of mammals in the world.[47] In North America, rodents vary in size from the 6- to 9-g (0.2- to 0.3-oz) Merriam's pocket mouse (*Perognathus merriami*) to the 16- to 30-kg (35- to 66-lb) beaver (*Castor canadensis*[13]). Given their high reproductive potential and adaptability to a variety of environments, rodents cause significant conflicts with human interests.[48] Conflicts include crop losses,[49] acting as reservoirs and vectors of infectious diseases,[50] and damage to human-made structures and the environment.[51,52]

9.6.2 Events necessitating depopulation

An enormous of amount of effort has been expended in the control of rodents.[53] While some rodents can suffer dramatic declines with control measures (eg, beavera), as a rule, rodent populations rebound quickly following depopulation[49] owing to immigration and reproduction. Thus, if depopulation is deemed necessary, those involved must be clear about the ultimate goal and the amount of land that needs to be depopulated.

Depopulations of rodents may be required at points of disease outbreaks to prevent the spread of the infection to naïve populations of humans or other animals, to protect the environment, or to protect threatened or endangered species.

9.6.3 Implementation of depopulation techniques

9.6.3.1 Methods of capture

Trapping—Trapping involves the use of devices capable of capturing animals without the trapper being present. Devices are broadly categorized as live traps (including cage [ie, wire-mesh-walled] and box [solid-walled] traps, footholds, encapsulated-foot traps, and cable restraints)[15] and lethal traps (conibear-style traps and snares).[16] Trapping is heavily regulated only when furbearing animals, such as beavers, are targeted.[21] Careful selection of and modification or adjustment of traps by adequately trained, experienced personnel can substantially reduce injuries and nontarget captures to improve efficiency and humaneness.[2,20,21] Trapping minimizes environmental risks, as it does not introduce toxins. Trapping is efficient especially for aquatic rodents, although set variety is helpful in capturing so-called trap-wise animals. Traps must be checked regularly, requiring a significant personnel time investment or financial investment in remote sensing technology (eg, TrapSmart system[a]), and some devices may pose significant injury risks to users and nontarget animals. New technology is being developed that allows for traps that capture, kill, and then reset (ie, Goodnature traps[b]).

9.6.3.2 Preferred methods

Kill trapping—See 9.6.3.1 Methods of capture.

Gunshot—Shooting with rifles, shotguns, and air rifles is limited to the larger rodents such as beavers or colonial rodents such as prairie dogs. Shooting success may be improved with the use of bait, noise suppressors, hunting with thermal imaging, or spotlighting.[54] Nontarget take is extremely rare with shooting, and appropriate shot placement and type of bullet results in minimal animal suffering. Potential disadvantages to gunshot include difficulty in accessing animals in rough terrains and the need for sufficient space to ensure human and nontarget species safety. Additionally, this may be an extremely time- and labor-intensive method, requiring highly trained, skilled personnel to carry out correctly. Poor shot placement may result in further animal suffering, as wounded animals may flee and be difficult to locate. Adverse weather conditions may also contribute to poor shooting success, thus delaying or preventing completion of a successful depopulation effort. Technological advances in firearms equipment have increased its usefulness when rapid and targeted reductions of rodents (ground squirrel and larger) are necessary.

9.6.3.3 Permitted in constrained circumstances

Rodenticides—Rodenticides are toxic chemicals designed to kill rodents that consume them. There is extensive literature addressing the use of rodenticides.[48,55] The information that follows will be exceptionally brief **(Table 1)**.

Rodenticides are organized into two broad groups based on their mode of killing. Anticoagulant rodenticides disrupt the clotting ability of blood, causing rodents to die by internal and sometimes external hemorrhage. Nonanticoagulants kill rodents by other means.

While rodenticides are very efficient and cost-effective for killing rodents, their effects are not instantaneous. Generally speaking, zinc phosphide and strychnine can kill in 12 to 24 hours, bromethalin and second-generation anticoagulants can kill in 3 to 4 days, and first-generation anticoagulants can kill in 4 to 5 days. Delays can also be caused by the need to prebait with nontoxic grain in some circumstances, such as for zinc phosphide used for ground squirrels. It should be noted that prebaiting does not always lead to improved control.[56] For some species, the efficacy of rodenticides can vary substantially, and concern regarding nontarget toxicosis is high.[57] Some rodenticide use requires a pesticide license, and there may be restrictions on use at a location or during a certain period or both.

Ignitable gas cartridges—These cartridges contain carbon and sodium nitrate that, when ignited, emit carbon monoxide, sodium carbonate, and nitrogen gas.[25,26,58] These cartridges are used to kill denning ro-

Table 1—Comparison of the relative advantages and disadvantages of individual rodenticides.

Rodenticide	Type	Baiting required	Use	Secondary risk to birds	Secondary risk to mammals	Targets
Warfarin	Bleeding	Multiple	Struct	Slight	Low	Mice, N Rat
Chlorophacinone	Bleeding	Multiple	Struct and Ag	Slight	Highest	Mice, N Rats, Voles, PDgs, Pckt Gphrs, Grd Sq
Diphacinone	Bleeding	Multiple	Struct and Ag	Moderate	Highest	Mice, N Rats, Voles, PDgs, Pckt Gphrs
Bromadiolone	Bleeding	Single	Struct	Moderate	Moderate	Mice, N Rats
Difethialone	Bleeding	Single	Struct	Highest	Moderate	Mice, N Rats
Brodifacoum	Bleeding	Single	Struct	Highest	Highest	Mice, N Rats
Bromethalin	Nerve disruption	Single	Struct	Low	Low	Mice, N Rats
Cholecalciferol	Calcium poisoning	Multiple	Struct	Low	Low	Mice, N Rats
Zinc phosphide	Metabolism disruption	Single	Struct and Ag	Low	Slight	Mice, N Rats, Voles, PDgs, Pckt Gphrs, Grd Sq
Strychnine	Convulsive	Single	Struct and Ag	Possible	Possible	Pckt Gphrs

Ag = Agricultural. Grd Sq = Ground squirrels. Mod = Moderate. N Rats = Norway rats. Pckt Gphrs = Pocket gophers. PDgs = Prairie dogs. Struct = Structural, both inside a building and in a lawn abutting a building.

Sources: npirspublic.ceris.purdue.edu/state/state_menu.aspx?state=MT and npic.orst.edu/factsheets/rodenticides.html.

dents such as ground squirrels (*Urocitellus* spp) and prairie dogs (*Cynomys* spp). The EPA has registered at least two cartridges. The EPA-registered product 56228-61 may be used for woodchucks (*Marmota monax*), yellow-bellied marmots (*Marmota flaviventris*), ground squirrels, and prairie dogs. The EPA-registered product 10551-1 may be used for pocket gophers, Norway rats, and ground squirrels. Both are general-use pesticides and do not require a pesticide license.

Ignitable cartridges are labor-intensive, as occupied burrows must be located and treated individually. Burrows must be secured to ensure gas remains inside the burrow. Care must be taken to avoid smothering the burning cartridge with soil, as this will reduce the amount of toxic gas emitted. Products have use restrictions that hinder their use in areas with human structures. Care must be taken to avoid treating dens of nontarget animals.[58] Fire safety is essential, as ignitable cartridges can cause fires. Time to death varies depending on concentration of gas. Rats within 11 feet of the burning cartridge could die between 4 and 37 minutes.[25]

Carbon monoxide injectors—Carbon monoxide injectors use exhaust from a combustion engine. A tube or pipe inserted into a rodent burrow acts as a pathway for injecting gas into the burrow, causing death rapidly.[26,59] Several commercial products are sold, including the PERC Pressurized Exhaust Rodent Controller[c] and the Cheetah Rodent Control Machine.[d] Carbon monoxide injectors are relatively new devices that are easy to use and are faster to apply than trapping or fumigation.

These devices are not regulated by the EPA, though may be regulated by some states. Research has shown that they can be effective, but not to the expected EPA standard of 70% kill.[60,61] The efficacy of the device may increase as insights on application and improvements in the device advance. These devices have potential to impact nontarget species when incorrectly applied. Use is also restricted to rodents with intact burrows because efficacy decreases as gas dissipates.[62]

Aluminum phosphide—Aluminum phosphide is a solid fumigant that releases toxic phosphine gas when exposed to moisture. The precise mechanism by which aluminum phosphide kills is not clear, but there is evidence that phosphine gas is cardiotoxic.[27] It is registered under various EPA numbers (eg, 72959-4, 72959-5) and is a restricted-use product owing to its toxicity.

A written fumigation management plan is required before use. Aluminum phosphide carries lower fire risks than ignitable cartridges and, when used properly, is safe for applicators.[28] It is more toxic and therefore more effective than ignitable cartridges; however, it cannot be used in residential areas or within 100 feet of structures.

Sodium flouroacetate (compound 1080)—This compound is a toxicant formulated with bait that is capable of killing rodents.[63] It is highly toxic, kills efficiently, and is relatively inexpensive. As with other toxins, secondary toxicosis to nontarget species is a significant risk. Sodium flouroacetate is not presently registered by the EPA for control of rodents.

Propane-oxygen exploders—Propane-oxygen exploders mix bottled propane and bottled oxygen gases, which are injected into a burrow system and ignited.[64] Death occurs by external and internal concussion, which appears to be a humane death.[65] These devices are not regulated by the EPA and carry no secondary toxicosis to nontarget species. However, ignition carries risks of fire and injury to personnel, and concussive forces may damage underground utilities.

9.6.3.4 Not recommended

Predators such as domestic cats[66] have been touted as a natural means to control rodents. Predators are rarely species specific, may not eliminate or sufficiently reduce target populations, serve as disease vectors, and cause environmental damage, among other unintended and unwanted effects. Raptors under the guidance and control of a handler may be considered, but are unlikely to be effective for depopulation events in which many rodents must be killed. Dogs under the control of handlers may increase efficiency of identifying active burrows or flushing animals in some circumstances.

9.7 Ungulates

9.7.1 General considerations

Ungulates are typically considered game species in North America and are generally protected under state laws governing hunting. Ungulates include deer (*Odocoileus* spp), moose (*Alces alces*), elk (*Cervus elaphus*), bighorn sheep (*Ovis canadensis*), bison (*Bison bison*), and feral pigs (*Sus scrofa*). The wide range of ungulate body size is an important consideration in firearm equipment selection (firearm caliber and projectile type) to ensure a safe, predictable, humane outcome. Similarly, PCB systems must be evaluated for appropriate powder charge size for size of animal and be maintained to ensure working effectiveness. State laws and regulations apply to most ungulates in the United States, and the Endangered Species Act may be applicable to some populations. These regulations may need to be addressed before handling or terminating the lives of free-ranging ungulates. Regulatory agencies that may have a role in enforcing these and other laws include the US Fish and Wildlife Service and state wildlife agencies.

Methods of euthanasia are preferred for depopulation of ungulates, but they are not always practical under many field conditions because of difficulty in establishing restraint.

Free-ranging ungulates are primarily managed through regulated harvest methods (ie, recreational hunting) under routine conditions. Increasing harvest levels is often not a reliable means of achieving depopulation objectives, and the involvement of agency or other professionals may be required. For example, management concerns related to chronic wasting disease will likely require a professional response.

9.7.2 Events necessitating depopulation

Depopulation of ungulates may be required as a disease control strategy. This is a particular concern for infectious diseases that may impact agricultural species. Culling initiated because of damage to natural resources or human interests (structures, crops, animals) is not depopulation and is likely to be resolved by routine management strategies.

9.7.3 Implementation of depopulation techniques

9.7.3.1 Methods of capture

Capture of ungulates can be challenging and requires trained personnel. Capture methods include direct capture and gunshot.

Direct capture—Direct live capture of ungulates may be accomplished by several different approaches. Physical restraint capture methods include drop nets, Clover or box traps, corral traps, and net guns deployed from a helicopter. These methods require special equipment and trained personnel with sufficient skill to accomplish the task. Capturing ungulates can be difficult and can pose a personnel safety risk. There are varying degrees of animal stress associated with each method.[67] Alternatively, ungulates can be captured by means of remote immobilization techniques. Animals should be killed as soon as possible after being secured to minimize stress.

Gunshot—Gunshot is a method of capture that typically results in rapid death. Ideally, skilled professionals should be available who will be capable of placing shots to target brain tissue for the most rapid death. If brain tissue is needed for testing, or where conditions create uncertainty or inability to target the brain or near-brain CNS (cervical spine C1 through C3), or where a sufficient number of highly skilled professionals are not available, other vital organs (heart, lung—thoracic cavity) may be more appropriate targets. Firearms may be subject to firearm-specific regulation, and safety of personnel, public, and nontarget animals is imperative when employing this method. Firearm use is generally classified as humane killing, but can attain the status of euthanasia when used by skilled shooters.

9.7.3.2 Preferred methods

Physical methods—These methods include gunshot,[68,69] manually applied blunt force trauma, and PCB.[70] Exsanguination[5] is the only physical method that is not generally considered a euthanasia method and is best reserved as a secondary method to ensure death. Physical methods have the advantages of inducing rapid death when appropriately applied and avoidance of toxic residues in carcasses. Gunshot, PCB, exsanguination, and blunt force trauma can be conducted with readily available equipment.

Each of the physical methods requires an accurate understanding of anatomic landmarks, trained personnel with appropriate levels of technical expertise, and safe use of equipment. Blunt force trauma is limited to use on small or juvenile ungulates that are physically restrained. Gunshot requires compliance with regulations and attention to safety for nontarget animals, personnel, and the public. Considerations should be made for potential lead contamination of carcasses.[71,72] Ammunition that does not contain lead is preferable, where possible. Tissue destruction at the site of impact can hinder postmortem investigations for targeted organs. Penetrating captive bolt equipment must be well maintained and clean to ensure proper action. Applying physical methods to large numbers of animals can be logistically difficult to accomplish, particularly if there are time constraints. Unrestrained animals can injure personnel. These methods may be considered aesthetically displeasing. Improperly applied, physical methods can escalate rather than alleviate suffering, and landmarks for some species are not well described.

Expired injectable anesthetic agents—In cases of limited availability of injectable agents, the use of expired anesthetic agents may be considered.

9.7.3.3 Permitted in constrained circumstances

Injectable anesthetic agents—Overdoses of injectable anesthetics may be used to terminate the lives of ungulates,[5,73] but carcasses cannot be used for consumption. Because of tissue residues, noninhaled agents are not considered acceptable for depopulation by most state wildlife agencies; however, in an emergency situation, this method may be considered. Intramuscularly administered succinylcholine chloride has been evaluated for use in free-range deer and can be used as an immobilizing agent if promptly followed by use of a captive bolt or other method to cause a rapid death.[70] Meat is not fit for human consumption after exposure to unregistered chemical agents such as succinylcholine, but succinylcholine does not result in environmental contamination or have secondary toxicosis concerns, in contrast to other injectable agents.

Injectable anesthetics act readily and are aesthetically acceptable, and administration can be straightforward if animals are controlled properly. However, they can be difficult to administer effectively if an animal is not adequately restrained, and large volumes of drugs may be required. Other considerations include environmental contamination by carcasses and secondary toxicosis to nontarget species, possible aesthetically displeasing and potentially unsafe excitation phases of anesthesia, and the fact that personnel can be injured by unrestrained animals and exposure to agents.

When trained personnel, sufficient agent, safe conditions, and safe disposal are available, injectable agents can be effective for depopulation of ungulates. However, these conditions can be difficult to meet when large numbers of ungulates must be depopulated.

Toxicants—While there are currently no registered toxicants for free-ranging ungulates in the United States, Lapidge et al[74] and Shapiro et al[75] have reported on the progress of the development of the toxin sodium nitrite as a potential toxicant for free-ranging wild swine in Australia and United States. Sodium nitrite is considered a humane toxicant because it causes 20 to 30 minutes of mild clinical signs (including ataxia and labored breathing), unconsciousness, and death.[74] It is currently undergoing field trials and research in the United States.[74]

Sodium nitrite can be remotely delivered through automated feed-dispensing systems[74] that are designed to increase the selectivity toward feral swine and decrease bait distribution to nontarget species. Remotely delivered sodium nitrite has the potential advantage of being able to be delivered to large numbers of feral swine with minimal cost and manpower. Secondary toxicosis to other species consuming poisoned ungulates is considered to be minimal[74]; however, nontarget species are susceptible to sodium nitrite poisoning if bait is consumed directly. The use of a species-specific delivery system is critical for using sodium nitrite.[74]

9.7.3.4 Not recommended

Inhaled agents—Use of inhaled agents alone to terminate the life of an ungulate is generally not practical owing to the large amounts of agent required and the stress of physical restraint for use of these agents. It is possible to use these agents for neonate depopulation, as physical restraint is more easily accomplished in these small ungulates.

9.8 Reptiles and Amphibians

9.8.1 General considerations

Reptiles and amphibians represent two diverse classes of animals. (Recently, herpetofauna has undergone an extensive taxonomic appraisal. The class Amphibia remains unchanged, and the former class Reptilia has been reorganized as three distinct taxonomic classes. The class Chelonia includes all turtles and tortoises; class Reptilia contains tuatara, lizards, and snakes; and class Eusuchia has been assigned for all crocodilians [crocodiles and alligators]. While these changes have been embraced by the Center for North American Herpetology, they have not been internationally acknowledged.) Reptiles include four main orders: Crocodilia (crocodiles and alligators), Rhynchocephalia (tuataras), Squamata (lizards and snakes), and Testudines (turtles and tortoises). Amphibians include three main orders: Anura (frogs and toads), Caudata (salamanders), and Gymnophiona (caecilians). These groups represent a diverse range of anatomic, physiologic, and ecological adaptations. Many of these species are threatened or endangered and may be regulated by the CITES, the US Fish and Wildlife Service (Department of the Interior), states, or other regulatory authorities. Species such as cane toads (*Rhinella marina*), bullfrogs (*Lithobates catesbeianus*), and Burmese pythons (*Python bivittatus*) pose ecological and other risks where they have become invasive pests.

9.8.2 Events necessitating depopulation

Most free-ranging, native indigenous reptile and amphibian species are unlikely to require depopulation. This is because reptiles and amphibians are unlikely to be a substantive risk for introduction of infectious agents to humans or domestic animals. Some species pose toxin or physical trauma risks to humans and other animals. There may be scenarios where depopulation is warranted for controlling infectious disease that is limited to reptiles or amphibians (eg, *Batrachochytrium dendrobatidis* or *Ophidiomyces ophiodiicola*), but justification for this has not currently been established.

9.8.3 Implementation of depopulation techniques

Methods of depopulation applied to reptiles and amphibians can be limited by the animal's anatomy (such as Testudines' shells); size (for mature individuals of large species); tolerance for anoxia; and disposal concerns, including avoiding cases of secondary toxicosis where drug residues may be present.[30,76,77] Furthermore, the difficulty of determining whether death has occurred often requires the use of secondary methods to ensure death.

9.8.3.1 Methods of capture

Capture of reptiles will vary for terrestrial and aquatic settings and by species' natural history.

Direct capture—A range of traps (pitfall, drift fence, aquatic funnel, hoop), nets, hook and line capture for alligators, seines for amphibian larval forms, or methods of hand capture (snake tongs, snares) may be useful for capturing reptiles or amphibians. Daily or more frequent trap monitoring is a standard expectation.[78] Capture of mature individuals of large species and those that pose toxin or other risks requires appropriate equipment and trained personnel and can pose a personnel safety risk.

Gunshot—This is a method of capture that results in death. Ideally, a gunshot will target brain tissue for a quick death, but this may not occur under field conditions where there is uncertainty or inability to target vital areas. Furthermore, firearms may be subject to firearm-specific regulation, can be a risk to personnel, and are generally classified as humane killing.

9.8.3.2 Preferred methods

Methods of euthanasia as described in the AVMA Guidelines for the Euthanasia of Animals[5] or the AVMA Guidelines for the Humane Slaughter of Animals[79] are generally most applicable for terminating the lives of reptiles and amphibians.

Immersion—Immersion in water treated with anesthetic agents (buffered MS-222, benzocaine) can be used to euthanize some aquatic species or stages (tadpoles) of reptiles and amphibians.[76] Piscicides such as Rotenone may also be of value for causing death in aquatic amphibians.[80]

Immersion agents act readily, are aesthetically acceptable, and administration can be straightforward. Anesthetic agents may be difficult to obtain in sufficient volume for use in some bodies of water and pose a contamination risk for treated water. These agents may be less likely to be effective for species with keratinized integuments with reduced permeability (eg crocodilians). Toxicosis to non-target species and environmental contamination of carcasses may be difficult to prevent. In addition, aesthetically displeasing and potentially unsafe excitation phases of anesthesia are possible with immersion agents. Furthermore, exposure to immersion agents is a safety concern for personnel. Secondary methods may be needed to ensure death.

Injectable anesthetic agents—Overdoses of injectable anesthetic agents can be used to end the lives of reptiles and amphibians. These anesthetics act readily, are aesthetically acceptable, and administration can be straightforward in some cases. Injectable anesthetic agents can be difficult to administer effectively because of limited access to peripheral veins in many species, although intracardiac administration can be appropriate for some species.[81] Reptile and amphibian anatomy (chelonian shell, thickly keratinized scales) can limit access for IM or intracoelomic administration, aesthetically displeasing and potentially unsafe excitation phases of anesthesia are possible, and personnel can be injured by unrestrained animals and exposure to agents. In addition, injection of large numbers of animals can be logistically difficult to accomplish, particularly if there are time constraints. Possible environmental contamination by carcasses and secondary toxicosis must also be considered when injectable anesthetics are used.

When trained personnel, sufficient agent, safe conditions, and safe disposal are available, injectable agents can be effective for euthanasia of reptiles and amphibians. However, these conditions can be difficult to meet when large numbers of animals must be addressed.

9.8.3.3 Permitted in constrained circumstances

Expired injectable anesthetic agents—In cases of limited availability of injectable agents, the use of expired anesthetic agents may be considered.

Physical methods—Physical methods of euthanasia include gunshot, double pithing, blunt trauma to the brain followed by double pithing to confirm death, PCB,[82] decapitation, and exsanguination.[5] Exsanguination is not generally considered a euthanasia method for reptiles and amphibians owing to these species' tolerance for anoxia, but may be useful as an adjunctive method to ensure death in insentient animals. Similarly, decapitation generally warrants a secondary method to destroy brain tissue, and pithing of sentient animals does not meet euthanasia standards.

Physical methods that destroy brain tissue have the advantages of inducing rapid death and avoidance of toxic residues in carcasses. Gunshot, blunt trauma to the brain followed by double pithing to confirm death, decapitation, and exsanguination can be conducted with readily available equipment.

Each of the physical methods requires an accurate understanding of anatomic landmarks, trained personnel with appropriate levels of technical expertise, and safe use of equipment. Tissue destruction can hinder postmortem investigations. Improperly applied, physical methods can escalate rather than alleviate suffering, and landmarks for some species are not well described. Penetrating captive bolt equipment must be well maintained and clean to ensure proper action. Gunshot requires compliance with regulations and attention to safety for other animals, personnel, and the public. Applying physical methods to large numbers of animals can be logistically difficult to accomplish, particularly if there are time constraints. Personnel can be injured by unrestrained animals. These methods may be considered aesthetically displeasing.

Inhaled agents—Use of inhaled anesthetic agents and gases such as CO_2 to terminate life is generally not practical for reptiles and amphibians because of their ability to hold their breath and their tolerance for anoxia.[76] This can result in prolonged procedures, but may be useful under some conditions where animals are in containers and where time is not a constraint. The use of containers can be helpful where the species poses a risk to personnel safety.

9.8.3.4 Not recommended

Hypothermia—Hypothermia is an inappropriate method of restraint or euthanasia for amphibians and reptiles unless animals are sufficiently small (< 4 g [0.1 oz]) to permit immediate and irreversible death if placed in liquid N_2 (rapid freezing). Hypothermia also reduces amphibians' tolerance for noxious stimuli[5] and is therefore not recommended for depopulation.

9.9 Footnotes

a. TrapSmart LLP, Vernon, NJ.
b. Goodnature Ltd, Wellington, New Zealand.
c. H & M Gopher Control, Tulelake, Calif.
d. Cheetah Industries, Paso Robles, Calif.

9.10 References

1. Friend M, Franson JC. Disease control operations. In: Friend M, Franson JC, eds. *Field manual of wildlife diseases. General field procedures and diseases of birds*. Biological Resources Division information and technology report 1999-001. Washington, DC: US Department of the Interior and US Geological Survey, 1999;19–46.
2. Schemnitz SD, Batcheller GR, Lovallo MJ, et al. Capturing and handling wild animals. In: Silvy NJ, ed. *The wildlife techniques manual: volume 1: research*. 7th ed. Baltimore: The Johns Hopkins University Press, 2012;64–117.
3. O'Hare JR, Eisemann JD, Fagerstone KA, et al. Use of alpha-chloralose by USDA Wildlife Services to immobilize birds, in *Proceedings*. 12th Wildl Damage Manag Conf 2007;103–113.
4. Nelson PC. Bird control in New Zealand using alpha-chloralose and DRC1339, in *Proceedings*. 16th Vertebr Pest Conf 1994;259–264.
5. AVMA. AVMA guidelines for the euthanasia of animals: 2013 edition. Available at: www.avma.org/KB/Policies/Documents/euthanasia.pdf. Accessed Feb 7, 2019.
6. Weatherhead PJ, Bider JR, Clark RG. On the feasibility of surfactants as a blackbird management tool in Quebec, in *Proceedings*. Bird Control Semin 1979;291–301.
7. Woronecki PP, Dolbeer RA, Seamans TW. Field trials of alpha-chloralose and DRC-1339 for reducing numbers of herring gulls, in *Proceedings*. Great Plains Wildl Damage Control Workshop 1997;148–153.
8. Klug BJ, Turmelle AS, Ellison JA, et al. Rabies prevalence in migratory tree-bats in Alberta and the influence of roosting ecology and sampling method on reported prevalence of rabies in bats. *J Wildl Dis* 2011;47:64–77.
9. Racey PA, Hutson AM, Lina PHC. Bat rabies, public health and European bat conservation. *Zoonoses Public Health* 2012;60:58–68.
10. Finn LS, Finn TG. Bat management: excluding bats from manmade structures. In: Barnard SM, ed. *Bats in captivity. Volume 4: legislation and public education*. Washington, DC: Logos Press, 2012;227–248.
11. Bat Conservation International. Bats in buildings. Available at: www.batcon.org/pdfs/education/fof_ug.pdf. Accessed Feb 14, 2019.
12. Lollar A. *Standards and medical management for captive insectivorous bats*. Weatherford, Tex: Bat World Sanctuary, 2010.
13. Lollar A, Schmidt-French B. *Captive care and medical reference for the rehabilitation of insectivorous bats*. Weatherford, Tex: Bat World Sanctuary, 1998.
14. Reid FA. *Mammals of North America*. 4th ed. Boston: Houghton Mifflin Co, 2006.
15. Roemer GW, Gompper ME, Van Valkenburgh B. The ecological role of the mammalian mesocarnivore. *Bioscience* 2009;59:165–173.
16. Vantassel SM, Hiller TL, Powell KDJ, et al. Using advancements in cable-trapping to overcome barriers to furbearer management in the United States. *J Wildl Manag* 2010;74:934–939.
17. Vantassel SM. Wildlife management professionals need to redefine the terms: lethal control, nonlethal control, and live trap. *Human Wildl Interact* 2012;6:335–338.
18. Northeast Furbearer Resources Technical Committee. Trapping and furbearer management in North American wildlife conservation. 2nd ed. July 2015. Available at: www.neafwa.org/uploads/2/0/9/4/20948254/trap-fur-mgmt_final.pdf. Accessed Feb 14, 2019.
19. Association of Fish & Wildlife Agencies. Furbearer management and best management practices for trapping. Available at: www.fishwildlife.org/afwa-inspires/furbearer-management. Accessed Mar 27, 2019.
20. Turkowski FJ, Armistead AR, Linhart SB. Selectivity and effectiveness of pan tension devices for coyote foothold traps. *J Wildl Manag* 1984;48:700–708.
21. Association of Fish & Wildlife Agencies Furbearing Conservation Technical Work Group. Best management practices for trapping in the United States. Available at: www.dec.ny.gov/docs/wildlife_pdf/trapbmpsintro.pdf. Accessed Feb 14, 2019.
22. Blom FS, Connolly G. *Inventing and reinventing sodium cyanide ejectors: a technical history of coyote getters and M-44s in predator damage control*. Research report 03-02. Fort Collins, Colo: USDA APHIS National Wildlife Research Center, 2003.
23. Hooke AL, Allen L, Leung LK-P. Clinical signs and duration of cyanide toxicosis delivered by the M-44 ejector in wild dogs. *Wildl Res* 2006;33:181–185.
24. Connolly G, Burns RJ, Simmons GD. Alternate toxicants for the M-44 sodium cyanide ejector, in *Proceedings*. 12th Vertebr Pest Conf 1986;318–323.
25. Savarie PJ, Tigner JR, Elias DJ, et al. Development of a simple two-ingredient pyrotechnic fumigant, in *Proceedings*. 9th Vertebr Pest Conf 1980;215–221.
26. Ramey CA, Schafer EW Jr. The evolution of aphis two gas cartridges, in *Proceedings*. 17th Vertebr Pest Conf 1996;219–224.
27. Proudfoot AT. Aluminum and zinc phosphide poisoning. *Clin Toxicol (Phila)* 2009;47:89–100.
28. Baker RO, Krieger R. Phosphine exposure to applicators and bystanders from rodent burrow treatment with aluminum phosphide, in *Proceedings*. 20th Vertebr Pest Conf 2002;267–276.
29. McLeod L, Saunders G. *Pesticides used in the management of vertebrate pests in Australia: a review*. Orange, NSW, Australia: New South Wales Department of Primary Industries, 2013.
30. Drew ML. Wildlife issues. In: American Association of Zoo Veterinarians. *Guidelines for euthanasia of nondomestic animals*. Yulee, Fla: American Association of Zoo Veterinarians, 2006;19–22.
31. Hampton JO, Mawson PRM, Coughran D, et al. Validation of the use of firearms for euthanising stranded cetaceans. *J Cetacean Res Manag* 2014;14:117–123.
32. Greer LL, Whaley J. Marine mammals. In: American Association of Zoo Veterinarians. *Guidelines for euthanasia of nondomestic animals*. Yulee, Fla: American Association of Zoo Veterinarians, 2006;66–74.
33. Moore M, Walsh M, Bailey J, et al. Sedation at sea of entangled North Atlantic right whales (*Eubalaena glacialis*) to enhance disentanglement. *PLoS One* 2010;5:e9597.
34. Dunn JL. Multiple-agent euthanasia of a juvenile fin whale, *Balanoptera physalus*. *Mar Mamm Sci* 2006;22:1004–1007.
35. Harms CA, McLellan WA, Moore MJ, et al. Low-residue euthanasia of stranded mysticetes. *J Wildl Dis* 2014;50:63–73.
36. Daoust PY, Ortenburger AI. Successful euthanasia of a juvenile fin whale. *Can Vet J* 2001;42:127–129.
37. Øen EO, Knudsen SK. Euthanasia of whales: the effect of .375 and. 458 calibre round-nosed, full metal-jacketed rifle bullets on the central nervous system of common minke whales. *J Cetacean Res Manag* 2007;9:81–88.
38. Donoghue M. *IWC 58: workshop on whale killing methods and associated welfare issues euthanasia of stranded cetaceans in New Zealand*. IWC/58/WKM&AWI 10. Agenda item 4.4. Impington, England: International Whaling Commission, 2006.
39. Lawrence K. Euthanasia of stranded whales. *Vet Rec* 2003;153:540.

40. Bonner WN. Killing methods. In: Laws RM, ed. *Antarctic seals: research methods and techniques*. Cambridge, England: Cambridge University Press, 1993;150–160.
41. Sweeney JC. What practitioners should know about whale strandings. In: Kirk RW, ed. *Kirk's current veterinary therapy 10*. Philadelphia: WB Saunders Co, 1989;721–727.
42. Daoust PY, Crook A, Bollinger TK, et al. Animal welfare and the harp seal hunt in Atlantic Canada. *Can Vet J* 2002;43:687–694.
43. Coughran D, Stiles I, Fuller PJ. Euthanasia of beached humpback whales using explosives. *J Cetacean Res Manag* 2012;12:137–144.
44. International Whaling Commission. *Report of the workshop on welfare issues associated with the entanglement of large whales*. IWC/62/15. Agenda item 5.2.1. Impington, England: International Whaling Commission, 2010.
45. Knudsen SK, Øen EO. Blast-induced neurotrauma in whales. *Neurosci Res* 2003;46:377–386.
46. Gulland FMD, Nutter FB, Dixon K, et al. Health assessment, antibiotic treatment, and behavioral responses to herding efforts of a cow-calf pair of humpback whales (*Megaptera novaeangliae*) in the Sacramento River Delta, California. *Aquat Mamm* 2008;34:182–192.
47. Macdonald DW, Fenn MGP, Gelling M. The natural history of rodents: preadaptations to pestilence. In: Buckle AP, Smith RH, eds. *Rodent pests and their control*. Boston: CAB International, 2015;1–18.
48. Corrigan RM. Rats and mice. In: Hedges SA, ed. *Mallis handbook of pest control: the behavior, life history, and control of household pests*. Valley View, Ohio: Mallis Handbook LLC, 2011;11–149.
49. Witmer G, Sayler R, Huggins D, et al. Ecology and management of rodents in no-till agriculture in Washington, USA. *Integr Zool* 2007;2:154–164.
50. Wobeser G, Ngeleka M, Appleyard G, et al. Tularemia in deer mice (*Peromyscus maniculatus*) during a population irruption in Saskatchewan, Canada. *J Wildl Dis* 2007;43:23–31.
51. Timm RM, Fisher DD. An economic threshold model for house mouse damage to insulation, in *Proceedings*. 12th Vertebr Pest Conf 1986;237–241.
52. Day JW Jr, Hall CAS, Kemp WM, et al, eds. *Estuarine ecology*. Baltimore: John Wiley and Sons, 1989.
53. Eisemann JD, Petersen BE, Fagerstone KA. Efficacy of zinc phosphide for controlling Norway rats, roof rats, house mice, *Peromyscus* spp, prairie dogs and ground squirrels: a literature review (1942–2000), in *Proceedings*. 10th Wildl Damage Manag Conf 2003;335–349.
54. DeNicola AJ, Williams SC. Sharpshooting suburban white-tailed deer reduces deer–vehicle collisions. *Human Wildl Confl* 2008;2:28–33.
55. Witmer GW, Fagerstone KA. The use of toxicants in black-tailed prairie dog management: an overview, in *Proceedings*. 10th Wildl Damage Manag Conf 2003;359–369.
56. Baril SF. *Efficacy of 2% zinc phosphide applied with and without a prebait for control of the Columbian ground squirrel*. Helena, Mont: Montana Department of Agriculture, 1980.
57. Proulx G. On the misuse of pesticides to control northern pocket gophers and Richardson's ground squirrels in agriculture and the pressing need for sustainable solutions, in *Proceedings*. 10th Prairie Conserv Endanger Species Conf 2014;134–157.
58. Dolbeer RA, Bernhardt GE, Seamans TW, et al. Efficacy of two gas cartridge formulations in killing woodchucks in burrows. *Wildl Soc Bull* 1991;19:200–204.
59. Crabtree DG. Review of current vertebrate pesticides. Available at: digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1021&context=vpcone. Accessed Feb 27, 2019.
60. Baldwin RA, Meinerz R, Orloff SB. An update on tools for effective management of pocket gophers in alfalfa, in *Proceedings*. 43rd West Alfalfa Forage Symp 2013;119–124.
61. Baldwin RA, Marcum DB, Orloff SB, et al. The influence of trap type and cover status on capture rates of pocket gophers in California. *Crop Prot* 2013;46:7–12.
62. Orloff SB. Evaluation of pressurized exhaust device to control pocket gophers and Belding's ground squirrels in alfalfa. 25th Vertebr Pest Conf 2012;329–332.
63. Clark JP, Miller G. *Conditional registration request for the use of compound 1080 to control ground squirrels in California*. Sacramento, Calif: California Department of Food and Agriculture, 1995.
64. Sullins M, Sullivan D. Observations of a gas exploding device for controlling burrowing rodents, in *Proceedings*. 15th Vertebr Pest Conf 1992;308–311.
65. Shadel RA. Efficacy of concussion blast equipment for the elimination of groundhogs in burrows, in *Proceedings*. 23rd Vertebr Pest Conf 2008;53–55.
66. Hildreth AM, Vantassel SM, Hygnstrom SE. Feral cats and their management. NebGuide EC1781. Available at: extensionpublications.unl.edu/assets/pdf/ec1781.pdf. Accessed Feb 14, 2019.
67. DeNicola AJ, Swihart RK. Capture-induced stress in white-tailed deer. *Wildl Soc Bull* 1997;25:500–503.
68. DeNicola AJ, Weber SJ, Bridges CA, et al. Nontraditional techniques for management of overabundant deer populations. *Wildl Soc Bull* 1997;25:496–499.
69. Caudell JN. Review of wound ballistics research and its applicability to wildlife management. *Wildl Soc Bull* 2013;37:824–831.
70. Schwartz JA, Warren RJ, Henderson DW, et al. Captive and field tests of a method of immobilization and euthanasia of urban deer. *Wildl Soc Bull* 1997;25:532–541.
71. Stewart CM, Veverka NB. The extent of lead fragmentation observed in deer culled by sharpshooting. *J Wildl Manag* 2011;75:1462–1467.
72. Grund MD, Cornicelli L, Carlson LT, et al. Bullet fragmentation and lead deposition in white-tailed deer and domestic sheep. *Human Wildl Interact* 2010;4:257–265.
73. American Association of Zoo Veterinarians. *Guidelines for euthanasia of nondomestic animals*. Yulee, Fla: American Association of Zoo Veterinarians, 2006.
74. Lapidge SJ, Wishart M, Smith K, et al. Development of a feral swine toxic bait (Hog-Gone) and bait hopper (Hog-Hopper) in Australia and the USA, in *Proceedings*. 14th Wildl Damage Manag Conf 2012;19–24.
75. Shapiro LC, Eason C, Bunt S, et al. Efficacy of encapsulated sodium nitrite as a new tool for feral pig management. *J Pest Sci* 2016;89:489–495.
76. Baier J. Amphibians. In: American Association of Zoo Veterinarians. *Guidelines for euthanasia of nondomestic animals*. Yulee, Fla: American Association of Zoo Veterinarians, 2006;39–41.
77. Baier J. Reptiles. In: American Association of Zoo Veterinarians. *Guidelines for euthanasia of nondomestic animals*. Yulee, Fla: American Association of Zoo Veterinarians, 2006;42–45.
78. American Society of Ichthyologists and Herpetologists. Guidelines for use of live amphibians and reptiles in field and laboratory research. 2nd ed. 2004. Available at: www.asih.org/sites/default/files/documents/resources/guidelinesherpsresearch2004.pdf. Accessed Feb 14, 2019.
79. AVMA. AVMA guidelines for the humane slaughter of animals: 2016 edition. Available at: www.avma.org/KB/Resources/Reference/AnimalWelfare/Documents/Humane-Slaughter-Guidelines.pdf. Accessed Feb 7, 2019.
80. Witmer GW, Snow NP, Moulton RS. Efficacy of potential chemical control compounds for removing invasive American bullfrogs (*Rana catesbeiana*). *Springerplus* 2015;4:497.
81. Mader DR, Divers SJ, eds. *Current therapy in reptile medicine and surgery*. St Louis: Saunders Elsevier, 2014.
82. Nevarez JG, Strain GM, da Cunha AF, et al. Evaluation of four methods for inducing death during slaughter of American alligators (*Alligator mississippiensis*). *Am J Vet Res* 2014;75:536–543.

10: Captive Wildlife

10.1 General Considerations

Captive wildlife may be defined as any nondomestic animal located in an enclosed (fenced area or building), controlled situation, managed by humans. Institutions or facilities housing captive wildlife in the United States are subject to federal and state regulations. In some instances, by state statute, these facilities may be required to have detailed disaster preparedness plans in place.

10.1.1 Preparedness initiatives

Several initiatives, which may prevent the need to depopulate captive wildlife, are ongoing. These strategies aim to prevent, mitigate, respond to, and recover from disasters in this animal category. In collaboration with the USDA, the Zoo and Aquarium All Hazards Preparedness Response and Recover Fusion Center is developing a "Secure Zoo" strategy, designed to prevent introduction of infectious disease into all captive wildlife facilities. Aligned with other "Secure" programs for agricultural species, Secure Zoo is intended to preserve captive wildlife populations and sustain facility operations in the face of an FAD threat. "Zoo Ready," another Zoo and Aquarium All Hazards Preparedness Response and Recover Fusion Center initiative, promotes all hazards planning and training to respond to a variety of emergencies. One of its goals is to prevent animals from exposure to life-threatening situations in which emergency depopulation may be necessary. Zoo Ready also encourages advance planning with state and federal animal health officials to identify strategies to isolate captive wildlife from potential emerging disease threats.

10.2 Events Necessitating Depopulation

Depopulation of captive wildlife species is driven by the severity of the event (eg, an FAD that cannot otherwise be contained), welfare considerations (eg, animals starving because of natural disasters), or other catastrophic incidents that will necessitate the decision to rapidly depopulate, rather than humanely euthanize, the animals.

Emergent situations such as natural disaster or rapidly spreading infectious disease may challenge the availability of preferred euthanasia techniques, necessitating the use of alternative methods. More research is needed to determine the most efficient, safest, and most humane depopulation techniques for captive wildlife.

There are two main emergency situations for captive wildlife facilities that may initiate the discussion of depopulation: facility failures/natural disasters, or infectious disease. Natural disasters such as tornadoes, fires, and floods are spontaneous and may occur so rapidly that there is no time to move animals to safety. These instances where time is sufficiently limiting that standards of euthanasia must be compromised will be very uncommon.

In the event of infectious disease outbreaks, captive wildlife can generally be contained to reduce the spread of disease.

10.3 Special Considerations

10.3.1 Facility considerations

Captive wildlife exist in a variety of settings, from zoological institutions to semi–open-range game reserves to small traveling petting zoos. As such, habitat, enclosures, public access, and other such factors listed in the following must be considered when choosing depopulation techniques.

- Semi–open range: factors to consider include accessibility, the presence of multiple species, and the presence of numerous animals (vs more limited numbers in conventional exhibits).
- Small zoo exhibits: factors to consider include concrete-based exhibit substrates and walls, hiding places, visibility, and whether multiple animals are present.
- Large zoo exhibits: factors to consider include accessibility, multispecies exhibits, and the presence of numerous animals.
- Aviaries: factors to consider include many of those just described, depending on whether the exhibits are small or large.
- Exhibit integrity: factors to consider include compromised fences or other damage from natural disasters.
- Supplies available: factors to consider include the availability of euthanasia solution, anesthetics, weapons and ammunition, and other supplies.
- Disposal: factors to consider include whether local landfills will accept animals (especially if injectable anesthetics are used), biosecurity, the availability of on-site burial, or the ability for composting.

Before mass depopulations occur, officials must consider the legal issues involved, including international, national, state or provincial, and local regulations as applicable and dialogue with authorities where appropriate. Additional legal concerns include property rights related to both the animals in question and access to their locations.

10.3.2 Species considerations

The natural history and behavior of the species to be depopulated must also be considered when a method is chosen. Individual handling for euthanasia of animals not conditioned to human contact may be more stressful than remote methods of humane killing. Social individuals may not separate from each other, necessitating group depopulation.

- In chutes or other handling devices, nondomestic species that are seldom handled do not react the same way as domestic species.

- Appropriate equipment for processing hoofstock (eg, chutes, alleys) may be lacking in many facilities.
- Many species in captive facilities are critically endangered. Collection of genetic material (sperm, ova, other tissues) may be a consideration in method used and time period for carrying out the depopulation.

Many captive wildlife species are also considered dangerous animals by nature (eg, large carnivores, megavertebrates, many primates); however, any animal in an unfamiliar or stressful situation may become unpredictable and dangerous. Human safety is of utmost importance when depopulation of captive wildlife is attempted. Only individuals properly trained and experienced working with the species in question should participate in depopulation efforts.

10.3.3 Personnel considerations

Captive wildlife are typically cared for by a dedicated animal husbandry staff; thus, the human-animal bond cannot be discounted even in emergency depopulation situations. Careful consideration should be given to humans who care for these captive animals—caretakers should be given the choice to be present or not during depopulation.

Qualified personnel who are familiar with the natural history of each species are required to safely carry out depopulation of captive wildlife. Individuals carrying out the depopulation must be adequately trained and proficient with the chosen depopulation techniques. Incorrect application of any technique may produce undue suffering and must be avoided.

Fatigued personnel may be dangerous to themselves and others or may not effectively carry out the depopulation. It is of utmost importance to provide enough qualified individuals so that breaks can be provided while not compromising the efficiency of the objectives.

10.3.4 Logistic considerations

In an emergency situation with compromised enclosure integrity, there may be a chaotic situation with many animals no longer easily contained. Safety of humans is first priority in these situations and may dictate the method of depopulation chosen. Advance planning before emergencies is of utmost importance, and considerations should be given to the following logistic issues:

- Large volumes of euthanasia solution and anesthetics may be required. Sources for these medications should be identified before the depopulation is begun.
- Supplies, personnel, and supportive services for personnel (eg, water, PPE, food, equipment) may be costly. Financial provisions should be made before the event.
- Disposal of animals, especially large animals, may be challenging. The risk of secondary toxicities must be mitigated with strict biosecurity and coordination with appropriate agencies for disposal.
- Access to exhibits and facilities may be limited, especially in the case of a natural disaster. Appropriate vehicles and equipment should be sourced before a depopulation is begun.
- Adjacent exhibits pose multiple challenges: they may be at risk from an infectious disease, their integrity may be compromised, or they may contain dangerous animals. These exhibits may also be helpful to contain escaped animals or serve as safe places for personnel.
- Electricity may not be available in a natural disaster or other emergency. Provisions such as generators, flashlights, equipment that does not require electricity, and manual methods for opening and closing cages must be made.
- Communications are extremely important during emergencies. Cell phones and radios may not be functional during these situations. Thus, logistics must be made clear to all personnel before a depopulation is begun. Central meeting locations and times are suggested to ensure that the objectives are carried out as planned or altered as needed.
- Depopulation methods used in agricultural settings may not work in captive wildlife collections for the following reasons:
    - Foam: captive wildlife collections are not typically composed of large populations of exclusively ground-dwelling birds in confinement (eg, many captive bird species can jump and perch above the foam).
    - CO_2 is not effective for species that hibernate, are fossorial, are neonates, or otherwise have a high tolerance for anoxia.
    - Captive bolt may be effective for birds, mammals, or large hoofstock that are trained or easily restrained. However, in many of these circumstances, other euthanasia methods may be as practical or more practical.

10.4 Implementation of Depopulation Methods

Scientific research on methods of depopulation for captive wildlife in managed settings has not been published to date. Additional differences from agricultural settings are the dearth of information on how to depopulate captive wildlife and biological characteristics that confound application of methods for livestock and biomedical research populations.

10.4.1 Preferred methods

In the unlikely event that depopulation is deemed appropriate, many captive animals may be accessible through normal containment and handling methods. Depopulation, in this situation, may be accomplished as a series of individual euthanasia procedures utilizing species-specific euthanasia techniques previously described in the AVMA and American Association of Zoo Veterinarians euthanasia documents.[1,2] Generally, this type of depopulation allows for sufficient preparation without significant time constraints. Removal of smaller populations of individuals within collections of captive wildlife has been reported, especially for infectious disease control (eg, *Cryptosporidium* infection in reptiles, inclusion body disease of snakes).

10.4.2 Permitted in constrained circumstances

Instances in which recognized euthanasia methods may not be possible include animal escapes or groups of animals contained in large enclosures such as large free-flight aviaries or open-air hoofstock populations.

For animal escapes, methods suggested in the wildlife section of this document may be indicated (see chapter 9).

For animals in large enclosures or social animals that cannot be separated, food treated with α-chloralose or other anesthetics or tranquilizers may be successful at immobilizing animals for application of euthanasia methods. When using treated food, regularly check animals for immobilization at a distance that does not create distress. This method may have variable success, as it depends on animal consumption of treated food. It may be necessary to employ adjunct or other methods of humane killing when treated food is used for a depopulation attempt. Where the previously discussed methods are not possible or successful, firearms may be required as described in chapter 9 (Free-Ranging Wildlife) and appendix B (Remarks on Shooting From a Distance) of this document.

Additionally, in cases of limited availability of anesthetic and euthanasia agents, the use of expired pharmaceuticals may be considered.

10.4.3 Not recommended

Not applicable.

10.5 References

1. American Association of Zoo Veterinarians. *Guidelines for euthanasia of nondomestic animals*. Yulee, Fla: American Association of Zoo Veterinarians, 2006.
2. AVMA. AVMA guidelines for the euthanasia of animals: 2013 edition. Available at: www.avma.org/KB/Policies/Documents/euthanasia.pdf. Accessed Feb 7, 2019.

Appendix A: Summary Chart of Method Categories

A1 Definitions

A1.1 Preferred methods

These methods are given highest priority and should be utilized preferentially when emergency response plans are developed and when circumstances allow reasonable implementation during emergencies. Preferred methods often correspond to techniques outlined in the AVMA Guidelines for the Euthanasia of Animals,[1] with adjustments as necessary for constrained time periods and large populations of animals.

A1.2 Permitted in constrained circumstances

These methods are permitted only when the circumstances of the emergency are deemed to constrain the ability to reasonably implement a preferred method. Potential constraints that might result in use of methods in this category include, but are not limited to, zoonotic disease risk, human safety, depopulation efficiency, deployable resources, equipment, animal access, disruption of infrastructure, and disease transmission risk.

A1.3 Not recommended

These methods should be considered only when the circumstances preclude the reasonable implementation of any of the preferred methods or methods permitted in constrained circumstances and when the risk of doing nothing is deemed likely to result in more animal suffering than that associated with the proposed depopulation method. Examples of such situations include, but are not limited to, structural collapse or compromise of buildings housing animals, large-scale radiologic events, complete inability to safely access animals for a prolonged period of time, or any circumstance that poses a severe threat to human life or animal populations.

A2 Methods by Species

Depopulation methods by species were summarized **(Table 1)**.

Table 1 appears on the next page.

Table 1—Depopulation methods by species.

Species and setting	Preferred	Permitted in constrained circumstances	Not recommended
All species	All POE and POHS methods for all species as applicable	Expired, compounded, nonpharmaceutical-grade euthanasia agents or anesthetics	Untrained = unacceptable
Chapter 1: Companion animals	POE Euthanasia solution Injectable anesthetic overdose Two-step method utilizing euthanasia solution titration or anesthetic overdose to unconsciousness followed by secondary method (eg, IV KCl, physical method) Inhalant anesthetics via chamber (< 7-kg body weight), with unconsciousness possibly followed by secondary method CO, CO_2 per POE	Expired, compounded, nonpharmaceutical-grade euthanasia agents or anesthetics Alternate routes (intrahepatic, intrarenal) of barbiturate euthanasia solutions IV injection of > 60% magnesium sulfate with sedation (dogs only) α-Chloralose, urethane (research only) Decapitation following sedation (< 20-kg body weight)	Neuromuscular blocking agent followed within 50 s by secondary measure Ultrapotent opioids (feral animals) Nitrous oxide followed by secondary method Distance gunshot (feral, uncatchable animals) Maceration (< 75-g body weight) Cervical dislocation, nonanesthetized (rabbits, rodents) Electrocution with sedation or anesthesia
Chapter 2 Laboratory animals	POE and POHS		
Small laboratory and wild-caught rodents	POE	Inhalant anesthetic overdose (combine cages, prefill chamber) Injectable agents Expired, compounded, nonpharmaceutical-grade euthanasia agents or anesthetics IP injection of 70% ethanol Use of single needle or syringe for up to 5 animals (unless needle becomes dull)	
Dogs, cats, ferrets, and rabbits	Euthanasia solution Injectable anesthetic overdose Two-step method utilizing euthanasia solution or anesthetic agent titration to unconsciousness followed by secondary method (eg, IV KCl, physical method)		
Sheep, goats, and swine (supplement to chapters 4 and 5)	POE and POHS	Expired, compounded, nonpharmaceutical-grade euthanasia agents or anesthetics	
Nonhuman primates	Two-step method utilizing euthanasia solution or anesthetic agent titration to unconsciousness followed by secondary method (eg, IV KCl, physical method)	Expired, compounded, nonpharmaceutical-grade euthanasia agents or anesthetics Gunshot	
Aquatic vertebrates	Immersion anesthetic agents	Rapid chilling for large non–cold-adapted fish Pithing Blunt force trauma with secondary method	
Avian and poultry (supplement to chapter 6)	Two-step method utilizing euthanasia solution or anesthetic agent titration to unconsciousness followed by secondary method (eg, IV KCl, physical method)	Expired, compounded, nonpharmaceutical-grade euthanasia agents or anesthetics	
Chapter 3: Cattle	POE and POHS Gunshot PCB (alternative shot placements) Barbiturate or anesthetic overdose	Expired, compounded, nonpharmaceutical-grade euthanasia agents or anesthetics PCB (with sedation) Electrocution	Oral toxins
Chapter 4: Swine	POE and POHS Injectable anesthetic overdose Inhalant gases Gunshot Nonpenetrating captive bolt PCB Electrocution Manual blunt force trauma	Expired, compounded, nonpharmaceutical-grade euthanasia agents or anesthetics VSD+ Sodium nitrite	
Chapter 5: Small ruminants, cervids, and camelids	POE and POHS Physical methods CO_2 in small ruminants < 2 mo old Injectable anesthetic overdose	Longer-range gunshot (animals that cannot be captured) Expired, compounded, nonpharmaceutical-grade euthanasia agents or anesthetics	Gunshot at a distance of > 3 ft with a confined or restrained animal
Camelids	PCB		
Chapter 6: Poultry	POE and POHS		
Floor-reared, confined poultry, including aviary-style housing	Water-based foam generators Water-based foam nozzles Whole-house gassing Partial-house gassing Containerized gassing Cervical dislocation Mechanically assisted cervical dislocation Captive bolt gun	Gunshot VSD+ Exsanguination Controlled demolition Decapitation	VSD alone
Cage-housed poultry	Whole-house gassing Partial-house gassing Containerized gassing	Compressed air foam Cervical dislocation Mechanically assisted cervical dislocation Captive bolt gun VSD+ Decapitation	Water-based foam generators Water-based foam nozzles Gunshot VSD alone
Outdoor-access poultry	Captive bolt gun Cervical dislocation Mechanically assisted cervical dislocation Containerized gassing	Water-based foam generators Water-based foam nozzles Partial-house gassing Gunshot via firearm or pellet gun Exsanguination Controlled demolition Decapitation Cervical dislocation	Whole-house gassing VSD alone

Table 1—Depopulation methods by species. (continued)

Species and setting	Preferred	Permitted in constrained circumstances	Not recommended
Ratites	POHS Mechanically assisted cervical dislocation Captive bolt gun Ingested or injected agent Gunshot	Cervical dislocation Controlled demolition Containerized gassing Exsanguination after stunning or sedation Whole-house gassing Partial-house gassing Water-based foam generators Compressed air foam VSD+ Decapitation	Water-based foam nozzles VSD alone
Companion, lifestyle, or high-value birds	Captive bolt gun Containerized gassing Ingested or injected agent Cervical dislocation	Gunshot Water-based foam generators Water-based foam nozzles Compressed air foam Decapitation	VSD alone Controlled demolition Exsanguination Whole-house gassing
Fertilized eggs, embryos, or neonates	Containerized gassing Cooling Freezing Maceration		
Chapter 7: Equids	POE and POHS Two-step method utilizing euthanasia solution or anesthetic agent titration to unconsciousness followed by secondary method (eg, IV KCl, physical method) Gunshot PCB	Expired, compounded, nonpharmaceutical-grade euthanasia agents or anesthetics Gunshot at a distance Exsanguination via the rectum under anesthesia Alternative routes for euthanasia or anesthetic agents (intrarenal, intrahepatic)	Choral hydrate IV injection of > 60% magnesium sulphate Oral toxins
Chapter 8: Aquatic animals	POE and POHS Immersion agents, injectable agents, and physical methods (per POE) Electrocution (per POHS)	Chlorine Rotenone CO_2 Dry ice Hypothermal shock (rapid chilling) Decapitation Cervical transection	Calcium oxide Quick lime and formalin Dewatering
Aquatic invertebrates	Immersion in noninhaled agents (eg, magnesium salts, clove oil, eugenol, ethanol), with a secondary step where possible		
Chapter 9: Free-ranging wildlife	POE		
Birds	Inhaled agents Physical methods per POE Injectable agents: anesthetic agents, barbiturates, T-61	Expired, compounded, nonpharmaceutical-grade euthanasia agents or anesthetics Surfactants	Gunshot Oral agents
Bats	Inhalant anesthetic	Overdose of injectable anesthetic Expired, compounded, nonpharmaceutical-grade euthanasia agents or anesthetics	Physical methods Gunshot Pesticides, baits, fumigants
Carnivores	Gunshot	Ignitable gas cartridges Aluminum phosphide Sodium cyanide	Sodium fluoroacetate
Marine mammals	Overdose of injectable anesthetics Physical methods: gunshot, manually applied blunt force trauma, implosive decerebration	Expired, compounded, nonpharmaceutical-grade euthanasia agents or anesthetics	Inhaled agents Exsanguination
Rodents	Kill traps Gunshot	Ignitable gas cartridges Carbon monoxide injectors Sodium fluoroacetate Aluminum phosphide Rodenticides Propane-oxygen exploders	Predators
Ungulates	Physical methods: PCB, gunshot, manually applied blunt force trauma	Injectable agents Toxicants	Inhaled agents
Reptiles and amphibians	Immersion in anesthetic agents Injectable anesthetic agents	Expired, compounded, nonpharmaceutical-grade euthanasia agents or anesthetics Physical methods Inhaled agents	Hypothermia
Chapter 10: Captive wildlife	POE	Shooting at a distance	

Appendix B: Remarks on Shooting From a Distance

B1 Introduction

Firearms may be selected as a method of depopulation owing to a number of different factors, solely or in combination. These factors include but are not limited to, access to animals, humane concerns, trained personnel availability, personnel fatigue, reasons for depopulation, logistics, availability of alternate methods and supplies (including ammunition), ability to target vital organs, safety risks to humans and unintended targets, environmental concerns, legal firearm use, aesthetic concerns, and public perceptions. Appropriate selection of methods and judgment under pressure and changing circumstances will be best when there is advance consideration of potential field scenarios and prior practice. Ideally, firearm use results in minimal handling distress and instant loss of consciousness owing to projectiles entering the brain. In such instances, firearm use for depopulation can be classified as euthanasia.

The humaneness of firearms as a depopulation technique depends almost entirely on the skill, appropriate equipment, and judgment of the shooter.[2] If properly carried out, it is one of the most humane methods of killing or euthanizing free-range wild animals. If inexpertly carried out, shooting can result in wounding that may cause considerable pain and suffering.

B2 Training

Training is essential for ensuring humaneness of depopulation with firearms. This training must include approaches that ensure skilled marksmanship; an understanding of safety principles, animal anatomy, and animal behavior; humane animal handling; use of appropriate combinations of firearms and bullets for the intended purpose; and appropriate judgment under field conditions. Additional data are needed for a greater understanding of appropriate firearm use for domestic[3] and nondomestic species[2,4–6]; gunshot must account for anatomic differences in vital organ location as well as the energy required to penetrate and sufficiently damage vital organs. Consequently, current recommendations in this document are largely empirical and not comprehensive. Additional research into terminal ballistics and wildlife needs to be conducted to increase our understanding of minimal calibers and loads that can be used to effectively euthanize wildlife.

Training and continued practice should result in shooters who can accurately place shots in target organs that result in immediate or rapid insentience. Under confined conditions, shooters should achieve immediate insentience by targeting the brain at a success rate of at least 99% with one shot. At a minimum, short-term provisional recommendations of the Panel are that shooters should be able to consistently place shots in a 2-inch target with a rifle at a distance of 100 yards. This recommendation compels shooters to prioritize heart and lungs as a target because there is insufficient accuracy to routinely target the brain unless the firearm is applied at close range (< 50 yards). However, training is currently available for wildlife that results in shooters being able to routinely place shots in a target of < 2 inches at a distance of 100 yards and thereby achieve immediate insentience in over 99% of animals with one shot by targeting the brain.[2] The Panel expects that government and private organizations will prioritize development of training programs that achieve a 1-inch target at a distance of 100 yards for future depopulation efforts.

B3 Safety

Safety must be the first priority for personnel using firearms. Firearms must be handled with caution and maintained in good working order before and during depopulation efforts. There must be assurance that humans, nontarget animals, valued objects (eg, vehicles, other machinery, tanks), buildings, or other concerns are not in the line of fire or vulnerable if there is a ricochet from a missed shot or a shot that passes through the animal's body. Shooting in environments where there is concrete, packed gravel, metal, or other hard surfaces poses a particular risk for ricochets and should be avoided or compensated for to the extent possible. Understanding animal anatomy and firearm characteristics so that target organs are shot with minimal risk of pass-through is essential for minimizing risk to others and objects in the environment. Where possible, lead-containing ammunition should be avoided to minimize carcass and environmental contamination. Use of nonlead ammunition may pose a trade-off with accuracy, lethality, and safety in some cases.[4]

General safety principles for firearm use include the following:

- Assume that all firearms are loaded.
- Always be aware of the direction the muzzle is pointing.
- Never point firearms at oneself, others, or other unintended targets.
- Keep fingers off the trigger until ready to fire.
- Do not fire if unintended targets are at risk from missed shots, penetrating shots, or ricochets in the backdrop.
- Always remove ammunition from firearms when the firearms are not in use.
- Never place the muzzle of the firearm against an animal's body; a minimal muzzle distance of 1 to 2 feet from the body will minimize the risk of gun barrel explosions due to shooting when the muzzle is too close to the body.
- Ricochets can be minimized by the positioning of firearms perpendicular to the skull, with a bullet path from the cerebrum to the foramen magnum when the brain is targeted at a close distance.

B4 Animal Handling

A solid understanding of animal behavior and handling is critical for use of firearms during depopulation efforts. Personnel must understand when panic behavior is likely to occur owing to shooting, other human activities, animal group responses, environmental causes, or other reasons. This understanding will permit personnel to minimize animal distress by adjusting activities to the extent possible.

Basic humane husbandry methods should be used to move animals into settings or positions where shooting accuracy is maximized and distress is minimized whenever possible and practical. Guiding confined animals into restraint devices is preferable if shooting can be conducted safely. Ideally, escaped domestic animals can be guided into smaller, confined areas. Free-ranging domestic animals that cannot be practically guided, feral animals, and wildlife may need to be shot at a distance.

B5 Firearm Considerations

Appropriate firearms and ammunition must be used to enable a rapid humane death[3,4] **(Table 2)**. Accuracy and precision of firearms should be tested on a firearms range before shooting operations. It is strongly recommended that shooters use a range finder for estimating distances during any shooting operation.

One risk associated with firearms as a depopulation method is the potential lead contamination of carcasses.[6,7]

An animal should only be shot if all the following conditions are fulfilled:

- A humane kill (immediate insensibility) is judged as highly probable.
- The shooting is carried out by experienced, skilled, and responsible shooters who have been deemed suitable to the task and have proven marksmanship.
- The animal is within the ethical range of the shooter and the equipment being used. Caudell et al[8] defined the ethical range as the longest shot that can be taken that will result in a humane kill (instantaneous or near-instantaneous incapacitation) with a low chance of missing the targeted area (previously defined as a 1% chance of missing the target) and no compromise of safety. The ethical range is dependent upon each situation, the skill of the shooter in varying positions, and the effective range of the firearm and ammunition being used.
- The animal can be clearly seen and recognized.
- It is safe to shoot (ie, there is a safe backstop and no hard surfaces or water near the target).

If in doubt, do not shoot.

Field shooting operations may not always result in a clean kill for all animals; therefore, prompt follow-up procedures are essential to ensure that all wounded animals are located and killed quickly and humanely. Death can be confirmed by observation of the following:

- The carcass is limp and muscles are relaxed (the legs should not be stiff, stretched out, or tense). This should not be confused with reflexive uncoordinated limb movements, gasping, or gagging that can occur immediately after death and that can be a source of concern for observers who are unfamiliar with these signs.
- No head or tail movement or shaking.
- No rhythmic breathing.
- No eye blinking (eyes are fixed and glazed).

If there is any doubt about the verification of death, another lethal shot should be taken. In addition to those observations just described, death can be confirmed by touching the cornea of the eye in an attempt to elicit a blink response. The pupils of the eyes should be totally dilated, and there will be a loss of color in the mucous membranes, which become mottled and pale without refill after pressure is applied.

Shooting should not be carried out if any of the following are true:

- There are objects in the background that create unsafe conditions (eg, people, buildings, potentially explosive equipment, other animals not intended to be killed).
- Shooters are amateur or untrained.
- The shot is beyond the ethical range of a trained shooter and the equipment on hand.
- There is insufficient light for the use of night vision or thermal equipment, or adequate artificial light is not available.
- When shooting at a distance, the nature of the ter-

Table 2—Firearm selection, shot placement, and recommended shot distances to maximize efficiency and humaneness based on situational necessity and considerations (vs shooter convenience) when culling deer.

Caliber	Brain or C1-C3 (yards)	C4 to upper thoracic (yards)	Heart or thoracic cavity (yards)
.22 rimfire subsonic	0–40 (head only)*	Not recommended	0–100*
.223/.22–250	0–125	125–200	200–400*
.243/.25–06	0–125	125–250	250–400*
.270/.300	0–125	125–250	250–400

*Use discretion on orientation—knowledge of exact anatomy relative to external morphological features is necessary.

Cervical spine targets may be used by trained personnel.[5]

rain reduces accuracy and prevents the humane and prompt dispatch of wounded animals. If an animal is out of range or obscured by rock or vegetation, do not shoot.

B5.1 Physical shooting methods

Only shoot when an animal's kill zone can be clearly seen and is within effective killing range of the firearm being used and the capabilities of the shooter.

The head (brain), upper cervical spine (C1 through C3), or chest (heart and lungs) should be the target. A shot to the brain or upper cervical spine is optimal for a quick and humane death. Chest shots may be preferable under some circumstance, as the heart and lungs are the largest vital area and an accurate shot is more achievable under some field conditions or where shooter accuracy is limited. Although shots to the head are more likely to cause instantaneous loss of consciousness, consideration needs to be given to the risk of missing a smaller, challenging target area and also to the destruction of tissues that may be needed for disease testing.

B6 Bullet Selection

The selection of bullets that match the firearms chosen for specific settings and objectives is critical for maximizing the humaneness and safety of depopulation efforts. Bullets can be solid points, hollow points, or full metal jacket. Full metal jacket and some solid-copper bullets do not expand or fragment[8] on impact with targets, and they pose the greatest risk for exiting the body. These bullets also do not transfer energy efficiently to target tissue, and consequently, full metal jacket bullets are not recommended.[9]

B7 Bullet Velocity

The terminal velocity of bullets must be high enough that the bullet penetrates the animal to a depth sufficient to cause trauma to the targeted organ or structure. Also, bullets must strike with enough velocity to allow the bullet to function properly. Many bullets are designed to expand or fragment when they strike soft tissue (eg, muscle, lung). This process of expansion and fragmentation increases the diameter of the primary wound channel, causing trauma and bleeding. Higher-velocity bullets also cause a temporary wound channel to form, which can cause additional trauma to body tissues distant from the permanent wound channel. This can be critical to causing rapid incapacitation when the primary target is missed by a short distance.

In general, subsonic bullets are a poor choice for euthanizing wildlife. In the initial decision-making process, subsonic bullets may appear to be a suitable choice. They are quiet because they do not break the sound barrier (and with a suppressor there is almost no noise to disturb other animals), and those unfamiliar with the use of subsonic rounds may perceive them as being safer because they move slower. But subsonic bullets are likely to result in a long incapacitation and can be less safe than rounds fired at supersonic velocities. Subsonic bullets strike with speeds insufficient to cause a significant temporary wound channel to form and often will not expand unless the bullets have been designed by the manufacturer to expand or fragment at low velocities (ie, < 1,000 feet/second[4]). Subsonic bullets can also pass through an animal with little deformity, causing the bullet to exit the animal with little trauma (other than the primary wound channel), low loss of speed, and the potential to cause additional damage behind the target. For these reasons, subsonic rounds are not recommended in most situations.

B8 Selection of Firearms

The following factors must be considered when firearms are selected for a particular depopulation effort:

- Safety and accuracy are primary considerations.
- Choice of firearms with sufficient muzzle energy and bullets of appropriate mass to penetrate target organs under the extant circumstances.
- Licensing and regulations regarding firearms may be an issue; thus, it is important to know and understand all gun use and possession laws.
- Public perception also varies regionally; thus, sensitivity may influence one's choices. For example, utilizing what appears to be a so-called assault weapon may not be the best choice.
- Discharging any kind of firearm is very likely to spook animals within hearing distance; thus, ideally, the procedures should take into account animal reaction (ie, anticipate such behavior). The use of suppressors (silencers) is acceptable in some jurisdictions but requires that such firearms be resighted when a suppressor is affixed to ensure accuracy.
- Aerial use of firearms must be conducted only by appropriately trained and experienced personnel.

B9 Handgun

As with rifles, handguns come in a variety of actions, calibers, and barrel lengths. The appropriate firearm and caliber combination must be selected for the task at hand. Just as with rifles, trained shooters will need to know their ethical limit with each handgun that may be used. Unfortunately, there has been little empirical research conducted into the use of handguns and the minimum calibers and loads necessary to rapidly incapacitate wild and domestic species.

In general, handguns are suitable for targets at short ranges (ie, < 10 yards) and are typically used on the skull and the upper cervical spine of the targeted animals. The AVMA Guidelines for the Euthanasia of Animals[1] indicate that handguns may not achieve sufficient muzzle energy to penetrate the skull from all orientations and destroy brain tissue when euthanizing animals weighing more than 400 lb (180 kg). However, recommendations vary for the minimum muzzle energy needed to destroy the brain tissue of larger animals.[9,10] This variation is likely due to the dearth of peer-reviewed published data on this topic, and recommendations for higher minimum muzzle energies are more likely when shooter experience and skill are less extensive; skilled, trained professionals can be more effective using lower muzzle energies because they are more capable of accounting for caliber, animal size, shot angle, and special anatomic considerations. Consequently, as a general concept intended to cover all circumstances when the objective is to instantly destroy brain tissue, rifles, larger-caliber handguns, or smaller-caliber handguns with heavier loads or longer barrels should be considered when there is a need to penetrate the dense bone structure of heavier animals' skulls.

Under ideal conditions, animals being shot with pistols should be stationary and facing the shooter. The bullet should enter the skull as described in the AVMA Guidelines for the Euthanasia of Animals,[1] and the bullet flight should be directed toward the spinal column to prevent exit. In some situations a bullet placed to the temple, shot laterally through the brain, is very effective, but assurance of a safe backdrop is more critical owing to the increased risk of projectile pass-through. Suggested firearm characteristics are as follows:

- A .22 pistol loaded with solid-point .22 long-rifle bullets is possibly the most used choice. A .22 produces the least noise for minimizing auditory stimuli that alarm animals.
- Alternative loads and calibers include .380, 9 mm, .38 Special, and .45 ACP. However, the load must also be high enough for these bullets to penetrate sufficiently. These calibers should be considered on the basis of the bone the bullet is intended to penetrate. The general rule is that you should use the least amount of energy necessary to penetrate and adequately destroy the target tissue to ensure a humane and safe outcome.
- Larger calibers (.357 Magnum, .41 Magnum, .44 Magnum, and others) are acceptable, but are very loud (unless suppressed), have a heavy recoil, and create considerable tissue damage, increased tissue and fluid splatter behind the targeted animal, and increased possibility of the bullet exiting from the animal. However, large-caliber pistols may be necessary for penetrating the skull of larger animals with robust cranial bones if a rifle or shotgun is not available.

B10 Rifle

In comparison with pistols, owing to longer barrels, rifles generally have higher muzzle velocities and greater accuracy at a distance. Therefore, rifles may be more useful for many depopulation efforts. Multiple rifle action types (single action, bolt action, semiautomatic, and fully automatic) exist. The proper rifle action should be chosen for the situation at hand.

Rifles can be used at any range, but pistols are more manageable at closer range and in confined environments. As previously discussed, adjustments in caliber and bullet selection may be necessary for respective distances.

As with a pistol, under confined settings, animals shot with a rifle should be stationary and in front of the shooter. Long shots are possible with a rifle when it is not possible to safely catch and control the animal. The Panel recommends the following be considered when rifles are used at long distances (> 25 yards):

- Rifles equipped with a 3X or greater powered scope are preferred when possible.
- In situations with many targets, semiautomatic actions may be appropriate.
- Trained and experienced shooters who are well acquainted with the use and maintenance of the chosen rifle must be used.
- Shooters must account for distance, windage, and angles.
- Rifles must be resighted before the event to assure accuracy, as scopes and open sights can be affected via vibration.
- Spinal shots may be necessary for animals moving away from the shooter. In such instances, the preferred target is the cervical spine (from the occipital bones down to the thoracic spine). This is a more difficult shot, and angles are critical for desired bullet placement.
- The Panel recommends using calibers and bullets correlated to the animal size and using expandable bullets (the bullet mushrooms, thereby expanding the size of the bullet diameter for causing greater tissue damage).
- The rifle and shooter's accuracy is greatly improved when using rifle rests (eg, tripod, sand bags).
- The shooter should be prepared to take additional shots. Thus, considerable ammunition should be immediately accessible on the basis of the number of select animals and the environment.

B11 Shotgun

Shotguns loaded with pellets are typically used for shooting at moving targets, while those that are loaded with slugs or have rifled barrels are more useful for intermediate-range stationary targets. Shotguns are loud (they are difficult to use with effective noise suppression) and, depending on the shot load (BBs of various sizes or slugs), may create extensive tissue damage and tissue splatter. Shotguns with pellet projectiles can be acceptable for euthanasia at short distances because they have sufficient energy to penetrate the skull and are less likely to exit the body than are projectiles from pistols or rifles. Quality shotguns with rifled barrels using slugs are effective for thoracic shots < 100 yards. Alternatively, shotguns fitted with a smoothbore barrel with larger pellets (preferably buckshot) are acceptable at medium distances with the appropriate choke (< 30 yards), but should be an alternative choice when possible.

B12 Additional Considerations

Define project objectives and determine acceptable shot placement (eg, brain or upper cervical spine only, lower cervical or upper thoracic, thoracic, any shot placement acceptable). This will determine overall strategy, shot placement prioritization, and whether to shoot.

Determine species size and other anatomic considerations; acceptable shot placement criteria; anticipated ranges; firearm, optics, and accessories quality and type; personnel skill and experience; and shooting techniques (eg, supported on platform of vehicle, relative number of points of contact for stability, field improvisation, helicopter). This will determine caliber and projectile selection.

Minimize psychological stress by minimizing conspecific awareness of the operation through limited direct line of sight or auditory stimuli.

Use body weight and skull thickness and configuration (eg, antlers, horns, unique anatomy around braincase) to determine caliber range and options and bullet type. Also, shot placement (eg, head, spine, body) will determine caliber and bullet type. Finally, increased distance to targets will affect energy loss. This will result in a loss of precision, which can be partially compensated for with a range finder, as well as require firearms that deliver more kinetic energy.

As the average anticipated engagement distance increases, one should select a firearm in the next higher caliber category (.22, .223/22-250, .243/25-06, .270/308, .300 Magnum/.338, .400+) for every 50 to 100 m. Calibers of .400+ are designed for megafauna at closer ranges. Convert caliber to kinetic energy range.

Use the most frangible bullet possible to maximize safety by minimizing pass-through risks. The bullet must penetrate peripheral tissue to impact select tissue with enough retained energy to be reliably lethal.

B13 References

1. AVMA. AVMA guidelines for the euthanasia of animals: 2013 edition. Available at: www.avma.org/KB/Policies/Documents/euthanasia.pdf. Accessed Feb 7, 2019.
2. DeNicola AJ, Weber SJ, Bridges CA, et al. Nontraditional techniques for management of overabundant deer populations. *Wildl Soc Bull* 1997;25:496–499.
3. Thomson DU, Wileman BW, Rezac DJ, et al. Computed tomographic evaluation to determine efficacy of euthanasia of yearling feedlot cattle by use of various firearm-ammunition combinations. *Am J Vet Res* 2013;74:1385–1391.
4. Caudell JN. Review of wound ballistics research and its applicability to wildlife management. *Wildl Soc Bull* 2013;37:824–831.
5. DeNicola AJ, Miller DS, DeNicola VL, et al. Assessment of humaneness using gunshot targeting the brain and cervical spine for cervid depopulation under field conditions. *PLoS One* 2019;14:e0213200.
6. Grund MD, Cornicelli L, Carlson LT, et al. Bullet fragmentation and lead deposition in white-tailed deer and domestic sheep. *Human Wildl Interact* 2010;4:257–265.
7. Stewart CM, Veverka NB. The extent of lead fragmentation observed in deer culled by sharpshooting. *J Wildl Manag* 2011;75:1462–1467.
8. Caudell JN, Stopak SR, Wolf PC. Lead-free, high-powered rifle bullets and their applicability in wildlife management. *Human Wildl Interact* 2012;6:105–111.
9. USDA. Operational guidelines: euthanasia. January 2004. Available at: www.dem.ri.gov/topics/erp/nahems_euthanasia.pdf. Accessed Feb 14, 2019.
10. Humane Slaughter Association. Humane killing of livestock using firearms. Available at: www.hsa.org.uk/humane-killing-of-livestock-using-firearms-introduction/introduction-2. Accessed Feb 14, 2019.