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REPORT ON TTD IN ICELANDIC FIN WHALE HUNT

Killing efficiency in the Icelandic fin whale hunt 2014

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Background and brief summary of results

Survival time (ST), Time to death (TTD) and Instantaneous death rate (IDR) are terms that are used to measure and quantify the killing efficiency or standard of killing methods and practices used in whaling operations (Øen 1995). Sampling and analysis of ST and TTD data in a standardised manner make it possible to compare the killing efficiency of different hunting practices and hunting gears and also measure the impact of developments, changes in hunting practices and training of hunters etc.

A NAMMCO Expert Group Meeting in 2010 to assess TTD data and results from whale hunts (NAMMCO 2010) recommended sampling of TTD data from several hunts, including the Icelandic hunt of fin whales (*Balaneoptera physalus*) with the aim to compare and evaluate the killing efficiency of hunting methods and identify possible improvements and implementation of these in the hunt. NAMMCO recommended that data of TTD should be collected and analysed with covariates (animal size, shooting distance and angle of harpoon cannon shot, hit region and detonation area) like it had been done for more than 5000 minke whales (*Balaenoptera acutorostrata*) in Norway during 1981-2002 (Øen 1995, 2003).

To follow up these recommendations the Directorate of Fisheries in Iceland engaged the author of this report to organize the sampling of TTD data from the Icelandic fin whale hunt in 2014 and also to process and organise the analysis of the data in compliance with the NAMMCO recommendations.

In 2014 TTD data was sampled from 50 fin whales caught from two vessels. The results show that 84% of the whales had died instantly. The whales were killed with 90 mm Kongsberg harpoon canons and Whale Grenade-99 modified with 100 g of pressed penthrite as explosive. Grenade detonation in the thorax (chest), in or at the thoracic spine, neck or brain resulted in 100% instant death. This is superior to the results recorded from hunts using black powder grenades and also for most other hunts of whales where TTD has been recorded. Also the penthrite grenade has shown to be far more reliable in function and safer in use than grenades with black powder as explosive that had been used earlier.

Work to improve the killing efficiency in the Icelandic fin whale hunt 1985-2013

Development work to improve the killing efficiency in the hunt of fin whale in Iceland has been an on going process initiated and financed by the company Hvalur hf since 1985.

The hunt in 2014 was carried out using 90 mm Kongsberg harpoon canon and a new harpoon grenade designed to trigger the detonation of 100 g of the explosive penthrite (PETN) at a depth of 110 cm after penetration into the whale. The development of the grenade, which was concluded in 2013 replaced "The Black Powder Grenade" with 650 g of black powder as explosive, a type of grenade that has been used for large whales for at least 70-80 years.

Fin whale hunting using black powder grenade

Black powder belongs to the so-called primary explosives. These explosives are very sensitive in nature and can be brought to explode by external heat, pressure, friction, mechanical shock or electric sparks. If it gets wet it will misfire. Black powder also contains sulphur, which smells and affects taste and causes waste of meat. The black powder used in whale grenades is packed in a cast iron casing that splits up (fragments) into small and larger pieces upon detonation. The whales are killed of a combination of the blow and the splints from the iron casing. The wounding and killing efficiency of such splints is however unpredictable as it depends on which organs that are hit and if they are fatally wounded.

No systematic sampling of data regarding killing efficiency (TTD) of black powder grenades seems to be carried out except a few data sampled from the fin and sperm whale (*Physeter* macrocephalus) hunt in Iceland. Rowsell (1979) examined 16 sperm whales and three fin whales during butchering. Based on organ damages he concluded that onset of unconsciousness was rapid in eight whales, while onset of unconsciousness was slow in seven whales. Four whales had been reshot with a second harpoon. Lambertsen and Moore (1983) observed the kill and flensing (butchering) of 19 fin whales and estimated a median TTD to three minutes and the mean TTD to five minutes. No whales were recorded instantly dead but six whales were recorded unconscious instantly or within 10 seconds. The median and mean time to unconsciousness were estimated to two minutes and about 3.5 minutes, respectively. The longest survival time recorded was 16 minutes.

Development of the penthrite whale grenade for 90 mm harpoons

Secondary explosives, like penthrite (PETN), are much more stable than black powder and carry greater explosive power. Penthrite is thermally the most stable and least reactive of its category of explosives. High temperatures are needed (4 250 ˚C) to set it off and penthrite detonates even if it has become wet. Penthrite has proven to be very efficient to render whales unconscious and/or dead almost instantly by producing pulses of “shock” and pressure waves that travel spherical (in all directions) at hypersonic speed causing severe damage to vital organs. Massive lacerations, bleedings and cuts, usually occur at the detonation site, and injuries and bleeding are often found in the brain, heart, lungs and other vital organs (Øen EO, 1995; Knudsen and Øen, 2003). Consequently, there is no need for a casing that produces splints at the detonation. In addition penthrite does not affect the usefulness or taste of the meat because it does not dissolve in water, and upon detonation it breaks down into natural gases and water.

1985-1989

Experiments on 90 mm harpoon grenade technology started in Iceland in 1985 and continued to 1989 in conjunction with the Icelandic program of whale research. The experiments showed that it was possible to instantly kill a fin whale and safely use the contemporary Norwegian minke whale grenade with a charge of 22 g of penthrite fuse on 90 mm harpoons.

A prototype penthrite grenade was made using the core of the contemporary Norwegian minke whale grenade in 1986. The prototype was equipped with a casing of steel large enough to accommodate 100 g of penthrite fuse. After shooting tests at artificial targets the grenade was used for the hunt of several fin and sei whales (*Balaenoptera borealis*) from 1986 to 1989 and a few fin whales in 2006. In 1986 one member of the flensing crew sampled data on TTD for 10 fin and 16 sei whales. Based on information from the gunner on behaviour of the whales after being hit and observations at the flensing the IDR was estimated to approx. 70-80%. However, no systematic necropsy of the whales or statistical analysis of the data had been undertaken. The only firm conclusion that can be drawn from these data is that detonation of 100 g of penthrite fuse in the chest or near the spinal column in the chest or neck resulted in instant death (Øen 1986).

2009-2014

When the commercial fin whale hunt in Iceland was restarted in 2009, a new penthrite grenade, Whale Grenade–99 with 30 g of casted/pressed penthrite, had been developed and implemented in the Norwegian minke whale hunt (Øen EO, 2006). This grenade is made of aluminium. The former grenade of steel from the 1980ies that had been modified for fin whale hunt 1986 was no longer produced. The new minke whale grenade had therefore to be modified to accommodate a 100 g penthrite charge and a longer and stronger trigger line. A prototype was made and tried in the fin whale hunt in 2009 and with some minor modifications in 2010. However, in cases where the heavy 90 mm harpoon with the grenade in the tip hit hard bones it misfired due to damage of the aluminium core.

No fin whaling took place in Iceland in 2011 and 2012. Before the hunting season 2013 the prototype from 2009 was re-designed. The aluminium core was replaced with stainless steel and the nylon trigger line was replaced with a 90 cm long Dynex® braid 60 line with knot breaking strength of 425 kg. The trigger hooks were moved from the grenade core and fixed with a metal plate to the serving rope for the harpoon claws. The function of the grenade and trigger line was thoroughly tested on artificial targets before it was implemented in the hunt. Gunners and crews were informed how to safely handle and use the grenade and the gunners were instructed to aim the harpoon at the chest of the whale and from the side. Also the crews at the flensing plan were instructed how the grenade was constructed and how to safely handle grenades that were suspected for misfire (duds).

The new grenade was well received by the hunters. However, inspection of carcasses during flensing showed that the gunners often fired at the whales from a narrow angel from behind instead of from the side. Also two serious incidents of premature detonation of the grenade in front of the harpoon canon were reported. Examination of these incidents revealed that the trigger line was not sufficiently fixed and triggered the detonation when the harpoon accelerated out of the barrel. Except of the flaw with the trigger line, the grenade functioned well and needed no further modification.

Prior to the 2014 hunting season the gunners and crews attended a training course where i.a. the incidents with the trigger line and results from the 2013 trials were discussed in details in addition to issues covering safety and function of the grenade, anatomy of the fin whale with particular emphasis on position of vital organs like the central nervous system (brain, spinal column in chest and neck) and the cardiovascular system (heart, lungs and large vessels in the chest). The gunners were instructed of the importance of aiming the harpoon grenade at the chest and to hold the shot until they could fire at the whale from the side (45°-135° relative to the animal's long axis).

<u>Electronic sights for 90 mm Kongsberg harpoon canon</u>

Harpoon guns are traditionally equipped with fixed simple open sights that cannot be easily adjusted. Open sights generally are used where the rear sight is at significant distance from the shooter's eye. They provide minimum occlusion of the shooter's view, but at the expense of precision. Since the eye is only capable of focusing on one plane, and the rear sight, front sight, and target are all in separate planes, only one of those three planes can be in focus. The challenge to the harpoon canon gunner is therefore to keep the focus on the correct plane to allow for best sight alignment. Open sights can be replaced by telescopic sights also for harpoon canons to give an accurate aiming point. However, as bad weather and rain might disturb the view of telescopic sights the open iron sights may still be fitted alongside the other sight for back-up usage.

Different telescopic sights were studied before one was chosen for trials late in the 2014 hunting season. New open iron sights of stainless steel were made and a telescopic sight - Red Ring Holosight® (RRH) - were mounted to the open sight pole of the 90 mm Kongsberg canon and fired in at an artificial target before the new sights were implemented in the hunting. The exact result of the shooting with the new sights is not known. The trial took place too late to be included in the sampling of TTD data in 2014. Also other types of holosights may be assessed. However, the gunners claim that the new sights were very successful and they do not want to go back to use traditional open iron sights.

Sampling of TTD data and results from the 2014 season

Prior to the hunting season 2014 the data-sampling scheme that had been used for collection of TTD data for minke whales in Norway (Øen 1995, 2006) was adapted to sampling TTD data for fin whales. An experienced Norwegian veterinary officer well trained for TTD data collection after several season in the Norwegian minke whale hunt, was engaged and trained for this specific job. In addition to TTD, the behaviour of the whale after being shot, data on whale length, estimated range of shooting, the angle between the shot direction and the whale's long axis, the impact point on the whale, the detonation site, necropsy finds, grenade function and possible reshooting should be recorded.

The necropsy was given high priority and was carried out at the land station. To avoid any selection of animals, the veterinarian left the boat to do the necropsy of each carcass available, and then went out again with the first possible boat after the necropsy was finished. In cases of necropsy of whales where he had not been present on board at the killing, information of behaviour of the whales when shot and angle of shot were collected from the gunners' report schemes, available video recordings and interviews with the gunners and crews.

The time from a strike to the animal's death was recorded by using stop-watch. The time of death was recorded as recommended by The International Whaling Commission (IWC 1980), which is the moment at which cessation of flipper movement, relaxation of the mandible, or sinking without any active movement occur. In addition to these behaviour signs of death the recorded TTD should be verified through the findings of organ damage demonstrated at the autopsy. Shooting range and angle of the shot relative to the animal's long axis were estimated without instrumental aid.

Reports were received for 50 fin whales. No whales were reported lost.

The statistical analyse of sampled data was carried out by Professor Lars Walløe of The University of Oslo and the results of the survival plot (TTD) for the 50 fin whales are shown in Fig. 1. Instantaneous death was recorded for 42 whales (84 %). The whales not instantly killed (8) were reshot with penthrite grenade. The median survival time for those whales was 8 minutes with the shortest survival time of 6.5 minutes and the longest survival time of 15 minutes.

In 2014 like in 2013 the gunners have tended to shoot the whales slightly more from behind (about 135°-180° - relative to the animal's long axis) than from the recommended side position (45°-135° - relative to the animal's long axis). The analysis showed that also whales shot slightly from behind had high IDR (Fig. 2). Results from minke whaling however show that it is a significant higher risk for "poor hits", stray shots or detonation outside the most vital areas followed by longer survival time by shots fired from the front (0°- 45°) or from behind (135°-180°) than shots fired from the side (45°-135°) (Øen 1995, 2006). Five of the eight fin whales that survived the first shot had been shot from behind or from the front.

Detonation in the chest, in or at the thoracic spine, neck or brain resulted in 100% instant death. Detonation inside the chest caused bleedings and severe damage and injuries to vital organs like heart, lungs and major blood vessels.

The recorded size/length of the whales varied from 50 to 69 feet. The shooting distance varied from 15 to 60 meter. There was a tendency that longer fin whales survived longer, and survival also increased with shooting distance. However, the differences were small and not statistically significant (8 whales). In the minke whale hunt with penthrite grenade no difference is recorded in TTD between small and larger whales, but TTD tends to increase with increased shooting range (Øen 1995).

Comments and conclusions

Results obtained from autopsy of minke whales killed with penthrite grenades show that, in addition to the direct damage the detonation inflicts on the organ or organ systems it detonates in, penthrite causes shock wave-induced acute traumatic brain injury of sufficient severity to account for an instantaneous or very rapid loss of sensibility, even when it detonates in an area remote from the skull (Knudsen and Øen, 2003).

Observations have shown that when a whale is hit and fatally wounded in vital areas by a penthrite grenade as it rises to the surface to blow it will stop swimming immediately, roll on to its back, float for a short time before sinking with slacken jaw and the flipper along side the body. In contrast, if it is fatally hit as it dives after blowing, it will pull out some of the harpoon line before stopping and sinking. If the whale does not die or loose consciousness rapidly, it usually maintains its normal position in the water and starts swimming, dives and resurfaces to blow (Øen 1995). Consequently, confirmation of death based on the behavioural signs alone cannot always be performed.

There are also cases when the IWC criteria (IWC 1980) are not met in animals that are unconscious and dead (Øen 1995). For instance, weak tail movements may be registered, or the flippers may be held at an angle for some time even if there are no signs of life. Further, when a whale rolls over on its back gravity will prevent the jaw from slacken and it will remain closed. Also studies of brains of minke whales have shown that movements definitely occur in animals with severe traumatic brain injury incompatible with a persistent sensibility or life. In some cases, whales may hold their flippers out at an angle to the body while thrashing their tails violently for a minute or two before all movements cease and the flippers relax along sides of the body. Neuropathological examinations have shown that these movements often occur in whales with severe traumatic brain injury incompatible with persistent sensibility (Øen 1995; Øen and Knudsen, 2003) and that spinal reflexes probably trigger these convulsions after motor control of the spinal cord has been lost due to damage of the higher controlling centres in the brain. For comparison, in slaughter animals the occurrence of such convulsions are considered to be a good indicator that the animal is unconscious (Blackmore and Delany, 1988).

The data from the fin whale hunts with black powder grenades are limited and incomplete. The data available show that no whales were recorded instantly dead and only six out of nineteen (31%) were recorded unconscious within 10 seconds (Lambertsen and Moore 1983). The recorded data from the hunt with penthrite grenades in 2014 show an instant death rate of 84%, which is slightly higher than recorded for minke whales (Øen 1995; 2006). A direct comparison between black powder and penthrite grenades has some weaknesses due to lack of exact data from the hunt with black powder grenades. Nevertheless, it can be concluded that the killing efficiency of the penthrite grenades used in 2014 is superior to the former black powder grenades. Also the penthrite grenade is far more reliable in function and safer to use for the hunters.

Eight out of 50 whales were not recorded instantly dead and were reshot. The detonation of the first grenade had occurred outside the thoracic area. Five of these whales had been shot from the front or from behind which gives a higher risk of detonation outside the most vital areas. The median TTD for those whales was 8 minutes, which is about the time it takes to re-load the canon, sight in and wait for the opportunity to fire. The electronic sights that were tried and will be implemented in the future hunt improves sighting and may contribute to more accurate shooting.

The videos that were used in cases where the veterinarian had not been on board during the shooting and watched the killing of the whales was helpful with regard to information on the behaviour of the whales and angle of shot. However, video recordings used alone without necropsy of the whales can only be used to make very rough estimates of the TTD.

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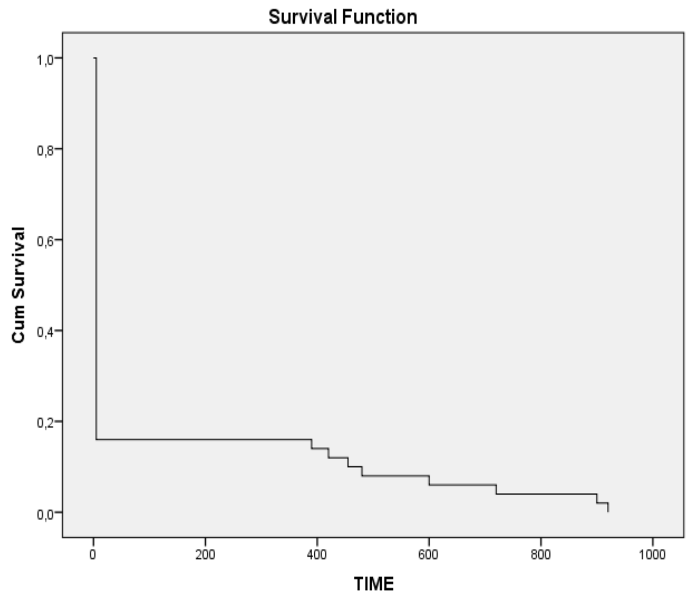

Fig. 1. Survival plot of 50 fin whales caught in Iceland 2014.
Horizontal axis: Time in seconds.
Vertical axis: proportion of whales still showing signs of life.

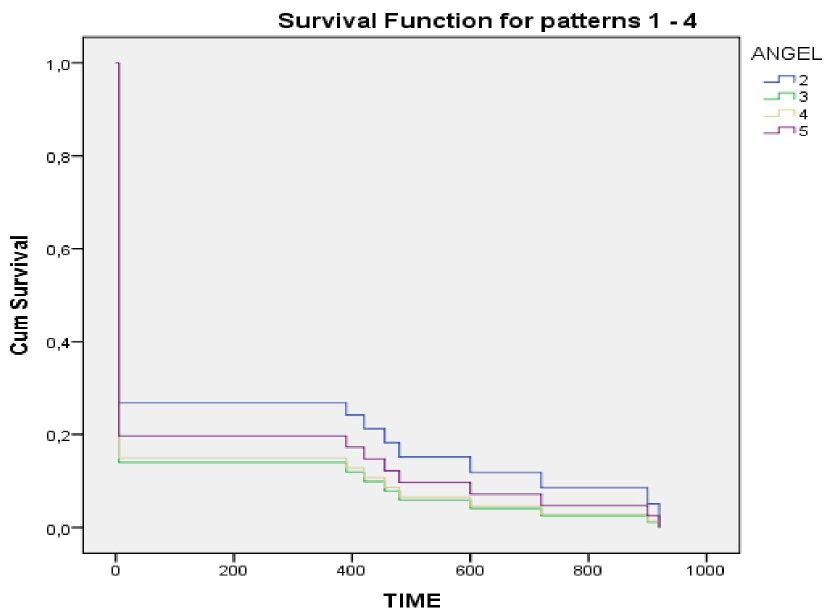

Fig. 2. Survival as function of angle for fin whales shot from different angles relative to its long axis:
2: 0°- 45°, 3: 45°-135°, 4: 135°- 180°, 5: Right from behind.
Horizontal axis: Time in seconds.
Vertical axis: proportion of whales still showing signs of life