Norwegian minke whaling
Research to improve hunting and killing methods for minke whales in Norway

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<u>Current whaling practice</u>
In Norway only one species is hunted, namely the minke whale. The minke whale hunt as it is carried out in Norway today, and which is termed "modern minke whaling", began some 80 years ago (*Jonsgård* 1992). However, the hunting of whales has much longer traditions. The first written sources of hunting of whales in Norway are from the 9th century AC (*Gulberg* 1890). And a unique and very age-old method used to catch minke whales was to enclose them in a narrow bay or inlet, and kill them with arrows infected with the spore-forming bacterium *Clostridium septicum* (*Nielsen* 1890, *Øen* 2001).

The hunt is conducted with small (50 feet) or medium sized (60-120 feet) fishing boats that are rigged for whaling in the spring and summer season. The current hunting weapons consist of 50 mm and 60 mm harpoon guns with corresponding harpoons equipped with a penthrite grenade developed in 1997-1999 and rifles with full metal jacket, round nosed ammunition of calibres 9.3, .375 and .458 (minimum calibre 9,3 mm) as back-up weapons. The harpoon is connected to a line, forerunner, made of nylon or other synthetic materials, which runs through a spring system to a winch. The harpoon grenade is loaded with 30 g pressed penthrite as explosive. A triggering device, a twin hook connected to an elastic nylon cord, triggers the detonation of the penthrite when the grenade has travelled about 70 cm into the whale.

The boats go searching for whales on known whaling grounds, which sometimes are found close to the whaler's home. The boats search the actual area in relatively slow speed (4-6 knots/h) looking for whales or flocks of birds feeding on fish or krill. If birds are spotted, it is usual to wait there for some time if a whale eventually should come and start feeding on the pray. In such situations it is not unusual that the whales approaches and come close to the boat If not the boat idles up to the area where the whale is expected to blow next time or starts following the whale usually in a moderate speed and tries to get close enough to fire the harpoon. No instruments are used during this approach as it might scare the whale.

The hunter usually aims the harpoon at the thorax. And the whale is shot from the side whenever possible. A minke whale which is hit deadly as it rises to the surface to blow normally stops swimming, rolls on to its back, and floats for a short time before sinking. If it is deadly hit as it dives after blowing, it sinks without surfacing or pulls out some of the harpoon line before stopping. If the whale does not loose consciousness or die rapidly, it maintains its normal position in the water and dives actively and resurfaces to blow after some minutes. Therefore, if the whale does not immediately turn over on its back after being hit, or stops pulling out the line, it will routinely be hauled to the boat as fast as possible to check whether it is dead, and the gunner will be ready to fire the back-up rifle when the whale comes to the boat. The rifle is usually fired at close range and when the whale's head is over water. The shot is directed to the brain of the whale and many hunters fire a bullet in the brain as a matter of routines.

When the whale is lying at the boat side, a wire or rope is put around its tail before it is hauled on to the boat across the deck through an open gate in the gunwale. The meat and blubber is placed on grates on the deck and cooled before being stored on ice in the hull until it is brought to processing in land.

Each gunner is required to pass an annual and obligatory shooting test, both with rifle and harpoon gun. Prior to the hunt the boats and hunting gears are controlled and approved for hunting by governmental inspectors from the Norwegian Directorate of Fisheries and the Norwegian Food Safety Authority. From 2006 on the hunt is monitored at-sea by an electronic trip recorder, “Blue Box”, and in spot controls at sea and harbours by authorised personnel from the Norwegian Directorate of Fisheries.

Research programs 1981-2004

From 1981 to 2004 Norwegian scientists at Norwegian School of Veterinary Science have conducted three major research projects to improve and assess the hunting and killing methods for minke whales in Norway. These projects have 1) aimed to develop alternative methods to improve the animal welfare and the hunter’s safety associated with the hunting and 2) to verify the efficacy of the methods by autopsy and neuropathological studies of animals killed. The research programs had its most extensive research periods in 1981-86, 1992-95 and 1997-2004. The research has resulted in development of new weapons technology, improved hunting techniques and routines and obligatory education and training of hunters and inspectors. Four types of whale grenades with the potent supersonic explosive penthrite have been developed; two harpoon grenades for 50 mm and 60 mm harpoons and one for 90 mm harpoons used for fin and sei whales in Iceland in the late 1980ies (*Øen* 1987), and one grenade for the traditional darting gun used by traditional subsistence hunters of bowhead whales in Alaska (Øen 1995e).

Improvements have been implemented also on the other parts of the hunting gears. Most of the traditional open harpoon gun sightings are gradually being replaced by optical sights in most of the harpoon guns. The harpoons and harpoon lines are modified and reinforced to prevent breakages and a Norwegian whaler developed a new harpoon, which can be adjusted to fit to the barrel of the individual harpoon guns, which improves its ballistic properties and marksmanship. Minimum calibre of back-up weapons has been established. Hunting practice has been changed to improve the instantaneous death rate (IDR) and time to death (TTD). Formalised, obligatory workshops and training courses for hunters were carried out on a regular basis from 1984 to 2005.

The inventions, improvements of hunting gears, education and training of hunters have resulted in improved hunting practice and animal welfare associated with the hunt. The statistics show a considerable increase in IDR. The TTD has been reduced accordingly and losses of wounded animals are less than one per thousand according to the reports from veterinarian inspectors in 2000 to 2002.

The data on the performance of different killing methods have been collected for scientific purposes by mainly veterinarian inspectors, for 5552 minke whales from 1981 to 2002. Results from this research have been reported to IWC on a regular basis in workshops and annual reports. The impact of the research program on the IDR and TTD is shown in Fig. 1.

Fig. 1 shows that the percentage of animals that died rapidly in 1981-83 was about 17 %. The average TTD was 11 min 20 sec. The percentage of re-shooting with harpoon was 17 % (*Øen* 1995a). In 2000 to 2002 the IDR was about 80 % with an average TTD of 2 min 17 sec using the criteria adopted by the International Whaling Commission (IWC/33/15), which may include periods when the animal may have been unconscious or already dead (IWC/47/18, IWC/51/12). Only 0,5 % needed a second shot with harpoon grenade. Two doctoral studies on developments in whaling and killing efficiency in whaling (EO Øen: Killing methods for minke and bowhead whales in 1995 and SK Knudsen: Assessment of insensibility and death in hunted whales in 2004) have been defended for the veterinary doctoral degree (Dr. med. vet.) at Norwegian School for Veterinary Science. From 1992 to 2003, twenty-one extensive reports and publications in scientific journals have been presented to and discussed in four workshops organized by the IWC, in addition to annual reports. After 2003 IWC has received two annual reports and one review paper has been published in an international scientific journal.

More details about these 25 years of work to improve weapons, whaling practice and animal welfare in the Norwegian minke whaling are described in the following chapters.

1981- 86

Research program I: Developments of alternatives and/or improved weapons and hunting methods in Norwegian minke whaling

A five years research program to improve the weapons, hunting methods and replace the cold harpoon started in 1981. From the IWC, Norway was initially encouraged to investigate the possible use of high-velocity projectiles (IWC, 1980) in the minke whale hunt. However, Norway widened the scope of the program to also include a more comprehensive study of several possible alternatives, with design, trials and the adaptation of new equipment and also the training of hunters.

Explosive grenades for whales were developed into a relatively effective killing method for the large whales as early as the 1870s (Johnsen, 1940). They were steadily improved, and black powder grenades were considered to be the best killing method for large whales as late as in 1960 (IWC, 1960). The black powder grenades, which commonly were loaded with 650 g black powder, were used with harpoons of 90 mm calibre. For smaller guns, including 1.5" (37mm), and 2" (50 mm), which were occasionally used to catch fin whales from smaller fishing vessels or to re-shoot whales, also black powder harpoon grenades that contained about 120g black powder seems to have been used.

When harpoon guns were introduced in the minke whaling in thee 1920ies the harpoon shells were not filled with explosives. The main reasons were probably that black powder was expensive and the fuse igniting the powder burned too slowly to set off the shell inside the animal. However, the empty shell ("cold grenade") was continued used on the harpoon head, but gradually it was replaced with a pointed iron head ("cold harpoon"). The smallest boats (35-50 feet) had no winch on board. They used a technique similar to techniques still used by some aboriginal whalers. The harpoon line was connected to a buoy and was thrown over board to be retrieved later. Whales that survived the harpoon shot was re-shot with a second harpoon or dispatched with lances and in more modern days, with rifles. This hunting method was banned in Norway in 1983 after several requests from the conductor of the research program.

No data on the killing of minke whales with cold harpoon had been collected, nor were any reports from controlled experiments on other killing techniques for minke whales available except for the ongoing Japanese project to investigate the possible use of penthrite for whale grenades. It was therefore highly important to start to collect data on the cold harpoon to serve as a reference data bank for possible improvements (Øen 1983a, 1995a).

There were several issues to take into account when planning the project; Minke whales sink when they are dead. The whales therefore must be "hooked" in a way simultaneously with or immediately after they are dead; Also the cold harpoon had been used Norway for many generations and was a very familiar piece of equipment; The hunting was (and still is) carried out from small vessels built for fishing, not hunting; The fishermen hunt whales as a sideline, and are not professionals; The minke whale hunt was a dangerous enough occupation as it was, and the introduction of new methods could not be allowed to further increase the risks; The profit from the hunt was limited and did not give basis for large investments on the boats. All these factors had to be taken into consideration, although little emphasis was given to the economic consequences at the planning. The safety of the crew, and the effectiveness of the method, received the highest priority, in the mentioned order.

Rifles
Before 1981 the rifles used to dispatch wounded whales was usually of calibre 6,5, 7,62 or 8 mm. The ammunition was often soft nosed bullets or full metal-jacketed, but *pointed*, bullets. These were scarcely sufficient to kill an adult minke whale rapidly. One of the first recommendation that was given after the project started in 1981 was therefore to immediately increase the prescribed minimum rifle calibre and to ban soft pointed and pointed ammunition and replace them with full metal-jacketed bullets with round nose and an impact energy of minimum 8400 joules at 100 m (E_{100}).

Electricity, drugs and compressed air (gas)
A review was made on the possible use of electrical harpoons (*Øen* 1983b) and drugs (*Øen* 1984). This did not result in any new design of equipment or field trials as it was very unlikely that electrical harpoons would prove to be effective (1995b). Drugs would not represent an independent alternative either, as an anaestezised or dead minke whale would sink. Drugs therefore, only could be used in conjunction with harpooning. Another and even more complicating and obvious fact was that any drugs that might have been used, would have been extremely dangerous both to the operator and to the consumer of the whale meat.

The use of compressed gases was also considered as it had been discussed as a possible killing method at the IWC workshop on whale killing methods in 1980 (*IWC*, 1980). A prototype gas harpoon was constructed and tested on a dead minke whale. After this trial, this method was not further considered (*Øen* 1983c, 1995d).

Field trials

High-velocity projectiles
Field trials with 20 mm high-velocity projectiles (HVP) were conducted in 1982-83. After two field trials, it was concluded that although they would probably have been very effective for killing whales they could only be used in conjunction with harpooning, not as an independent method. The conclusion was that the large calibre rifle, which

already had been introduced in the hunt, was a faster and more effective method to dispatch wounded whales compared to a separate gun with 20 mm high-velocity projectiles (*Øen* 1995c).

Traditional and modified cold harpoons

Modified, blunt-nosed, cold harpoons, were designed and fields tested in parallel with trials with HVP. The trials showed that the time to death (TTD) was somewhat reduced compared to the traditional sharp-pointed harpoon. However, these improvements were not sufficient to recommend the continued use of cold harpoons. However, the trials showed that in addition to improving TTD the blunt harpoon design also improved its ballistics as well as the marksmanship. The design of the most successful blunt harpoon used in the trials, was therefore transferred to the penthrite grenade that was developed later (*Øen* 1983c, 1995b).

Penthrite grenades

The first trials with penthrite grenades started in 1983, continued through 1984, and were concluded after a comprehensive field study in 1985-1986 (Øen 1995d).

Before the development work started in Norway, a thorough assessment of the Japanese prototype was conducted. It was also tested in the field, but it could unfortunately not be successfully transferred to the Norwegian hunt without major modifications. It was therefore decided to develop a penthrite grenade that was designed for the Norwegian weapons and hunting practice. Three different prototypes were tested in a small scale field trial in 1983 (*Øen* 1995b). After this trial two of the prototypes were chosen for further development before being tested in extensive field trials in 1984. After these trials one of the prototypes was approved for further modification and further trials in 1985. After the 1985 season it was approved for hunting, but the collection of data continued also in 1986 to qualify its function (*Øen* 1995d). This grenade was used in Norway until 2000, when it was replaced with an improved and safer penthrite grenade (Whale grenade-99).

Results of field testing1984-86

Data collected from the Norwegian hunt using traditional cold harpoons in 1981-1983 (*Øen* 1983b, 1995a) showed that about 17 % of the animals died within the first minute. The penthrite grenade (1984-86) increased the percentage of animals that were killed instantly (IDR) or very rapidly by 2.7 times to about 45 % (Øen 1995d). The median and average survival times were considerably reduced. The percentage of whales that were re-shot with harpoons was reduced from 17 % using cold harpoon (*Øen* 1995a) to 4 % using the penthrite grenade (*Øen* 1995d). However, some long survival times were still recorded especially when whales broke free and had to be retrieved before re-shooting. At that time re-shooting with rifle also often took long time as the rifle usually was kept indoors, unloaded and had to be retrieved and loaded before the shooter was ready. At that moment whales that had survived might already have dived or moved out of shooting range.

The influence of shooting range and whale size on killing time for cold harpoon (1981-83) was studied by Cox regression (proportional hazard) and by a combination of logistic regression for the whales killed instantantly and Cox regression for whales surviving longer than 10s. The time to death was significantly dependent on both covariates in the Cox regression. The analyses based on a combination of logistic regression and Cox regression gave similar results. However, the fraction of the whales killed instantaneously was only dependent on shooting range and not significantly on animal size (*Øen* 1995a).

Statistical analysis of data from the hunt in 1984-86 showed that although whale size (length) and the range and angle of the shot relative to the animal's long axis all influenced survival time, whale size was only a statistically significant factor when the whale did not die instantaneously or very rapidly. It also showed that marksmanship, technical standard of hunting gears, and the hunting techniques, were crucial for a good result. This meant that better training of gunners, improved hunting gears like cannons, sighting implements, ropes and winches together with rapid re-shooting of wounded animals, would reduce the number of animals that lived for several minutes (*Øen* 1995d).

Greenland and Iceland

The 22 g penthrite grenade from 1984-85 was later also introduced by the Greenland Home Rule Government in the Greenlandic hunt of minke and fin whales and was also modified to accommodate 90 mm harpoons and used for fin and sei whales in the Icelandic scientific catch in 1985 and 1986. The grenade contained 100 g of penthrite and the detonation was triggered 100-120 cm inside the whale's body. This grenade was used for 14 fin whales, 10 of which were recorded immediate dead and 15 sei whales, where 14 were reported dead immediately (Øen 1987).

1992- 96.

Research program II: Further developments of alternatives and/or improved weapons and hunting methods in Norwegian minke whaling

The traditional minke whale hunt was temporarily halted from 1987 to 1993. In 1992 only scientific whaling took place in Norwegian waters.

Scientific whaling 1992

Based on the experience from the former projects in 1981– 86 and the project manager's experience from other whale hunts a program to improve the hunting practices was set up prior to the scientific whaling season of 1992. To improve marksmanship and the ballistics of the harpoons, only harpoons that were consistent in weight were permitted. Specific instructions were given the gunners on shooting and catching routines. The recommended range for harpoon shots was set to 30 m and whenever possible the animals were to be shot from the side and hauled in to the boat immediately to determine whether re-shooting with rifle was needed. During the hunt the rifle had to be kept beside the gunner at all times.

The Safe and Arming Mechanism (SAM) of the whale grenade of 1984-85 was a very complex construction. It had several built-in safety elements in addition to both instantaneous detonation devices and delayers. For extra safety it was equipped with a self-destructive element. To avoid armed grenades from being hauled on board the grenade detonated in the water if it failed to hit the whale.

In 1992 new grenades were ordered from the manufacturer. However, it was too late discovered that some grenades failed to detonate. A comprehensive fault finding program was established in cooperation with the manufacturer and subcontractors. This study finally revealed that the flaw was caused by a production error with too narrow tolerances for some pieces of the SAM. If two pieces with narrow tolerances were assembled the mechanism failed to arm the grenade. Test shootings showed that the deficiency might cause 10 % malfunction. Fortunately this was not the case during the hunt according to the reports from the scientists on board. In spite of this error the results from the scientific hunt in 1992 showed a slight increase of IDR from 45 % in 1984-86 to 49,5 % in 1992 and also the median and mean values of TTD were slightly reduced (*Øen* 1995b).

The remaining grenades from this production Lot were disassembled, repaired and retested prior to the 1993 season.

Traditional hunt 1993-95

Before the traditional hunt was resumed in 1993, the hunting gears were reinforced. The required tensile strength of harpoons, fore-runners, wires, winches and braking devices was increased from the former 1,500 kg to 5,000 kg. The harpoons were standardised in weight, and the harpoon claws were modified and reinforced. The 60 mm harpoon guns were modified by the introduction of a new and more reliable trigger mechanism. Gunners and licence-holders were required to take part in obligatory workshops and courses covering issues like anatomy of minke whales with particular emphasis on positions of vital organs like brain, heart and lungs. They were instructed in personnel safety, maintenance of weapons, weapons ballistics, hunting techniques, shooting with rifle, etc and each gunner was required to pass a shooting test using harpoon gun and rifle. They were also instructed to shoot the animal from the side whenever possible and to haul it to the boat immediately to determine whether re-shooting with rifle was needed. During the hunting the rifle had to be kept beside the gunner at all times.

The results from the 1993 hunt again showed a slight increase in IDR from 49.5 % to that 54 % (*Øen* 1995b). The obligatory courses for the licence holders and gunners therefore continued. Animal's anatomy, shooting with harpoon gun and rifle and rapid hauling in of the animals were again emphasised. The reports received for the traditional hunt in 1994 showed that all signs of life had ceased instantly in 59 % of the cases. The average survival time was 185 seconds. In 1995 the reports show that all signs of life ceased instantly in 62 per cent of the whales and the mean survival time was 204 seconds.

The influence of the covariates year, shooting range and whale size on survival time for the traditional hunt in 1993 and 1994 were studied by Cox regression (proportional hazard) and by a combination of logistic regression for whales killed instantaneously and Cox regression for whales surviving >10s. The analyses showed that in 1993 and 1994 the year or size of the animal did not significantly influence the survival time on whales that died instantaneously or survived for more than 10s. The shooting range, however, had still a significant influence on survival time. Similar analyses from 1984-86 showed that both whale size and shooting range significantly influenced survival time if the whales did not die instantaneously or rapidly. The change was probably a combination of improved shooting, resulting in a higher proportion of instantaneous deaths and unconscious animals, improved hunting gears and stricter standards of hunting routines which imposed and made it possible to haul in both large and smaller whales quickly for control and possible re-shooting with rifle (Øen and Walløe 1996).

1996- 2004
Research program III:
Part 1: Further developments of alternatives and/or improved weapons and hunting methods in Norwegian minke whaling

<u>Development and field testing of a new and improved harpoon grenade for minke whales (Whale grenade-99)</u>

After the problems with the safe and arming mechanism (SAM) in the production Lot of the whale grenade of 1992, the confidence to its SAM was definitely reduced. In the next production a new dysfunction occurred with the SAM. It was the build in safety, the self-destruction element that should prevent armed grenades from being hauled on board when the harpoon missed, that failed in some cases. The manufacturer could not guarantee that this could be repaired and would not give any guarantee for improvements in future productions. It was therefore decided to look for alternatives and the planning process to design a new penthrite grenade started in the fall 1996.

In 1997 the Norwegian Research Council funded a project at Norwegian School of Veterinary Science, Department of Arctic Veterinary Medicine on the hunting and killing methods for whales, seals and large terrestrial wild animals. The development of a new SAM or an alternative grenade became a part of this project. A new SAM was designed and constructed in cooperation with Norwegian Defence Research Establishment (NDRE). After thorough testing in laboratories, the first demonstration types were constructed and tested in shooting trials on land-based proving grounds before a prototype (Prototype 1) was build. This SAM had a reversible safety mechanism that so the grenade could be safely retrieved and reused if it missed the target. The penthrite charge was increased to 30 g of pressed penthrite. Pressed penthrite is safer to handle in the production and need smaller space. The weight of the grenade was reduced by 40%, which improved the harpoon ballistics.

The prototype was thoroughly tested on land, demonstrated and preliminary approved for transport and trials at sea by the Norwegian Directorate of Fire and Explosion Prevention.

Field trials with prototype grenades in 1997, 1998 and 1999
In 1996 season the hunt was conducted with the grenade developed in 1984-85. In the three hunting seasons of 1997 to 1999 three different prototypes of the new grenade under development were used in addition to the “old” grenade. Trained veterinarian inspectors in addition to scientist working on the development project collected data from all boats.

Prototype 1 of the new grenade was used for 14 minke whales on one whaling vessel in 1997. Seven of these whales were recorded instantaneously dead. The average survival time was 125 s and the longest survival time was 7 min. Some components failed to function satisfactorily in all cases and after the trials the prototype was modified and re-tested in laboratories and several trials on land based proving grounds before a new batch of the second prototype (Prototype II) was manufactured for further trials in a larger ield trial in 1998.

Prior to the 1998 hunting season a weapon workshop was held for gunners and licence holders. They got detailed instructions and were trained in the handling and use of the new grenade. The harpoons were modified with a new connector to accommodate the SAM. The grenades were numbered individually and the gunners had to describe the performance of each grenade in addition to the description recorded by he inspectors. Because grenades that failed for any reason could be re-secured, they were legally returned to the manufacturer for inspection.

In 1998, 625 minke whales were recorded killed with Prototype II. Sixty-four per cent of the animals were reported instantly dead. The 75 % fractile (Q_3) of the median survival time was 300 s and the average was 198 s. One whale that broke free was re-shot after 68 minutes (*Øen* 1999). In total, 36 grenades were returned for inspection and control. Eleven had failed because the trigger rope was broken when it passed through solid bones, 8 grenades failed due to flaws with the connector between harpoon and grenade which resulted in that it failed to arm the grenades, and 17 failed because a spring in the SAM of some grenades, due to delivery problems, had been replaced with a spring that was not qualified and failed to function properly in some grenades.

All components that had failed in 1998 were modified and replaced with new and improved pieces. A third version of the grenade (Prototype III) was manufactured and used on 5 whaling vessels in 1999. And like earlier, scientists or inspectors were present on every whaling boat. Each grenade had been numbered the gunners should fill in the form to describe grenade performance. Data on the killing were collected on all boats and grenades that had failed or not performed correctly were sent back for inspection and control. Prototype III was used for 129 whales. The results showed that 72 % of the whales were recorded instantly dead. The average TTD was 201 s.

After the 1999 season, the trigger hooks and some elements in the SAM were further improved before the grenade was subjected to a Competent Authority Approval (CAA) set up by the Norwegian Directorate of Fire and Explosion Prevention. Passing this specific approval tests was one of the conditions to authorise legal transport and common use of the grenade on whaling (fishing) boats. The approval tests were designed and carried out in accordance with specific UN recommendations. The grenade passed the CAA and was accordingly approved by Directorate of Fire and Explosion Prevention in January 2000 under the name of "Whale grenade 99". After this approval the Directorate of Fisheries in Norway decided that the former and less safe penthrite grenade from 1984 should be banned from the hunt.

The total numbers of animals recorded killed with the two types of penthrite grenades from 1996 to 1999 were 387, 503, 625 and 591 and the recorded TTD were 59, 61, 63, and 62 per cent, respectively. The analysis showed no statistical significant difference between the four seasons and about 60 % (61.3 %) of the animals died instantly (Fig. 1) and about 50 % of animals surviving the grenade detonation according to IWC criteria of death, were recorded dead within the next 5 minutes. The longest survival time of 86 minutes was recorded in 1999 for one animal that was hit by a stray shot and was re-shot with a second grenade (Øen 1997, 1998, 1999, 2000).

2000-2002

The flaws on certain components that had occurred during production in the development phase showed the importance of a detailed and more comprehensive control of the production process. From 2000 on, the production of the whale grenade therefore became subject for a more exhausted quality control. A new quality control regime was instituted where i.a. every single movable piece and all parts of the grenade that are vital for the function are visually controlled, control measured after production and numbered by external competent controllers. The results are recorded in a production protocol which is presented to the customer's controller for final approval or rejection of the production. The assembling of grenades is overviewed and spot controlled by the customer's controllers and a pre-decided number of grenades are randomly sampled by the controller for a final visual inspection, Fabric Acceptance Control (FAT) and finally shooting trials before the production Lot is accepted. The customer's controller has the right to unexpected controls of the production lines and the product any time during the production.

This exhausted quality control has become a very important part of the production and has given results. According to the whalers and inspectors, the number of grenades that fail to function properly is very low. When grenades that have failed have been controlled, the main reasons for failing have been occasional use of harpoons where the connector has not been fitted correctly and thus prevents the grenades from being armed, the trigger ropes are slit due to passage through solid bones before detonation or the harpoon has stopped in solid backbones before the grenade has went deep enough to detonate.

From the 2000 season all vessels were equipped with the new grenade. The hunters attended an obligatory course where they were given a detailed instruction in grenade function, function of the SAM and the importance of correct harpoon connector design. In 2000, governmental inspectors, trained veterinarians and three whale biologists, collected data on the killing the whales and the performance of the grenade. In 2000, 481 minke whales were killed with the new grenade and 78.3 % of the whales were recorded as dead instantly. The average TTD was 2 minutes. In 2001 the corresponding figures were 552 whales with an instant death rate of 79.7 %. The average TTD was 2 min 25 s. In 2002, 634 whales had been recorded and 80.7 % of these whales had been recorded instantly dead. The average TTD was 2 min 21 s. The longest TTD was recorded in 2001 and 2002 where two whales broke free and had to be retrieved and re-shot with grenades.

The results for the 1667 minke whales caught in the three years are shown in Fig. 1 and 2. The analysis showed that about 80 % of the animals died instantly (Fig. 2). It was no statistical significant difference between the three seasons.

The results showed that the animal dies instantaneously or very quickly if the grenade hits and detonate centrally in the thorax or near the central nervous system (Fig. 3, Table 1). Also detonation in the cranial part of the abdomen or in musculature dorsal to the thorax can result in instantaneous or very rapid death, but the effect of such hits are less reliable as described in more details in the next chapter.

The angle of the shot relative to the animal's long axis also influenced survival time (Table 2). Shots from directly in front (0°-10°) or behind (170°-180°) gave poorer results than shots directed from the side (45°-135°) because the likelihood of hitting the animal so that detonation would take place in the most vital organs is considerably lower in such cases. However, if a whale was injured in the central nervous system, heart, lungs or major blood vessels (aorta, vena cava) it generally lost consciousness and died rapidly regardless of the angle of the shot.

1998-2004

Research program III:

Part 2: Assessment of insensibility and death in hunted minke whales; study of trauma and its consequences caused by the currently used weapons in the Norwegian minke whale hunt

The second part of the Norwegian Research Council funded project at Norwegian School of Veterinary Science, Department of Arctic Veterinary Medicine was a study to examine the trauma and its consequences caused by the weapons and ammunitions used in the Norwegian minke whale hunt.

The major aims of the study were to investigate: (1) pathological lesions caused by penthrite grenade detonation in minke whales, with special emphasis on the central nervous system (CNS); (2) whether the currently used rifle ammunitions in the Norwegian hunt are capable of penetrating the skull of minke whales and cause sufficient damage to the CNS to account for an instantaneous loss of sensibility; and (3) if the "IWC criteria" are valid to determine time to death (TTD) in whales (*Knudsen* 2004).

The materials in the study were collected during regular minke whaling on two boats in Norwegian waters during four hunting seasons (1997-2000) and compromise of 66 minke whales. All whales were examined in the field for gross pathological damages. The subsequent histological analyses took place in laboratories and focused in particular on damages inflicted on the CNS.

Penthrite grenade

Material collected in the field period 1998-2000 from totally 37 animals killed with a single penthrite grenade showed that the intra-body detonation of 30 g of penthrite was capable of causing caused massive multi-organ damages in the animals, including severe and fatal neurotrauma. The instantaneous or very rapid lethal detonating area ranged from the dorsal skull to the rostral abdomen. Detonation of the grenade in near vicinity of the brain resulted in trauma similar to severe traumatic brain injury (TBI) associated with a direct blow to the head. Detonation in more distant areas from the skull resulted in injuries resembling acceleration-induced diffuse TBI (dTBI). Depending on detonation site the neuropathological changes varied from very severe brain tissue laceration with concomitant skull fractures and regular decapitation to histological intracerebral haemorrhages in central brain areas. Although the majority of the whales also had fatal damage to several other vital organs/organ systems, it was concluded that the neurotrauma significantly contributed to that the whales instantaneously or very rapidly lost consciousness and died without any lucid intervals (*Knudsen and Øen* 2003, *Knudsen* 2004).

Rifle

Materials collected in the field period 1997-1999 from totally 29 minke whales re-shot with rifles showed that a round nosed full-jacketed projectile of calibres .375 or .458 is fully capable of penetrating the skull of a minke whale and cause severe and massive damage to the CNS Direct hits in the brain caused skull fractures, very severe brain parenchyma laceration and in-driven bone fragments. When the projectile penetrated the cranium near the brain (<20 cm) or in the upper cervical spine, extensive gross intracranial haemorrhages were generally produced as well as displaced skull fractures in some cases. The brainstem and central areas of cerebrum were frequent sites of haemorrhages. It was concluded that when rifles of calibres .375 or .458 are used with round nosed full metal-jacketed ammunition, minke whales hit with one single round in the brain, in the near vicinity to the brain (<20 cm) and in the upper spinal cord will immediately loose consciousness and die (*Øen and Knudsen* 2003, *Knudsen* 2004).

"IWC-criteria" of TTD

The results obtained in the study further confirmed that whales may show agonal reflex movements after they loose consciousness and that the "IWC-criteria" are not fully adequate to determine exactly when a whale loose consciousness or die. When TTD are solely determined on the basis of these criteria, which in practice is immobility, a significant proportion of animals will be recorded as being sensible or alive when they most likely are unconscious or dead. If the IWC criteria are used in conjunction with a post mortem examination, however, the estimated TTD will be closer to the real TTD for a majority of the whales. Consequently, this method can be used to compare different hunting techniques and methods provided that competent personnel collect the data and the same protocol are used for the data collection and analysing. However, if the pathological examination does not include investigations of neurotraume, it is likely that the TTD of some animals still will be overestimated (*Knudsen* 2004, *Knudsen* 2005).

Summary and recommendations

What are satisfactory methods of killing animals? Opinions vary and there is no easy answer. There are those who want requirements to be stipulated that could guarantee that all animals would lose consciousness or die instantaneously without being subjected to fear or pain. This might seem an ideal goal, but it is so far removed from reality that it is doubtful whether it would in fact be to the benefit of animal welfare. Not under any circumstances could these results be achieved or these requirements complied with. The aim must nonetheless be to minimize instances where animals are not killed instantaneously as far as is technically possible.

The definition accepted as a working definition for "humane killing" at the Workshop on Humane Killing Techniques for Whales of the International Whaling Commission (IWC) in 1980 and later reaffirmed in 1992 states that: "Humane killing of an animal means causing its death without pain, stress or distress perceptible to the animal. That is the ideal. Any humane killing technique aims first to render an animal insensitive to pain as swiftly as technically possible. In practice this cannot be instantaneous in the scientific sense."

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Some people compare the relatively rapid killing of an animal by euthanasia and slaughter with hunting. The methods are so different that any real comparison is impossible. This kind of comparison is nonetheless widespread.

But laws and regulations governing the slaughter of domestic animals not only include animal welfare considerations. In the more or less industrialized slaughtering of livestock in abattoirs, involving billions of animals worldwide each year, legislation on killing methods does not give exclusive priority to animal welfare considerations. A great number of other considerations are given attention: economics, trade conditions, safety of personnel and the working environment and, in some countries, religion and traditions. In other countries other considerations may decide the methods that are accepted. For example are some species labeled as so-called pest animal, which seems to justify un-orthodox killing practices. Animal welfare considerations belong somewhere in this list, but are by no means at the top and animal welfare may be pushed far into the background.

The killing process in slaughterhouses consists of two stages. The animals are first rendered unconscious by stunning or anaesthesia, and thereafter killed by bleeding out, which should be achieved before the animals regain consciousness. The stunning procedure in abattoirs is usually carried out by means of a blow or shot directed at the brain (mechanical stunning), by electricity, or with carbon dioxide (CO_2) gas. Animals slaughtered in slaughterhouses are usually tame, used to human contact and can in most cases be held or restrained as they are stunned and later killed. However, despite the controlled conditions under which the killing takes place, inadequate stunning attempts occur. This is mostly because inadequate stunning devices and techniques are used, although inadequate training and lack of experience of the operators, in addition to unforseen circumstances, may also result in unsuccessful stunning

The techniques suitable for the stunning and killing of domestic animals in slaughterhouses are not applicable to wild animals or to animals unaccustomed to being enclosed or handled by people. In contrast to the slaughter of domestic animals, under hunting conditions the animal must be rendered unconscious and bled-out more or less in one and the same operation as the hunter tries to inflict so much damage to the animal's vital organs such as the central nervous system or the circulatory system, with one or more projectiles, that the animal dies as a result.

However, none of projectiles employed either for stunning slaughter animals or hunting larger species are so effective that an animal will die instantaneously, or rapidly, regardless of where the projectile is applied or hits the body. The effect will largely depend on the site of impact, and since in hunting the projectiles are fired from a distance and the animals often present a moving target, hunting involves a larger risk of only wounding the animal than when slaughterhouse techniques are used. This may result in that the animal escape and death may take place minutes, hours, or even days later, if the animal does not recover from its wounds.

Also when retrieving wounded big game, is a common and recognised practice not to start searching for or pursue the animal until about an hour or so after it has been shot. The purpose of this is to give the animal time to calm down, and become weaker from loss of blood and impaired function due to injury and pain in the affected limbs and organs. If the animal does not lose consciousness as it calms down, the injured parts of the body will begin to be painful, and this will aggravate the effect of the injuries and contribute to impaired mobility. This practice may appear to be a violation of humane principles but is nevertheless employed because hunters claim from experience that a wounded animal will then be retrieved and killed more rapidly than if it were disturbed and scared again shortly after being wounded.

Whales are free-living animals and cannot, like domestic animals, be restrained or immobilized before being killed. The killing of whales has, therefore, to take place according to the same principles as those applied for wild terrestrial mammals.

If we focus exclusively on the moment the animal is stunned or killed, ie when the bolt or the electric shock or the projectile hits the animal, the risk of longer survival will be greater for hunted animals than for animals that are slaughtered. On the other hand, most hunted animals will be killed without realizing that they are being hunted, and they will not be subjected to the long-term stress and pain experienced by animals for slaughter before they are killed. In the arguments used against hunting, this positive element of hunting is played down while the negative aspects of the slaughter of domestic animals are often trivialized.

However, no activity can be defended merely on the basis that other corresponding activities are just as "bad". On the other hand, the whale hunting cannot be judged in isolation from all other activities where animals are handled by people or are killed according to generally accepted standards. In connection with both slaughtering and hunting, there will always be some animals which survive the killing attempt, no matter the method employed or the prior precautions taken. The aim should, nevertheless, be to reduce the likelihood of this occurring to an absolute minimum, and if several methods are possible, the one resulting in most rapid death should be chosen. Thus, in principle, neither economic, cultural nor religious considerations should be decisive for the choice of method. This would result in all methods which are less acceptable from an animal welfare point of view being quickly eliminated, and move killing methods towards the "humane" end of the spectrum.

The weapons and ammunitions used in the Norwegian hunt for minke whale hunt of to day is when applied as recommended, highly effective in causing instantaneous or very rapid deaths. The harpoon grenade used to day must be regarded as having a wide lethal area compared to conventional weapons used in other forms of big game hunts. And the results from the Norwegian studies support the already established recommendation that for welfare reasons the whales should be shot from the side at the thorax or neck, and that all animals should be hauled in fast for control. As a precaution the hunters should still be recommended to re-shoot any animal that moves or otherwise shows any possible signs of life or as a matter of routine, even though some of these animals are unconscious and dead. This recommendation is based on that it is a good and responsible hunting practice for all large animal hunting in Norway to fire too many rounds than too few.

To further improve the TDD in Norwegian minke whale hunt, factors like more training (both quantitative and qualitative), improved marksmanship, and maintenance of weapons and hunting gears are identified as the probably most important elements.

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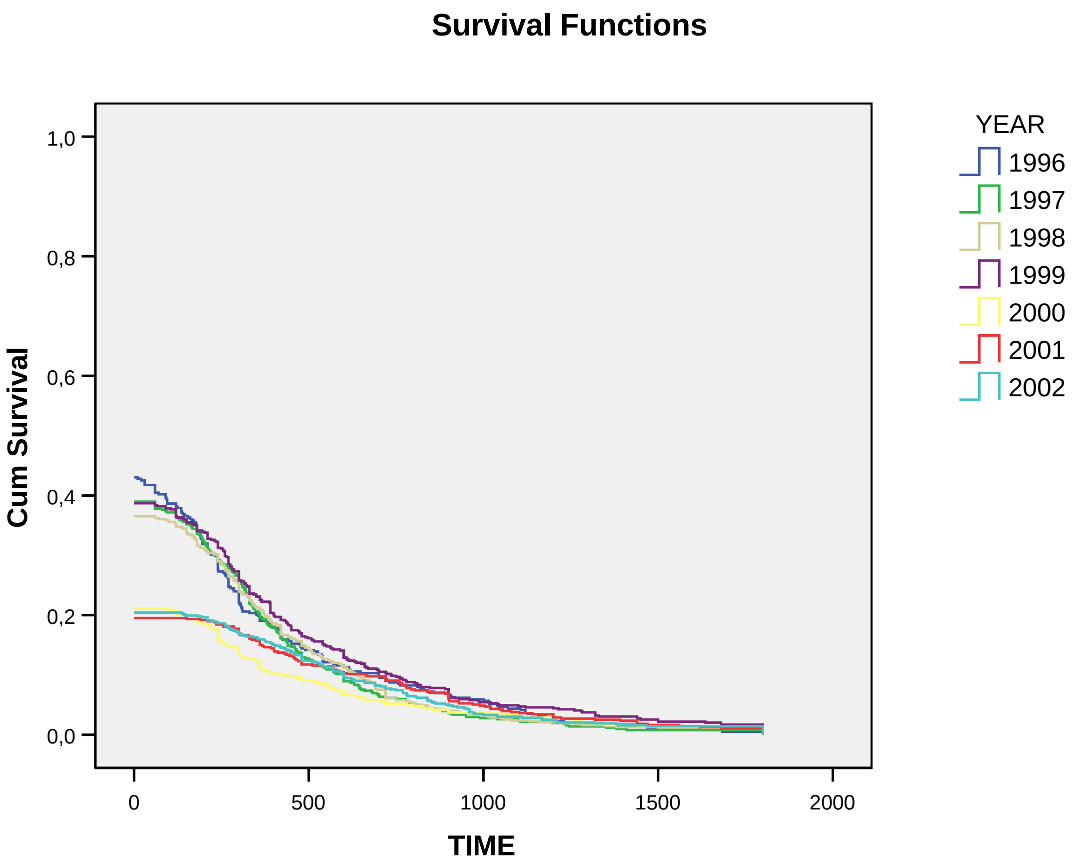

Figur 1. Survival plot for 2106 minke whales shot in 1996-99 with penthrite grenades developed in 1984-85 and prototypes of the new penthrite grenade under devlopment in 1997-99 (plots starting at about 0.4) and 1667 minke whales shot in 2000-02 with the new penthrite grenades developed in 1997-99 (plots starting at about 0.2). Horizontal axis: Time in seconds. Vertical axis: proportion of whales still showing signs of life.

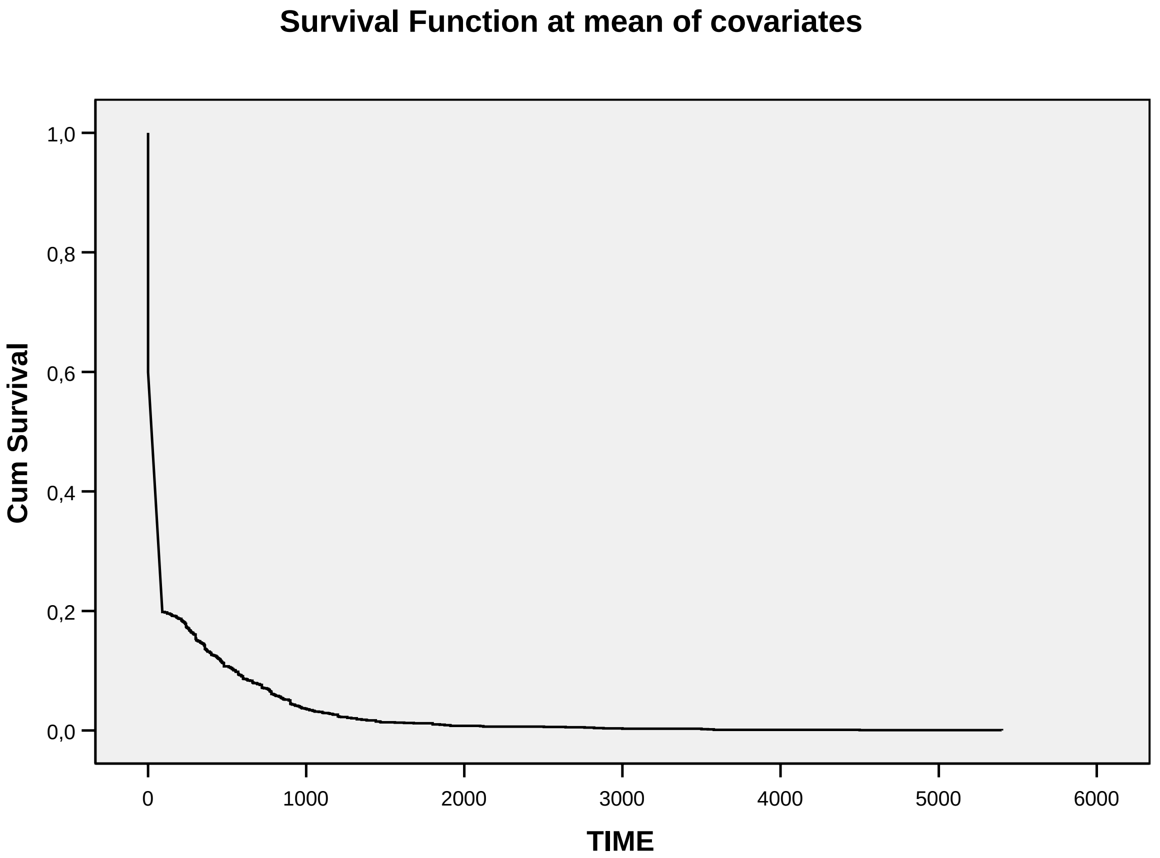

Figure 2. Survival plot for 1667 minke whales shot in 2000-02 with the new penthrite grenades developed in 1997-99. Horizontal axis: Time in seconds. Vertical axis: proportion of whales still showing signs of life.

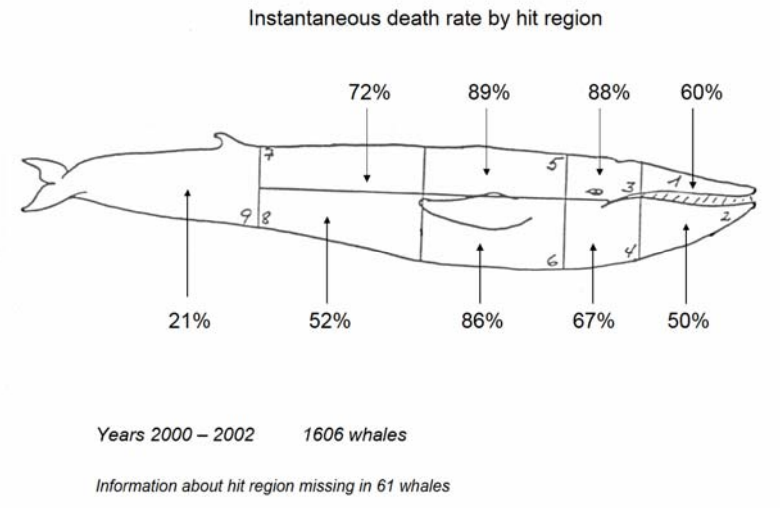

Figure 3. Figure of minke whales used for comparison of the effect of hits in different regions of the animal.

Table 1. The influence of the Instant death rate of whales (IDR) related to hitting areas in the Norwegian hunt of minke whales 2000-02.

HITREG 1 * INSTANT Crosstabulation

			INSTANT		Total
			0	1	
HITREG 1	1	Count	2	3	5
		% within HITREG 1	40,0%	60,0%	100,0%
	2	Count	3	3	6
		% within HITREG 1	50,0%	50,0%	100,0%
	3	Count	7	49	56
		% within HITREG 1	12,5%	87,5%	100,0%
	4	Count	6	12	18
		% within HITREG 1	33,3%	66,7%	100,0%
	5	Count	81	659	740
		% within HITREG 1	10,9%	89,1%	100,0%
	6	Count	44	260	304
		% within HITREG 1	14,5%	85,5%	100,0%
	7	Count	79	204	283
		% within HITREG 1	27,9%	72,1%	100,0%
	8	Count	69	75	144
		% within HITREG 1	47,9%	52,1%	100,0%
	9	Count	39	11	50
		% within HITREG 1	78,0%	22,0%	100,0%
Total		Count	330	1276	1606
		% within HITREG 1	20,5%	79,5%	100,0%

Table 2. The influence on instantaneous death rate (IDR) of the angle of the shot relative to the animal's long axis in the Norwegian hunt of minke whales 2000-02.

ANGEL

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0°-10°	10	,6	,6	,6
	10°-45°	84	5,0	5,1	5,8
	45°-135°	859	51,5	52,6	58,3
	135°-170°	607	36,4	37,1	95,5
	170°-180°	74	4,4	4,5	100,0
	Total	1634	98,0	100,0	
Missing		33	2,0		
Total		1667	100,0		