# Failure of two consecutive annual treatments with ivermectin to eradicate the reindeer parasites (*Hypoderma tarandi*, *Cephenemyia trompe* and *Linguatula arctica*) from an island in northern Norway

Arne C. Nilssen[1], Willy Hemmingsen[2] & Rolf E. Haugerud[3]

[1] Tromsø Museum, University of Tromsø, N-9037 Tromsø, Norway (arnec@imv.uit.no).
[2] Institute of Biology, University of Tromsø, N-9037 Tromsø, Norway.
[3] NOR, c/o Department of Arctic Veterinary Medicine, N-9292 Tromsø, Norway.

*Abstract:* The highly efficient endectocide ivermectin is used to reduce the burden of parasites in many semidomestic reindeer herds in northern Fennoscandia. In the autumn of 1995 and 1996 all reindeer on the island of Silda (42 km$^2$) were treated with ivermectin in an attempt to eradicate the warble fly *(Hypoderma (=Oedemagena) tarandi* (L.)), the nose bot fly (*Cephenemyia trompe* (Modeer)) (Diptera: Oestridae) and the sinus worm (*Linguatula arctica* Riley, Haugerud and Nilssen) (Pentastomida: Linguatulidae). Silda is situated 2-3 km off the mainland of Finnmark, northern Norway, and supports about 475 reindeer in summer. A year after the first treatment, the mean abundance of *H. tarandi* was reduced from 3.5 to 0.6, but a year after the second treatment the mean abundance unexpectedly had increased to 4.5. After one year without treatment, the mean abundance and prevalence of the three target parasites were at the same level, or higher, than pre-treatment levels. The main hypothesis for the failure to eliminate the parasites is that gravid *H. tarandi* and *C. trompe* females originating from untreated reindeer in adjacent mainland areas dispersed to the island during the warm summer of 1997 (possibly also in 1998). As these oestrids are strong flyers, it may not be too difficult for them to cross >2-3 km of oceanic waters. There are no good explanations for the failure to eradicate *L. arctica,* but the results indicate that there may be elements in its life cycle that are unknown. The conclusion of the study is that it may be difficult or impossible to eradicate these parasites permanently, even locally such as on islands unless adjacent areas on the mainland are also cleared.

**Key words:** control, eradication, flight capacity, Oestridae, Pentastomida, ivermectin, *Rangifer tarandus.*

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## Introduction

Ivermectin (Ivomec ®) was first used in Europe in 1981 (Egerton *et al.*, 1980; Roncalli, 1989), and it is extensively used in many parts of the world to control for internal and external parasites in domestic livestock (Roncalli, 1989; Forbes, 1993). In North America, the greatest effect on cattle grub (*Hypoderma lineatum* and *H. bovis*) populations came with the introduction and widespread use of ivermectin (Scholl *et al.*, 1986; Scholl, 1998). In Europe, ivermectin and related compounds also assisted in controlling and eradicating cattle grubs (Losson *et al.*, 1998; O'Brien, 1998), and as a consequence of long-lasting treatment programs cattle grubs have been eradicated from Ireland (O'Brien, 1998) and Great Britain (Coles *et al.*, 1992; Tarry *et al.*, 1992; O'Brien, 1998).

Ivermectin is also used in the reindeer industry in North America (Dieterich & Craigmill, 1990), in Fennoscandia (Haugerud *et al.*, 1993; Oksanen, 1995, 1999), and in Russia (Klement'eva, 1987), with the main target parasites being the reindeer warble fly *Hypoderma* (=*Oedemagena*) *tarandi* (L.) and the nose bot fly *Cephenemyia trompe* (MODEER) (Diptera: Oestridae) (Nordkvist *et al.*, 1983; Nordkvist *et al.*, 1984; Norberg, 1989; Haugerud , 1993). The reindeer sinus worm *Linguatula arctica* RILEY, HAUGERUD & NILSSEN (Pentastomida), and gastrointestinal nematodes, are also killed by ivermectin (Haugerud *et al.*, 1993).

In the reindeer industry, ivermectin is primarily used to suppress high larval burdens of *H. tarandi* and *C. trompe*. Reindeer are treated once a year, in late autumn or early winter, and as a rule, mostly calves are treated (Haugerud *et al.*, 1993, Nilssen *et al.*, 1999).

Oestrids of cattle and reindeer are extremely susceptible to treatment with ivermectin, and there is approximately a 1000-fold overkill when the recommended dose of 0.2 mg/kg is used in cattle (Baron & Colwell, 1991). Because of this high efficiency, and the eradication of cattle grubs in other countries, the objective of this study was to determine if herd treatment with ivermectin would result in eradication of *H. tarandi* and *C. trompe* from an island in northern Norway. In addition, the pentastomid *L. arctica* was included.

It is expensive and logistically difficult to treat all reindeer in a large area (*e.g.* the county of Finnmark in Norway, or similar areas). Treating all reindeer in single herds is possible, but there may be risks of "invasions" of flies originating from neighbouring, untreated or partly treated herds. Reindeer oestrid flies are good fliers and experimental studies with oestrid flies have shown a flight capacity of several hundreds of km (Nilssen & Anderson, 1995); the longest recorded distances flown in the field (released and recaptured flies) were 90 and 45 km for *H. tarandi* and *C. trompe*, respectively (Gomoyunova, 1976).

About 25 years ago, (Kummeneje, 1976; 1979) tried to eradicate reindeer oestrids on islands in northern Norway with Warbex (a systemic organophosphorous insecticide), an antiparasitic drug less efficient than ivermectin. He succeeded in suppressing the *H. tarandi* populations by 94-99% on a few islands, but the populations increased to "normal" just two years post treatment. He concluded that 100% elimination was necessary. Complete eradication was probably impossible with Warbex due to its poor efficiency, but it was thought that, with proper administration, eradication might be possible with any of the highly efficient new endectocides like ivermectin. Since the parasites included in this study are host specific and confined within the host at known times, they should theoretically be easy to eradicate in an eradication programme.

## Material and methods

*Study area*

The island of Silda was chosen as the target location for this eradication experiment. This island, situated 2-3 km from the nearest adjacent mainland, also was one of the islands used in the previous eradication study 25 years ago (Kummeneje, 1979). Silda is a small island (70°19'N; 21°45'E) near the coast of western Finnmark, northern Norway. It is 15 km long, and has an area of 42 km$^2$ and it is part of reindeer pasture district 29 of West-Finnmark. Until some years after World War II, the island supported several small farms and a small fishing village, but the island no longer supports any permanent human settlements. The island is dominated by steep mountains, which reach an altitude of 628 m a.s.l., and most areas are almost inaccessible (Alm & Gamst, 1997).

The island is used as summer pasture for approx. 475 reindeer. These reindeer spend winter inland close to the border of Finland. In April the herd migrates northward towards the coast of the mainland, from where the reindeer are transported to Silda by ship in early May. Oestrid larvae drop from reindeer from late April to late June (Nilssen & Haugerud, 1994); consequently, the reindeer transfer the majority of their oestrid parasites to the summer grazing pastures on the island. Later, when the adult oestrid flies have emerged from the puparia and mated, they may easily come in close contact with their host because the herd remains on the island until September-October. Reindeer herders have at times observed intense harassment by the oestrids, especially during warm summers (Oddvar Sara, pers. comm.).

*Treatment and monitoring*

The experiment started in late November 1995, after the entire herd of 473 reindeer from Silda had been moved towards the winter grazing area near Kautokeino in the inner (continental) area of Finnmark (a distance of about 180 km). The initial pretreatment levels of parasites were determined from samples obtained from 30 slaughtered reindeer. Sampling for *H. tarandi* was carried out by counting second instar larvae under the skin on raw hides of all the slaughtered animals (as described by Folstad *et al.*, (1989)). The heads of all slaughtered reindeer were frozen and transferred to the laboratory where *L. arctica* was sampled by examining the sinuses (see Haugerud, 1988), and first instars *C. trompe* were sampled with a rinsing-sieving technique described by Nilssen & Haugerud (1995).

Shortly after the seasonal slaughtering, all animals in the remainder of the herd were injected subcutaneously with a standard dose, 0.2 mg/kg body weight, implying a solution of 1 ml for small calves, 2 ml for normal adults, and 3 ml for large adults of injectable ivermectin (Ivomec veterinary injection 10 mg/ml; Merck, Sharp & Dohme B. V., Haarlem, Holland). A veterinarian ensured that all animals in the herd were treated. A green paint was applied to mark each treated animal.

After its seasonal northward migration in spring 1996, the herd was shipped to Silda, where it spent the summer. On 25 November 1996 (one year post treatment), all slaughtered animals ($n$=52) were sampled for *H. tarandi* (*C. trompe* and *L. arctica* were not sampled this year). The remainder of the herd (those not slaughtered) was treated with ivermectin as described above. Migrating reindeer again were shipped to Silda in the spring of 1997, and on 19 December 1997, the same sampling procedure used in 1996 was repeated. Again, only *H. tarandi* was sampled ($n$ =65, *i.e.* all slaughtered animals). This sampling provided the infestation levels one year after two consecutive treatments. Reindeer were not treated with ivermectin in December 1997. However, animals that spent the summer of 1998 on Silda were again sampled on 1 February 1999 when *H. tarandi*, *C. trompe* and *L. arctica* were sampled in the same way as described above, after which the experiment was terminated. Parasitological terminology is in accordance with Bush (1997).

*Summer temperatures during the infestation periods*

Daily air temperature data (measurements at 0700, 1300 and 1900h) for the infestation period (July and August) for 1996, 1997 and 1998 were obtained from The Weather Bureau of North Norway for two weather stations, Loppa and Tromsø. The island of Loppa is situated about 12 km from the centre of Silda, but has a position more isolated in the ocean so that the climate is more oceanic with lower maximum temperatures than Silda and its adjacent mainland. Because there are no other meteorological stations close to Silda, the data from Loppa was combined with a more distant station. Although it is situated ca 150 km southwest of Silda, Tromsø was chosen because this station has an oceanic climatic influence probably more comparable with that of Silda than the climate of Loppa. Each pairs of contemporary temperatures from these two stations were averaged and used in the analyses.

## Results

After the first treatment both mean abundance and prevalence of *H. tarandi* were considerably reduced in 1996, but this parasite was not eradicated completely (Fig. 1). *C. trompe* was not sampled in 1996, partly because of practical reasons, but also because the abundance of *H. tarandi* indicated that larvae of *C. trompe* would be scarce. Normally, the mean abundance of *C. trompe* is much lower than that of *H. tarandi*. The pre-treatment mean abundance of *C. trompe* was only 22.6% of that of *H. tarandi* (Table 1), which is nearly identical to previous results in 327 reindeer in northern Norway in 1988 and 1989 when the corresponding figure was

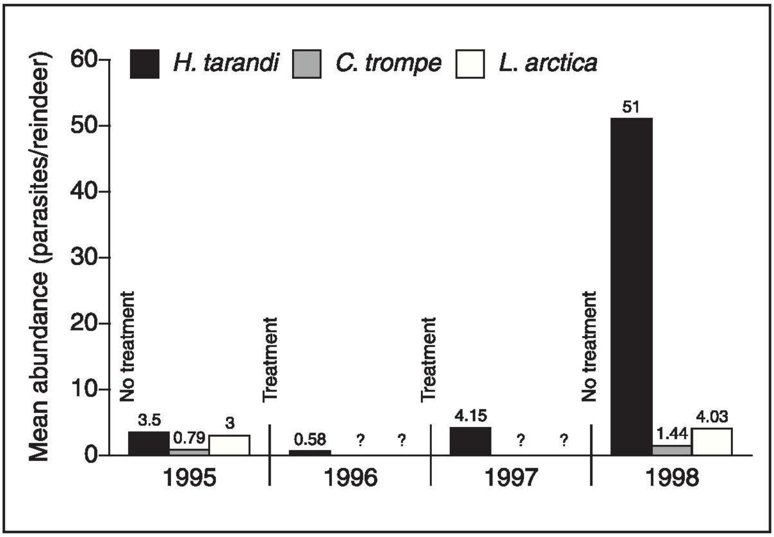


Fig. 1. Graphical illustration of the eradication experiment. Effect on parasite burden following ivermectin treatment of all reindeer on the island of Silda. For details, see Table 1.

Table 1. Mean abundance and prevalence of oestrids and *L. arctica* before and after treatment of all reindeer on the island of Silda. The sample size (*n*) corresponds to all slaughtered reindeer. *C. trompe* and *L. arctica* were not sampled in 1996 and 1997.

| | *n* | mean abundance | (range) | % infected | (95% conf. limits) |
|---|---|---|---|---|---|
| **Before treatment (1995):** | | | | | |
| *H. tarandi* | 30 | 3.50 | (0-16) | 60.0 | (40.6-77.3) |
| *C. trompe* | 29 | 0.79 | (0-17) | 10.3 | (2.1-26.5) |
| *L. arctica* | 29 | 3.00 | (0-17) | 69.0 | (50.6-85.3) |
| **After one treatment of all reindeer (1996):** | | | | | |
| *H. tarandi* | 52 | 0.58 | (0-6) | 15.4 | (6.5-27.9) |
| *C. trompe* | 0 | ? | ? | ? | - |
| *L. arctica* | 0 | ? | ? | ? | - |
| **After two treatments of all reindeer (1997):** | | | | | |
| *H. tarandi* | 65 | 4.15 | (0-20) | 58.5 | (44.6-70.6) |
| *C. trompe* | 0 | ? | ? | ? | - |
| *L. arctica* | 0 | ? | ? | ? | - |
| **After two treatments + one year without treatment (1998) (sampling 1. Feb. 1999):** | | | | | |
| *H. tarandi* | 40 | 51.00 | (8-156) | 100.0 | (91.7-100) |
| *C. trompe* | 41 | 1.44 | (0-6) | 43.9 | (27.7-60.5) |
| *L. arctica* | 40 | 4.03 | (0-28) | 67.5 | (50.2-81.4) |

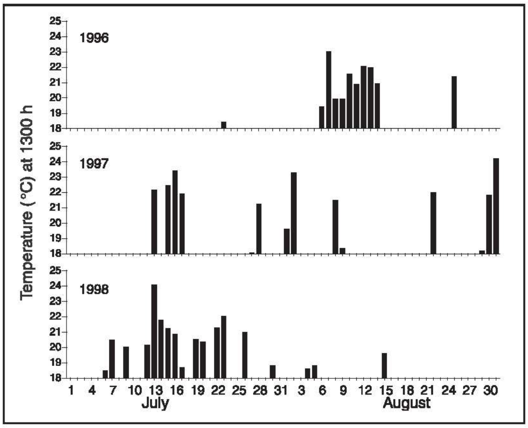


Fig. 2. Mean temperature values from weather stations at Loppa and Tromsø (recorded daily at 0700, 1300 and 1900h) (data from Vervarslinga for Nord-Norge (The Weather Bureau of North Norway); only values >18 °C at 1300h are shown to illustrate warm periods that would be indicative of high flight activity of oestrids.

18.7% (Nilssen *et al.*, 1998). Based on these results, the mean abundance of *C. trompe* would have been: 0.58 x 18.7% = 0.11 in 1996. Among the 52 reindeer sampled therefore, we would expect only 52 x 0.11 = 6 *C. trompe* larvae.

Sampling for the three parasite species at two years after the last treatment revealed that all were present (none had been eradicated). For all three species, the mean abundance was higher than before the first treatment in 1995.

When the months of July and August are compared for temperatures at 1300h, the summers of 1996, 1997 and 1998 (the infestation years for the three last samplings) were different (Fig. 2). In 1996 August was the warmest summer month. In 1997 and 1998, however, July was the warmest.

## Discussion

Although ivermectin is a highly efficient anti-parasitic drug, two consecutive annual treatments of the entire reindeer herd on the island of Silda did not eradicate any of the targeted parasite species. After the first treatment, the population of *H. tarandi* was considerably reduced, but not completely eradicated. After the second treatment, a further reduction in the *H. tarandi* population was expected but on the contrary, the mean abundance was higher than before the treatment started. The further increase observed 26 months after the second treatment (the sampling in 1999, which reflects the infestation in 1998), may be attributable to climatic factors, as it has been shown that

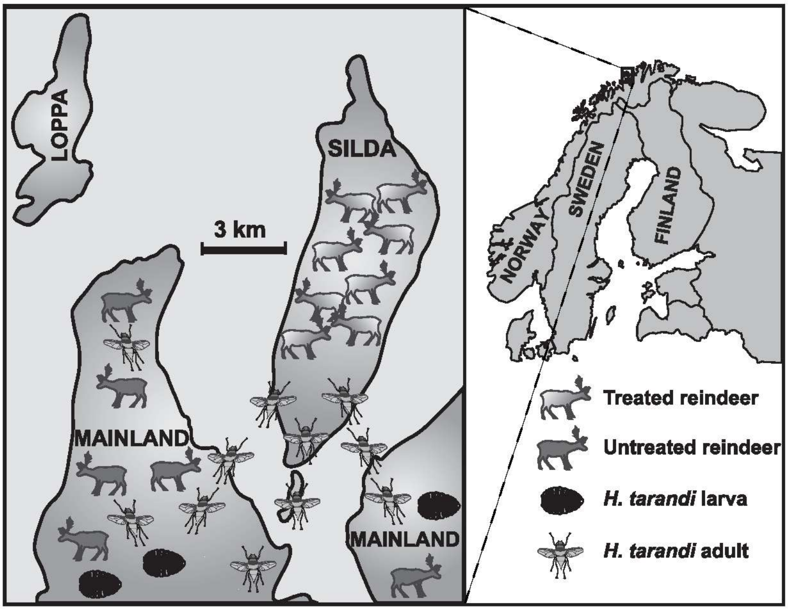


Fig. 3. Map showing the islands of Silda and Loppa (where one of the meteorological stations was located) and adjacent mainland areas. The figure illustrates the flight immigration hypothesis: *H. tarandi* females originating from larvae dropped from untreated reindeer on the mainland were able to fly over oceanic water to infect treated reindeer on Silda in July 1997 (also possibly in July 1998). Female *C. trompe* also likely dispersed to Silda in 1997 or 1998, or in both years.

larval burdens of reindeer oestrids vary greatly between years (Nilssen & Haugerud, 1995; Nilssen *et al.*, 1998). Both 1997 and 1998 had favourable temperatures in July when the main infestation occurs.

The most interesting result, and the most difficult to explain, is that *H. tarandi* increased in mean abundance and prevalence from 1996 to 1997. We expected a further decrease, but observed a 7.8-fold increase in mean abundance. We propose three hypotheses for this unexpected result.

*1. The flight immigration hypothesis*

The two reindeer oestrids have the capacity of flying long distances (Gomoyunova, 1976; Nilssen & Anderson, 1995), which is considered an advantageous attribute for species associated with migratory hosts (Gomoyunova, 1976; Howard & Conant, 1983, Nilssen & Anderson, 1995). In the case of reindeer oestrids, larvae are often dropped far from the summer grazing land where seasonal infestation occurs. Even during the infestation period the reindeer often move long distances to graze or to avoid oestrid attacks. In the present study, the distance *per se* is not the problem because Silda is only separated by 2-3 km from the nearest mainland (Fig. 3). Although Russian researchers have suggested that reindeer oestrids are unwilling to fly over open waters (even a river 500 m wide is thought to be a barrier (Saveljev, 1971)), females of *H. tarandi* have been observed flying over large freshwater lakes (Nilssen, unpubl. data). It is therefore feasible for *H. tarandi* to fly over open arctic oceanic waters during periods of high temperatures and calm weather.

The flight activity of both reindeer oestrids is dependent on temperature, light intensity and wind (Anderson & Nilssen, 1996b, and references therein). Their lower temperature threshold for flight is 8-10 °C (if exposed to direct sunshine), but under most environmental conditions they become active at temperatures exceeding 12-15 °C, and intense harassment of reindeer by the flies is only observed with temperatures >18-20 °C (Anderson & Nilssen, 1996b). In July of 1997 and 1998 temperatures were frequently > 18 °C. The majority of adults emerge from the puparia in the beginning of July (Nilssen, 1997a), and high temperatures for many days shortly after eclosion, as in 1997 and 1998, are essential conditions to create a mass occurrence of newly emerged flies. Temperature data shows both 1997 and 1998 were typical years when there could be a mass concentration of host-seeking oestrids in the period 12 – 23 July, and this could account for the dispersal of many flies to off shore islands like Silda. Compared to 1997 and 1998, the late, cool summer of 1996 probably resulted in only small numbers (if any) of *H. tarandi* and *C. trompe* dispersing to Silda.

As mated *H. tarandi* females are known to fly for much longer durations and distances than unmated females (Nilssen & Anderson, 1995), the flight immigration hypothesis implies primarily that such individuals flew from mainland areas to Silda in July 1997. The mainland areas adjacent to Silda are summer grazing areas for untreated reindeer. From the increase in the larval burden of *H. tarandi* found in 1997, it is believed that from 10 to 100 individuals may have dispersed to Silda.

Flight immigration also may have occurred in 1998 because, as mentioned, the July weather was similar to that in 1997. This second immigration, however, is not required to explain the high larval burden in 1998 because the population in the Silda herd alone in 1997 probably was high enough to give rise to the population size in 1998.

*2. The treatment failure hypothesis*

If it is postulated that the reindeer, not slaughtered in December 1996, had the same mean abundance (0.58) and prevalence (13.46%) as the sampled (slaughtered) animals, we can calculate that this remaining herd of 420 reindeer altogether harboured 0.58 x 420 = 244 *H. tarandi* larvae, and that 420 x 13.46% =57 reindeer were infected. If untreated, 244 would be the maximum estimated number of larvae that could be brought back to Silda, *but all these reindeer were treated*. The recommended dose of ivermectin used (0.2mg/kg) has a 1000-fold overkill (Baron & Colwell, 1991), so if some reindeer for some reason did not get the full dose, probably all larvae would have been killed. The other possibility is that some reindeer "escaped" treatment. If it is assumed that 12 reindeer (4.9%) were untreated, we would have 0.58 x 12= 7 *H. tarandi* larvae that could be brought to Silda the following spring (1997). However, it is highly unlikely that this quantity of larvae could give rise to the increased larval burden (mean abundance 4.5 and prevalence 58%) observed by the end of 1997. If it is postulated a mortality of 20% in the pupal stage occurred it would result in 5-6 adults, and as the sex ratio is 1:1 (Nilssen, 1997a), there would be at maximum three males and three females. If all three females were successfully mated, each with a potential fecundity of 600 eggs (Nilssen, 1997b), there would be a potential of 1800 eggs in total that – if transmitted – could hatch to larvae and infect reindeer. With a mortality of 20% during the first larval instar, there would be 1800 x 80% =1440 larvae in the whole herd in November 1997. In 1997 the sampling revealed a mean abundance of 4.5 larvae, or an estimated number of 470 x 4.5 = 2115 larvae in the whole herd.

Although there are many uncertainties in these calculations, the difference between 1440 and 2115 is such than that there is a possibility that the hypothesised *H. tarandi* population in 1996, despite treatment, could give rise to the population observed in 1997. However, the figure of 1440 is probably far too high, especially as the *realised* fecundity is much lower than the potential of 600 eggs per female. As observed earlier, most females do not succeed in depositing all their eggs (Anderson & Nilssen, 1996a). Additionally, it is believed that the proportion of reindeer successfully treated exceeded 95%, the percentage used in the above calculations.

On the other hand, because *total* eradication was not achieved after the first treatment, the possibility that a few reindeer may not have been treated with ivermectin cannot be ruled out.

*3. The guest reindeer hypothesis*

This hypothesis acknowledges that a few untreated reindeer from other herds could have intermingled with the Silda herd during its northward spring migration. The reindeer owner was fully aware of that such an intermingling of reindeer from other herds would ruin the experiment, and consequently, did everything to prevent this. After the experiment, the owner asserted that no "foreign" reindeer were shipped over to the island during the study years. Therefore, our opinion is that the reasoning for this hypothesis is weak.

Due to missing samples we know less about the effect of ivermectin treatment on *C. trompe* and *L. arctica*. We know, however, that neither of them was eradicated after completion of the experiment. *C. trompe* might have been eradicated both in 1996 and 1997, but as it occurred with fairly high number in 1998, we hypothesise that, as for *H. tarandi*, immigration occurred in 1996 or 1997, or in both years.

The fact that *L. arctica* also was not eradicated is more difficult to explain. The only published test of the vulnerability of *L. arctica* to ivermectin, is a field experiment that showed nearly 100% efficiency (Haugerud *et al.*, 1993), but little is known about the dose response. In the present study, as well as in the previous field experiment (Haugerud *et al.*, 1993), doses adjusted for oestrids were used. If ivermectin, as used against oestrids, is not 100% effective this would explain the failure to eradicate the species.

The life cycle of *L. arctica* is only partially known (Riley *et al.*, 1987), but it is thought that the species survives the winter within the host, and that the eggs, which are deposited in summer, do not survive the winter. Fresh eggs do not withstand frost (R. E. Haugerud, unpubl. data), but older eggs (*i.e.* eggs not transmitted to reindeer) may have increased cold hardiness. If so, older eggs might have survived one or two winters before infecting the host. Consequently, it would be necessary to treat more than two years in succession, as was done the present experiment.

Whatever the explanation for the failure to eradicate the three parasite species, the experiment shows, as with similar experiments, that parasites are often difficult to eradicate under natural conditions. Several previous studies have shown that even under intense control pressure, oestrid populations have an unexpected ability to rebound to pre-control levels (Rich, 1965; Breyev, 1973; Kummeneje, 1979; Scholl *et al.*, 1986), most probably because of their great dispersal potential, their high efficiency to transmit their progeny to the host, and, not the least, their high fecundity and the decreased immune response in hosts deprived of antigenic stimulation through contact with the parasite.

Previous eradication trials, and the present study, show that a nearly 100% elimination is necessary if the aim is to eradicate the parasite. A permanent eradication will, however, not be achieved if there are possibilities for immigration. If the flight immigration hypothesis for the present study is correct, which is virtually certain, better results would be obtained if the experiments were carried out on islands that are more distant from the mainland.

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## References

**Alm, T. & Gamst, U. R. B.** 1997. The vascular flora of Silda (Loppa, Finnmark) (In Norwegian, English abstract). – *Polarflokken* 21 (1): 17-34.

**Anderson, J. R. & Nilssen, A. C.** 1996a. Trapping oestrid parasites of reindeer: the relative age, fat body content and gonotrophic conditions of *Cephenemyia trompe* and *Hypoderma tarandi* females caught in baited traps. – *Med. Vet. Entomol.* 10: 347-353.

**Anderson, J. R. & Nilssen, A. C.** 1996b. Trapping oestrid parasites of reindeer: the response of *Cephenemyia trompe* and *Hypoderma tarandi* to baited traps. – *Med. Vet. Entomol.* 10: 337-346.

**Baron, R. W. & Colwell, D. D.** 1991. Mammalian immune responses to myiasis. – *Parasitol. today* 7 (12): 353-355.

**Breyev, K. A.** 1973. Some general principles of the control of parasitic arthropods as exemplified by the control of warble flies. – *Entomol. Rev.* 50: 142-151.

**Bush, A. O., Lafferty, K. D., Lotz, j. M. & Shostak, A. W.** 1997. Parasitology meets ecology on its own terms: Margolis revisited. – *J. Parasitol.* 83 (4): 575-583.

**Coles, G. C., Tarry, D. W. & Sinclair, I. J. B.** 1992. Vaccination Against Warble Fly? – *Parasitology Today* 8 (7): 236.

**Dieterich, R. A. & Craigmill, A. L.** 1990. Safety, efficacy, and tissues residues of ivermectin in reindeer. – *Rangifer* 10 (2): 53-56.

**Egerton, J. R., Birnbau, J., Blair, L. S., Chabala, J. C., Conroy, J., Fisher, M. H., Mrozik, H., Ostlind, D. A., Wilkins, C. A. & Campbell, W. C.** 1980. 22,23 Dihydroavermectin B1, a new broad-spectrum antiparasitic agent. – *British Vet. J.* 136 (1): 88-97.

**Folstad, I., Nilssen, A. C., Halvorsen, O. & Andersen, J.** 1989. Why do male reindeer (*Rangifer t. tarandus*) have higher abundance of second and third instar larvae of Hypoderma tarandi than females? – *Oikos* 55: 87-92.

**Forbes, A. B.** 1993. A review of regional and temporal use of avermectins in cattle and horses worldwide. – *Vet. Parasitol.* 48 (1-4): 19-28.

**Gomoyunova, N. P.** 1976. *Biologiya ovodov severnykh oleney* (in Russian). Novosibirsk "Nauka", Sibirskoe Otdedenie, Novosibirsk 1976.

**Haugerud, R. E.** 1988. A life history approach to the parasite - host interaction *Linguatula arctica* Riley, Haugerud and Nilssen, 1987 - *Rangifer tarandus* (Linnaeus, 1758). Cand. scient. thesis in ecology, zoology. University of Tromsø.

**Haugerud, R. E., Nilssen, A. C. & Rognmo, A.** 1993. On the efficacy of ivermectin against the reindeer sinus worm *Linguatula arctica* (Pentastomida), with a review on ivermectin treatment in reindeer. – *Rangifer* 13 (3): 157-162.

**Howard, G. W. & Conant, R. A.** 1983. Nasal botflies of migrating wildebeest from western Zambia. – *J. Nat. Hist.* 17: 619-626.

**Klement'eva, E. V.** 1987. Efficacy of Ivomek against *Oedemagena* and *Cephenemyia* infection in reindeer. – *Voprosy veterinarnoi toksikologii, entomologii i deratizatsii* 11: 91-94.

**Kummeneje, K.** 1976. Rapport fra forsøk med bekjempelse (utryddelse) av reinbrems på Tjeldøya, Nordland fylke 1974/75. – *Reindriftsnytt* 5: 14-18.

**Kummeneje, K.** 1979. Some treatment trials for eradication of the reindeer grub fly (*Oedemagena tarandi*). – *In*: Reimers E., Gaare E. & Skjenneberg S. (eds.). *Proceedings from the Second Int. Reindeer/Caribou Symp. Røros, Norway*: Direktoratet for vilt og ferskvannsfisk, Trondheim, 459-464.

**Losson, B., Lonneux, J.-F. & Liebisch, A.** 1998. Chapter 9. Chemoprophylaxis and chemotherapy of cattle hypodermosis. – *In*: Boulard C., J. S., Pithan D., O'Brian D., Webster K. & Sampimon O. C. (eds.). *EUR 17534 - COST 811 - Improvement in the Control Methods for Warble fly in Livestock*: Luxembourg, pp. 62-67.

**Nilssen, A. C.** 1997a. Effect of temperature on pupal development and eclosion dates in the reindeer oestrids *Hypoderma tarandi* and *Cephenemyia trompe* (Diptera: Oestridae). – *Environ. Entomol.* 26 (2): 296-306.

**Nilssen, A. C.** 1997b. Factors affecting size, longevity and fecundity in the reindeer oestrid flies *Hypoderma tarandi* (L.) and *Cephenemyia trompe* (Modeer) (Diptera: Oestridae). – *Ecol. Entomol.* 22: 294-304.

**Nilssen, A. C. & Anderson, J. R.** 1995. Flight capacity of the reindeer warble fly, *Hypoderma tarandi* (L.), and the reindeer nose bot fly, *Cephenemyia trompe* (Modeer) (Diptera: Oestridae). – *Can. J. Zool.* 73 (7): 1228-1238.

**Nilssen, A. C., Åsbakk, K., Haugerud, R. E., Hemmingsen, W. & Oksanen, A.** 1999. Treatment of reindeer with ivermectin - effect on dung insect fauna. – *Rangifer* 19: 61-69.

**Nilssen, A. C. & Haugerud, R. E.** 1994. The timing and departure rate of larvae of the reindeer warble fly *Hypoderma* (=*Oedemagena*) *tarandi* (L.) and the reindeer nose bot fly *Cephenemyia trompe* (Modeer) (Diptera: Oestridae) from the reindeer. – *Rangifer* 14 (3): 113-122.

**Nilssen, A. C. & Haugerud, R. E.** 1995. Epizootiology of the reindeer nose bot fly, *Cephenemyia trompe* (Modeer) (Diptera: Oestridae), in reindeer, *Rangifer tarandus* (L.), in Norway. – *Can. J. Zool.* 73 (6): 1024-1036.

**Nilssen, A. C., Haugerud, R. E. & Folstad, I.** 1998. No interspecific covariation in intensities of macroparasites of reindeer, *Rangifer tarandus* (L.). – *Parasitology* 117: 273-281.

**Norberg, H. S.** 1989. Ivermectin og rein. – *Reindriftsnytt* 23 (1): 16-18.

**Nordkvist, M., Christensson, D. & Rehbinder, C.** 1984. Ett fältavmaskningsförsök med ivermectin (MSD) på renar. – *Rangifer* 4 (2): 10-15.

**Nordkvist, M., Rehbinder, C., Christensson, D. & Rönnbäck, C.** 1983. A comparative study on the efficacy of four anthelmintics on some important reindeer parasites. – *Rangifer* 3 (2): 19-38.

**O'Brien, D. J.** 1998. Chapter 3. Warble fly prevalence in Europe 1997 after Cost 811. – *In*: Boulard C., J. S., Pithan D., O'Brian D., Webster K. & Sampimon O. C. (eds.). *EUR 17534 - COST 811 - Improvement in the Control Methods for Warble fly in Livestock.* Luxembourg: Office for Official Publications of the European Communities, pp. 20-27.

**Oksanen, A.** 1995. Poro ja ivermektiini (Reindeer and ivermectin). – *Suomen-Elainlaakarilehti* 101 (9): 553-556.

**Oksanen, A.** 1999. Endectocide treatment of the reindeer. – *Rangifer* Special Issue No. 11: 1-217.

**Rich, G. B.** 1965. Systemic treatments for control of cattle grubs *Hypoderma* spp. in an isolated range herd. – *Can. J. Animal Sci.* 45: 165-172.

**Riley, J., Haugerud, R. E. & Nilssen, A. C.** 1987. A new species of a pentastomid from the nasal passages of the reindeer (*Rangifer tarandus*) in northern Norway, with speculation about its life cycle. – *J. Nat. Hist.* 21: 707-716.

**Roncalli, R. A.** 1989. Environmental aspects of use of Ivermectin and Abamectin in livestock: Effects on cattle dung fauna. – *In*: Campbell W. C. (ed.). *Ivermectin and Abamectin.* Corrected edition 1990 ed. N. Y. Berlin Heidelberg London Paris Tokyo: Springer-Verlag, pp. 173-181.

**Saveljev, D. V.** 1971. Renstyngens biologi och kampen mot dessa insekter. – *In: Rensymposium. Rovaniemi, Finland*: Lantbruksarbetsgruppen inom Kommittén för vetenskaplig-teknisk samverkan mellan Finland och Sovjetunionen, Helsingfors, pp. 84-86.

**Scholl, P. J.** 1998. Chapter 5. The current status of hypodermosis in North America. – *In*: Boulard C., J. S., Pithan D., O'Brian D., Webster K. & Sampimon O. C. (eds.). *EUR 17534 - COST 811 - Improvement in the Control Methods for Warble fly in Livestock. Luxembourg*: Office for Official Publications of the European Communities, pp. 38-41.

**Scholl, P. J., Colwell, D. D., Weintraub, J. & Kunz, S. E.** 1986. Area-wide systemic insecticide treatment for control of cattle grubs, *Hypoderma* spp. (Diptera: Oestridae): Two approaches. – *J. Econ. Entomol.* 79: 1558-1563.

**Tarry, D. W., Sinclair, I. J. & Wassall, D. A.** 1992. Progress in the British hypodermosis eradication programme: the role of serological surveillance. – *Vet. Rec.* 131: 310-312.

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