neurotrauma and that the area within which a detonation may be instantaneously or very rapidly lethal, ranges from the dorsal skull to the rostral abdomen. The neurotrauma varied from very severe brain tissue laceration with almost total disintegration of gross architecture, concomitant skull fractures and regular decapitation, and massive gross evident bleedings in meninges and brain substance, to histologically-evident intra-cerebral haemorrhages in central vital brain areas resembling acceleration-induced diffuse traumatic brain injury (dTBI) (Knudsen & Øen 2003). The pathological findings were thereafter used in conjunction with recorded behavioural observations to *evaluate* the IWC criteria (Knudsen 2005); the criteria were not used to determine time to unconsciousness/death, as Knowles and Butterworth state. This confirmed that whales, like any other mammal, may show agonal reflex movements after they must have lost consciousness, and that *immobility* is not a valid measure for evaluating the animal welfare implications of hunting methods (Knudsen 2005). The conclusions were that when TTD in whales is determined solely on the basis of the IWC criteria, a significant proportion of the animals will be recorded as being sensible or alive when they are in fact unconscious or dead (Knudsen 2004, 2005).

In their discussion, Knowles and Butterworth (2006, p 56, paragraph 1) present what appear to be *their* theories on the possible mechanisms by which the detonation of a penthrite grenade causes injury. These are in fact quotations from Knudsen and Øen (2003). For the interested reader, the original publication presents a review of relevant ballistic literature as the scientific basis for the proposed injury mechanisms (Knudsen & Øen 2003).

In addition to incorrect citation of original publications, and in some cases, failure to acknowledge them, Knowles and Butterworth also demonstrate a lack of technical knowledge of the hunting methods. There is apparent confusion about difference between the 'harpoon' and the 'harpoon grenade' as well as about the 'impact site for the harpoon' and the 'detonation site of the harpoon grenade'. They claim that one "harpoon misfired" (Knowles & Butterworth 2006, p55). If that were the case this whale would still be swimming in the sea. In addition, Knowles and Butterworth (2006, p56) use the designation 'impact site' in their figure. In ballistic terminology 'impact site' is equivalent to point of impact or 'hit point', which in this context relates to the 'harpoon' rather than the 'grenade'. The harpoon travels through the animal, usually at an oblique angle when the animal is shot from the side, while the harpoon grenade is designed to detonate in vital organs inside the animal during the course of the milliseconds it takes for the harpoon to pass through the whale's body (Øen 2003). This means that the exact hit point for the harpoon is not critical: the relevant question is which organs are affected by the detonation of the grenade. The detonation has been proved to have a much wider impact area than the harpoon itself (Knudsen & Øen 2003). The figures presented by Knudsen (2004) and replicated by Knowles and Butterworth (2006, p56) do not show the impact site for the harpoon, but the recorded detonation site of the harpoon grenade. This is a significant difference, as hits with a harpoon at various different areas on a whale may result in exactly the same fatal injuries as a result of the detonation of the harpoon grenade.

It is not reasonable to conclude, as Knowles and Butterworth (2006) do, that the abdomen of the whale is a more critical target area than the area near the brain (Knowles & Butterworth 2006, p57). For reasons of animal welfare, we do not agree with this conclusion, but will continue to recommend that whalers should target the foremost part of the whale so that the harpoon grenade can cause fatal damage to the brain and the vital organs in the thorax (heart, lungs, large blood vessels) and thus render the animal very rapidly or immediately insensible.

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Response to Knudsen, Øen and Walløe's letter 'Minke whale hunt and animal welfare'

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The points Knudsen, Øen and Walløe raise do not in any way alter the conclusions as presented in Knowles and Butterworth (2006) that: "The data drawn together in this commentary suggest that in order to cause immediate immobilisation and, perhaps, an immediate stun in Minke whales harpooned using the Norwegian 'Whalegrenade-99'

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it is necessary to hit a relatively restricted target area. The reported rate of 80% of whales immediately immobile following harpooning in the Norwegian hunt suggests proficient marksmanship under difficult conditions. However, it also suggests that an improvement in this rate may be unlikely. While the acceptability of 20%, as a minimum, of whales left with the potential to suffer following grenade detonation is a significant focus of debate, the question of whether an immediately immobile whale is stunned remains."

Knudsen, Øen and Walløe state "It is not reasonable to conclude, as Knowles and Butterworth (2006) do, that the abdomen of the whale is a more critical target area than the area near the brain (Knowles and Butterworth 2006, p57)."

Nowhere do we suggest the above, in fact we write: "The proximity of the detonation to the brain is of obvious importance in determining its effectiveness", nor do we suggest *anywhere* that the current recommendations to the hunters should be altered.

They suggest that our figure is a "replicate" of Knudsen, but is not acknowledged. Firstly, our figure is clearly not a replicate as Knudsen (2004) shows a diagram containing two whales, ours is of a single whale with additional detail. We have not referenced Knudsen in the legend to the figure, but in the text have written: "Following Knudsen (2004), larger marks indicate a cluster of five detonations and the smaller marks..."

Knudsen, Øen and Walløe point out that, "immobility is not a valid measure for evaluating the animal welfare implications of hunting methods (Knudsen 2005)" and suggest that we disagree with this. This is clearly a misrepresentation of our view as in Knowles and Butterworth (2006) we state, "The assumption that immobile animals are either unconscious or dead may be an erroneous one and the distinction between an immobile animal, which may retain the potential to suffer and one that is insensible to pain, continues to be the focus of research and debate in the IWC (Brakes *et al* 2004; Butterworth 2005; Knudsen 2005)."

In our discussion we do discuss the possible mechanism of energy propagation explaining our figure and this is indeed in agreement with the general literature and also that of papers reviewed by Knudsen and Øen (2003).

They claim that we are confused between the harpoon, gun and grenade. We agree that it would have been more technically correct, and clearer, to refer to a grenade misfire rather than a 'harpoon misfire'. A 'harpoon gun' can misfire, which would result in failure to launch the harpoon, however, it is obvious from the text that the harpoon did impact the animal and that it was the grenade (as part of the harpoon) which misfired.

Additionally, they state that we have confused detonation site and impact site. Indeed, the legend to the figure does incorrectly contain the word 'impact' rather than detonation. However, in every other instance throughout the text, and when referencing the figure, the word detonation is used (38 times in total throughout the text).

Knudsen, Øen and Walløe do raise a number of useful points of small detail regarding our commentary on their data. It is most unfortunate that they were unable to bring these to our attention when they were sent a pre-publication draft of the paper.

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