Historical Records

AN ANALYSIS OF JAPANESE WHALE KILLING DATA WITH SPECIAL EMPHASIS ON THE USE OF THE ELECTRIC LANCE AS A SECONDARY KILLING METHOD[1)]

Lars WALLØE[2)]

Abstract

During the IWC Workshops on whale killing methods in 1992 and 1995 Japanese whalers were criticized for the use of the electric lance as a secondary killing method. It was claimed, especially by Australian scientists, that the use of the electric lance resulted in long survival times and much suffering. The times to death for 891 whales were analysed by logistic regression and Cox regression. For 560 of these a secondary killing method was used; the electric lance was used in 326 cases, and a cold harpoon in 234 cases. The median killing time for the electric lance was 40 s and for the cold harpoon 4.7 minutes. The analyses showed that the electric lance killed the whales much faster than the cold harpoon. At the time, Japanese laws did not allow the crew to keep firearms on board fishing or whaling vessels. These laws have been changed, and today the use of a shot from a rifle through the brain of the whale is the preferred secondary killing method.

(This abstract was prepared in August 2021 in accordance with request from the Publication Committee for the Cetacean Population Studies (CPOPS)).

Key words: electric lance, whale killing methods, minke whales, Kaplan-Meier plots, Cox regression.

Preamble

The present paper was prepared for the IWC Commission meeting in Aberdeen in 1996. The work was supported by the late Seiji Ohsumi, who was head of the Japanese delegation to the IWC Scientific Committee, and Mr. Kazuo Shima, the Japanese Commissioner to the IWC at the time. Although the main results were presented orally and discussed during the Commission meeting, and copies of the manuscript were distributed to the participants, the article was never properly published. Killing methods for whales were not considered part of the terms of reference for the IWC Scientific Committee, and the manuscript could therefore not be published in its series of scientific papers. On the occasion of publication of the memorial volume for the late Seiji Ohsumi, we have now tried to retrieve it.

[1)] The present scientific article was originally prepared for the IWC Commission meeting as document (IWC/48/WK 2—1996) in Aberdeen, Scotland, in 1996. The paper is reproduced here in accordance with the request from the CPOPS Publication Committee, to commemorate the days when Dr. Seiji Ohsumi was active at the IWC Scientific Committee.

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AN ANALYSIS OF RECENT JAPANESE WHALE KILLING DATA WITH SPECIAL EMPHASIS ON THE USE OF THE ELECTRIC LANCE AS A SECONDARY KILLING METHOD

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Introduction

Killing methods for minke whales have improved considerably during the past 15 years (IWC/47/18-1995). The IWC held its first workshop on the topic in 1980 ('Workshop on humane killing techniques for whales' —IWC/33/15). The workshop made a number of recommendations for future research and development, and also recommended a set of criteria which should be used to measure time to death in whales. These were the time "taken for the mouth to slacken, the flipper to slacken and all movement to cease." The workshop recognised that these criteria probably overestimated the time to death, since work on dolphins had shown that these animals, like other mammals, may have agonal reflex movements.

Workshops on whale killing methods in 1992 (IWC/44/REPHK) and 1995 (IWC/47/18) evaluated the progress made since 1980 and made new recommendations. Although a wide range of views was expressed at these workshops, the data presented seemed to indicate that the killing methods currently being used for minke whales by Japanese and Norwegian whalers compared favourably in efficiency with those used in the hunting of large terrestrial animals in Europe and North America (Lockyer –IWC/47/WK1; Øen and Walløe—IWC/47/WK9).

However, some of the participants at these two workshops, especially in 1995, strongly criticised the use of the 'electric lance' as a secondary killing method (e.g. Blackmore IWC/47/WK2). On the other hand, the Japanese Government presented a paper to the 1995 workshop which appeared to indicate that the electric lance killed whales very rapidly (IWC/47/WK 11). Unfortunately, the paper did not give much information except for the mean times to death for some subgroups.

During the workshop, I received the impression that the participants did not understand the content of the paper properly, and that its claim that the mean time to death was only 44 seconds when the lance was used was not believed. I therefore proposed to my Japanese colleagues that I should reanalyse the Japanese data on killing times, using statistical methods which I had previously used on similar data from Norwegian whaling operations (Øen and Walløe 1995). The present paper contains the main results of this analysis.

Materials and Methods

The primary data for the present analysis consist of the killing times and a number of covariates for all whales included in the Japanese scientific catches of minke whales in the Southern Ocean and in the North Pacific respectively during the last two hunting seasons.

In all 891 minke whales were taken: 330 in 1994–95 and 440 in 1995–96 in the Antarctic Ocean, and 21 in 1994 and 100 in 1995 in the North Pacific. All whales were taken by the same whaling vessel and by and large by the same crew of whalers. Only 6 different gunners operated the harpoon gun during these two years.

The killing time, i.e. the time from a strike by the penthrite grenade harpoon until the whale was declared dead according to the criteria established by the IWC (IWC/33/15 1980), was recorded using a stop-watch. If a whale died instantaneously or within a few minutes, no secondary killing method was used. But if the whale showed signs of life after the first hit, the crew prepared to use one of the two available secondary killing methods. The first of these was to shoot a second (cold) harpoon into the whale. This operation could be repeated. The second method available was to use electrical stunning.

The following is a short description of electrical stunning as carried out by Japanese minke whalers. The whale is pulled up to the catcher boat and two electrodes ('electric lances') are inserted through the blubber into the muscular tissue underneath, one in front of the heart and one behind. The whale is killed by sending alternating current between the electrodes. The mechanism responsible for the death of the animal is probably fibrillation of the heart, causing complete cessation of circulation. When the current is switched on, the animal body usually undergoes convulsive muscular contractions, and it is not possible to apply the IWC death criteria. The current is therefore switched off at regular intervals. The duration of each bout of current is reported to be about 10 seconds.

The electric lance was sometimes used in addition to a cold harpoon if the first (or second) cold harpoon failed to kill the animal.

In most cases the whalers chose the secondary killing method they considered most suitable in the circumstances. If, for instance, the whalers considered that the first harpoon was in danger of being pulled out, a second harpoon was used. On the other hand, if the whale was close to the boat, it was often not possible to shoot it with a second harpoon, but the electric lance could conveniently be applied.

In some cases either secondary killing method could be used with an equal chance of success as judged by the whalers. During the Antarctic whaling operations, the use of the cold harpoon or electric lance as the secondary killing method was randomised for 123 of these animals, 61 during the 1994–95 season and 62 during the 1995–96 season. This group of whales is designated the 'experimental' group.

In addition to the time to death the data file contained the following covariates for each whale: a letter identifying the gunner, the body weight, the body length, 'experimental' or not, (first) secondary method (none, harpoon, lance), number of cold harpoons, voltage and amperage of electric current, time to firing of (first) cold harpoon, time to use of lance, loss/recapture, and in addition a serial number which could be used to obtain additional information about individual whales if desired. All 891 records were complete.

The data were analysed by conventional statistical methods. Since many of the variables have empirical statistical distributions with long tails to large values (e.g. time to death), non-parametric tests and estimation methods were used. Most of the results are presented as survival plots. For some variables, survival analysis with censoring was used, and the survival distributions were estimated by product-limit (Kaplan-Meier) methods (BMDP1L). The influence of covariates on time to death was investigated by Cox regression (proportional hazard) and by a combination of logistic regression for whales killed instantaneously (<10 s) and Cox regression for whales surviving more than IOs (BMDP2L+BMDPLR). To investigate possible differences between gunners and seasons, a general mixed model analysis of variance including gunners as a random variable was used (BMDP3V).

Results

Fig. 1 presents the distribution of times to death for all 891 whales which are included in the analysis. Two whales which were first lost and later recaptured survived for 96 and 130 minutes respectively and are not represented on this graph (but are included in the statistics). 26% of the whales died instantaneously. The median survival time was 4.8 minutes, 9.5% of the whales lived for more than 10 minutes, and 3.1% for more than 15 minutes. Thirty five whales were lost and later recaptured using grenade or cold harpoons, 32 because the harpoon pulled out and 3 because the fore-runner broke. All whales with survival times longer than 20 minutes were from this group of 35 lost and recaptured whales.

Fig. 2 shows that there were only minor differences between the results obtained from dif-

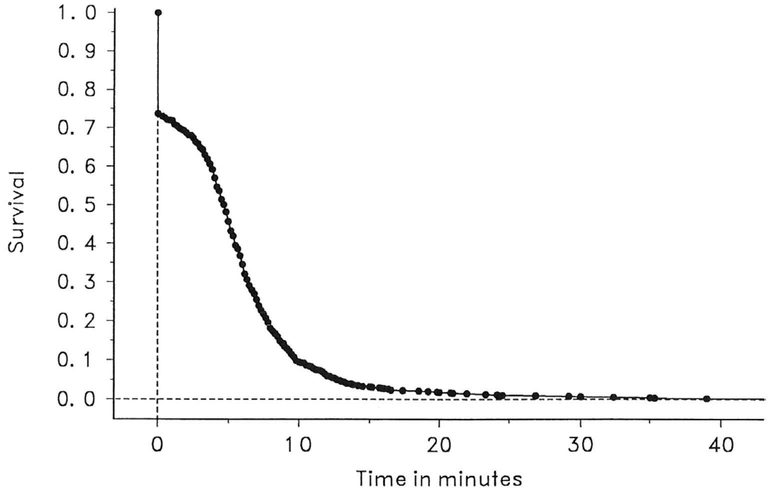

Fig. 1. Survival plot for all 891 minke whales caught during Japanese scientific whaling in the two-year period from April 1994 to April 1996. Abscissa: Time in minutes after the whale was hit by a grenade harpoon. Ordinate: Fraction of whales still showing signs of life. Each dot represents the time of death of one or more whales. Two whales which were lost and recaptured survived for 96 and 130 minutes, respectively and are excluded from the graph (but not from the statistical calculations). Median survival time: 4.8 minutes.95% confidence interval for the median: (4.5–5.0) minutes.

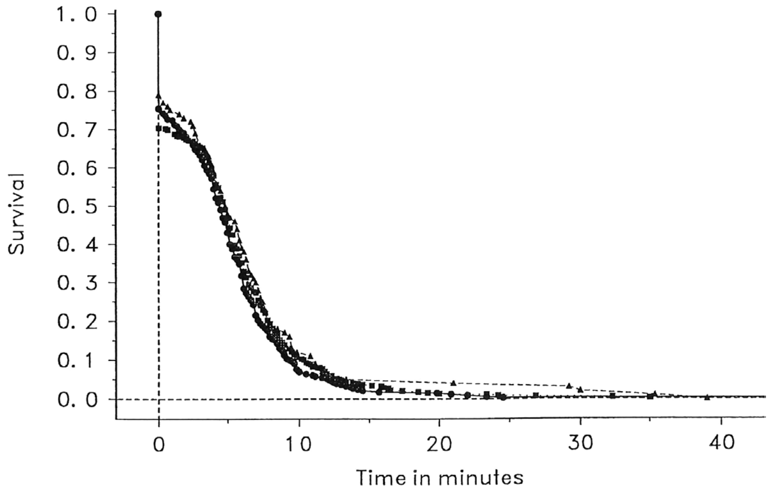

Fig. 2. Survival plots for whales caught in the North Pacific in 1995 (100—triangles), in the Antarctic Ocean in 1994–95 (330—circles), and in the Antarctic Ocean in 1995–96 (440—squares). Axes as in Fig. 1.

ferent oceans and years.

In addition to the 233 whales which died instantaneously, 98 whales died before a secondary killing method could be used. The survival plot for these 331 whales is shown in Fig. 3. The death rate for whales which were not killed instantaneously was 1.8% per minute when no secondary killing method was used.

For the remaining 560 whales (63%), a secondary killing method was used; the electric lance was used in 326 cases, and a cold harpoon in 234 cases. Only 111 of the 234 whales for which cold harpoons were chosen as the secondary killing method actually died as a result of being hit by this harpoon. The remaining 123 were finally killed by the electric lance. Thus, 449 whales in all were killed by the electric lance. In 326 cases the electric lance was used immediately after the grenade harpoon, and in 123 cases after one or more cold harpoons had failed to kill the animal.

Fig. 4 presents the distribution of total times to death for whales for which secondary killing methods were used, divided into two groups: 326 whales which were stunned with the elec-

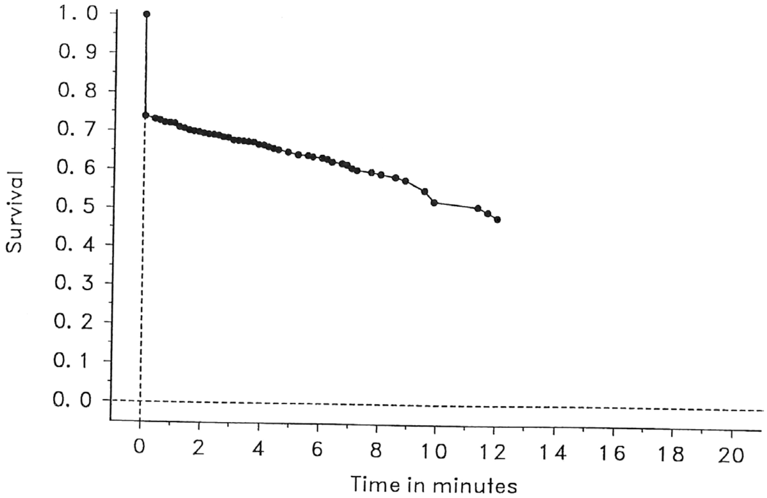

Fig. 3. Survival plot for the 331 whales which were killed by the grenade harpoon alone. Axes and symbols as in Fig. 1.

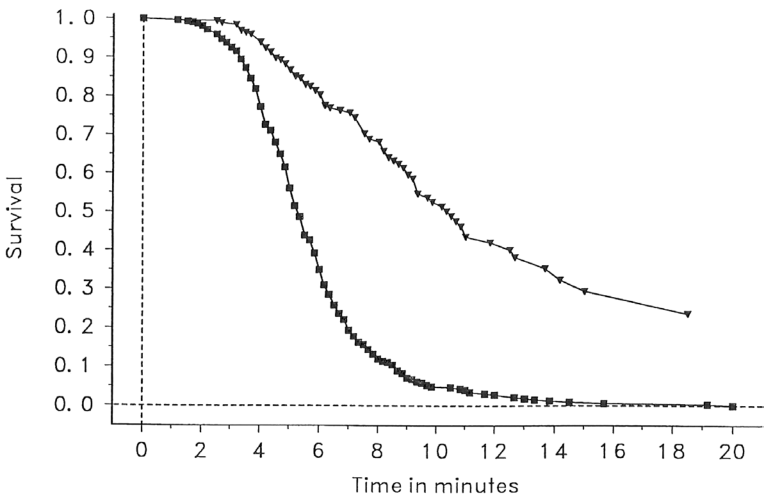

Fig. 4. Survival plots for whales for which the electric lance was used as the only secondary killing method (squares—n=326), and for whales which were shot with a cold harpoon (triangles, lost/recaptured excluded—n=199). The later were censored if and when the electric lance was used (53% censored). Median survival time for lanced whales: 5.3 (5.2–5.5) minutes, for whales that were cold harpooned 10.4 (9.3–12.5) minutes.

tric lance after being hit by a penthrite grenade, and 199 whales which were shot with a cold harpoon. Whales were censored from this plot if and when the electric lance was used after a cold harpoon. The 35 lost and recaptured whales have been excluded from this plot. If they had been included, the tail of the cold harpoon curve would have been lifted somewhat (so that survival at 15 minutes would have been 37.5% instead of 29.4% as in Fig. 4). Both curves in Fig. 4 display a plateau during the first few minutes due to the delay between the hit of the grenade harpoon and the use of the secondary killing method. The median delay was 5.8 minutes for harpooning and 4.3 minutes for lancing.

Fig. 5 presents a similar comparison between the two secondary killing methods, but only for the 123 whales which were randomised between the two methods. The median survival time for the harpooned whales was 8.4 minutes and for the lanced whales 6.1 minutes. The difference is statistically significant at the 1% level.

Fig. 6 shows the survival curve after application of the electric lance in the lanced group

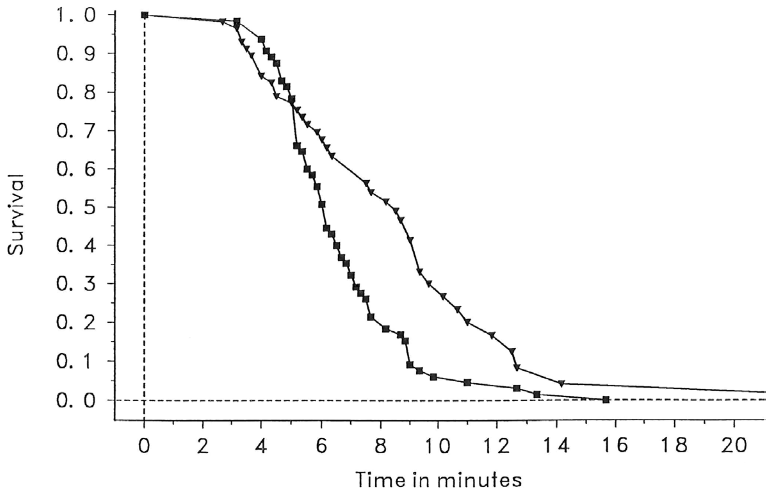

Fig. 5. Survival plots comparing the harpoon and lance as secondary killing methods as in Fig. 4, but only for the 123 whales which were randomised between the two methods. Median survival time for the harpooned group (n=58): 8.4 (7.5–9.3) minutes, for the lanced group (n=65): 6.1 (5.5–6.7). The difference between the two survival curves is statistically significant (p=0.002, Mantel-Cox test, two-sided).

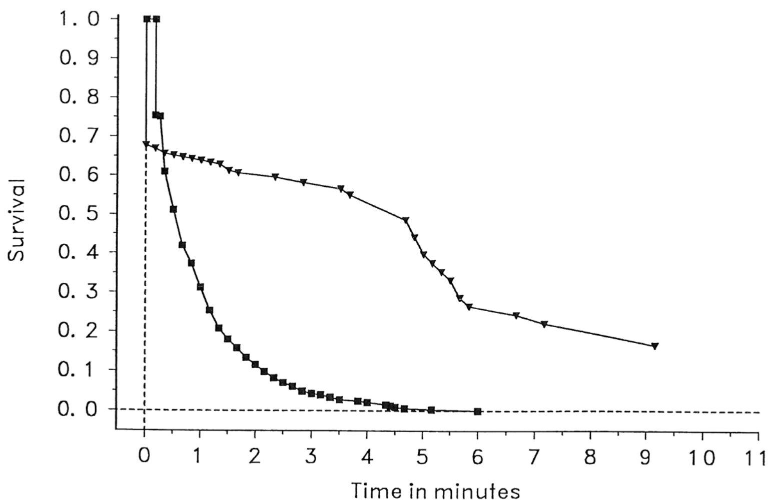

Fig. 6. Survival plots displaying the killing times for the two secondary killing methods. The abscissa is the time after the application of the secondary killing method. The median survival time for the lance was 0.7 (0.5–0.7) minutes (n=326). The median survival time for the cold harpoon was 4.7 (3.5–5.2) minutes (n=234). Harpoon whales were censored if and when the electric lance was applied (53 censored).

and the survival curve after being hit by the cold harpoon for the harpooned group. Harpooned whales were censored if and when the electric lance was used. The median killing time for the electric lance was 40 seconds. The cold harpoon killed 32% of the whales instantaneously, but even so the median killing time was 4.7 minutes. Removal of lost and recaptured whales from the harpooned group (35 whales) or addition of killing times in cases where the lance was used following one or more cold harpoons (123 whales) did not change the median survival times or their 95% confidence intervals, nor were there any noticeable changes in the survival plots.

Fig. 7 is identical to Fig. 6, except that only times to death for the 123 randomised whales are plotted. Results from the same 123 whales are also plotted in Fig. 8, the only difference being that harpooned whales which were later stunned by the lance have not been cen-

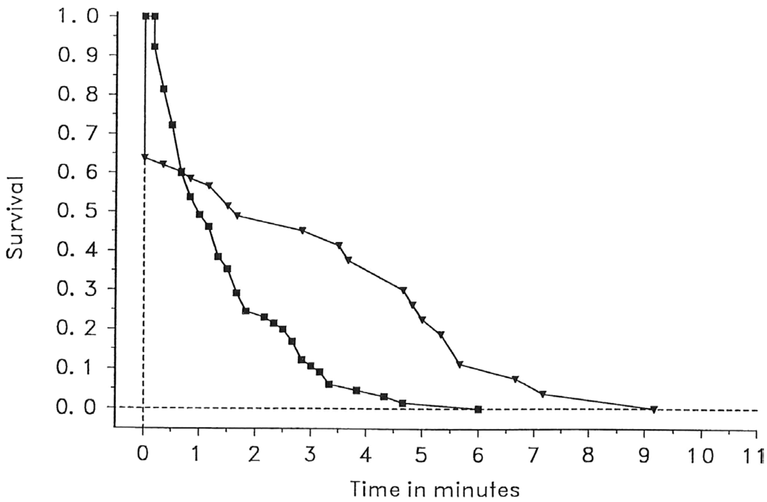

Fig. 7. Survival plots comparing the killing times for harpoon and lance as in Fig. 6, but only for the 123 whales which were randomised between the two methods. Harpooned whales were censored as in Fig. 6 (17 whales—29%). Median killing time for the cold harpoon was 1.6 (0.3–4.7) minutes (n=58), and for the electric lance 1.0 (0.7–1.5) minutes. The difference between the two survival curves is statistically significant (p=0.01, Mantel-Cox test, two-sided).

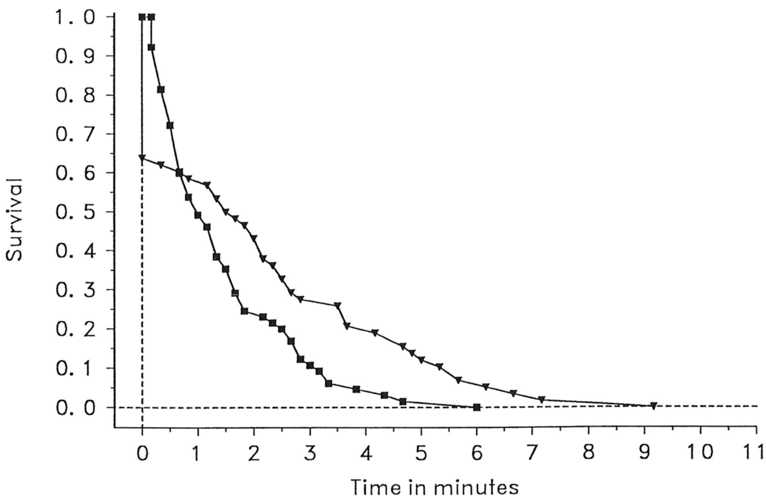

Fig. 8. Survival plots comparing harpoon and lance as in Fig. 7, but without censoring. Some of the whales in the harpooned group were therefore in reality killed by the electric lance after the cold harpoon had been used. Median killing time for the cold harpoon was 1.5 (0.3–2.3) minutes (n=58), and for the lance 1.0 (0.7–1.5) minutes (as in Fig. 7). The difference between the two survival curves is statistically significant (p=0.02, Mantel-Cox test, two-sided).

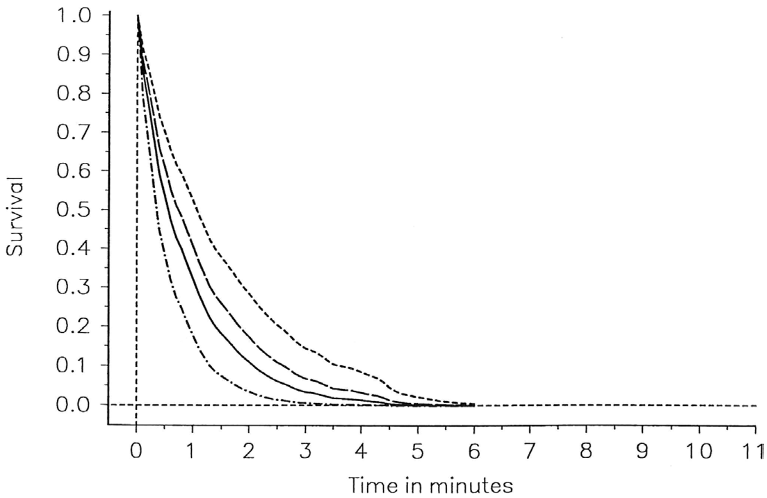

Fig. 9. Estimated survival curves after the onset of electrical stunning based on Cox regression for selected values of three covariates (whale length, voltage and amperage).
Solid line: 5 m, 110 V, 5 A.
Long dash: 5 m, 110 V, 10 A.
Dot—dash: 5 m, 220 V, 5 A.
Short dash: 10 m, 110 V, 5 A.

sored, but contribute the actual times of death to the statistics. This comparison corresponds to what is known as 'intention to treat' in medical applications of statistics. The differences displayed in both figures are statistically significant at the 1% level.

Whale length was the only covariate which influenced both the time to death from a hit by a grenade harpoon and the time to death from either a hit by a cold harpoon or from the onset of electrical stunning. The strength of this influence was similar in all subgroups and for both secondary killing methods, and is illustrated in Fig. 9. This figure also reveals the effect of voltage and amperage on the time to death from the onset of stunning. None of the other covariates recorded had any influence on the time to death, or on the fraction of whales which were killed instantaneously by a grenade harpoon. Nor were there any significant differences in killing efficiency between the six gunners.

Discussion

About one quarter of the whales taken in Japanese scientific whaling operations during the last two years died instantaneously from a hit by a grenade harpoon. Most of the remaining whales died within 15 minutes, either from injuries caused by the grenade or after the use of one of the two secondary killing methods available to the whalers, i.e. to shoot a cold harpoon into the whale or to use the electric lance.

The percentage of whales killed instantaneously is certainly an underestimate. There is general agreement that the death criteria for whales agreed in 1980 (IWC/33/15) are too strict (IWC/47/18), since there is no reason to believe that minke whales do not show agonal movements caused by spinal reflexes, seizures and convulsions similar to those in other mammals. Thus, some whales may very well have been dead or at least unconscious before a secondary killing method was used.

The similarity between the results obtained in different seasons and regions (Fig. 2) shows that the efficiency of Japanese killing methods is not much affected by differences in hunting conditions and environment.

Fig. 3 suggests that the death rate for whales which survived the first hit would have been very low if no secondary killing method had been employed.

Fig. 4 clearly shows that given the way the secondary killing used by the whalers, the lance kills whales much faster than the cold harpoon. However, the difference between the two curves may be caused entirely or partly by selection bias. In Fig. 5 the difference is smaller, but it is still present and statistically significant. In this 'experimental' group of whales the animals were randomised between the two secondary killing methods. We may therefore safely conclude that the lance kills the whales faster than the cold harpoon.

The lance curve in Fig. 5 ('experimental' group) is very similar to the lance curve in Fig. 4, but delayed by about one minute. This may be because whales which were too close to the boat could not be shot with a cold harpoon and were therefore excluded from the experimental (randomised) group.

A clear difference between the two methods is also revealed in Figs. 6, 7 and 8, which show plots of survival against the time from firing the cold harpoon or switching on the current. Again, the plots show that the electric lance kills the whales faster than the cold harpoon.

The most interesting result presented in these figures, however, is how fast the electric lance kills whales. The median time to death is about 40 s, and only some 5% of the animals survive more than 3 minutes (n=326, but n=449 gives the same result). The Japanese Government reported a mean time to death of 44 s based on 92 of these whales (IWC/47/WK11), which is in full agreement with the results from the present analysis.

The effect of covariates on the time to death from the onset of electrical stunning is illustrated in Fig. 9. The figure shows that the expected median killing time for a 10 m minke whale is about twice that for a 5 m whale, if the values of the other covariates are the same. This dependence on the size of the whale is not unexpected.

The electric lance operates as a constant voltage system, which means that the amperage is mainly determined by the resistance between the two electrodes. Fig. 9 shows that the killing time decreases as the voltage increases. The effect of amperage is perhaps more unexpected, as the killing time increases with increasing current between the electrodes. A possible explanation is that a high amperage is a result of current shunts between the electrodes in the seawater on the outside of the whale (or in seawater in the thorax and abdomen), which cause less current to flow through the tissues.

In last year's Workshop on Whale Killing Methods, Blackmore claimed that the electric lance could not "cause cardiac fibrillation except in a small minority of cases" (IWC/47/WK 2 and IWC/47/18), and recently New Zealand and the United Kingdom have repeated this claim in a note to IWC commissioners (1996) and in a summary (IWC/48/WK 1) of a paper in press (Blackmore et al. 1996), which refers to another paper in press by the same group of authors (Barnes et al. 1996). Although Blackmore's electrical measurements on carcasses and theoretical calculations may be of interest in some contexts, they are not relevant to an analysis of the effectiveness of the electric lance. The empirical evidence that the lance kills quickly is overwhelming.

Acknowledgements

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