THE FUTURE FOR SEA LICE CONTROL

IN CULTURED SALMONIDS:

A REVIEW

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A technical report to the
Marine Working Group
of
Scottish Wildlife and Countryside Link

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Preface

The future for sea lice control in cultured salmonids.

This paper reviews the problem of sea lice control, highlighting the limitations of currently available techniques. It examines promising avenues of research into alternative treatments, and suggests interim measures to reduce the environmental impacts of current methods until a reliable alternative is available.

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1 Introduction

1.1 The 'sea lice' of salmonid fish are ectoparasitic caligid copepods commonly found on fish in seawater, and often observed on adults returning to their spawning rivers. In the N.E. Atlantic the species to which this term usually refers are *Lepeophtheirus salmonis* (Kroyer, 1838) and *Caligus elongatus* (Nordmann, 1832), although there are many other species which occur throughout the world.

1.2 Both occur in small numbers on individual wild salmonids and whilst gross pathology can occur, it is rarely observed. However, with the introduction of marine aquaculture of rainbow trout (*Salmo gairdneri* Richardson) and Atlantic salmon (*Salmo salar* L.) in Norway, Scotland and Ireland, these parasites have become important pathogens of farmed fish. Whilst there remain examples of lice-free salmon farms in the Western and Northern Isles, many experience this parasite in very large numbers, causing severe damage to stocks.

1.3 The life cycle of caligid copepods comprises 10 stages, each separated by a moult. Both *L. salmonis* and *C. elongatus* conform to this pattern with two nauplius, one copepodite, four chalimus, two pre-adult, and one adult, stages. This life cycle is illustrated in Fig. 1.

1.4 The free-swimming stages (nauplius I & II and copepodite) form part of the zooplankton until the copepodite attaches to a host fish, often on the fins, gills or around the anus. The parasite remains attached as it passes through the succeeding chalimus stages, by means of a frontal filament secreted by the head. The fourth chalimus stage moults through two pre- adult stages to the adult male and female lice. These pre-adult and adult stages are not attached, moving freely over the surface of the fish.

1.5 The damage caused by caligid copepods results from their feeding activity on the skin of the fish. The extent and type of damage caused to fish by sea lice depends upon the density of infestation and development stages present. Taken singly, a fixed chalimus larva will cause less damage to the epithelium of a fish than a pre-adult or adult stage grazing over the entire body surface. Females will cause more damage than males due to their increased size. However, a heavy infestation of chalimus stages on a young smolt can be as deleterious as a lesser number of mature stages.

1.6 Initial lesions on infested fish appear as whitish spots or small ulcers, frequently found on the dorsum and peri-anal areas. Haemorrhages often occur in the peri-anal region, accompanied by local oedema, and seepage of blood between the scales is common. Lesions are also often found on the head, and may be so severe that the skull is exposed. Damaged fish may develop secondary infections. Death probably results from osmoregulatory failure (Wootten *et al.*, 1982).

1.7 At present the most widely used treatment for infestations of *L. salmonis* and *C. elongatus* is an organophosphate, Aquagard SLT ® (formerly known as Nuvan 500 EC®) (Ciba Geigy), active ingredient dichlorvos (2,2-dichlorovinyl dimethyl phosphate (DDVP)). This is applied as a bath treatment of 2 parts per million (ppm) (1 ppm active ingredient). In Norway, the compound Neguvon® (active component metrifonate or trichlorfon : 2,2,2-trichloro-1-hydroxyethylphosphoric acid dimethyl ester (Bayer)) has been used. In water a degradation of trichlorfon to dichlorvos occurs. The efficacy of both these compounds is temperature dependent (Samuelson, 1987).

1.8 These treatments are only effective against pre-adult and adult stages of sea lice, and do not kill chalimus stages. Both these compounds inhibit the acetylcholinesterase activity of the cholinergic nervous system. Recently however, there have been increasing numbers of reports from farmers that treatments are less effective than in previous years.

2 Limitations of the present treatment

2.1 Present treatment

2.1.1 The use of a chemical for the control of parasites on fish falls within the legal definition of medicinal use, for which a Product Licence is required under the Medicines Act to permit its import, sale or supply to the UK market. Currently, the only product licensed for use as a sea lice treatment on fish farms is Aquagard SLT® (Appendix 1).

2.1.2 To treat a cage of fish with Aquagard, the volume of a cage is reduced by drawing up the net. The cage is either totally enclosed by a tarpaulin 'bag' or a weighted tarpaulin skirt is hung around the perimeter of the cage to a depth of at least twice the reduced net depth. The correct amount of Aquagard is then added to the water. Throughout treatment the cage is oxygenated. After 30-60 minutes the tarpaulin is removed. Cues which are used by the farmer for removal of the tarpaulin during this period include observations of lice dropping off fish. In the event that a treatment goes awry, which can happen for a number of reasons, the treatment is aborted. For example, it is difficult to estimate bag volume and fish may be overdosed. An indication that this may be the case is heaviness of the nets. This is a sign that narcotised fish are settling at the bottom of the cage, where they are in danger of suffocation from the weight of those above.

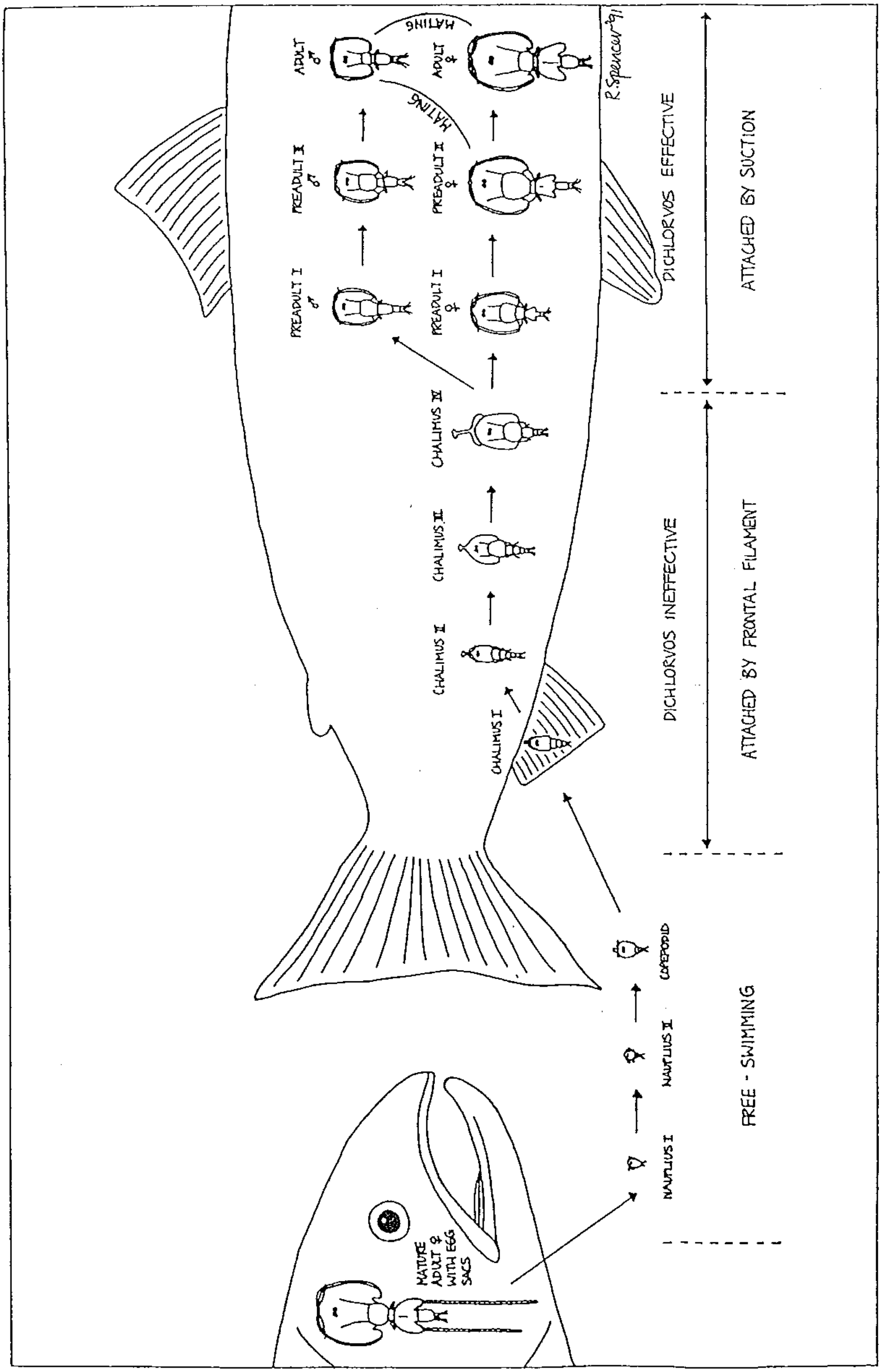

Fig 1. Life cycle of the salmon louse *Lepeophtheirus salmonis* (x 4 magnification)

2.1.3 From a practical viewpoint, Aquagard has well known undesirable side-effects, such as reduced growth of salmon, stress which may aggravate mortalities due to furunculosis, or damage to already weakened fish when inadequate filling of the tarpaulin occurs (Treasurer, 1991a).

2.1.4 Dichlorvos acts by inhibition of the enzyme acetylcholinesterase (AChE) in brain and other tissues. Duration of AChE inhibition after normal dichlorvos treatment is 2-3 weeks in the liver and brain of salmonids (Høy *et al.*, 1991). Since repeat treatments at an interval of 2 weeks are sometimes necessary, and the AChE inhibition may persist for a longer period, a regimen of repeat treatments may involve a higher risk of mortalities. Instances of mass mortalities of fish during and after treatment which have been reported may be attributed to this cause (Høy *et al.*, 1991). It has been suggested that dichlorvos may cause irreversible brain cell damage in fish (Vadhva & Hasan, 1986).

2.1.5 Whilst the prescribed treatment is 1 ppm dichlorvos for up to 1 hour, variation in treatment practices does occur (Ross & Horsman, 1988). On the discretion of the prescribing veterinary surgeon the dose rate can be altered, depending on particular circumstances. One instance when this may occur is during low water temperatures, since the efficacy of dichlorvos treatments is temperature dependent. Instead of the withdrawal period of 4 days from the last treatment, as stipulated in the product licence, the extended withdrawal period of 500 degree C days is then applicable. This is calculated by dividing 500 by the water temperature (ºC) e.g. at a water temperature of 10ºC the withdrawal period will be 50 days. In Ireland, the dose rate is often doubled in winter. In Scotland, some farms may use a higher dose for a shorter time. Such departures from the binding conditions of the product licence are not detected by the regulatory authorities, which are as yet insufficiently resourced to monitor practices effectively.

2.1.6 Undoubtedly controls on the use of dichlorvos have been inadequate in the past (e.g. no code of practice, no initial training or health monitoring for operatives), but changes have been made. Training courses run by the Agricultural Training Board have instructed over 500 salmon farmers in the responsible use of dichlorvos since 1989. Similar courses for fish farmers in Shetland are run by the North Atlantic Fisheries College. Workers using dichlorvos have had an additional safeguard since the establishment of the Control of Substances Harmful to Health (COSHH) regulations in 1990.

2.1.7 Lobster larvae have been shown to be particularly sensitive to dichlorvos (Egidius & Møster, 1987; Cusack & Johnson, 1990; McHenery *et al.*, 1991a) but latest studies suggest that only in the immediate pen area are concentrations of dichlorvos achieved capable of affecting lobster larvae (Dobson & Tack, 1991). Nuvan® has been shown to be toxic to marine phytoplankton at a concentration of 1ppm, although it is not certain whether this toxicity is due to the carrier, di-n-butyl phthalate, to a degradation product of dichlorvos, to another chemical present in the formulation such as an emulsifier, or to a combination of such factors (Raine *et al.*, 1990). Evidence for reduced sensitivity in non-target organisms such as the common mussel, *Mytilus edulis*, (McHenery *et al.*, 1991b) and amphipod *Hyale nilssoni* (Robertson *et al.*, 1991) has been found. Whilst there is no indication of any major impact of dichlorvos usage on the composition and abundance of the rocky shore invertebrate community adjacent to fish farms, there is evidence that dichlorvos is affecting some components of the community at a sub-lethal level (Robertson *et al.*, 1991).

2.2 Reduced sensitivity

2.2.1 In some water bodies which have been intensively farmed for a long period of time with heavy use of dichlorvos, lice are showing reduced sensitivity to dichlorvos (Jones *et al.*, 1992). Resistance of this kind is thought to be widespread throughout Scotland. There are very few reported instances of reduced organophosphate sensitivity in crustacea, but in insects this phenomenon has been well documented. Aphid populations are known to show resistance to several compounds (Hamilton *et al.*, 1981) and the oriental housefly *Musca domestica vicina* has been known to show insecticide resistance since 1966 (Yeoh *et al.*, 1981). Depending on the mechanism by which this reduced sensitivity has occurred, it is possible that lice may show cross-resistance to other organophosphates to which lice have not yet been exposed. This may reduce the efficacy of azamethiphos, another organophosphate, which is being considered as a potential replacement for dichlorvos (see 3.3.3).

2.3 Restrictions

2.3.1 Dichlorvos is on the 'Red List' of dangerous substances. At the North Sea Conference in 1987, the Government agreed that inputs of dangerous substances to the marine environment should be reduced by 50% between 1985 and 1995. This commitment was confirmed in the recent White Paper (HMSO, 1990a), and in the Government's response in December 1990 (HMSO, 1990b) to the Report of the House of Commons Select Committee on Agriculture inquiry into fish farming in the UK (HMSO, 1990c):

> *"The Government is determined to meet the commitment made at the North Sea Conference to reduce by 50 per cent the inputs of certain substances to the marine environment by 1995, including dichlorvos. Any application for extension to the*

licence for Aquagard beyond 1992 will need to be considered in the light of this commitment, and the presumption is that dichlorvos-based treatments for ectoparasites such as sea lice should be replaced by suitable alternatives."

2.3.2 The Government admits however, that it does not know how much dichlorvos was used in 1985, and in April 1991 had not yet assessed a target figure for dichlorvos discharges to the sea in 1995 (R. Otter, Dept. of the Environment, *pers. comm.*).

2.3.3 In November 1991 a consultation paper proposing national environmental quality standards (EQSs) for dangerous substances in water was prepared jointly by the Department of the Environment, Welsh Office, Scottish Office Environment Department and Department of the Environment (Northern Ireland) (DoE, 1991). The paper proposes environmental quality standards for the remaining substances on the UK Red List which do not yet have standards set, including dichlorvos. For the protection of marine life an EQS of 0.04 ug/l is proposed and applies outside a defined mixing zone. In addition, if dichlorvos is applied directly to the marine environment (ie in salmon farms), it is suggested that 24 hours after its release the maximum concentration outside a defined mixing zone should not exceed 0.6 ug/l. Furthermore, the concentrations one hour after the release outside the defined mixing zone should not exceed 25 ug/l. In some situations it may not be possible to monitor the short-term standards, and in these circumstances only the maximum concentration of 0.6 ug/l after 24 hours will be applicable. These standards are summarised in Table 1.

Table 1. Proposed standards for dichlorvos in saline water (ug/l) (DoE, 1991)

Annual average	0.04
Maximum allowable concentration (outside of the defined mixing zone)	
after 24 hours	0.6
after 1 hour	25.0
before next application	6.0

2.3.4 Irrespective of the above and other factors, consumer pressure may well determine that the use of dichlorvos in the salmon farming industry is phased out, as this conflicts with the clean image of salmon as a commodity.

3 The alternatives

3.1 Recent work in Britain and abroad has considerably increased current knowledge and understanding of the biology of the sea louse, and much attention has focused on alternative methods of control to replace the existing organophosphate treatment.

3.2 There is continuous research funded by drugs companies into new treatments and a wide range of compounds has been investigated. At the same time there has been much research into treatments which are not drug- based, involving the use of cleaner-fish and the development of a vaccine. Alternatives which have been studied in some detail are described below.

3.3 Biocides

3.3.1 Ivermectin

3.3.1.1 Ivermectin is used extensively as a parasiticide to treat cattle, pigs, sheep, goats, and horses. It is derived from the avermectins, a family of highly active, broad spectrum, macrocyclic lactone anti-parasitic agents which are isolated from fermentation of the soil actinomycete *Streptomyces avermitilis*. Ivermectin consists of two components designated as 22,23-dihydroavermectin-B_{1a} and 22,23-dihydroavermectin-B_{1b}, and contains no less than 80% of the former and no more than 20% of the latter (Halley *et al.*, 1989a). Its effect is due to increased release of the inhibitory neurotransmitter γ-amino-butyric acid (GABA) (Høy *et al.*, 1990). In arthropods and crustaceans this leads to inhibition of nerve pulse transmission at the neuro-muscular junctions resulting in paralysis and death. It is highly efficient against a wide range of internal and external parasites in many host species. Since it is structurally different from dichlorvos, the likelihood of cross-resistance is extremely unlikely.

3.3.1.2 Ivermectin is available in several formulations licensed under the names Ivomec® and Oramec® (MSD-AGVET, a division of Merck Sharp & Dohme Ltd.) for use as an injection, pour-on or drench treatment for cattle and pigs etc. Under the name Mectizan®, it is the drug of choice to treat *onchocerciasis* ('river blindness') in humans (BNF 1990).

3.3.1.3 Preliminary trials on the efficacy of Ivomec® against sea lice infestations were reported by Palmer *et al.* in 1987. Further trials are currently underway in Ireland, sponsored by Carrolls Aquaculture, to investigate control of sea lice by oral administration of ivermectin. According to newspaper reports (The Daily Telegraph, 8/7/91) and widespread rumour within the industry, ivermectin is also being used on fish farms in Scotland, even though it is not licensed for incorporation in feed or for use in fish. Its use by fish farmers, with or without instructions from a veterinary

surgeon, is illegal (J Rutter, Veterinary Medicines Directorate, *pers. comm.*). Both Ivomec®and Oramec® may be bought over the counter without prescription from agricultural merchants and veterinary practices.

3.3.1.4 Oral administration has the advantage of keeping quantities used to a minimum, but there are problems in ensuring that each fish receives the correct dose. The usual dose used in Ireland is 0.02 mg/kg body weight, fed once a week to smolts when they go to sea, for about 2-3 months (P. Smith, University College, Galway, *pers. comm.*). The drug takes about three weeks to act and its effect lasts for about four weeks, but more information is needed on tissue residue levels and withdrawal times before harvesting. Ivermectin is persistent in fish tissue at low temperatures and toxicity problems can occur at higher dose rates (Palmer *et al.*, 1987). The Irish Salmon Growers' Association has stipulated that farmers taking part in the experimental work should use ivermectin only on smolts or grower fish until October each year, then allowing a withdrawal period of at least 1000 degree C days before harvest for human consumption (Anon, 1991).

3.3.1.5 The environmental impact of ivermectin has not been sufficiently explored, especially the fate of uneaten food and faecal pellets containing the drug. Ivermectin is very poorly absorbed in the fish gut; most of it is passed in the faeces. After cattle are treated with ivermectin, the drug is eventually excreted in the faeces, where it retains its insecticidal effect. Manure-dwelling or feeding insects have been shown to be affected by drug residues in manure excreted by treated animals (Halley *et al.*, 1989b).

3.3.1.6 The ecological effects of this compound in the marine environment are not known. Aquatic organisms are sensitive to ivermectin (Halley *et al.*, 1989a). To date, the organism found to be most sensitive to ivermectin is the water flea, *Daphnia magna*. The 48-hour LC_{50} was 0.025 parts per billion (ppb) and the no observed effect concentration (NOEC) was 0.01 ppb. The drug may also affect the already problematic breakdown of organic matter under fish cages.

3.3.1.7 Work underway at University College, Galway for four years has investigated the environmental effects, efficacy and safety of ivermectin as a treatment for sea lice. Results show that the drug is efficacious, and a therapy is being designed which will clear a site of lice after only a few treatments. Primary environmental concerns were the effects on commercial shellfish, since salmon and shellfish farms are often in close proximity. Most adult shellfish (oysters, mussels, scallops) are 100 times more resistant to ivermectin than salmon, whilst their larvae are 50 times more resistant (P Smith, *pers. comm.*).

3.3.1.8 Merck Sharp and Dohme Ltd. has recently completed research with the Swedish feed company Ewos AB to study elimination of the drug by salmon into the marine environment, and impact on other marine life forms, as well as safety in salmon and potential for ivermectin residues. Ivermectin appears to be effective in dealing with sea lice. However, no product licence for its use in fish has been applied for by the manufacturers:

> *"We will initiate or sponsor efficacy trials on ivermectin against the salmon louse only after we are satisfied ivermectin can be safe for the environment, safe for salmon, and safe for people who consume salmon."*
> (W Grimshaw, MSD, *pers. comm.*)

3.3.1.9 Because of the alleged illegal use of ivermectin on fish farms MAFF is to start testing for the drug. A parliamentary question asking the Minister of Agriculture, Fisheries and Food what monitoring is undertaken to detect traces of ivermectin in farmed salmon on sale in the United Kingdom elicited the following response on 6 June 1991:

> *"Ivermectin is not licensed for use in fish in the United Kingdom and, to date, no monitoring has been conducted to detect residues in* (sic) *ivermectin in the edible tissues of farmed salmon on sale in the United Kingdom. However, surveillance for residues in farmed fish is currently being stepped up and testing for ivermectin will be included within the scope of the new arrangements."*

3.3.1.10 The River Purification Boards are not aware of any applications for consent to discharge ivermectin into the marine environment (Highland R P B *pers. comm.*).

3.3.2 Pyrethrum

3.3.2.1 A new medicine developed in Norway, Py-Sal 25 (Norsk Pyrethrum AS) in association with Vetrepharm Ltd., is based on 1% pyrethrum. Pyrethrum is extracted from the flower heads of a chrysanthemum *Chrysanthemum cinerariaefolium*. It is an insecticide, and has been used against internal parasites in animals and humans.

3.3.2.2 The pyrethrum is diluted with Exxol D100 S, a paraffinic oil with low aromatic content (Boxaspen & Holm, 1991a). In Norway this oil is allowed to be used in drinking water sources to combat mosquitoes. Pyrethrum is degraded by sunlight, and is therefore mixed with an antioxidant, piperonyl butoxide, to prolong its activity.

3.3.2.3 This method is based on the fact that sea lice and salmon have a different outer protective layer. The mucus of the salmon is mainly water soluble, whilst

the lice have a lipid layer in the outer part of the cuticle. Thus a compound mixed in oil will selectively penetrate the lice and not the salmon.

3.3.2.4 Several treatment methods have been tested. The pyrethrum mixture can be poured onto the surface of the water in the skirted fish pens, forming a floating layer of medication (Boxaspen *et al.*, 1990). Salmon leaping activity provides self-delousing with a minimum of stress, since parasite-laden fish tend to leap more often than non-infested fish. Scottish lochs are generally more exposed than Norwegian fjords, and it may not be practicable to contain the oily layer within cages for long periods. In bad weather the escaping oily mixture could pollute water bodies.

3.3.2.5 An alternative approach is to submerge the fish in a small reservoir of pyrethrum mixture (Boxaspen & Holm, 1991a). A tube is mounted alongside the fish cage, with one end out of the water and the rest underwater in a slanting position. The pyrethrum mixture is put into the tube and fish are made to swim through it. This may be a more reliable and controlled method, but it will induce more stress. This method could be used concurrently at times of fish handling such as grilse-grading and net changing. A large-scale experiment carried out in February 1991 resulted in a delousing effect of 96% (Boxaspen & Holm, 1991b). The pyrethrum treatment solution may be recovered afterwards.

3.3.3 Azamethiphos

3.3.3.1 Azamethiphos (S-(6-chloro-oxazolo [4,5-b] pyridin-2(3H)-on-3-yl- methyl)-0,0,dimethyl-phosphorothioate (Ciba Geigy)) is currently undergoing field trials, having received an Animal Test Certificate from the Veterinary Products Committee (VPC) as a potential lice treatment. Azamethiphos is a broad-spectrum organophosphorus insecticide, used against nuisance flies and other arthropods. Similar to dichlorvos, it acts as an inhibitor of acetylcholinesterase. Trials will compare the efficacy of azamethiphos at sites where dichlorvos resistance occurs and at sites of no recorded resistance.

3.3.3.2 Azamethiphos is being tested as a bath treatment, but unlike dichlorvos, the chemical is stored as sachets of powder which are dissolved in water to the required concentration of 0.1-0.2 ppm/hr, on site, when needed.

3.3.3.3 Azamethiphos is more toxic than dichlorvos. In trials, 60% of Atlantic salmon were killed at a concentration of 1.0 ppm, and all fish died at 3.0 ppm (Roth & Richards, 1991). Adult and pre-adult stages of sea lice were killed at a concentration of 0.01 ppm. Similar to dichlorvos and trichlorfon, azamethiphos does not kill larval chalimus stages. However, despite overall higher acute toxicity to salmon and lice, azamethiphos has a wider therapeutic margin than dichlorvos. It is better tolerated by salmon since its toxicity, as measured by AChE inhibition, is not cumulative.

3.3.4 Carbaryl

3.3.4.1 Carbaryl (1-naphthyl N-methylcarbamate), product name Sevin® (Rhone-Poulenc) has been considered as a potential sea lice treatment (Bruno, 1990). There has been worldwide licensed use of this compound since 1958 for the control of over 150 major pests. Like dichlorvos, it acts as an inhibitor of acetylcholinesterase. The degradation product of carbaryl, 1-naphthol, is more toxic to fish and molluscs than the parent compound. Carbaryl is rapidly absorbed to sediments, where 1-naphthol accumulates.

3.3.4.2 Treatment concentration of active ingredient is 0.3-0.5 mg/l/hr. The half-life of carbaryl in sea water has been reported as 38 days at 8ºC (Karinen *et al.*, 1967). To date, carbaryl has not been developed further as a sea lice treatment.

3.3.5 Onions and garlic

3.3.5.1 Towards the end of 1990, some fish farmers in Faroe and Shetland reported reduced sea lice problems after placing onions (*Allium cepa*) in the cages. Onions have long been known to have insecticidal and bactericidal properties, so it is not unexpected that they might also affect the behaviour of sea lice. The onions are cut in half, placed in mesh bags, and suspended in the cages for 3 days, after which time they are replaced with fresh ones. Early indications are that free-swimming juvenile lice are discouraged or deterred from attaching to fish (C. Young, Shetland Salmon Farmers' Association, *pers. comm.*).

3.3.5.2 The inhibitory effect of cut onions on the activity of the lice may be due to disulphide compounds, released as secondary products when onion tissue is cut or damaged. These products can be released from freshly cut onions, onion puree, and onion oil. The Shetland Salmon Farmers' Association has funded research on onions and sea lice with the University of Liverpool.

3.3.5.3 Garlic (*Allium sativum*) has also been tested in Scotland and Norway. Salmon fed with garlic mixed in moist pellet at a 10% level (wet weight basis) have been shown to have a significantly lower level of lice after 14 days, though this effect may not persist (Boxaspen & Holm, 1991b).

3.3.6 Others

3.3.6.1 The above are just some examples of the alternative sea lice treatments which have been studied in depth, but others have been or are being investigated.

3.3.6.2 The use of chitin-inhibitors which disrupt the formation of the skeleton of the sea louse, thereby rendering it unable to grow and reproduce successfully has been studied in Norway.

3.3.6.3 Synthetic pyrethroid bath treatments have been investigated in Britain and one compound was recently submitted for licensing as a potential sea lice treatment, but to date has not been taken further.

3.3.6.4 Hydrogen peroxide is being studied in Norway and Faroe for use as a bath treatment. The fish are heavily crowded in the nets for the treatment which lasts for about 20 minutes. Believed to be used at a concentration of 1 part per thousand, the liquid causes the formation of gas bubbles under the carapace of the lice which float to the surface where they can be skimmed off and removed. Hydrogen peroxide rapidly breaks down to water and oxygen, therefore no oxygenation of the cage is required during treatment.

3.4 Wrasse

3.4.1 The ideal method of lice control would be one which caused no harm to the environment and where effects were confined to the lice. One solution may be that of appropriate biological control.

3.4.2 There has been much press coverage recently of trials using wrasse species as cleaner fish for lice-infested salmon. Using a technique pioneered in Norway, pilot trials were carried out in 1989/90 by the Shetland Salmon Farmers' Association and Sea Fish Industry Authority, with goldsinny (*Ctenolabrus rupestris*) and rock cook (*Centrolabrus exoletus*). These were remarkably successful, and more and more farms are now putting wrasse with their fish. Whilst these two species are the most efficient at cleaning, two other species of wrasse, the corkwing (*Crenilabrus melops*) and females of the cuckoo wrasse (*Labrus ossifagus*) can be used. Best results are achieved when wrasse are allowed to grow up with the salmon smolts. Wild-caught wrasse may be acclimatised in captivity, and fed with shellfish, before introduction to salmon stocks, which should preferably be cleaned of lice prior to stocking.

3.4.3 Trials conducted by Marine Harvest and McConnell Salmon have shown that wrasse are successful in controlling lice on smolts and broodstock up to 6.5kg, but are unsuccessful with larger fish (Treasurer, 1991a). Wrasse are likely to browse on a fouled mesh rather than eat lice, therefore it is important to keep nets clean. Wrasse usually live in kelp beds, and prefer to hide, therefore 'kennels' are provided in which they can shelter whilst inactive. This helps to reduce stress, affords protection from birds and encourages them away from the 'dead sock' to which wrasse normally gravitate. Small wrasse can escape or become 'gilled' in the mesh of nets, and a minimum length of 100mm for the fishery should be set (Treasurer, 1991b).

3.4.4 Problems associated with wrasse include damage to salmon by hungry wrasse if lice numbers are low. Also, wrasse may be eaten by salmon if there is too great a size difference. Goldsinny wrasse are orange in colour and are easy prey for predators such as cormorants, shags and seals.

3.4.5 A major threat to the use of wrasse in controlling sea lice is that they can contract, carry and die from furunculosis, a bacterial disease causing serious losses to farmed salmon. Injection with antibiotic during an outbreak, and vaccination of wrasse may be effective against this disease. Imports of wrasse from other regions may bring diseases into a farm, and cause it to lose its Certificated status as regards the export of carcasses. The effectiveness of wrasse is likely to decline over winter because of short daylength and the fact that the fish may be stressed by low temperature and inclement weather conditions. In the natural situation, wrasse will move to deeper water or settle among rocks during the winter (Treasurer, 1991a).

3.4.6 Fishermen are now paid as much as £2 per live wrasse delivered to fish farms. Most wrasse are caught using prawn creels, but some are caught in fyke nets which can trap otters. The Vincent Wildlife Trust have supplied over 500 net guards to fishermen to prevent this happening. There is a danger that wild wrasse populations may be overfished in the future, and the Shetland Salmon Farmers' Association and Scottish Salmon Growers' Association are funding a breeding programme at the Seafish Industry Authority, Marine Farming Unit, Ardtoe. Golden Sea Produce Ltd. also has a wrasse-breeding programme at Hunterston.

3.4.7 Wrasse can be highly cost-effective, as the initial outlay is recovered within the equivalent of four treatments with Aquagard. However, fundamental problems in the technique have to be resolved, and further research is required (Treasurer, 1991a). The biology of wrasse is being investigated at Dunstaffnage Marine Laboratory and the Marine Biological Station, Millport (funded by SSGA and Crown Estate) and the EEC is funding Trinity College, Dublin to study the use of wrasse as cleaner fish in Scotland, Ireland and the Mediterranean.

3.5 Vaccine

3.5.1 Another "clean" solution is that of immunological control through vaccination. This has the advantage that treatment is confined to individual fish. Research inspired by a very successful vaccine developed against the Australian cattle tick (*Microplus boophilus*) is underway at University College Cork, Scottish Office

Agriculture and Fisheries Department and Institute of Aquaculture, Stirling funded by the EEC, and at Plymouth Polytechnic South West, funded by Unilever and SSGA.

3.5.2 Studies into aspects of the basic molecular biology and immunology of the sea louse are being conducted with a view to producing genetically cloned parasite antigens that can be incorporated into rationalised vaccine delivery systems (Grayson *et al.*, 1991). Suggested treatment is one vaccination before going to sea, with possibly a booster after 12 months.

3.5.3 In the long term immunoprophylaxis of sea louse infestations may become more of a viable reality, but at present an effective vaccine is years from being perfected.

4 Minimising the use of dichlorvos

4.1 SWCL member bodies advocate the withdrawal of the product licence for dichlorvos at the earliest possible opportunity. This is the Government's stated intention (see 2.8). However, it is recognised that the industry would suffer greatly if dichlorvos were to be forbidden without a suitable alternative being available. The product licence for dichlorvos was provisionally extended and is to be reviewed again in June 1992.

4.2 Until dichlorvos is withdrawn or replaced, its potential for environmental damage could be reduced in a number of ways. These are principally aimed at reducing the quantities used.

a. **Timing treatments** to coincide with peaks of pre-adult lice effectively targets the susceptible moult stages which cause the most damage to fish. This is very much more economical and can save a farmer a considerable amount of money, in terms of quantities of dichlorvos and labour. The lice stages present on 5 sample fish are counted weekly, to decide when to treat. After a few weeks, lice stages become more synchronised, and a treatment will virtually wipe out lice for a longer time than with a random treatment. Many farms have found this extremely effective.

   This method works best on younger sites, and on oceanic or more isolated sites, where reinfection is largely internal, rather than enclosed sites or sites in close proximity, which have a higher risk of re- infection. This method can fail when sites become suddenly infested with sea lice from wild fish.

b. **Complete tarpaulins** are more efficacious than skirts, requiring less than half the amount of dichlorvos because it is not flushed away during treatment. Farmers often favour skirts because they are quicker and easier to position, and cause less stress to fish. Some cage designs do not lend themselves easily to complete tarpaulin use because they are large in size, or lack secure walkways, e.g. Polarcirkel, Bridgestone, Dunlop, McLennan, and Farmocean. Square cages make treatment with complete tarpaulins easier, e.g. Wavemaster, Nordik, Viking, and Kames, being generally smaller in size with a walkway around the perimeter.

   More accurate dosing is required. Current dosing is based on estimates of cage volume, which may result in an error of up to ±30%, leading to large fluctuations in the actual concentration of drug in a cage. Further amounts may be added during treatment.

c. **Longer treatment period.** A 100% kill of susceptible stages with every treatment must be achieved. One way of ensuring this is to leave the dichlorvos in cages for longer than 1 hour if the fish appear healthy. At present this contravenes the current licence regulations. This practice would pose no greater threat to the environment, and would be more devastating to lice. A review of the licence conditions would be appropriate.

d. **Fallowing** is a very effective method of clearing a site of lice. It has the added advantage that when lice infestations reoccur, the lice are less likely to show reduced sensitivity to chemical treatments.

e. **Stocking densities.** Increases in disease rates are known to correlate with increases in stocking densities. The industry should therefore aim to reduce stocking densities, with consequent benefits in terms of reduced disease and chemical use.

4.3 A fish farmer usually treating fish every two weeks might be able to reduce treatment to once a month, if the above methods were to be adopted. By failing to adopt them, farmers are inflicting unneccessary impacts on the environment, stresses on their fish, and costs on themselves (Appendix 2).

4.4 Not all farms suffer severe lice infestations. Land-based pump-ashore fish farms do not have these problems, because water flow is faster and usually drawn from deeper layers than those which sea lice frequent. Many farms in Norway are situated in deep, strongly stratified water, and in some cases fish are able to clean themselves of lice by coming up to the surface freshwater layer. Certain remote fish farms in

the Western and Northern Isles are still free of sea lice problems.

4.5 In sea cage sites, lice populations generally take time to build up and 'younger' sites will often have fewer lice than the more established sites. Farms in areas of high freshwater runoff report sudden drops in the numbers of lice present on fish, with heavy rain. Selection of sites with good flushing rates, and high freshwater inputs, accompanied by good husbandry practices such as reduced stocking densities is very worthwhile.

4.6 The introduction of strategic health management agreements between different companies sharing the same loch system, incorporating a common policy for growing fish of similar year classes, stocking with smolts of tested health status, synchronisation of treatments where possible, and site fallowing etc. is vital. Where these have been implemented preliminary reports suggest beneficial results both in reducing infestations of lice and outbreaks of furunculosis, as well as a decline in resistance patterns of lice to dichlorvos and of the furunculosis bacterium to antimicrobial medicines (SOAFD, 1991).

4.7 Although fallowing of sites to allow year class separation is strongly recommended by SOAFD for disease control purposes, only 22% of sites practised this in 1990 (SOAFD, 1990). In 1991 this figure rose to 29% but the number of sea cage sites involved in fallowing is still unacceptably low when compared to the 97% of fresh water cage sites using fallowing (SOAFD, 1991).

5 Discussion points

5.1 The use of dichlorvos is not a long-term possibility for the industry, owing to increasing resistance, risk of environmental damage, the Government's commitment to phase out dichlorvos, and market forces reflecting an increasingly sensitive consumer response to the use of toxic chemicals.

5.2 There is no immediate solution as to a replacement for dichlorvos. None of the current alternative drug therapies for the treatment of sea lice infestations in cultured salmonids have been licensed, which means that they are unavailable for use by fish farmers legally. A treatment is needed which kills all stages in the shortest possible time, necessitating fewer treatments and potentially reducing the development of resistant genes in the population. There is also a need to concentrate efforts on ecotoxicological studies to show that any compound investigated as a potential sea lice treatment is safe for the environment.

5.3 Biological control is not yet perfected to suit all sites. The ideal solution of an effective vaccine will not be realised in the forseeable future.

5.4 The use of chemicals on fish farms is subject to inadequate policing. Rumours of illegal treatments therefore persist without verification or disproof. This works against environmental, industry and consumer interests. The random sampling of grower fish by a regulatory body would reduce the potential for the use of unlicensed chemicals on fish farms.

5.5 Measures for the amelioration of the use of dichlorvos are available. Steps can be taken by SOAFD, the industry, and regulatory bodies to provide advice, training, and improved regulation, with this objective, until the use of dichlorvos is replaced. Present measures are aimed only at members of representative associations, not all operators.

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Appendix 1.

Aquagard Sea Lice Treatment
(Excerpts from the National Office of Animal Health 'Compendium of Data Sheets for Veterinary Products 1990/91')

"...the prescribing veterinarian must ensure that farm staff have received adequate instructions in safe use of Aquagard. GREAT CARE should be taken to minimise the overall quantities used. Under the Water Act (1989) and Control of Pollution Act it is necessary to consult the relevant River Purification Board or Authority ...about the proposed quantities of Aquagard to be used and the possible frequency of use. The exact timing of treatment is a matter of expertise and judgement, operators must seek the advice of the prescribing veterinary surgeon. In 10-20 days...a population count should show whether a second treatment is necessary. A third treatment may be necessary after another 14 days after which fish should be lice free for considerable periods if all fish on the site have been simultaneously treated. Affected fish need to be bathed in 2 ppm Aquagard for a period of not less than 30 minutes and not more than 60 minutes. Initial dilution of the concentrate must be carried out on land ...and placed in a sealed container for transport to the treatment cages. The cage must be completely enclosed by a tarpaulin and as a minimum a tarpaulin skirt must be used. Care must be taken with this [latter] method to assess accurately the volume to be treated and to conduct the operation at times when minimal currents are flowing. Fish must not be slaughtered for human consumption during treatment. Fish may be slaughtered for human consumption only after 4 days from the last treatment. The relevant Water Authority must also be advised of the time of use and subsequently of the quantities used. "

Appendix 2.

An estimate of quantities of Aquagard used in one year on an average site of 10 cages (12m x 12m), with heavy and light louse infestations.

1. Heavy sea louse infestation (treatments every 3 weeks for 12 months)
   i. Skirt method = 1200 ml x 10 x 17 = 204 l Aquagard per year

   ii. Complete tarpaulin method = 600 ml x 10 x 17 = 102 l Aquagard per year, saving 102 l.

2. Light sea louse infestation (3 treatments per year)
   i. Skirt method = 36 l per year

   ii. Complete tarpaulin method = 18 l per year, saving 18 l.

Using this model, in the worst case scenario of a large site of 4 banks of 10 cages (12m x 12m), with a heavy infestation, treating using skirts every three weeks, without population monitoring, 816 l Aquagard would be used in one year. At a cost of £23 per litre, this would total over £18,000.

By converting to the complete tarpaulin method, the amount of Aquagard used at any one time could be halved, representing a saving of approximately £9,000 per site at current prices. By adopting the recommendations listed in this paper, the frequency of treatment might also be halved, saving the farmer a total of £14,000 per site, and considerably reducing the dichlorvos loading on the environment.

The amount of dichlorvos currently used by the Scottish industry as a whole is estimated as 10 tonnes (20,000 l Aquagard) per year (Ciba Geigy *pers. comm.*).