Overview of euthanasia of large whales[1]

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ABSTRACT

Large whales are not infrequently entangled in fishing gear. When unable to disentangle themselves, or be disentangled by humans, these cases can become protracted, with constriction of multiple body parts, soft tissue laceration, embedment in bone, and hemorrhage. This can lead to failure to feed, infection and emaciation. Euthanasia might be considered for such terminal cases in the interests of animal welfare. This paper reviews possible methods that have been used at sea in native and commercial whaling, and on the beach in the management of large whale strandings. It strives to review pertinent literature and data on the topic and lay out the advantages and disadvantages of each method and its potential applicability to euthanasia of such cases at sea and on the beach. None of this obviates the over-riding need for better entanglement avoidance measures.

KEYWORDS: WHALE, ENTANGLEMENT, EUTHANASIA

INTRODUCTION

Large whale euthanasia is the subject of this working paper. This paper does not necessarily suggest that large whale euthanasia, especially at sea is a suitable goal, it simply provides material to frame a discussion at the upcoming entanglement workshop in Maui, April 13-15 2010. Humans have evolved methods to kill whales for millennia. Constraints have included available vessels, methods of vessel propulsion, distance from safe harbor, and availability of industrial technology. There is a vast report literature concerning 'humane killing' of whales that resides within the records of the International Whaling Commission, see (Mitchell et al. 1986) and more recent reports (www.iwcoffice.org). This review does not attempt to summarize that material but attempts to extract salient information that will inform the current need to explore options for large whale euthanasia. There are a few peer reviewed papers on the subject of beached whale euthanasia (Daoust & Ortenburger 2001, Dunn 2006) and textbook chapters (Geraci & Lounsbury 2005, AVMA 2007). The current goal is to compare and contrast the various methods that might be used to euthanize large whales that are terminally entangled in fishing gear. Such whales cannot be disentangled and are in a lethal entanglement or will not survive after disentanglement due to exhaustion or because vital organs are severely hurt or damaged.

In contrast to whale killing methods designed for harvesting, whether in an industrial or a native hunt setting, euthanasia of whales is by its nature a less preplanned and pre-ordained undertaking. It is also unlikely to attract major investment, given the absence of any profit motive. Nonetheless, increasingly in various parts of the world, biologists, wildlife managers and veterinarians are called upon to euthanize large whales in distress. Experiences with some beached large whales along the North American east coast at least suggest that enhanced techniques for practical and humane euthanasia would be very valuable. To date there has not been a systematic review of possible physical and chemical methods, consequences, and possible best options. This paper attempts to establish a series of goals for such an activity, review the various options in terms of methods available for each species, especially in terms of current practice by different nations, consider risks and benefits, safety and training issues, and carcass and recovery considerations. It also aims to identify those situations for which euthanasia should be considered or recommended.

The paper considers the various methods that have been, or could be suitable for large whale euthanasia at sea or on the beach. The goal being to facilitate interested parties from different nations and cultures in establishing what

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might be appropriate for their particular situations. Each nation, and often region within a country, has unique legal, cultural, media, and political parameters to balance. Rather than paraphrase and opine upon the authorities that have written variously on the different possible techniques, this review has strived as much as possible to quote and attribute key portions of salient texts that inform the essence of the current goal.

The terms of reference for this workshop (IWC 2009) do not specify if there should be sole focus on animals at sea or if beach activities should also be considered. At least in the NW Atlantic, many chronically entangled right whales tend to die at sea, only beaching post mortem if at all. Although some other large whale species do live strand. To avoid precluding beach based technologies that may have utility at sea and vice versa this paper includes material from beach and at sea perspectives.

CRITERIA FOR EUTHANASIA

At Sea

There has been little if anything written about euthanasia of debilitated whales as opposed to hunting healthy large whales at sea. But entanglements in North Atlantic right whales that have been documented to be lethal, include those that incise the skin and blubber and seriously constrict one or more body parts (Moore et al. 2004) result in chronic, severe emaciation. Likewise in humpback and sei whales (Cassoff et al. In Prep). Thus for such cases where disentanglement is either not possible to attempt or has failed, then euthanasia could be considered. A complicating factor is the consideration of the welfare of the individual vs. the survival of the species, for species that are endangered, such as the North Atlantic and North Pacific right whales. In US waters medical intervention with a live but compromised free swimming cetacean requires a permit from the NOAA Office of Protected Resources. Such actions are not covered by normal regional stranding agreements. Similar legal constraints will be present in other nations.

Beached

It has been suggested that natural death for larger stranded whales may be the most humane and practical option (Geraci & Lounsbury 2005). Others have suggested that indications for euthanasia include disabling injuries, significant hemorrhage, rectal temperature below 35° C or above 42° C, blistering of the majority of the skin surface, loss of reflexes, loss of jaw tone or protruding penis (Greer et al. 2001, Geraci & Lounsbury 2005).

AVAILABLE AND POTENTIAL METHODS

Efficient euthanasia should aim to achieve rapid unconsciousness, be reliable, safe, irreversible, and practical (Greer et al. 2001). Respiratory paralysis is not regarded as an acceptable method (AVMA 2007). Methods to be considered are either physical or chemical.

Physical methods must induce rapid and relatively painless unconsciousness (Greer et al. 2001). Thus any thoracic approach, as commonly used in whaling should ideally induce percussive unconsciousness by the shock wave rapidly reaching the brain cavity such as described by the Norwegian minke whaling methods below.

PHYSICAL METHODS

Explosive harpoon

Where adequate vessels and technology are available, the tool of choice for killing whales being industrially harvested at sea for the past century and more has been a harpoon, fired from a deck mounted cannon with an explosive grenade. In the past 30 years there has been widespread adoption of penthrite (pentaerythritol tetranitrate) as the percussion agent of choice within the grenade. Harpoons are usually aimed at the chest with the intent of inducing peracute major laceration of great vessels, heart and lungs, inducing a precipitous loss of blood pressure and hence consciousness, and hopefully with traumatic brain injury from the blast wave.

Norwegian minke whales are killed with 60 and 70 mm harpoons. From (Knudsen 2005) concerning penthrite grenades: 'The results obtained from minke whales showed that the weapons in current use in Norway are highly capable of causing permanent brain damage of sufficient severity to account for an instantaneous or rapid loss of consciousness. Depending on where the penthrite grenade detonates it may cause shock wave-induced acute traumatic brain injury (TBI) in addition to the direct damage it inflicts on other organs or organ systems (Knudsen & Øen 2003). Based on the organ damage produced, including TBI, it was concluded that if the grenade detonated in an area ranging from the mid-thorax and forward to the skull, near 100% of the whales lost sensibility immediately or very rapidly. However, severe TBI was also registered when the grenade detonated at the interface between thorax and abdomen (Knudsen & Øen 2003). Further, the study revealed that one round with the currently used rifle calibres and ammunition in the Norwegian hunt is highly efficient in causing permanent and very severe brain damage when it hits in or near the brain or in the upper cervical spine (Øen & Knudsen 2007).'

(Knudsen & Øen 2003)'The results showed that intra-body detonation of the grenade in near vicinity of the brain resulted in trauma similar to severe traumatic brain injury associated with a direct blow to the head. Detonation in more distant areas of the body resulted in injuries resembling acceleration-induced diffuse traumatic brain injury. The authors conclude that even if several vital organs were fatally injured in most whales, the neurotrauma induced by the blast-generated pressure waves were the primary cause for the immediate or very rapid loss of consciousness and death.'

The grenade has later been implemented in the Greenlandic and Icelandic hunt for minke whales and in a modified form for hunting of fin whales (*Balaenoptera physalus*) in Greenland and Iceland (Øen pers. comm..).

In a study of 19 fin whales killed with 90mm black powder explosive grenade harpoons in Iceland, (Lambertsen & Moore 1983) 'post mortem observations were correlated with behavioral data to provide an estimated time to terminal unconsciousness ..(median 2 minutes).'

Whaling gun with penthrite - Alaska

Summary from (Alaska_Eskimo_Whaling_Commission 2009): 'The primary weapon used in the Alaskan Eskimo bowhead whale subsistence hunt is a hand-held darting gun, armed with an explosive projectile and a harpoon that attaches a line and float to the whale to assist in recovery.(Alaska_Eskimo_Whaling_Commission 2006).' This was adopted by native hunters from Yankee whalers in the 1800's. 'The natives were using black powder exploding projectile (the black powder projectile), the darting gun, and the shoulder gun. However, since 1987, the AEWC through its Weapons Improvement Program Committee (WIP Committee) has worked closely with Dr. Egil Ole Øen and Henriksen Mek. Verksted of Norway on the design, testing, and manufacture of a penthrite-loaded projectile for use in the hand-held darting gun. In the course of developing the penthrite projectile, the AEWC and Dr. Øen also found it necessary to modify the design of the darting gun barrel to accommodate the dimensions of the new projectile….The secondary weapon used in this hunt is a smooth bore, seven gauge shoulder gun used to shoot a finned projectile loaded with black powder. Under traditional practices and the rules of the AEWC Management Plan, the shoulder gun cannot be fired until after a line and float have been attached to the whale (Alaska_Eskimo_Whaling_Commission 2009).

Central to the introduction of the penthrite projectile was a safe and arming mechanism. A substantial hunter training and certification program has been undertaken. Techniques to handle and deploy the penthrite system are carefully explained. 'Great emphasis is placed on the importance of striking the whale between the base of the neck and the diaphragm, since explosion in the thoracic cavity will lead to rapid insensibility and death.' Whaling captains report that the reliability and percussiveness of the penthrite system have reduced the time to death and enhanced hunt safety and efficiency.

Data show a significant increase in efficiency (landed vs struck) for the Alaskan bowhead hunt (Alaska_Eskimo_Whaling_Commission 2009). In the period 1996 -2008 the average efficiency was 78%.

Peri-cranial Implosion- Western Australia and South Africa

Citing a working paper to this workshop with permission (Coughran et al. 2010): Coughran et al describe the conditions that warrant intervention with a live beached large whale that is a euthanasia candidate. Parameters include behavior, respiration, heart rate, body temperature, reflexes and trends therein. The charges are placed behind the blowhole and in line with the eye and detonated by a licensed 'shot firer', over a hessian sack, with sandbags piled around and over the charges. A D9 dozer 40m from the whale can be used to stabilize the whale's head with a sling around the rostrum attached to the dozer blade if needed. The dozer blade acts as cover along with a blast shield. Public are held back 500-1000m, preferably behind dunes. Charge tie down ropes are attached to tires on the beach cranial to each axilla overlain by sandbags. Extra sand bags are piled along the whale's flank for further stability if needed. A detailed equipment /stores/actions list, and detailed sketches and step wise photographs are given. The most recent 3 cases involved sticks of 125 gram Powergel Magnum (ICI Australia Pty. Ltd), a CE (compact explosive) with 50gram booster to be initiated with 2 lines of detonating cord. Four humpback cases are described with the number of Powergel sticks employed shown in parentheses except for the first case where an older different product was used. These cases were: a 9.1m animal that died instantly; a 10.5m animal that did not die after the first blast (5 sticks), nor after follow up with a 300 Winchester Magnum rifle, but did succumb after a second blast (10 sticks); a 9.8m animal that died instantly (14 sticks); and a 12.7m (22 sticks plus 2 cast G boosters - each equivalent to 6 sticks) that died instantly. It is notable that preparations after the decision to euthanize has been made can take days to complete. Reference to the submitted Working Paper (Coughran et al. 2010) is essential for full details of the methods employed. It is important to note that in the second case a delay incurred by close over flight by a media helicopter probably induced the initial charge to be displaced prior to detonation. The safety risk of aircraft electronics and other radios causing premature detonation cannot be overstated and reinforces the need for licensed operators. The authors recommend practice on dead animals, prior to use of the technique and before using it on species other than humpbacks.

Personal Communication, Michael Meyer March 3 2010: 'After a mass stranding of False Killer whales at Longbeach, Kommetjie, South Africa, the Department of Environmental Affairs was tasked with developing a draft National Response Plan for Cetacean strandings, to which 15 contributors from eight organizations provided input. The Draft Response Plan has not been formally approved as yet but participants were in agreement that euthanasia was ultimately the decision of the Incident Controller in consultation with other response personnel, including at least one veterinarian with suitable knowledge of cetaceans. Rifle shot is recommended for cetaceans under 8 m and explosives for larger cetaceans. Shooting into the heart of a large cetacean is not regarded as humane and we do not believe that lethal injections are a reliable method of euthanasia for whales larger than 8m.

Over the past 10 years I have recorded seven incidents in which large whales were euthanized. Rifle shot was used twice on large whales during this period, in 2000 and in 2009. The first incident involved a 10m Sei whale. Several bullets were directed at its heart using 303 and 308 rifles. The second incident involved a 12.35m humpback whale that was euthanized using a .375 caliber rifle. In the remaining five incidents, shaped cone-packed explosives which direct the force of explosion downwards were placed over the skull to create an "implosion". This is presently the preferred form of euthanasia for animals over 8m in length according to the Draft Response Plan. In total, this technique has been used successfully on ~10m whales in South Africa, and it has also been used on large baleen whales in Western Australia. Euthanasia using explosives should only be undertaken by explosive units that have experience with large whale implosions. The South African Police (SAP) explosive unit has been involved in all our implosions on large whales. Progressively, we have been refining the technique including the amount of explosive to apply.

I include the following case study: in 2005 a 10.42 m SRW stranded alive at Mnandi beach in False Bay. The charge used was 2 x (4kg each) cone pack CP40, which is a formed (directional) downward charge. The explosive unit placed the charge 15 cm behind the blowhole in a net, with sandbags attached to the charge hanging down to the ground on either side to hold it in place. The charge was "overbaked" as it blew a small crater into the braincase (see attached jpeg). Some minor pieces of blubber flew 30-40m. It was apparent that the charge would need to be slightly reduced in future, by one or possibly even two kg.'

A video of the method in use near Cape Town, South Africa can be seen online at
http://www.youtube.com/watch?v=JuVrMbwEtvs

New Zealand protocols, at least as of 2006, expressly preclude the use of explosives for stranded cetacean euthanasia (Donoghue 2006).

Ballistics

The AVMA panel on euthanasia suggest that an accurately placed gunshot may also be a conditionally acceptable method of euthanasia for some species and sizes of stranded marine mammals (AVMA 2007).

To develop a traditional yet humane technique the Makah tribe worked with Dr Allen Ingling to adopt a stainless steel toggle harpoon, and a .50BMG high velocity rifle (Ingling 1999b). In a subsequent paper (Ingling 1999a) Dr Ingling describes the key parameters for a travelling bullet – rotation (spin), translation (velocity) and precession (degree of wobble). Heavier bullets increase the rotational and translational momentum and reduce precession. A suitable aspect ratio and blunt nose also minimizes precession.

Allen Ingling (personal communication Feb 25 2010): 'The T Rex .577 caliber rifle has optimal projectile stability and penetration. When fired such that it penetrates the occipital bone close to perpendicular, it will destroy the brainstem inducing very rapid death. The system as used by the Makah is lethal for whales up to about 2m in diameter. This is with off-the-shelf components, .577 caliber, 750 grain projectile launched at 2460 ft./sec. resulting in an energy of 10,000 ft-lbs. In testing, we penetrated 34 feet of water with a heavier projectile in our test tank. Extrapolating to flesh at about twice the resistance to penetration as water that projectile would yield a penetration of 17 feet. Guessing at whale blubber and denser whale bone, at twice again resistance to penetration we would be down to 8-9 feet. With special modification of the projectiles we used in the .577 we should be able to achieve this depth of penetration which should suffice for the largest whale encountered. Also, the angle and target used in the Makah hunt was at a point of greatest depth on the carcass to reach the brain stem. Any other angle on the carcass would require less penetration. Obviously, a key factor in using this method is that the gunman needs extensive anatomy training in visualizing in 3D where the brainstem lies in the carcass. Also, the target does not need to be that precise. A projectile anywhere near the brain center or the upper cord will achieve the objective. I am confident in this system but clearly the modified cartridge should be assembled and tested on a carcass. This cartridge could be developed at little or no cost. Travel to a carcass would be the major expense.'

(Øen & Knudsen 2007) 'In the Norwegian hunt for common minke whales, 9.3mm, .375 or .458 calibre rifles are used as backup weapons to euthanise whales that are not deemed dead after being hit with a harpoon grenade. When using the rifle, the hunters aim at the brain of the animal. The present study investigates the effects of the two rifle calibres .375 and .458 and round-nosed, full-metal jacketed bullets in 29 common minke whales. The whales were examined *post mortem* shipboard and 22 of the brains were fixed *in situ* and later subjected to gross and light microscopic examination. The results show that the two types of bullets are fully capable of penetrating the skull and spinal bones of common minke whales and fatally damaging the central nervous system, resulting in immediate or very rapid loss of consciousness.'

South Africa - Personal Communication, Michael Meyer March 3 2010: 'Following the outcome of a recent stranding response involving a humpback whale, we have discussed running an experiment to assess the efficacy of using a .375 H H rifle with a 300grain solid bullet, followed immediately by a 300grain softnose bullet, on whales of larger than 12 m (using fresh carcasses). A professional hunter, Chris Snyman followed this approach to euthanase the humpback, which was stranded at the little Brak River in Mossel Bay in October 2009, due to a lack of facilities and experience with explosives. The effect of the solid bullet was to penetrate the blubber and muscle and shatter the braincase, while the follow-up softnose bullet shattered within the animal. The animal died within seconds of shooting. Mr Snyman proposed that a 458 express, 458 Lott with a 500 grain solid bullet at a velocity of 2150 - 2250ft/sec or even a 375 H H with a 380grain solid bullet would be suitable for whales of up to 12 m. This may provide a suitable alternative to explosives especially in situations where residential houses are in close proximity to the stranding, or where bedrock below the sand runs towards houses.'

New Zealand – (Donoghue 2006): Recommended calibers for cetaceans are as follows:
'Small whales or dolphins up to 2 m - any high powered rifle and standard sporting rounds;
Dolphins or whales 2.0 – 8.0 m - .303, .30-06, .308 using 180 grain soft or solid round nosed projectiles; Baleen whales 8 m and above - .303 using Mk.6 projectiles; .30-06 or .458 and solid round nosed projectiles; Sperm whales – The specialized Sperm Whale Euthanasia Device (SWED) only. The NZ SOP appended in (Donoghue 2006) also details firearm procedures. Sketches from (Donoghue 2006) of optimal target zones, to facilitate aim at the occipital condyles are shown in Figures 1 and 2. 'Due to the thickness of the blubber and other tissues overlying the target area in larger whales only solid round nose projectiles and down-loaded cartridges should be used. This will ensure maximum penetration with minimum deviation of the projectile from its intended course.'(Donoghue 2006)

An image showing the location of the occipital condyles in a right whale is shown in Figure 3.

In a study on cadavers, a 12 gauge shot gun was demonstrated to be only good for dolphins (Blackmore et al. 1995).

Notable in the above South Africa and New Zealand approaches is a lack of consideration of very high power rifles as discussed by Ingling above. Such rifles include .460 (Weatherby Magnum), .50BMG, .577 (T.Rex), and .700. Thus exploration of optimization of one of these larger caliber rifles is worth consideration for whales larger than the NZ and SA size limits for rifle use.

CHEMICAL METHODS

(Geraci & Lounsbury 2005) suggest that intravenous drugs are appropriate up to the size of a pilot whale. They suggest consideration of intracardiac injection after local anesthesia using a fabricated 'needle' of a length approximately half the diameter of the whale. Others suggest that intracardiac injection should only be given in anesthetized, moribund or unconscious animals (AVMA 2007). Intramuscular sedation of Midazolam at 0.02mg/estimated kg or 15mg/m may enhance venous access and human safety (Greer et al. 2001). Geraci and Lounsbury (2005) raise the concern of chemical residue harming predators and the need for appropriate disposal.

The AVMA guidelines for marine mammal euthanasia suggest 'barbiturates or potent opioids (eg, etorphine hydrochloride [M 99] and carfentanil) are the agents of choice for euthanasia of marine mammals, although it is recognized their use is not always possible and can be potentially dangerous to personnel. For stranded whales or other large cetaceans or pinnipeds, succinylcholine chloride in conjunction with potassium chloride, administered intravenously or intraperitoneally, has been used. This method, which is not an acceptable method of euthanasia as defined in these guidelines leads to complete paralysis of the respiratory musculature and eventual death attributable to hypoxemia. This method may be more humane than allowing the stranded animal to suffocate over a period of hours or days if no other options are available.'(AVMA 2007)

A summary of available US case reports with drugs and doses used is given in Table 1.

Barbiturate injection: A lethal pentobarbital dose is 60-200 mg/kg; 10mg/kg induces deep anaesthesia (Greer et al. 2001) and may cause apneoa and hence death. The required barbiturate dose can be reduced with the above midazolam premedication dose.

Pentobarbital (60ml) was delivered to a fin whale through the blowhole and then T-61 i/v caudally for successful euthanasia. In contrast the author estimated that without T-61 a total of 60-200 mg/kg, at 10,000kg, would have required 20 to 50 bottles of 100mls solution of pentobarbital (Dunn 2006).

Xylazine, T-61 and potassium chloride (KCl) were used successfully in an emaciated juvenile fin whale (Daoust & Ortenburger 2001), although xylazine caused fractiousness in a gray whale (Greer et al. 2001).

A non toxic general anesthetic followed by KCl is regarded as a suitable agent where scavenger toxicity has to be avoided (AVMA 2007). However KCl with a paralytic such as succinyl choline is not acceptable as it leads to paralysis without loss of consciousness.

Etorphine and acepromazine have been used for intramuscular euthanasia at 4.0ml/1.5m in whales (Barnett et al. 1999, Greer et al. 2001). Etorphine remains the drug of choice for cetacean euthanasia in the UK (Paul Jepson personal communication March 18 2010). Etorphine poses significant operator risks and risk to scavengers. It has been suggested that a combination of alpha 2 agonists such as detomidine or medetomidine and synthetic opioids such as carfentanil would achieve the same result (Daoust & Ortenburger 2001).

T-61, a drug currently not marketed in the United States, but available in many other countries including Canada, is comprised of a mixture of a neuromuscular blocking agent, 4,4_-methylenebis-(cyclohexyl-trimethyl ammonium iodide), which produces a curariform paralytic action on striated skeletal and respiratory muscles and rapidly induces circulatory collapse; a local anesthetic, tetracaine hydrochloride; and a strong hypnotic agent, N-[2-(m-methoxyphenyl)-2-ethylbutyl-(1)]-gamma-hydroxy-butyramide, which produces a strong narcotic action and concurrently paralyses the respiratory center (Dunn 2006). T-61 should be used only intravenously and at carefully monitored rates of injection, because there is some question as to the differential absorption and onset of action of the active ingredients when administered by other routes. (AVMA 2007)

At sea drug administration

Benzodiazepine anxiolytic and opioid sedative delivery at sea by ballistic intra muscular injection has been recently described to enhance disentanglement of free-swimming right whales (Moore et al. 2010). Thus if suitable intramuscular agents can be selected for at sea euthanasia, there is a potential delivery route.

Anesthesia /exsanguination

'Exsanguination can be used to ensure death subsequent to stunning, or in otherwise unconscious animals. Because anxiety is associated with extreme hypovolemia, exsanguination must not be used as a sole means of euthanasia (page 16 (AVMA 2007)'.

Craig Harms and Willaim McLellan (personal communication February 25th 2010): 'Right whale *Eubalaena glacialis* CALO 0901 on a remote shoal off Cape Lookout, SC, measured 975 cm total length, from which weight was estimated to be approximately 10,000 kg (Moore et al. 2004). Marked skin peeling, scavenger damage, and slow raspy breaths with a 69 sec inter-breath interval were noted, although the whale was alert to actions of the examiners. Sedative drugs were administered IM above the left pectoral fin with a 20 cm 18 ga needle (meperidine 200 mg [8 ml], acepromazine 200 mg [20 ml], midazolam 140 mg [28 ml], medetomidine 20 mg [20 ml]) and intranasal/blowhole (cf. (Dunn 2006); acepromazine 280 mg [28 ml]). The following day the whale was still living, with an initial respiratory rate of 2.2/min, scavenger damage and skin sloughing more extensive, spinal curvature more pronounced, and responsiveness to examiner activity reduced. Rescue and recovery not being an option, euthanasia was initiated by retrobulbar administration of a combination of sedative, analgesic and anesthetic drugs using a 35 cm 17 ga needle in an attempt to access the rich vascular supply behind the eye (midazolam 90 mg [18 ml], diazepam 150 mg [30 ml], acepromazine 450 mg [45 ml], xylazine 13,000 mg [130 ml] and medetomidine 22 mg [22 ml]), followed 26 min later by blowhole administration of 200 ml isoflurane liquid divided into doses of approximately 20 ml over 10 successive inspirations. Considering the whale to be in the best achievable state of analgesia under the circumstances, euthanasia was completed by exsanguination through the peduncle vessels. The whale died 2 hr and 2 min after the first drug administration and 1 hr and 4 min after initiating exsanguination. Drug residue assays were attempted for midazolam, diazepam, acepromazine and xylazine from plasma collected 45 min after injection, and for xylazine and midazolam from postmortem injection site tissues distant blubber. Only midazolam was detected from plasma, at 6.6 ng/ml, and only xylazine was detected from injection site tissues, at 630 µg/g. Residue results are interpreted to indicate reasonable drug distribution from the injection site, suboptimal but likely some sedation and analgesia prior to physical means of euthanasia, and negligible risk of secondary toxicity to scavengers.

Anaesthesia/ bilateral pneumothorax. According to the American Veterinary Medical Association Guidelines on Euthanasia (AVMA 2007) special considerations, euthanasia of nonconventional species, "*For wild and feral animals, many recommended means of euthanasia for captive animals are not feasible. The panel recognized there*

are situations involving free-ranging wildlife when euthanasia is not possible from the animal or human safety standpoint, and killing may be necessary. Conditions found in the field, although more challenging than those that are controlled, do not in any way reduce or minimize the ethical obligation of the responsible individual to reduce pain and distress to the greatest extent possible during the taking of an animal's life. Because euthanasia of wildlife is often performed by lay personnel in remote settings, guidelines are needed to assist veterinarians, wildlife biologists, and wildlife health professionals in developing humane protocols for euthanasia of wildlife." Further, "*In the case of free-ranging wildlife, personnel may not be trained in the proper use of remote anesthesia, proper delivery equipment may not be available, personnel may be working alone in remote areas where accidental exposure to potent anesthetic medications used in wildlife capture would present a risk to human safety, or approaching the animal within a practical darting distance may not be possible.*"

James Bailey DVM, MS, DACVA (personal communication March 28 2010). 'A two-stage euthanasia process involving sedation, analgesia or general anesthesia prior to euthanasia—although preferred—is generally not possible in large cetacean stranding situations. As well, these animals are often returned to the environment for natural assimilation and the injection of large volumes of euthanasia chemical solutions into the subject could place other species involved in this process at risk. Historically, it was commonplace to euthanitize subjects by inducing unconsciousness though anesthetic overdose, and respiratory arrest by bilateral pneumothorax to assure death. Given all of the aforementioned, if a large whale were determined unconscious, inducing bilateral pneumothorax would perhaps be regarded as a more humane death than for the animal to suffer multiples days stranded on a beach awaiting death.'

Carcass Disposal

There are many parameters that impinge on large whale carcass disposal, but in terms of choice of euthanasia method, the major issue is the risk to scavengers when chemical methods are used. There is limited information on this topic published, although (Greer et al. 2001) state that 3 grey whales and one pilot whale euthanased with 20 mg/kg pentobarbital showed muscle levels up to 1 µg/g. This would require a dog to consume 85kg of muscle per kg of bodyweight to reach a lethal dose. The above dose was 1/3 to 1/10 of the recommended lethal dose for whales, but still at the highest recommended dose, this would still require c. 8kg of muscle consumed per kg of dog. In spite of these preliminary data suggesting that the risk of lethality to scavengers is quite low, there is widespread expectation, in the US at least, that chemically euthanased animals should not be left accessible to scavengers. There is also the concern that barbiturates in the environment are very stable and will therefore become persistent pollutants (Peschka 2006). However, barbiturates are broken down by composting and hydrolysis disposal methods (Kieth Matassa, pers. comm.)

DISCUSSION

The key questions concerning large whale euthanasia include the following. Should terminally entangled whales be considered candidates for euthanasia if not beached? If so, what are potential methods of euthanasia? When a beached whale is deemed beyond rescue, what are the options for euthanasia? What are the risks and benefits, safety and training issues, and carcass and recovery considerations of each potential method? The pro

The advantages and disadvantages of each method are summarized in Table 2.

Public Involvement

(Coughran et al. 2010): 'It should be noted that, despite its effectiveness, the "implosion" option lacks subtlety and has significant potential to evoke an emotional response from members of the public that relate euthanasia to small narcotic injections delivered discreetly in city veterinary practices to small furry animals and assume that a whale can be put down in similar manner….The Police Department is responsible for the critical issues of public safety that emanate from public proximity to powerful animals and from the use of explosives, and local government authorities are responsible for public health issues and are therefore always involved in the management of each whale beaching incident. The State Government Department of Environment and Conservation is the lead agency

for all live beached whale incident management, supported by the Police Department and local government authorities.'

'A note on the involvement of vets: Generally this work is routine and doesn't require veterinarian assistance. It requires a pragmatic assessment of the situation by experienced staff and the follow through of simple euthanasia techniques if deemed necessary. Past experience has shown that the participation of veterinarians in this work can sometimes unnecessarily complicate matters.'(Donoghue 2006)

This comment is somewhat surprising but it is useful to note that such attitudes seem to remain at least as recently as 4 years prior to the date of this review. It is perhaps reasonable to suggest that veterinarians are trained and experienced to be uniquely qualified to understand the humane, public perception, and technical issues.

'In several countries, including New Zealand and the US, public opinion and press media considerations as well as personnel emotional and safety concerns are given just as high priority as animal welfare considerations when choosing killing method (Hyman, 2001; IWC, 2003b). However, in the author's point of view the attention and focus of the operator should be that the animal is killed as swiftly as possible.'(Knudsen 2005).

It is worth noting that large caliber weapons are often widely available aboard many national defense vessels. However, in regions where the general public have been accustomed to seeing marine mammals euthanased with drugs, there will need to be a substantial education component to any move towards using ballistics or explosives.

Conclusion

It is not the intent of this working paper to recommend one method over another, or that euthanasia should or should not be undertaken, but simply to lay out the available methods and possible risks and benefits of each so that there can be a discussion of such matters at the upcoming workshop.

It is perhaps reasonable that the workshop should attempt to classify available methods into one of three categories in the context of being at sea or on the beach, and of animal size and species.

1. Acceptable
2. Conditional given extenuating circumstances
3. Currently outside acceptable practice.

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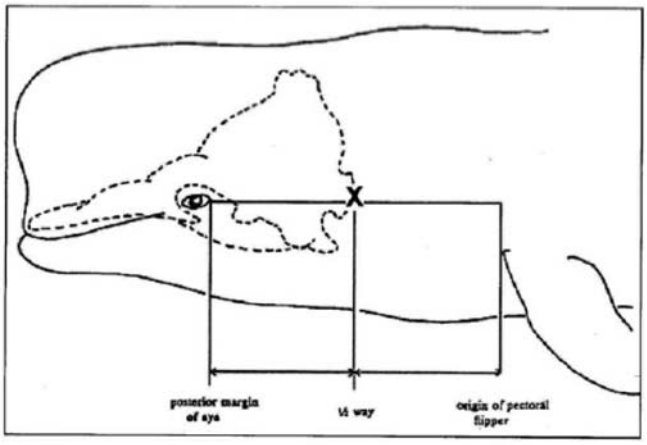

Figure 1 – Target area for shooting stranded whales. Target area accessed by a shot fired dorso-ventrally (from above or below) or laterally (from the side). Target area (occipital condyles) indicated by X. Legend and image adapted from (Donoghue 2006).

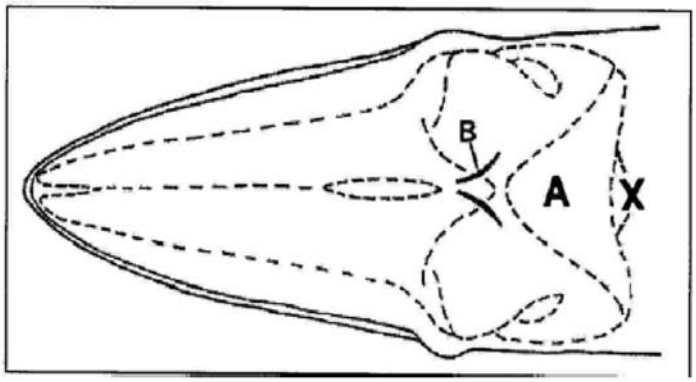

Figure 2. Alternative target area for shooting baleenopterid whales when cannot be shot laterally, showing braincase (A), blowhole (B) and target area (occipital condyles) X. If any doubt about target area three shots should be fired in line through the target area. Bystanders should be warned ahead of time that this is standard practice. Legend and image adapted from (Donoghue 2006).

Figure 3 – Post mortem view of head and anterior chest of a North Atlantic right whale (Eubalaena glacialis). The animal is lying on its back, with the head being dissected from the body at the level of the occipital condyles (medium arrow). The short arrow shows the insertion of the right flipper. The long arrow points to the right eye. Photo credit: Virginia Aquarium

Table 1 - Summary of Large Whale Chemical Euthanasia Reports

Source	Subject	Length	Route	Agents	Dose	Effect/ Comment
Daoust 2001	Emaciated juvenile fin whale	10.5m	i/v intercostal	Xylazine	5000mg	Expired gently during 1 hour post injection
				T-61	100ml	
				KCl	1200mmol in 600ml sterile water	
Barnett 1999			i/m	Etorphine Acepromazine	4ml per 1.5m	Not available. Major operator risk
Dunn 2006	Juvenile fin whale	13.5m	Blowhole with 30" extension to respiratory tract at end of expiration	Pentobarbital	60ml 390 mg/ml	Geatly diminshed fluke movements
			i/v caudal 20 min later	T-61	120ml	Rapid cessation of breathing with loss of heart beat after 20 minutes.
Walton pers comm	Sperm whale WJW003	12m	i/m	Acepromazine	5ml	No respirations or palpebral reflex at 1350
			i/m	Xylazine	15ml	
			i/v caudal	Barbiturate	280ml	
Walton pers comm	Humpback VAQS 2006-1066	604m	i/m	Xylazine	180ml 100mg/ml at 2013 hours	
				Barbiturate	180ml i/p at 2045 to 2050	last breath at 2103, dead at 2115
McLellan pers comm	Right whale KLC022	5m	i/m	Diazepam	200mg at 1310 hours	inadequate to apporach tail
			i/m	Diazepam	200mg at 1322 hours	
			i/m	Xylazine	2000mg at 1323 hours	
			i/p	Fatal Plus	120 ml of 390 mg/ml at 1334	
			i/p	Fatal Plus	120 ml of 390 mg/ml at 1336	dead 1357
Harms and McLellan pers comm	Right whale CALO0901	9.8m est. 10,000kg	i/m	Meperidine	200mg (8ml)	Day 1
			i/m	Acepromazine	200mg (20ml)	Sedated only
			i/m	Midazolam	140mg (28ml)	
			i/m	Medetomidine	20mg (20ml)	
			intranasal	Acepromazine	280mg (28ml)	
			Retrobulbar rete	Midazolam	90mg (18ml)	Day 2
			Retrobulbar rete	Diazepam	150mg (30ml)	
			Retrobulbar rete	Acepromazine	450mg (35ml)	
			Retrobulbar rete	Xylazine	1300mg (130ml)	
			Retrobulbar rete	Medetomidine	22mg (22ml)	
			Intranasal	Isoflourane	200ml over 10 inspirations	Sedated and then exsanguinated

Table 2 - Advantages and disadvantages of different large whale euthanasia methods

	Explosive Harpoon	Shoulder Gun with Penthrite	Shoulder gun black powder	High caliber rifle	Explosive behind blowhole	Sedation & exsanguination	Sperm Whale Euth. Device	Barbituate injection
Beach?	Y if mounted suitably	Y	Y	Y	Y	Y	Y	Y
At Sea?	Y	Y	Y	Y	N	N	N	N
Species	Any	Any	Any	Any	Any	Any	Sperm whale	Any
Size	Any - need right caliber	Any	Any	<8m*	Mostly >8m	Any	Any	Volume limited
Availability	Japan, Norway, Iceland	Alaska	Alaska, Chukotka	Any	South Africa and Australia	Wide	New Zealand	Wide
Environmental impact	Low, unless collateral damage	Low	Low	Low	Low	Low	Low	Potential scavenger side effect
Welfare	Good if instaneous	Moderate to good	Poor	Depends on aim	Good	Poor	Good	Good
Collateral damage	Potential	Potential	Potential	Potential	Nearby houses, especially if rock ledge	No	?	No
Human Safety	Potentially bad	Risky	Very Risky	Moderate	Potentially bad	If inadequatrely sedated	Moderate	Moderate
Training for use?	Yes	Yes	Yes	Yes	Licensed only	Veterinarian	Bamber only	Veterinarian
Aethestics	Problem	Problem	Problem	?	Problem	Problem	Problem	Expected in US
Equipment required	Cannon, harpoon, grnrades, explosive	Shoulder gun, explosive etc	Shoulder gun, explosive etc	Rifle, ammunition	Explosives etc , sand bags	Drugs and knife	SWED	Drugs
Portability	No	Possibly	Possibly	Yes	Difficult to travel, impossible to fly	Yes	Only in NZ	Yes
Toxic carcass residue	No	No	No	No	No	Minor	No	Yes

*Ingling pers. comm Mar. 25 2010 'Designer of .577 is willing to custom build a rifle and ammo specifically for this problem of penetration. He is confident he can increase penetration by 50% or so which could take out any whale in existence.'