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Advice on Euthanasia Techniques for Small and Large Cetaceans

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Research documents are produced in the official language in which they are provided to the Secretariat.

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I. ABSTRACT

This document reviews in a succinct form the special circumstances, problems, and current techniques associated with euthanasia of whales, with emphasis on species found in Canadian waters. Its purpose is to provide easily retrievable recommendations that will allow responders to deal promptly and efficiently with whales in distress in the event that euthanasia is the chosen course of action.

Considering the wide variety of species of small and large whales and the remarkably large size of some of these whales, much remains to be learned about the most humane and effective methods of euthanizing these animals. Moreover, each incident involving the prospect for euthanasia carries its own set of unique circumstances that defy prediction. Therefore, it is not the intent of this document to derive rigid rules of procedures from its recommendations.

Avis sur les techniques d'euthanasie pour les petits et grands cétacés

I. RÉSUMÉ

Ce document passe succinctement en revue les circonstances particulières, les problèmes et les techniques actuelles reliés à l'euthanasie des baleines, en mettant l'accent sur les espèces présentes dans les eaux canadiennes. Il vise à fournir des recommandations facilement disponibles qui permettront aux intervenants de s'occuper rapidement et efficacement des baleines en détresse dans les cas où l'euthanasie est la mesure adoptée.

Étant donné la grande variété des espèces de baleines, petites et grandes, et la taille extrême de certaines, il nous reste encore beaucoup à apprendre au sujet des méthodes d'euthanasie les plus efficaces et les plus appropriées du point de vue du bien-être animal. De plus, chaque incident impliquant la possibilité d'euthanasie a lieu dans des circonstances particulières et impossibles à prévoir. Ce n'est donc pas l'intention de ce document d'élaborer des règles de procédures strictes à partir de ses recommandations.

II. GENERAL CONSIDERATIONS

A. NEED FOR GUIDELINES

Different circumstances may require the euthanasia of a whale: stranding, entanglement in fishing gear, entrapment in ice, significant injury of a free-swimming whale from ship-strike, or a terminally ill animal in a captive situation. However, the most common situation is the presence of a severely debilitated, ill, or injured whale on shore. From an animal welfare perspective, this constitutes an emergency, but it is also a challenge to even the most prepared responders as all stranding events differ from each other in at least some respects. There are the sudden and urgent details of finding people who know best what to do, obtaining the resources for what needs to be done, taking the necessary action, and providing factual information to people on a shoreline that does not necessarily permit easy control of the situation. There will be circumstances when attempts to rescue the whale(s) are reasonable and may even be successful, but more often a dying animal is before us as is the social and cultural expectation that we can provide a humane death.

Veterinary science has much to say about the techniques and emotional-social elements of animal euthanasia, and with respect to most terrestrial animals is quite competent in this regard. It has less ability to inform us about how to ensure the successful euthanasia of a very large marine mammal. We need to improve our ability to provide a 'good death' for whales on short notice, in different locations, and in conditions of tide, surf, shoreline, and sometimes ice that can be difficult. This document seeks to fulfill some of that need, based on current knowledge.

The conservation status of different species of whales can vary substantially. Although this may influence efforts invested in trying to rescue an animal in distress, the welfare of the individual animal affected must take priority, especially if efforts at rescuing it will only prolong its suffering when chances of survival are minimal. All species of whales in Canada are under the jurisdiction of Fisheries and Oceans Canada which is responsible for the protection, conservation and management of marine mammals, and officials from this agency must be contacted before interacting with a whale or taking any decision with respect to euthanasia.

i. Definitions and current concepts of animal euthanasia

Whale: any Cetacean, regardless of age or size.

Small whale: porpoises, dolphins, and other whales less than 6 m in length.

Large whale: a whale of any species exceeding 6 m in length.

Stranded whale: one that is alive and cannot leave the shore without assistance.

Shoaled whale: one that is alive, appears ill, and does not leave the shallow water, although it appears capable of doing so.

Euthanasia:

1) the act or practice of killing or permitting the death of hopelessly sick or injured individuals (as persons or domestic animals) in a relatively painless way for reasons of mercy (The Merriam-Webster online dictionary);
2) a method of killing that minimizes or eliminates pain, distress, and anxiety experienced by the animal prior to loss of consciousness, and causes rapid loss of consciousness followed by cardiac or respiratory arrest and death (AVMA 2013).

Although the means to accomplish euthanasia of whales can be difficult, the clear intention is to prevent suffering as much as possible. Best practices include the following basic elements which are adopted in this document:

- the animal must be treated in a respectful manner at all times;
- the animal is in a terminal state of disease or injury, or has no hope of survival (e.g. dependent young animal that has lost its dam);
- loss of consciousness must be achieved prior to any significantly painful procedure;
- a certain, humane death must be achieved and confirmed.

Other elements of animal euthanasia that may be difficult to achieve when dealing with wild species include:

- a procedure done in a gentle and aesthetic manner;
- avoiding distress to people who see this procedure being done.

ii. Strandings, triage, entanglements, entrapments

Stranded whales always represent an emergency situation that can quickly attract the attention of the public and the media and arouse strong emotions. Not all animals in these situations can be rescued in a timely manner, and euthanasia may be the best recourse from an animal welfare perspective. Public opinion, press media considerations, and the responders' emotional concerns should not override the decisions that need to be taken on behalf of the animals involved, while ensuring the safety of all people nearby. If euthanasia ends up being the most appropriate action, it must be done as swiftly and as professionally as possible.

The problem of mass stranding greatly complicates the task of responders as they must triage the animals, care for those that may have a chance for survival, euthanize those that do not while ensuring that this process does not cause further stress to the other animals, and continue to evaluate the remaining animals. On this basis, the use of ballistics or explosives to euthanize animals in mass stranding events is not desirable because the noise generated by the procedure may further exacerbate the anxiety and fear in the conscious animals (Barco et al. 2012). Even if a decision is made to euthanize all animals involved in a mass stranding, all these animals should be deeply sedated before the euthanasia procedure is implemented (deep sedation being characterized by moderate depression of the central nervous system and an animal which is awake, relaxed, silent, and indifferent to mild pain). Any number of large whales, or even three or four small whales, in a mass stranding can easily exceed the local capacity for chemical euthanasia, and staff and equipment may simply not be available to accomplish needed euthanasia in a timely manner.

Whale entanglement in fishing gear is a recurring problem which seldom allows euthanasia. Whales may be seriously compromised by entanglement and eventually die, but the opportunity for euthanasia is reduced mainly because of the animal's continuous mobility. Alternatively, if the entangled animal is still alive and does not appear to be injured by the nets and lines when discovered, efforts to free it may well result in a good chance for its survival.

Entrapment of whales, either small or large, in rapidly forming or drifting ice is common in Atlantic Canada and in the north. When judged necessary, opportunity for euthanasia in these situations is also reduced. However, the use of ballistic methods (rifle and bullets) for small whales will permit utilization of meat from these animals for human consumption or to feed dogs, particularly in the north.

iii. Current standards for whale euthanasia

A review of the literature currently available on techniques of euthanasia used in small and large whales reveals many different techniques that are influenced by the size and species of the animal involved and the information and resources available (Greer et al. 2001; Geraci and Lounsbury 2005; Donoghue 2006; Greer 2006; Moore 2010; Barco et al. 2012; AVMA 2013; IWC 2006, 2014). A wide variety of species of whales have been dealt with by responders, but the actual number of individual animals of each species that have been successfully euthanized remains limited, especially for the larger species (Harms et al. 2014). Therefore many questions remain to be answered regarding the most appropriate techniques to be used under different circumstances and in different species.

B. HARMONIZATION OF ETHICS, ANIMAL WELFARE, AND PUBLIC EXPECTATIONS

The ethics of whale euthanasia are the same as for other animals: such action must only be taken when: 1) the whale is considered to be in an irreversible state of suffering, or is likely to soon reach this state; 2) euthanasia can be accomplished with a high likelihood of success; 3) the safety of the responders can be assured; and 4) environmental concerns are addressed. The aesthetic of euthanasia as perceived by those providing it and others who are merely watching must be considered, but it must not override the welfare of the animals involved (CCAC 2010).

Events when euthanasia of a whale may be necessary tend to lead to strong and sometimes conflicting opinions on the part of the public regarding the appropriateness of euthanizing an animal, or of withholding euthanasia. Many people have direct experience with ideal conditions of animal euthanasia, for example when an old, infirm pet has been euthanized by a veterinarian, with all consideration given to an unhurried, aesthetic, and peaceful process. The contrast of this experience with what may need to be done with a whale to achieve the same end can be unsettling. Regardless of the option chosen by the responders, it is essential that the details of the situation be carefully explained to members of the public and the media witnessing the incident, such as:

- the species involved;
- animal welfare issues at play that may dictate euthanasia;
- if euthanasia is elected, the procedure chosen, the proposed steps to be taken, and possible complications;
- alternatively, the reasons for withholding euthanasia.

C. CONTEXT OF GUIDELINES: WHALE SPECIES IN CANADIAN WATERS

This document limits itself to the species that are found most commonly in Canadian waters. However, it is understood that: 1) individual animals of other species can occasionally find their way into Canadian waters; and 2) faced with a lack of information on less common species, it is logical and appropriate for responders to apply to animals of these species techniques of euthanasia that have been shown to be efficient in more common species of comparable size. Table 1 lists the species most likely to be encountered in Canadian waters, including some of their characteristics (approximate length, weight, and blubber thickness of adult animals).

D. THE DECISION PROCESS: WHEN TO EUTHANIZE, AND THE ALTERNATIVES

All stranded whales must be given a proper physical examination, preferably by a veterinarian or biologist familiar with marine mammals. Based on a number of factors, including the resources and expertise available at the time, the following actions may be taken:

- return the animal to deeper water immediately;
- bring the animal into captivity for observation, if facilities are available;
- euthanize the animal;
- palliative care only, until natural death occurs.

Although due consideration must be given to the welfare of the animals involved, safety of the responders is paramount and must influence all stages of the decision process.

If examination and the circumstances of a diseased or injured animal suggest that euthanasia is appropriate, delay beyond the time required to obtain the equipment and personnel should be kept to a minimum. Exceptions to this principle include:

- environmental conditions of tide, surf, or ice which may dictate the timing of euthanasia;
- when euthanasia by physical means requires daylight for public safety.

In order to meet the requirements for whale euthanasia with regard to indications, methods, and outcome, the following conditions should apply:

- there should be evidence of animal suffering or imminent likelihood of suffering;
- the means to accomplish certain euthanasia, as described in Section III of this document, must be available and should be performed by someone experienced in euthanasia of animals; untrained people attempting euthanasia are more likely to increase suffering and stress experienced by the animals;
- human and environmental safety must be assured;
- in the event that euthanasia of more than one animal is required, there must be a plan to minimize stress to the animals prior to euthanasia;
- confirmation of death after euthanasia must be done as soon as possible;
- if members of the public or news media become involved to any extent, a full explanation of the situation must be provided;
- concurrently, the media and attending members of the public must be kept at a reasonable distance from the stranded whales, for the sake of public safety and also in order not to exacerbate the stress already experienced by these animals.

There will undoubtedly be circumstances when euthanasia cannot be reliably performed (e.g., a shoaled adult sperm whale; heavy surf conditions preventing access to the animal[s]). In such cases, it will be necessary to wait for nature to take its course and for death to occur in its own time (referred to as protected natural death with palliative care) (see section III D).

E. CLINICAL ASSESSMENT OF INJURED WHALES

The fate of a stranded whale cannot easily be predicted until it has been examined by a person experienced in such events, preferably a veterinarian. If the animal appears alert, strong, uninjured, and breathing at a rate normal for the species, it may very well survive if it can be quickly returned to deep water. If, however, it shows some of the signs listed below, its survival is much less likely, and the possibility of euthanasia should be considered from the outset. The decision to elect euthanasia may be based on a single overriding criterion or on a cumulative set of observations suggesting an unfavourable outcome for the animal in the short or long term. Signs that should arouse concern include:

- young animal still dependent on its mother, but without the mother present;
- poor body condition, revealing the outlines of the vertebral column;
- external evidence of serious injury;
- sun-induced blisters over much of the exposed skin surface;
- evidence of internal disease, such as bleeding or fluid discharge from body openings (mouth, blow hole, genital slit, anus);
- ocular nystagmus (rapid, involuntary, and usually lateral movement of the eyeball, indicating neurologic deficit);
- severe hypothermia or hyperthermia (deep rectal temperature < 35°C or > 40°C, respectively);
- long period of time stranded (> 24 hours for small whales; > 12 hours for large whales);
- increased breathing rate (>20 breaths per 5 min for porpoises and dolphins; >8 breaths per 5 min for pilot whales, belugas, narwhals; >5 breaths per 5 min for large whales);
- severe depression indicated by loss of normal protective reflexes (tongue withdrawal, palpebral and corneal, blow hole, anus), loss of jaw tone, protruding penis.

III. REVIEW OF SPECIFIC METHODS OF CETACEAN EUTHANASIA

A. THE EFFECT OF ANIMAL SIZE

The single most important factor affecting efforts to euthanize a whale is probably its size. While there are important differences as compared to domestic animals, the smaller whales may be euthanized with conventional drugs or firearms. Large whales are much more difficult to deal with, and in many circumstances euthanasia may be impossible. Caution must be used when determining the size of whales as the length of these animals can easily be underestimated, especially if they are still partly or completely submerged in water.

B. PHYSICAL METHODS (BALLISTICS, EXPLOSIVES, EXSANGUINATION)

i. Ballistics (rifle and bullets)

Ballistic methods must rapidly induce unconsciousness or death with minimum pain through destruction of the brain or the brain stem. (Barco et al. 2012). They require someone who has good knowledge of the principles of ballistics, especially terminal ballistics (which determine the size and nature of the wound in the target animal), who is familiar with the different types of rifles, shotguns, and bullets, and who has access to the appropriate equipment and has the proper permits to use them.

Conventional firearms are acceptable in smaller (<6 m long) whales. The choice of the calibre of ammunition for these animals is influenced by their size and thus the likelihood of the projectile (bullet) reaching vital organs, more specifically the brain or brain stem. In a partly submerged whale, however, any amount of water that the projectile needs to cross before hitting the target may greatly reduce its kinetic energy, and as a result, its ability to reach vital organs. In such a situation, it is advisable to wait for the tide to go down if it will expose more of the animal's head.

Shooting is not recommended for animals longer than 6 m, with the possible exception of minke whales, as it cannot guarantee immediate destruction of the brain. The reasons for this uncertainty include the very thick layer of soft tissues covering the head, the large size of the skull, the small size of the brain cavity in relation to the whole skull, and a lack of knowledge of the exact aim points, shooting angles, and terminal ballistics in larger animals. Present knowledge with respect to euthanasia by gunshot to the brain is inadequate to ensure effective euthanasia in a high percentage of large whales.

The design of the projectile (e.g., weight, types of jacket and tip) is at least as important as the calibre of ammunition in influencing the characteristics of the terminal ballistics and thus the potential for immediate brain destruction. In whales and also in large terrestrial mammals, the use of non-expanding (solid or full metal jacket) bullets, as opposed to expanding bullets, ensures maximum penetration with minimum deviation of the projectile from its intended course (Donoghue 2006; AVMA 2013).

All these elements need to be considered in order to avoid either insufficient penetration of the bullet into the brain or the brain stem or, at the opposite end of the spectrum, complete penetration of the whole thickness of the skull and exit of the bullet or its fragments, thus endangering other animals or people directly or through ricochets. Table 2 provides information on the calibres and types of ammunition currently recommended in different species and sizes of whales.

In discussing the use of gunshot as a general means of euthanasia, the Guidelines for the Euthanasia of Animals of the American Veterinary Medical Association (AVMA 2013) indicate that the head should be the preferred target area and that the firearm should be aimed so that the projectile enters the brain, causing instant loss of consciousness. An equally appropriate target in whales is the base of the skull (occipital condyles), at its articulation with the vertebral column, i.e., the junction between brain and spinal cord. Severe damage of the brain tissue in this area may not only sever the spinal cord, but it also destroys the very rich network of blood vessels which surrounds the spinal cord and constitutes the primary blood supply to the brain (Marshall 2002).

Because of the unique configuration of the head and skull of whales, and its considerable variation between species, it is critical to know the best shooting angles and points of aim in different species and sizes of animals. Unfortunately, much of this information is still lacking. According to general recommendations currently available for small whales, a dorsal approach or a lateral approach to firing at the head can be used. With the dorsal approach, appropriate for the smaller animals, the shot is aimed at a site slightly caudal to the blow hole and a short distance lateral to the dorsal midline down and back (caudo-ventrally) toward the center of an imaginary line drawn between the cranial edges of the flippers (Figure 1).

A lateral approach can also be used for small whales. The shot is aimed at the lateral side of the head, between one-third and halfway along an imaginary horizontal line drawn between the eye and the cranial edge of the flipper. With this approach, the projectile is expected to hit the base of the brain or the brain stem (Figure 2).

A third, dorso-lateral, approach for small whales is to take the shot between one-third and halfway caudal to the eye along an imaginary horizontal line between the eye and the cranial edge of the flipper, but at a 30-45° angle laterally from the dorsal midline of the head and perpendicularly to the skin surface. This will avoid the thick median and lateral ridges of bone characterizing the skull of small toothed whales such as harbour porpoises and Atlantic white-sided dolphins and should hit the thinnest part of the calvarium (Figure 3).

According to Norwegian workers, minke whales can be killed with a high-calibre firearm aimed at the brain, approximately 55-75 cm behind the blowhole (Øen and Knudsen 2007). Using this recommended distance, and depending on the size of the animal, the shot may hit the brain cavity or the base of the skull (occipital condyles). Based on measurements of the thickness of the calvarium (top of the skull forming the brain cavity) in this species, the thinnest part is approximately 5-10 cm on either side of the dorsal midline, close to the occipital condyles (Art Ortenburger, unpublished data). This indicates that in minke whales the shot should be directed perpendicularly to the skin surface at an aim point located slightly lateral to the dorsal midline (Figure 4). At a distance 55-75 cm behind the blowhole of an adult mink whale, the projectile should go either through the brain cavity or the junction between brain and spinal cord.

When possible, the animal should be shot at close range in order to ensure the best accuracy. If there is any doubt about the aim point, it is recommended to fire three shots in quick succession on a line through the target area. The degree of cavitation caused by high-power ammunition will ensure that the damage extends far beyond the immediate trajectory of the projectile.

Sperm whales represent a unique challenge because of the enormous size of their head and the toughness of their blubber. A specially designed “Sperm whale euthanasia device” (SWED) has been used on several occasions in New Zealand (Marsh and Bamber 1999; IWC 2014). It uses very powerful ammunition (14.5x114 mm, with a 950-grain bullet) fired with an extensively modified 11.8-kg firearm with a 2.4-m recoil. However, such a device is not available in this country.

ii. Explosives

Like ballistics, explosives must rapidly induce unconsciousness or death with minimum pain through destruction of the brain or the brain stem (Barco et al. 2012). They are considered the preferred form of euthanasia for very large whales. However, timely access to the necessary material and to experts who have the authorization and knowledge to handle it is unlikely unless specific training of personnel in the region has been implemented.

The only method of euthanasia with explosives that is adequately described consists of placing a charge on the head, caudal to the blowhole, shaped in a pyramid and sand-bagged to direct the blast down toward the brain (Coughran et al. 2012) (Table 2). Caution must be used not to underestimate the amount of explosive charge necessary to destroy the brain in a single blast and thus cause immediate death. (See: http://www.youtube.com/watch?v=JuVrMbwEtvs for an example of successful euthanasia of a southern right whale with explosives, near Cape Town, South Africa.) Coughran (IWC 2014) also described the successful use of explosives to cause severe fracture of the skull of a dead 10.8-m-long sperm whale found in a lateral position; the explosive charge was placed 60 cm directly caudal to the left eye. The extent of the skull damage suggested that immediate death would have occurred in a live animal.

For many years, Norwegians have commercially hunted minke whales with grenades delivered from a distance with a harpoon gun (Knudsen and Øen 2003). Penthrite (pentaerythritol tetranitrate) is the explosive of choice in this hunt. A penthrite-loaded grenade delivered with a modified harpoon (darting gun) is also used in subsistence hunts of bowhead whales by Alaskan Eskimos and Canadian Inuit (IWC 2007; Pierre-Yves Daoust, personal observation). Although the hunts for these whales using penthrite grenades have shown the potential for rapid death in a large proportion of the animals (Øen 1995; Knudsen 2005), the equipment currently used in these hunts is highly specialized and unlikely to be readily available.

iii. Exsanguination

Exsanguination ultimately causes death by depleting the brain of its supply of oxygen and glucose. However, all major blood vessels in whales are deeply located, and their severance involves the section of a substantial amount of soft tissue with an abundant supply of pain receptors. It is therefore essential that the animal be deeply sedated or anesthetized before resorting to this method of euthanasia.

Major blood vessels that are reasonably accessible for severance include the brachial arteries (in the axillary regions) and the caudal vascular bundle, located within the chevron canal deep on the ventral side of the peduncle (Barco et al. 2012; Harms et al. 2014). One should bear in mind that the profuse amount of blood flowing out of these blood vessels onto the beach could be unsettling to some of the people watching. Other methods include a gunshot to the heart and laceration of the heart or its arterial trunk (by means of a long thin knife inserted just ventral and caudal to the flippers) (Barco et al. 2012).

The Faroe Islands, in the eastern North Atlantic, have a long history of drive hunts for long-finned pilot whales. A "Faroese spinal lance" is used to rapidly kill these animals by severing the spinal cord and the surrounding blood vessels (the main blood supply to the brain [Marshall 2002]) with a single thrust followed by sideways movements (NAMMCO 2011). Although seemingly highly efficient, resulting in death of the animals within 5-10 sec, this lance is designed specifically for the long-finned pilot whale, likely requires some degree of practice, and probably could not be readily used in other species.

C. CHEMICAL METHODS (DRUGS)

i. Overview

The use of chemical methods for euthanasia of whales is not simple, and the involvement of a veterinarian is almost essential. It is usually expensive, may incur significant human hazards, and requires very specific knowledge of the drugs and injection techniques. It also requires recognition of animal physiologic responses to the effects of the drugs on the central and autonomic nervous systems. There is the added complication that the best outcome for chemical euthanasia usually results from use of multiple drugs that are given in a specific sequence (Barco et al. 2012). While standard veterinary drugs and equipment can be used to good effect in whales up to 3 m long, significant problems with venous access and with the quantity of drugs required impose practical limits on larger animals and, for the latter, in cases of mass stranding. Finally, the use of chemical methods implies that the carcass can be disposed of appropriately in order to avoid any potential for ecotoxicity (environmental contamination). This is especially important in northern regions where whale meat is commonly used for human consumption or to feed dogs.

ii. Drug dosing

Developing accurate drug doses is an exacting process requiring considerable research, which has not been done for any drug in any whale species. Dosing of all drug and nondrug euthanasia chemicals for whales remains a matter of educated guess. Doses in use and described in the literature for this purpose have been developed for a few species based simply on clinical results. There is sufficient information on the differences of drug dose requirements and effects for terrestrial mammals for us to know that there may be unpredictable and important differences between whale species. Because our goal is to kill the animal, we need not be concerned with overdosing. However, even if specific dosing information were known for these animals, there remain important considerations of cost and ecotoxicity which follow from use of euthanasia drugs.

The appropriate doses for most of the sedative and anesthetic drugs used for euthanasia are well-known for domestic animals, and are expressed in terms of milligrams of drug per kilogram of body weight. This simple, linear relationship breaks down with very small or very large animals. For example, the dose of virtually any sedative drug per kg of body weight may be 250 times higher for a mouse than an elephant. In general, the doses used for domestic livestock work well in whales that fall into the same weight range. For larger whales, dosing drugs of the kind used for euthanasia requires dose scaling. The usual method of dose scaling is to calculate dosages on metabolic body size, which based on standard pharmacological principles is the animal's weight in kg raised to the 0.75 power. The literature pertaining to whale euthanasia to date has not considered this important detail, but there is evidence from the case reports of successful drug euthanasia that dose scaling applies as expected to the larger whale species. In this document (Table 3; Figures 5 and 6), dose scaling begins with a factor of 0.9 for body weight of 1200 kg, 0.8 at 4100 kg, and continues with 0.75 for a weight of 14,000 kg and higher (Sharma and McNeil 2009). For ease of use, Figures 5 and 6 provide drug doses based on the animal's length converted from its weight according to Geraci and Lounsbury (2005, Figure 6.3).

iii. Injection sites

Numerous injection sites for euthanasia by drugs have been described, including intravenous, intraperitoneal, intracardiac, intramuscular, and into the retrobulbar (ocular) venous plexus. In addition to the above sites, administration of drugs directly into the blowhole has been used. All authors correctly point out the ease of inadvertent injection into the blubber layer, and resulting failure of drug absorption, by those unfamiliar with whale anatomy. Moreover, stranded whales may shunt blood from the periphery to core blood vessels, as happens during diving, and this may result in protracted response to the drugs, for example if these are given intramuscularly. Finally, peripheral blood vessels may have collapsed in animals in shock or in a state of hypothermia (Barco et al. 2012).

The normal, humane, and most effective avenue of injection for euthanasia is intravenous. In whales, unfortunately, veins are difficult to find, are often underwater, and anatomically consist of numerous small vessels arranged in a ring surrounding an artery as part of a countercurrent heat exchange system. Vessels of the mid-ventral groove of the tail peduncle and the median or cephalic veins of the flippers (J.S. Reidenberg [Icahn School of Medicine at Mount Sinai], Sue Dawson [Atlantic Veterinary College, University of Prince Edward Island], personal communications) are perhaps the easier to reach, although working in proximity to the tail poses a greater risk to the operator depending on the size of the whale. Figure 7 depicts the common sites for intramuscular and intravenous injection, and Table 1 provides the blubber thickness of normal adult whales of various species in cases where intramuscular injection is selected.

Because there are very few veterinarians with experience in locating the veins of whales, the easiest routes of administration of drugs for sedation and euthanasia for most circumstances are currently and will likely remain the intramuscular and intracardiac methods. Both can be easily learned, are effective, and are far less difficult than the others. While administration of euthanasia solutions into the blowhole appears simple and therefore attractive (Dunn 2006; Kolesnikovas et al. 2012; Harms et al. 2014), so far it seems to be less effective and may be less safe than the preferred avenues.

Intramuscular injection in smaller whales is straightforward and when compared to large domestic animals requires only that longer needles be used to ensure that the drugs are not injected into the blubber layer. The necessary needles for small whales are likely to be found in most veterinary practices and will permit reliable intramuscular injection in the epaxial musculature near the animal's maximum girth (Figure 7) for the species indicated in Table 4. The blubber thickness of large whale species varies greatly, and conventional needles may be inadequate to inject bowhead and right whales which have exceptionally thick blubber. An alternative intramuscular site without a blubber barrier is the tongue, which may be accessible in debilitated baleen whales. For intramuscular injection of any drug in any species, a small injection volume is necessary to ensure rapid absorption. Concentrated drug solutions are available in some cases, or the standard drugs may be injected, ideally to a limit of 10 ml, in as many sites as needed to provide the full calculated dosage.

Sperm whales are unique in the remarkable toughness of their blubber, which makes the use of most needles and injection techniques more difficult.

Intracardiac injection in smaller whales is not difficult, and when this route is used for injection of lethal drugs with standard veterinary needles, rapid death will result. Two methods are possible: the parasternal or the lateral approach. In the parasternal approach, a 90 mm x 18 ga spinal needle is inserted close to the palpable sternum, at the level of the caudal edge of the flippers, and directed dorso-medially until a free flow of blood issues from the needle (Figure 8a). The external part of the needle will also be seen to move from side to side in concert with each heartbeat. Insertion of the needle from the left side of the sternum may improve the chances for entry into the heart. In the lateral approach, which is often the only possible approach for large whales, a needle equal in length to approximately one-half of the diameter of the whale is inserted just behind the caudal edge of one of the flippers and directed toward the same point on the other side of the body (Figure 8b). A free flow of blood indicates entry into a heart chamber or great vessel in the thorax, and injection should begin immediately.

For large whales a large needle is required, which may have to be fabricated from available materials (e.g., automobile brake line, copper tubing) on short notice. A range of lengths between 1 and 1.6 m and of diameters between 6 and 25 mm should serve for most whales. The needle needs to be very strong and stiff to penetrate the tough blubber, and to not be bent by the force of the contracting heart muscle. Either an obturated needle (i.e., with a solid removable rod filling its lumen) or a solid-tip needle with side ports will prevent it from becoming plugged by blubber or muscle as it is inserted. The exterior end of the needle must accept syringes for drug injection (i.e., Luer-fitted needle), or have some other adapter to permit injection of large quantities of euthanasia chemicals. At least two needles should be available since one might be damaged in the first attempt. Because administration of a large volume of drug is often required for large whales, the use of a mechanical device to accelerate the process, such as a commercial garden sprayer pressurized reservoir, is advisable (Harms et al. 2014).

Prior to needle insertion, the skin and body wall should be thoroughly anesthetized with local anesthetic, ideally down to and including the pleural membrane. Given that death is often delayed in large whales when euthanized by drug injection, the needle should be removed when all drugs have been injected to reduce cardiac pain and prevent damage to a needle that may be needed again.

The following principles for injection of sedative and euthanasia drugs in whales are recommended:

Small whales: use standard medical equipment, which will be found in any veterinary practice working with farm animals, for intramuscular, intravenous, or intracardiac injection.

Large whales: specially built needles will be needed for successful drug injection; these will not be found in a veterinary practice.

iv. Pre-euthanasia sedation

Sedation is not required prior to administration of a lethal drug, but is preferred whenever circumstances permit since it reduces animal distress and increases safety for people working around the stranded whale. For these reasons, sedation is also considered appropriate when physical methods of euthanasia are used, and in circumstances of mass stranding. In addition, sedation makes chemical euthanasia less difficult by reducing the amount of euthanasia drug required. There are four commonly available and lower-cost drugs available; none are approved by Health Canada's Veterinary Drug Directorate for use in whales, however, this detail does not preclude their use when indicated under the rules of extra-label drug use.

Acepromazine is a common veterinary tranquilizer which is usually given by injection. In terrestrial mammals, it allays anxiety, slows and reduces responses to most stimuli, lowers blood pressure slightly, and has persistent effects for several hours. It is commonly found in almost any veterinary practice. Preferred formulation: 10 or 25 mg/ml.

Xylazine is a common veterinary sedative and produces analgesia and profound CNS depression and lowers cardiac output, but maintains defensive behaviours in most animals. It is commonly found in almost any large animal veterinary practice. Preferred formulation: 100 mg/ml.

Detomidine is pharmacologically similar to xylazine, but its effects are prolonged with less muscle weakness. It is found in most equine veterinary practices, and is more expensive than most other drugs of the type. Preferred formulation: 10 mg/ml.

Diazepam is commonly found in most small animal veterinary practices and produces less CNS depression and muscle weakness. It has few effects on the cardiovascular and pulmonary systems, and is moderate in cost. Preferred formulation: 5 mg/ml.

Veterinary experience with the use of opiates such as morphine for sedation of whales is very limited, their effects are not predictable, and therefore their use is not recommended.

Suggested dosages of the sedatives described above for whales are provided in Table 3 and Figure 5; approximate costs are described in Table 5. Numerous other tranquilizing/sedating drugs are available, and their effects on whales are likely to be similar to what is seen in terrestrial mammals. The drugs described above are considered most relevant for this document, as they will be most often found in sufficient quantity when needed on short notice.

v. Euthanasia drugs and chemicals

The standard references on animal euthanasia list a number of chemical agents for this purpose. Most can be quickly eliminated for use in whales, for reasons of lack of ready access, or for being unsuitable for whales. For example, methods of delivery of gaseous agents (e.g., carbon monoxide, isoflurane) are lacking for whales. For other drugs, there is a lack of supporting literature of their effects when used for euthanasia (e.g., ketamine, butorphanol) making them more experimental for this application than is acceptable. Two commercially available drugs may be currently considered appropriate for euthanasia of whales. A single chemical agent which is readily available may also be considered.

Pentobarbital sodium, a barbiturate, is the best known and most often employed drug for euthanasia of domestic animals. Its effects are predictable, and it is readily available. It is, however, a scheduled drug (Department of Justice, Government of Canada 2014), and possession and use require the appropriate licenses which are usually restricted to veterinarians. Pentobarbital reliably provides for an unconscious state prior to death and is also an effective sedative at doses less than required for euthanasia. Pentobarbital is also a stable drug and may be found unchanged in the carcass months after euthanasia. Because of this, deaths of wild animals from scavenging of carcasses are known to occur, and the ecotoxicity of pentobarbital is therefore a major concern. Preferred formulation: 340 mg/ml.

T-61 is a proprietary combination of three agents which result in an unconscious state, prevent muscle activity, and stop the heart. It is one of the very few agents that, in contrast to opiates and barbiturates, are not scheduled and so can be used by a trained layperson. However, like pentobarbital sodium, it must be given by intravenous or intracardiac injection, its use in whales has been rare, and there is less known of its full range of effects.

A 30% solution of potassium chloride (KCl) can be given by intravenous or intracardiac injection to cause cardiac arrest. This results in unconsciousness in a short time, and death ensues some minutes later. It is considered inhumane to cause death by this means alone, since the animal will likely experience severe cardiac pain. However, its use in this manner may be permissible if, prior to injection of KCl, the whale is deeply sedated with either xylazine or detomidine which have potent analgesic effects. This combination has many virtues of cost and ecosystem safety, yet it is somewhat difficult to use in practice, and requires injection of large volumes.

Suggested dosages of the euthanasia drugs described above are provided in Table 3 and Figure 6. Approximate costs of sedation and euthanasia are described in Table 5; these costs are comparable to those calculated in Harms et al. (2014).

Other chemical methods of euthanasia include the controversial use of ultra-potent opiates (carfentanyl, etorphine). These drugs have very specific uses for capture and immobilization of large wild animals and are mostly found in zoos or used for wildlife research. While they have several attractive features for whale euthanasia, including administration by intramuscular injection, they are considered extremely dangerous for people in the vicinity, as would be the whale carcass to scavengers. These drugs should be avoided, given the facts that they are not easily obtained, can be quite expensive, and present unreasonable danger to humans.

In the past, chemical killing of whales has also been accomplished by techniques that do not render the animal unconscious (e.g., succinylcholine, a paralytic agent which causes death by preventing normal respiration) and that are painful. Such methods of killing are inhumane and must not be used. There are also a few novel methods which make use of unusual chemical poisons (e.g., carbon monoxide) or routes of administration to whales such as intranasally through the blowhole. While these may be humane, they require further development before they can be recommended.

D. PROTECTED NATURAL DEATH WITH PALLIATIVE CARE

Protected natural death with palliative care (PNDPC) is defined here as the supervised palliative care given to a whale which is expected to die, but cannot be euthanized. It should be made clear to all responders, observers, and news media that such a decision is not a passive act, that it does not imply just walking away from the dying whale, but rather that it represents a carefully considered and deliberate choice to provide for the best possible death for the whale as permitted by the circumstances. The decision for PNDPC may be required because of insufficient access to human and technological resources (for example, the inability to humanely kill a partly submerged sperm whale) or because of concerns for the responders' safety. However, it is a comprehensive decision, taken by specialists on-site with knowledge of the circumstances and with authority to do so, and it should only be made when active methods of euthanasia have been carefully considered and deemed unavailable or excessively dangerous.

It is clear from the current literature that euthanasia of large whales (sperm whales, baleen whales) requires very specialized equipment and people knowledgeable and experienced in its use, whether it relates to chemical or physical methods of euthanasia. If this equipment and the experts are not readily available, the option to let the animal die on its own must be seriously considered. To paraphrase Barco et al. (2012), "If an animal's life is to be taken, it should be done with the highest degree of respect". Allowing the animal to die on its own in relative peace is respectful if the alternative is to apply substandard methods of euthanasia that may end up breaching basic principles of animal welfare (Greer et al. 2001; Geraci and Lounsbury 2005).

The possibility of PNDPC has some advantages:

1. it is always an option,
2. should the circumstances or local conditions and expertise/equipment change suddenly, the responders can always revert to active euthanasia, and
3. it prevents the unhappy results of a failed attempt to euthanize the whale.

The decision for PNDPC incurs a whole range of actions aimed at minimizing the animal's discomfort. Human safety remains a paramount factor when attempting to implement these actions. The animal must indeed be protected from scavengers, drowning, harsh weather, and well-meaning but highly intrusive people who just want to touch a whale. Without intervention, small whales are usually moribund or dead 1-2 days after stranding, but large whales may remain alive for several days (Marsh and Bamber 1999). The tendency for larger whales to survive longer may relate to larger absolute muscle oxygen stores and a lower mass-specific metabolic rate (Noren and Williams 2000).

The most important features of PNDPC include:

- keep all people, animals (including potential scavengers), and vehicles (including boats) at a reasonable distance throughout the day and night, except as needed for responders to provide direct palliative care;
- constantly ensure minimal noise and disturbance by people or vehicles;
- help the whale to maintain an upright position;
- keep the whale's blow hole uncovered and unobstructed;
- flush the eyes with water if needed;
- withhold medical treatment that may prolong life;
- dig holes for the flippers, and fill with water in summer;
- in winter, provide protection from wind, cover the dorsal fin and flukes with cloth soaked in vegetable or mineral oil (unless the whale is mostly submerged);
- in summer, provide shade, cover the body with wet cloth leaving the dorsal fin exposed (unless the whale is mostly submerged).

IV. CONFIRMATION OF DEATH

According to Close et al. (1996) in reference to experimental animals, the only reliable means of confirming death in an animal is the absence of a heartbeat, which can be difficult to assess in a large animal in the field. Even in a small whale, this requires a stethoscope; with a large whale, a portable electrocardiogram is probably necessary. Alternatively, it should be possible for the responders to use a combination of simpler criteria to confirm loss of sensibility and death in a whale, regardless of its size (Barco et al. 2012):

- loss of reflexes (tongue withdrawal, palpebral and corneal, blow hole, anus);
- loss of jaw tone;
- loss of tail movements;
- fixed and dilated pupils;
- protruding penis;
- absence of respiration over an extended period, although this can be hard to assess in animals that normally hold their breath;

- no capillary refill on the tongue's surface.

As with any other vertebrate, the immediate moment of death in a whale may be accompanied by so-called post-mortem reflexes such as tremors and forceful tail movements ("flurrying"), analogous to paddling in terrestrial mammals. These reflexes are more likely to occur when using physical methods of euthanasia that target the brain or its base as its destruction stops the normal inhibitory signals travelling from its higher control centres down the spinal cord (Guyton and Hall 2006). Also, because different species may react differently to drugs and because there are few opportunities to learn about the use of sedatives and barbiturates in many species of marine mammals, unexpected terminal reactions may occur when chemical methods of euthanasia are used.

V. CARCASS DISPOSAL

A. INFLUENCE OF METHOD OF EUTHANASIA

Euthanasia procedures may require a considerable amount of time to prepare and implement. However, their successful completion does not represent the end of the responders' responsibilities, especially if chemical methods have been used, as the presence of sedatives, barbiturates, and/or opiates in the carcass constitutes a source of potential poisoning of animals and humans (Bischoff et al. 2011). Death of wild animals, such as bald eagles, from secondary poisoning following consumption of flesh of animals euthanized by barbiturates is well documented (Barco et al. 2012). Moreover, a dose of sedative, barbiturate, or opiate acquired through scavenging does not need to be directly lethal in order to adversely affect the survival of an animal in the wild.

Methods of disposal of whale carcasses contaminated with drug residues include: incineration (for small carcasses), burial (for small and large carcasses), and composting. Towing the carcass to sea does not resolve the problem of ecotoxicity as far as the marine environment is concerned. Moreover, the carcass stands a good chance of coming back to shore. Pentobarbital has been shown to persist for decades in anoxic groundwater and also to withstand rendering (O'Connor et al. 1985; Eckel et al. 1993), but it may be broken down by composting (Schwartz et al. 2013) or alkaline hydrolysis.

Concern for ecotoxicity stemming from methods of euthanasia is not confined to the use of drugs. Responders must also be aware of the potential for lead poisoning in scavengers if lead ammunition has been used for euthanasia by physical means and if the area of the carcass where the bullet penetrated remains accessible to these animals (Hunt et al. 2006).

B. VALUE OF CARCASS

The scientific value of performing a necropsy on stranded and subsequently euthanized whales cannot be emphasized strongly enough. Because it is often logistically challenging to study marine mammals in the wild, it is particularly important to maximize the information obtained during stranding events in order to monitor anthropogenic causes of stranding, emerging infectious diseases, and population demographics and genetic makeup (Geraci and Lounsbury 2005).

A necropsy is best led by a veterinary pathologist with expertise in marine mammals. However, this requires some degree of planning. Small whales can be transported to more convenient sites for the actual necropsy and also for disposal of the carcass. The necropsy of large whales is more challenging since it needs to be done at a burial site agreed upon by the authorities responsible for disposal of the carcass and since a team of several people and often heavy machinery are needed to complete this task in a timely manner.

Carcasses of whales that have been euthanized by means other than chemical methods may also be used in some communities for human consumption or to feed dogs.

VI. RECOMMENDATIONS FOR WHALE EUTHANASIA IN CANADA

For the specific euthanasia protocols listed below (Table 6), the first principle must be: "…when expertise and necessary equipment are available." The methods for each set of animal circumstances are listed in decreasing order of preference, however, this ranking should be the first detail to be discarded when specific circumstances on the beach suggest that a different approach is needed.

A. GENERAL RECOMMENDATIONS

Both the published literature and direct experience with whale euthanasia make clear that advance preparation will lead to better outcomes. At the national or regional level, such preparation includes:

1. identification of the people, specialized equipment, and the consumable supplies needed;
2. training of responders and those who will perform euthanasia;
3. acquisition of special equipment and supplies, distributed to selected sites, to be held until needed;
4. devising the logistics of moving trained people and the needed supplies to the sites of stranding.

A list of supplies sufficient to euthanize six small whales or one large whale includes:

- likely to be available from local sources (but this should be confirmed at each site):
    - acepromazine, 50 ml, 10 mg/ml;
    - xylazine, 50 ml, 100 mg/ml;
    - pentobarbital sodium, 400 ml, 340 mg/ml, or T-61, 800 ml;
    - conventional syringes, needles, and intravenous tubing used in farm animal veterinary practice;
    - 12 ga shotgun and slug ammunition;
    - rifle and expanding or non-expanding ammunition, .222 Remington, 5.56 x 45 NATO, or 7.62 x 39;
    - rifle and expanding or non-expanding ammunition, .308 Winchester, 30-06, or 7.62 x 51 NATO;
    - rifle and non-expanding ammunition, .375 or .458;
- not likely to be available from local sources:
    - potassium chloride, 5 liters of a 30% solution;
    - specially-built needles for intracardiac injection (obturated or solid-tip with side ports; Luer-fitted; stainless steel; from 30 to 160 cm long).

Sedation and chemical methods of euthanasia require that there be a certainty of control of the carcass until it can be safely disposed of.

Euthanasia by gunshot should be avoided during hours of darkness or whenever the bullet must pass through more than a few centimeters of water.

B. SPECIFIC TECHNIQUES – BEST PRACTICES IN DECREASING ORDER OF PREFERENCE

i. Small whales

One animal: deep sedation by intramuscular injection followed by euthanasia by:

1. intravenous injection of a euthanasia drug; or
2. intracardiac injection of a euthanasia drug; or
3. gunshot to the brain.

Small number of animals: all animals to be euthanized should first be sedated by intramuscular injection, then euthanized by:

1. intravenous injection of a euthanasia drug; or
2. intracardiac injection of a euthanasia drug; or
3. simultaneous gunshot to the brain of as many of the selected animals as possible, and the rest in rapid sequence.

Large number of animals: do nothing until careful planning has been completed, which has as its purpose the selection of those animals requiring euthanasia and the most rapid simultaneous euthanasia of as many of these animals as possible in the shortest possible time. Sedate each animal by intramuscular injection and mark them with white livestock crayon at the same time. If a gunshot to the brain is the selected option, mark aim point on each animal. If a quick, simple, and gentle method of covering the animals' eyes can be found (e.g., towel), do this for all animals. Considering the difficulty of finding large amounts of the appropriate drugs on short notice, the best options in decreasing order of preference are:

1. simultaneous gunshot to the brain of as many of the selected animals as possible, and the rest in rapid sequence, while striving to ensure that this process does not cause further stress to those animals that may have a chance for survival; confirm that death has occurred for each animal after all have been shot once; reshoot any animal not dead from the first shot; or
2. intravenous injection of a euthanasia drug; or
3. intracardiac injection of a euthanasia drug; or
4. protected natural death with palliative care for those animals which may not be reached in time for euthanasia.

ii. Large whales

On shore: deep sedation by intramuscular injection followed by euthanasia by:

1. intracardiac injection of a euthanasia drug or KCl or both; or
2. explosives; or
3. protected natural death with palliative care.

In water: deep sedation by intramuscular injection followed by protected natural death with palliative care.

iii. Sperm whales

Sperm whales: same as in large whales above, although the very tough and thick blubber of these animals makes injections particularly challenging.

VII. SUGGESTIONS FOR RESEARCH

The need for euthanasia of whales, especially of the larger species, is an uncommon occurrence. Because of this and of the great length of the Canadian coastlines, it is unlikely that, at any given time, more than a few people will have the opportunity to acquire expertise in the euthanasia of more than one or two species. Information obtained from these few occurrences should be recorded, documented, and shared.

A priority area for research is better information on the use of ballistics for euthanasia of whales. This pertains particularly to the anatomical location of the brain and brain stem with respect to standard external landmarks (eyes, blowhole, flippers) and to skull thickness. This needs to be addressed for as many individual species as possible, since it is not clear to what extent, if any, generalizations can be made among species regarding the best aim points for the shot.

For the largest whales, further development of the use of explosives should be investigated. Information needed includes specific charge energies and arrangement, and the standard operating procedures that will assure human safety.

The few reports of combinations of drugs, lethal doses of euthanasia drugs, and particular methods of injection described in the literature for larger whales need to be replicated.

Inhalation methods of chemical euthanasia, using the blowhole for drug administration, hold promise. However, many details of equipment, human safety, and pharmacological properties of the drugs related to their absorption through mucous membranes (Sigurdsson et al. 2013) should be addressed before this approach can be used with good expectations of success.

Although not in the purview of research, training is the essential basis for successful efforts of the kinds described in this document. Conservation officers, veterinarians, and staff of recognized stranding networks should all be included in a training program that would convey the essentials of whale euthanasia. No other effort will be more likely to improve the results of future events on the beach.

VIII. CONCLUSIONS

Over the past many years of whale euthanasia, and in all of the current literature, the available choices have coalesced equally into two avenues: drug/chemical, and ballistic/explosives. Concurrently, the public has come to favor the use of drugs for euthanasia in a manner that imitates what is normally seen when domestic animals are euthanized. Yet, a more complete view of the circumstances of whale euthanasia suggests that chemical methods have some important disadvantages, such as ecotoxicity, inherent difficulty in performing the necessary tasks (thus requiring a higher level of training on the part of the responders), and actual cost. By comparison, physical methods generally tend to be more accessible and more successful, despite an inherently more unpleasant aesthetic dimension.

In all instances of whale stranding where euthanasia may be considered, the possibility of protected natural death with palliative care must not be ignored if appropriate technical resources and expertise are not available. This is particularly true for large baleen whales and sperm whales.

IX. REFERENCES

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X. TABLES AND FIGURES

Table 1. Species of whales most likely to be encountered in Canadian waters, including the approximate body length, weight, and blubber thickness (dorso-laterally at level of maximum girth) of normal adult animals. The blubber thickness is provided to ensure appropriate intramuscular injection when needed.

Toothed whales:

Species	Length (m)[1]	Weight (kg)[1]	Blubber thickness (cm)
Harbour porpoise (*Phocoena phocoena*)	1.5 - 1.7	60 - 80	1.5 - 2.5 [2]
Dall's porpoise (*Phocoenoides dalli*)	1.8 - 2.2	100 - 200	1.0 - 1.8 [3]
Atlantic white-sided dolphin (*Lagenorhynchus acutus*)	2.2 - 2.7	180 - 235	2 - 2.5 [2]
Pacific white-sided dolphin (*L. obliquidens*)	2.1 - 2.5	145 - 200	0.6 - 0.8 [3]
Long-finned pilot whale (*Globicephala melas*) [4]	3.8 - 6	800 - 2000	2.5 - 3.5 [2]
Beluga (*Delphinapterus leucas*) [4]	3 - 4.5	500 - 1,400	7 - 10; up to 15 [5]
Narwhal (*Monodon monoceros*)	4.2 - 4.7	1,000 - 1,600	4 - 9 [6]
Killer whale (*Orcinus orca*) [4]	7 - 9	4,000 - 8,000	2.0 - 5.6 [3]
Sperm whale (*Physeter macrocephalus*)	9 - 12.5	12,000 - 20,000	12 - 15 [2]

1 Geraci and Lounsbury (2005).
2 P-Y Daoust, personal observation.
3 Lisa Spavin (Department of Fisheries and Oceans, British Columbia), personal communication.
4 Females smaller than males (Geraci and Lounsbury 2005).
5 Stéphane Lair (Faculté de Médecine Vétérinaire, Université de Montréal), personal communication; O'Corry-Crowe (2002).
6 Finley and Gibb (1982) (during summer).

Baleen whales:

Species	Length (m) [1]	Weight (kg) [1]	Blubber thickness (cm)
Minke whale (*Balaenoptera acutorostrata*)	7 – 9	6,000 - 9,000	3 - 4 [2]
Humpback whale (*Megaptera novaeangliae*)	12 - 16	30,000 - 45,000	3.5 - 6 [7]
Fin whale (*B. physalus*)	20 - 24	50,000 - 80,000	6 - 8 [8]
North Atlantic right whale (*Eubalaena glacialis*)	15 - 17	45,000 - 90,000	15 - 30 [9]
Bowhead whale (*Balaena mysticetus*)	15 - 20	70,000 - 100,000	up to 28 [10]
Grey whale (*Eschrichtius robustus*)	11 - 15	16,000 - 35,000	15 [11]
Blue whale (*B. musculus*)	12.8 - 16	100,000 – 150,000	17 [12]

[7] In smaller (approximately 10 m long) animals, William McLellan (Biological Sciences and Center for Marine Science, University of North Carolina), personal communication.
[8] Brodie and Paasche (1985); Lockyer and Waters (1986).
[9] Miller et al. (2011).
[10] Rugh and Shelden (2002).
[11] Jones and Swartz (2002).
[12] Berman-Kowalewski et al. (2010).

Table 2. Physical methods of euthanasia currently recommended for different sizes of whales: rifle and shotgun ammunition, and explosives.

Species	Method
Whales < 2 m long	- Any rifle calibre equal to, or greater than, .222 Remington, with standard projectiles (minimum muzzle energy of 1140 foot-pounds).[1] Cartridges with high muzzle energies and nonexpanding projectiles may easily exit the animal and pose a safety concern.
	- 12-ga shotgun with slug; dorsal, dorso-lateral, or lateral approach (see text).
Whales 2-6 m long	- Rifle calibre equal to, or greater than, .303, using 150-grain, expanding or non-expanding projectiles (minimum muzzle energy of 2400 foot-pounds).[1,2]
	- Rifle calibre .308 Winchester, using 150-grain, expanding or non-expanding projectiles; dorsal, dorso-lateral, or lateral approach (see text).[3, 4]
Whales 6-12 m long	Rifle calibre .375, using 300-grain non-expanding, round-nosed projectiles, or caliber .458, using 500-grain non-expanding, round-nosed projectiles (minimum muzzle energy of 4600 foot-pounds).[5]
Minke whale	Rifle calibre .375, using 300-grain, non-expanding, round-nosed projectiles, or caliber .458 (11.6 mm), using 500-grain, non-expanding, round-nosed projectiles. Shot aimed at the brain, which lies 55-75 cm caudal to the blowhole depending on the size of the minke whale. Also used as secondary weapon during the Norwegian commercial hunt.[6]

[1] Donoghue (2006).
[2] Barco et al. (2012).
[3] Lawrence (2003).
[4] Daoust and Ortenburger (personal observation).
[5] Moore (2010).
[6] Øen and Knudsen (2007).

Species	Method
Grey whale	Rifle calibre .50 BMG or .577 T-Rex, using 750-grain, non-expanding, round-nosed projectiles (minimum muzzle energy of 10,000 foot-pounds). Shot aimed near the center of the brain or the cervical (upper) spinal cord, thus requiring a good knowledge of anatomical landmarks. Used in Aboriginal hunts.[5]
Sperm whale	(Single animal, 12.5 m long, Norway) Rifle calibre .458, using 500-grain, non-expanding, round-nosed projectiles (as in the commercial minke whale hunt). Shot aimed at lateral side of the head, approximately 65 cm caudal to the eye, along an imaginary horizontal line drawn from the eye.[7]
Humpback whale, Southern right whale	Explosive charge (4 kg for humpback whale, 6 kg for southern right whale), shaped in a pyramid and sand-bagged to direct the blast down toward the brain, assisted in larger whales by two 50-g compact explosive boosters added on top of the explosive charge (to ensure its optimal detonation and to direct the blast downward). Explosive placed externally just caudal to the blowhole, and ignited by electric detonators or waterproof shock tube initiators.[8]

[7] Øen (2012).
[8] Coughran et al. (2012), IWC 2014.

Table 3. Summary of chemical methods of sedation and euthanasia and injection sites.

Animal size: small

Drug Type	Drug	Dose, mg/kg	Route[1]
Sedative	acepromazine	0.10	i.v, i.m.
	xylazine	0.40	i.v. i.m
	detomidine	0.02	i.v. i.m.
	diazepam	0.5	i.v, i.m.
Euthanasia	pentobarbital	110[2]	i.v. i.c.
	T-61	0.3 ml/kg	i.v. i.c.

Animal size: large

Drug Type	Drug	Dose, $mg/kg^{0.75}$	Route[1]
Sedative	acepromazine	0.10	i.v, i.m.
	xylazine	0.40	i.v, i.m.
	detomidine	0.02	i.v, i.m.
	diazepam	0.5	i.v, i.m.
Euthanasia	pentobarbital	110[2]	i.v. i.c.
	T-61	0.3 ml/kg	i.v. i.c.

[1] i.v.: intravenous (preferably); i.m.: intramuscular; i.c.: intracardiac.
[2] 110 mg/kg if the animal has not been sedated; 55 mg/kg if the animal is sedated.

Table 4. Some common species of whales, their blubber thickness (in normal adult animals), and sizes of needle required for injection into the epaxial muscle mass.

Species	**Blubber thickness (cm)**	**Needle size, length (gauge)**
Harbour porpoise	1.5 – 2.5	63 mm x 20
Atlantic white-sided dolphin	2 – 2.5	63 mm x 20
Beluga / Narwhal	4 – 10	152 mm x 18
Long-finned Pilot whale	2.5 - 3.5	63 mm x 20
Minke whale / humpback whale	3 – 6	90 mm x 18

Table 5. Approximate costs of sedation and euthanasia.

Species	**Sedation (acepromazine) & Euthanasia (Pentobarbital)**	**Sedation (acepromazine) & Euthanasia (T-61)**	**Euthanasia (acepromazine, xylazine, & KCl)**	**Sedation (acepromazine) & Euthanasia (gunshot)**[1]
Adult dolphin (230 kg)	$32	$81	nr[2]	$7
Adult humpback whale (40,000 kg)	$199[3]	$580[3]	$350[3]	nr[4]

[1] Calculations for rifle ammunition assume $0.20 for a single shot for a dolphin.
[2] Nr: not recommended.
[3] Based on dose scaling relying on metabolic body size. If drug dosages were based on actual body size, the estimated cost would be higher by one order of magnitude.
[4] Based on theoretical calculations, the estimated cost would be $81.

Table 6. Summary of recommendations for euthanasia of whales.

Size[1] and Number	Gunshot (minimum caliber)	Explosives	Chemical	Protected natural death with palliative care	Likelihood of success	Problems	Comment
one small whale	#2-[2] .222 for porpoise, dolphin; .308 for pilot whale; .375 for minke whales	NR[3]	#1- acepromazine or xylazine, 30 minutes, then intravenous or intracardiac pentobarbital	not appropriate	high		chemical methods preferred
few small whales	#2- simultaneous shooting recommended	NR	#1- sedate all animals first, then euthanize in sequence	not appropriate	high	difficult to prevent live animals from seeing death of others or hearing gunfire	chemical methods preferred
many small whales	#1- simultaneous shooting recommended	NR	deep sedation of most animals may be possible	may be unavoidable	moderate	significant ecotoxicity may result with chemical methods	it is best if viable animals can be rescued prior to euthanasia of terminal cases
one large whale	#2- only with training and appropriate equipment (e.g., .458 or .50 BMG)	#4- only with training and appropriate charges	#1- requires training, special needles, and large quantities of euthanasia drugs	#3✔ [4]	moderate	significant ecotoxicity may result with chemical methods	gunshot possible in whales up to 12 m long; requires minimum muzzle energy of 4600 ft-lbs
few large whales	NR	NR	#1- requires training, special needles, and large quantities of euthanasia drugs	#2✔	low	significant ecotoxicity may result with chemical methods	human safety may be a consideration with chemical method
sperm whale	NR	NR	NR	#1✔	not available	considered the most difficult species to euthanize	chemical methods may be possible; efficacy of shooting has rarely been shown

[1] Small whales are defined as less than 6 m long, large whales as more than 6 m long.
[2] #1-#4: ranking of methods for most likely circumstances, in decreasing order of preference.
[3] NR: not recommended due to potential for inhumane results, low success, or poor public perception.
[4] ✔: recommended at the present time, although euthanasia may be possible where expertise and equipment permit.

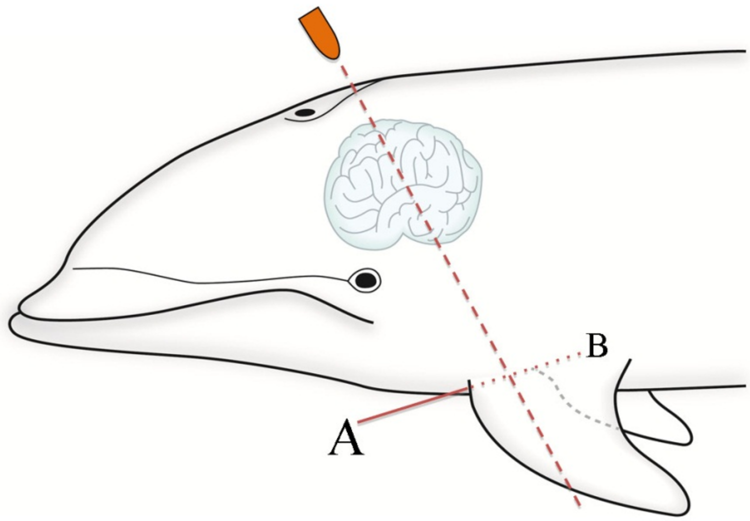

Figure 1a. Dorsal point of aim for shooting small whales, based on anatomical landmarks. The shot is aimed at a site slightly caudal to the blow hole and a short distance lateral to the dorsal midline down and back (caudo-ventrally) toward the center of an imaginary line (A-B) drawn between the cranial edges of the flippers. (Illustrated by Daniel Hartwig, Citrus Design, PEI.)

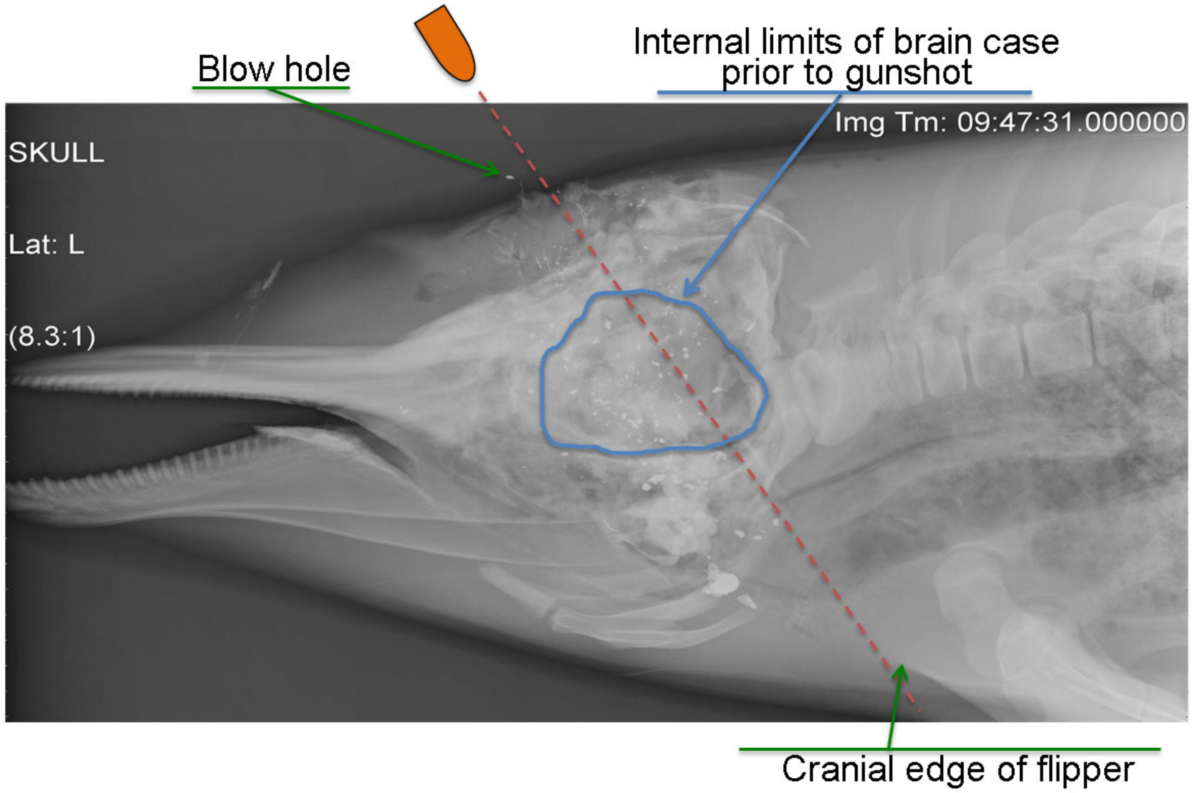

Figure 1b. Radiograph of a harbour porpoise shot with .223 soft-point ammunition according to the anatomic landmarks shown in Figure 1a. There was extensive destruction of the calvarium and brain. Numerous bullet fragments (bright white particles) are visible in the caudal region of the skull, including the brain cavity.

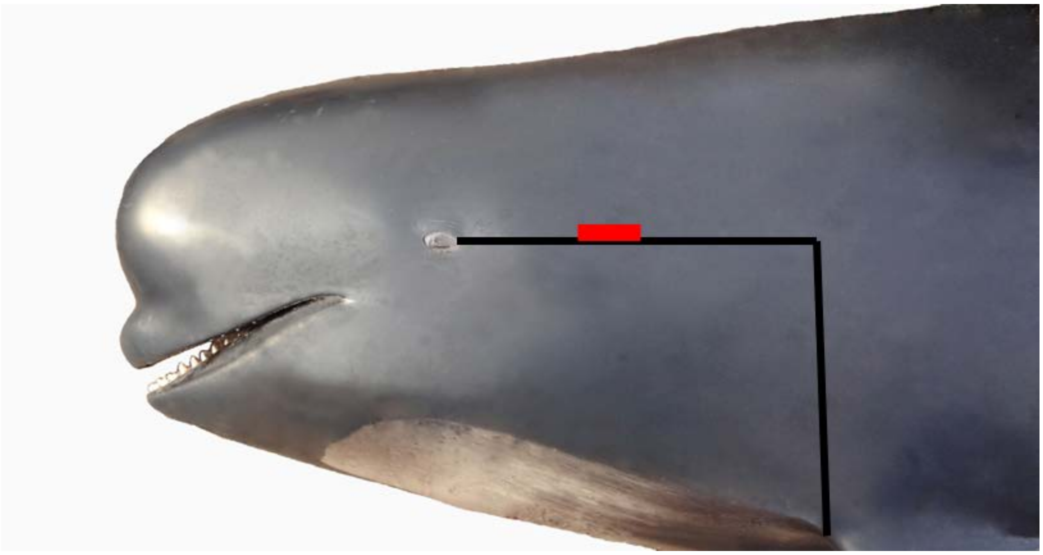

Figure 2. Lateral point of aim for shooting small whales, based on anatomical landmarks. The shot is aimed at the lateral side of the head, between one-third and halfway (red) along an imaginary horizontal line drawn between the eye and the cranial edge of the flipper. With this approach, the projectile is expected to hit the base of the brain or the brain stem near the occipital condyles.

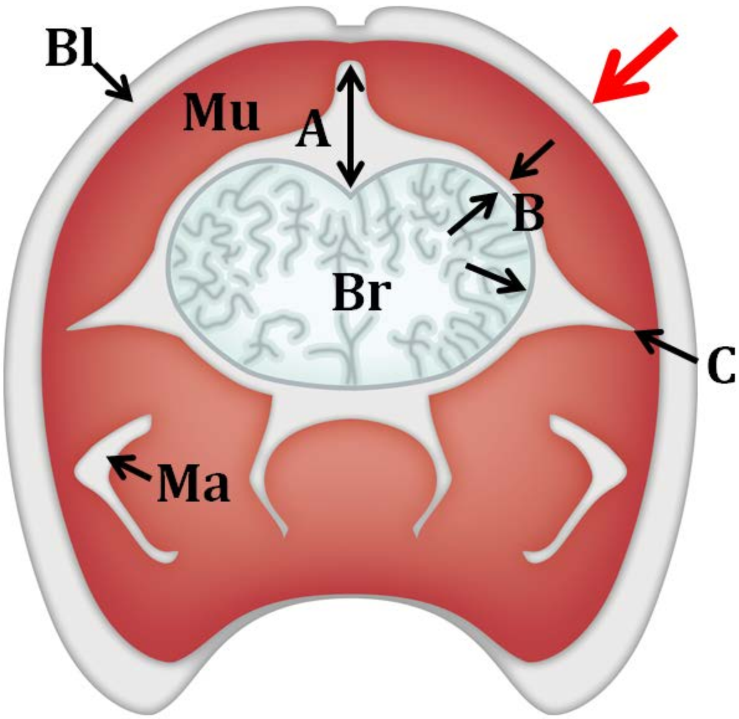

Figure 3. Diagram of the transverse section of the head of a small whale showing the dorso-lateral point of aim (large red arrow) for shooting. As in Figure 2, the shot is taken between one-third and halfway caudal to the eye along an imaginary horizontal line between the eye and the cranial edge of the flipper, but at a 30-45° angle laterally from the dorsal midline of the head and perpendicularly to the skin surface. The calvarium along the dorsal midline (A) and laterally (C) is much thicker than along the dorsolateral aspect (B). Bl, skin and blubber. Br, brain. Ma, mandible. Mu, muscle tissue. (Illustrated by Daniel Hartwig, Citrus Design, PEI.)

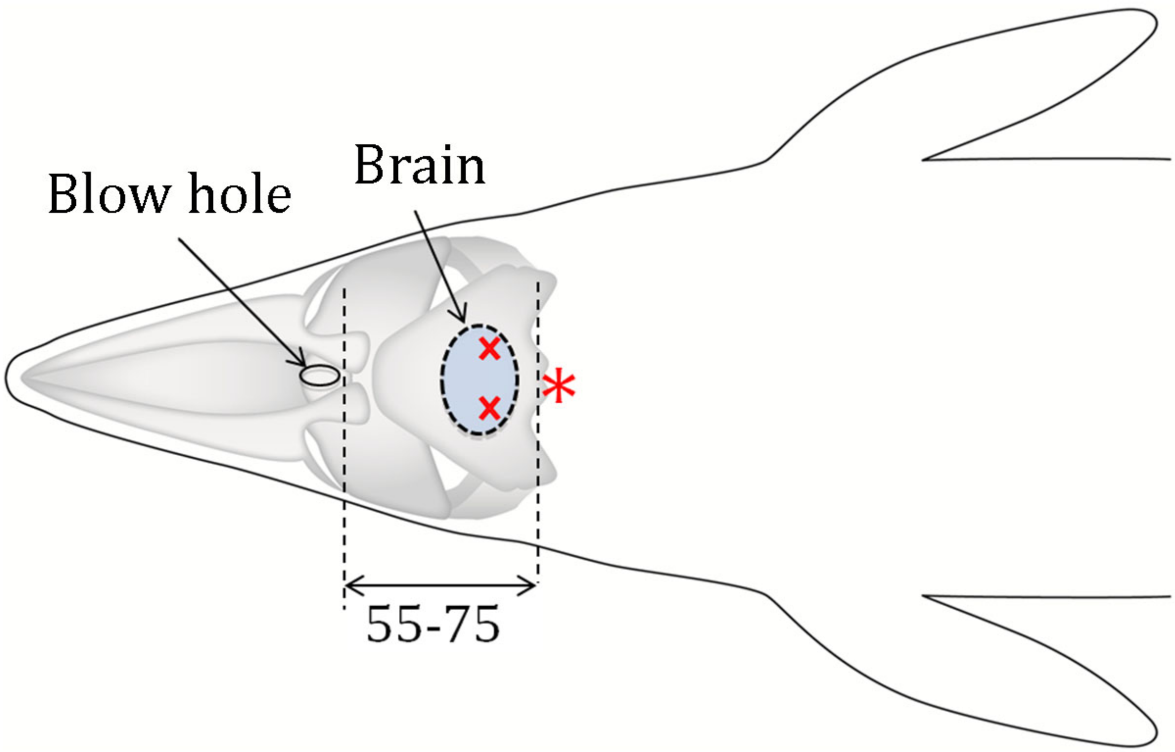

Figure 4. Point of aim for shooting an adult minke whale, based on anatomical landmarks. The thinnest part (X) of the calvarium in this species is approximately 5-10 cm on either side of the dorsal midline, close to the occipital condyles. This indicates that the shot should be directed perpendicularly to the skin surface at a point located slightly lateral to the dorsal midline. At a distance 55-75 cm behind the blowhole (depending on the size of the whale), the projectile should go either through the brain cavity or the junction between brain and spinal cord (*). (Illustrated by Daniel Hartwig, Citrus Design, PEI.)

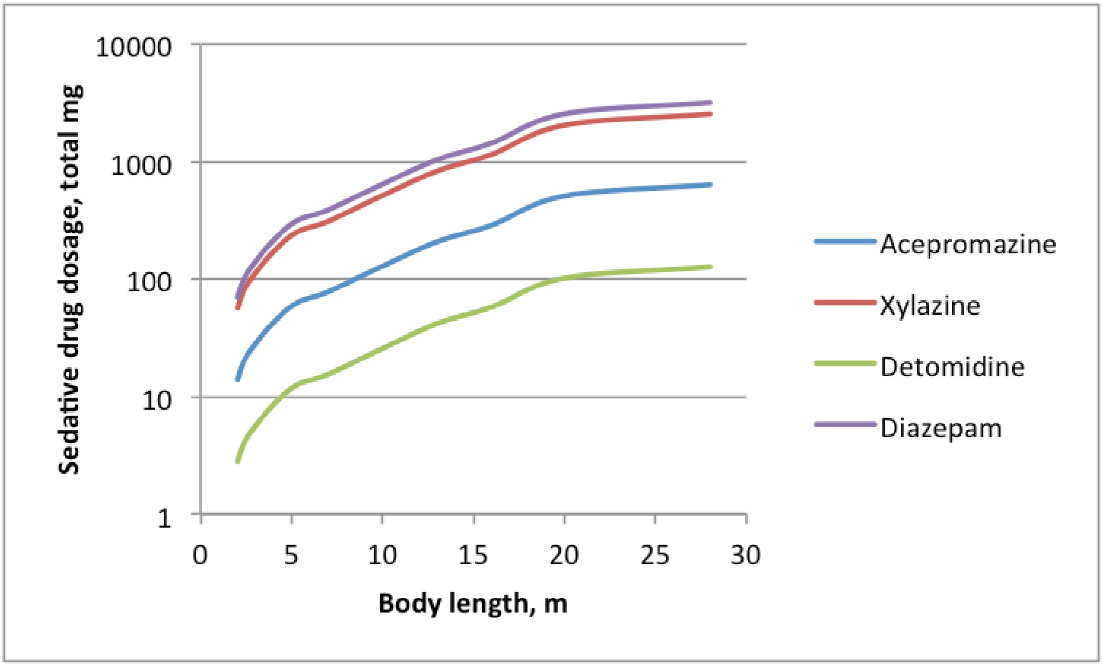

Figure 5. Sedative drug doses for whales. All drug dosages from the graph above are suggestions based on broad experience with these drugs in terrestrial mammals, and in some cases with Cetaceans. They are based on doses which have not been validated or approved by any regulatory, clinical, or scientific agency. All sedative doses assume either an intravenous or intramuscular route of administration. For intramuscular use, a maximum total volume of 10 ml per site should be injected. The extreme range of Cetacean body mass (encompassing 4 orders of magnitude) requires dose scaling for drug dosages. Scaling begins at a body length of 5 meters and stabilizes at 10 meters; scaling is calculated from: dosage = dose x ($BW_{kg}^{0.9\text{-}0.75}$).

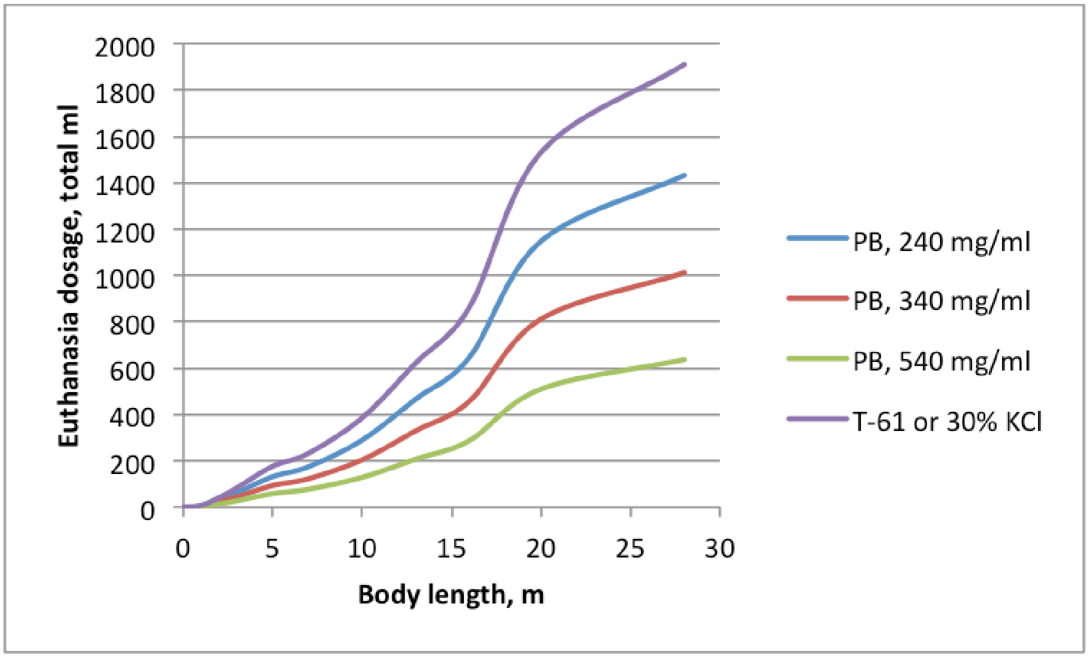

Figure 6. Euthanasia drug doses for whales. PB, pentobarbital sodium. All drug dosages from the graph above are based on broad experience with these drugs in terrestrial mammals, and in some cases with Cetaceans. They have not been validated or approved by any regulatory, clinical, or scientific agency. All euthanasia drug doses assume an intravenous or intracardiac (preferred) route of administration; other routes of administration are not recommended. All euthanasia drug dosages in the graph above assume that the animal has been sedated. If this cannot be accomplished, the dosages shown in the graph should be doubled. The extreme range of Cetacean body mass (encompassing 4 orders of magnitude) requires dose scaling for drug dosages. Scaling begins at a body length of 5 meters and stabilizes at 10 meters; scaling is calculated from: dosage = dose x $(BW_{kg}^{0.9\text{-}0.75})$.

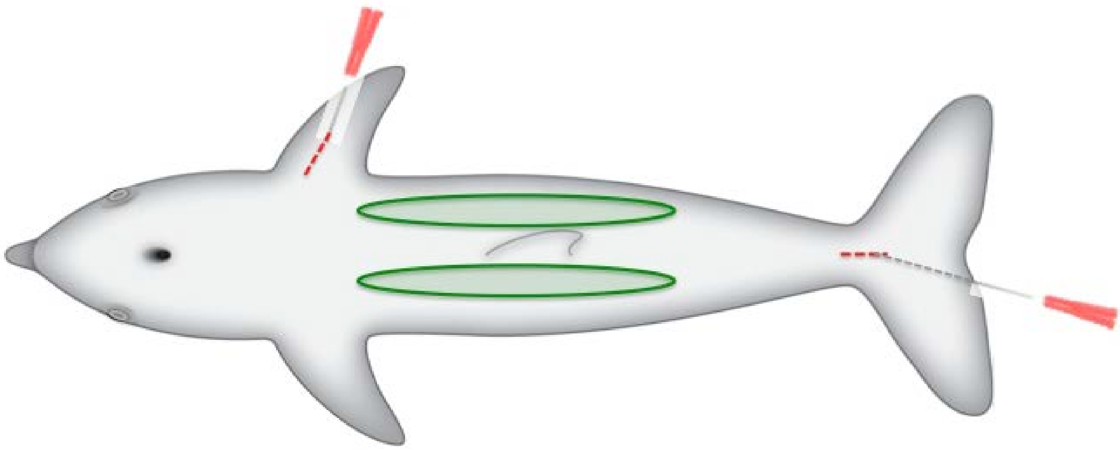

Figure 7a. Common sites for drug injection in whales: intramuscular (within the epaxial muscle mass [green]) or intravenous (within the veins of the mid-ventral groove of the tail peduncle or the median or cephalic veins of the flipper [red]). (Illustrated by Daniel Hartwig, Citrus Design, PEI.)

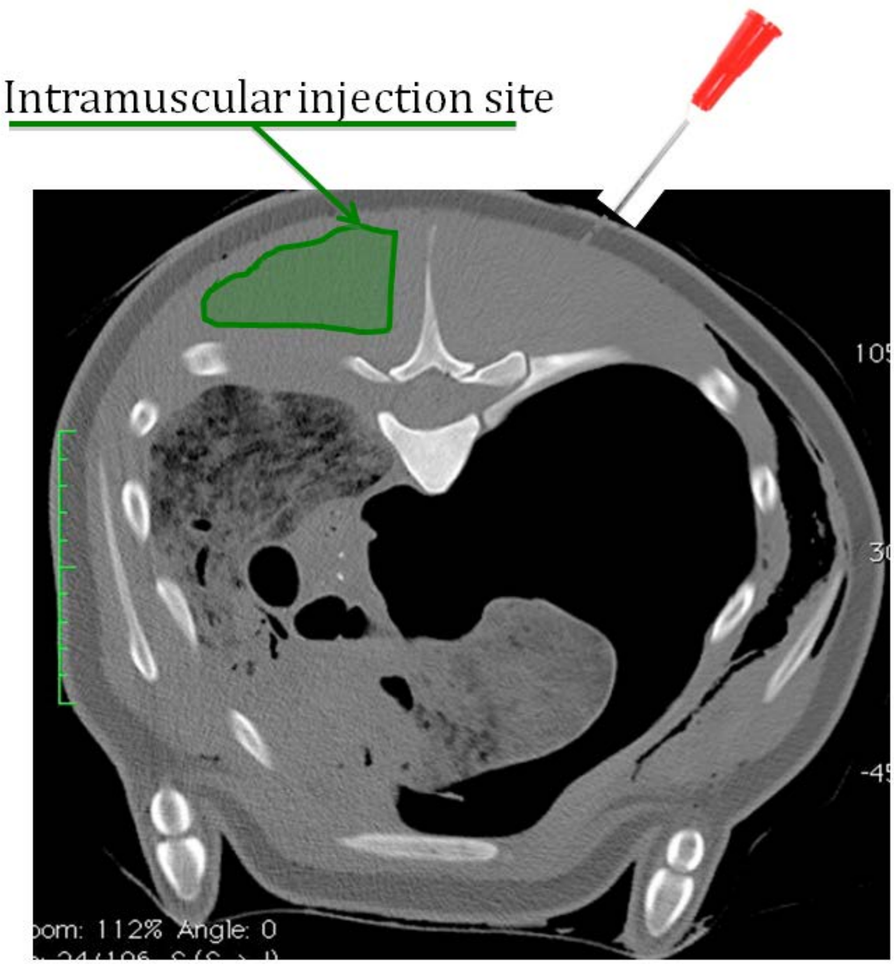

Figure 7b. Intramuscular injection site in epaxial muscle mass (green area). (Modified from: [Marine Mammal Radiology slide show: dolphin CT, dolphin ultrasound, whale fracture, whale CT]().)

Figure 8a. Parasternal approach for intracardiac injection in small whales. A 9 cm-long spinal needle is inserted close to the palpable sternum, at the level of the caudal edge of the flippers, and directed dorso-medially until a free flow of blood issues from the needle. No excessive traction must be exerted on the flipper if it is held.

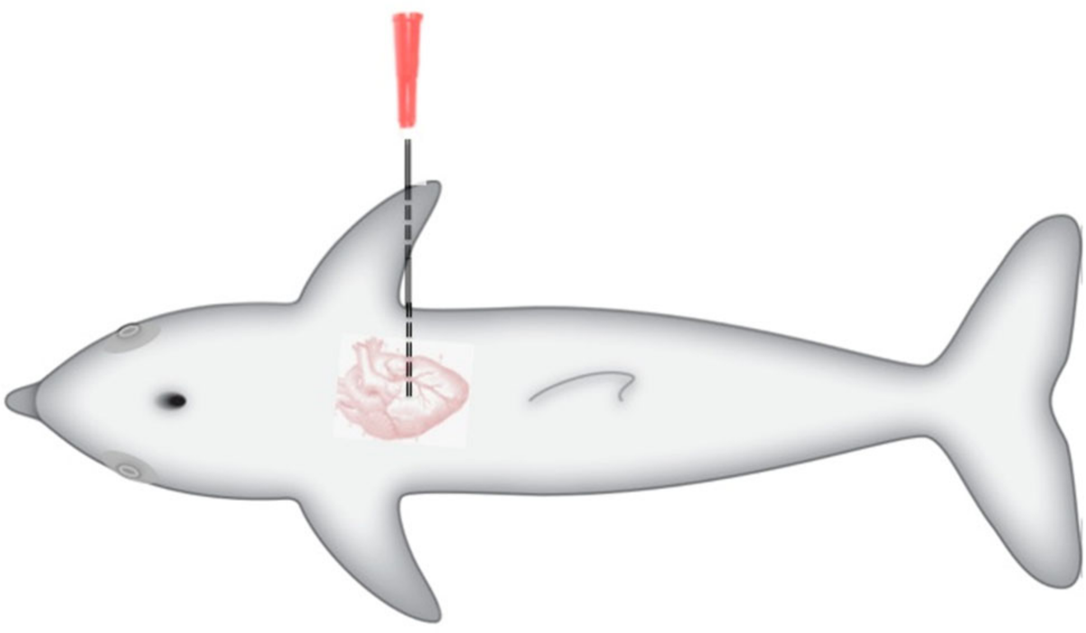

Figure 8b. Lateral approach for intracardiac injection, often the only possible approach for large whales. A needle equal in length to approximately one-half of the diameter of the whale is inserted just behind the caudal edge of one of the flippers and directed toward the same point on the other side of the body. A free flow of blood from the needle indicates entry into a heart chamber or great vessel in the thorax. (Illustrated by Daniel Hartwig, Citrus Design, PEI.)