

Silent Spring of the Sea

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Rachel Carson's classic book *Silent Spring* (1962) first raised public awareness of the environmental risks of human-made chemicals such as DDT, PCBs and dioxins. In her less well-known previous books, *The Sea Around Us* (1951) and *The Edge of the Sea* (1955), she marvelled at the wonders of the ocean.¹ A half-century later the sea has become a sink for a Molotov cocktail of cancer-causing chemicals and contaminants. Rivers carry pollutants from agricultural runoff, industrial discharges, hazardous wastes and human sewage. Pesticides used in terrestrial farming systems are so noxious that they have wiped out whole river systems. Hormone-disrupting compounds can even change the sex of fish. The sea, some seven-tenths of the earth's surface,² is the world's waste depository—our toxic toilet.

We have polluted our marine environment to such an extent that we are literally reaping the consequences via the bioaccumulation of contaminants up the food chain. In the Northern Hemisphere hotspots of chemical contamination—the Baltic, Mediterranean and North seas—wild fish from European waters are now eight times more contaminated than those from the South Pacific.³

As well, the World Health Organization has issued a caution acknowledging elevated pollution levels in farmed fish, saying “the risk of consuming contaminated fish must be weighed in view of the beneficial nutritive effects of fish.”⁴ A paper published in January 2004 in the prestigious scientific journal *Science* revealed that farmed salmon was contaminated with fourteen cancer-causing chemicals including DDT, PCBs, dieldrin, dioxins, chlordane, toxaphene, lindane and hexachlorobenzene. Researchers found that farmed



CARTOON BY ADRIAN RAESIDE

salmon from Scotland, the Faroe Islands and Norway were so contaminated that it is safe to eat only three to six servings a year.⁵ The salmon farming industry likes to portray itself as an innocent bystander caught up in the crossfire, but it knew as early as the 1970s that the fuel supply for farmed salmon (fish oil and meal from wild-caught fish) was contaminated with carcinogenic chemicals—well before the latest revelations in *Science*.⁶

However, the contamination issue represents only the tip of the iceberg. Not all the chemicals deposited in the sea are there by accident. Some of the same chemical companies that Carson described in *Silent Spring* as mounting a “crusade to create a chemically sterile, insect-free world” now peddle their wares for use in the sea in aquaculture.

The list of chemicals deployed since *Silent Spring* was published reads like a litany of crimes against nature: canthaxanthin, dichlorvos, azamethiphos, cypermethrin, teflubenzuron, ivermectin, emamectin benzoate, TBT and malachite green, to name those put under the microscope here. The chemical conveyor belt has been well stocked by some of the world’s largest chemical

companies: Novartis (Ciba Geigy), Hoffmann-La Roche, Bayer, Unilever, Merck Sharp Dohme, Norsk Hydro, BP, Shell, American Home Products, Cynamid and Schering Plough. As Carson so presciently warned back in 1962: “What we have to face is not an occasional dose of poison which has accidentally got into some article of food, but a persistent and continuous poisoning of the whole human environment.”

Welcome to the “Silent Spring of the Sea.”

The Chemical Arms Race

Many of the pesticides, insecticides and fungicides used by salmon farmers are derived from the Second World War’s chemical weapons programs,⁷ and the agricultural sector. As salmon farming expanded rapidly in the 1970s and 1980s, so did its appetite for new chemicals.

Just as intensive agriculture uses chemicals to treat diseases and parasites, so too does the aquaculture industry. The crucial difference between agriculture and aquaculture is that some common chemicals used in sea cage salmon farms were intended for use on land, not in the sea. Sea lice breed in their billions on factory salmon farms and are to salmon what ticks are to cattle and sheep. Yet chemicals designed for use on terrestrial livestock such as chickens, sheep and cattle simply are not suitable for use on aquatic species such as salmon. Even on land these chemicals are highly toxic, but in the marine environment their effects are magnified.

Shellfish in particular are considered collateral damage in salmon farming’s “War on Sea Lice.”⁸ Chemicals that effectively kill sea lice (until the lice build up a resistance) also affect other members of the crustacean family—including lobsters, crabs and shrimps—and other aquatic species like oysters and mussels. Besides causing immediate death, the chemicals can also produce paralysis, premature moulting and impotence in shellfish. “It is all very well to say that the fish farmers want to hit the sea lice before they spawn in March. But this is when shellfish such as crabs, lobsters and prawns also spawn, and the treatments used could hit them as well,” says Hugh Allen of the Mallaig and North West Fishermen’s Association in Scotland.

Salmon farmers’ response to the disease and parasite problem has typically not been to reduce stocking densities, scale back on production or leave the sea bed fallow so it can recover. Instead they have resorted to an ever more powerful arsenal of dangerous and hazardous weapons, pressuring agricultural chemical companies to develop novel treatments for use in aquaculture. If chemicals do not exist or are not suitable for use in the sea, some salmon

farmers merely use what is available, even if it means breaking the law and ignoring manufacturers' labels indicating the chemicals are marine pollutants, not to be used near water, let alone in water.

The illegal use of chemicals is only part of the problem. Governments' role in legalizing toxic chemicals for use in the sea is tantamount to state-sponsored pollution and borders on corruption. Chemical companies have lobbied so successfully that the decision to license chemicals is based more on political and economic expediency than consumer or environmental safety. Often governments have granted licences for toxic chemicals to be used on salmon farms before proper scientific risk assessments are carried out, or after assessments based not on rigorous (and expensive) field trials but on simulated modelling—sacrificing science for speed. There is a time lag between approval of chemical use and the publication of peer-reviewed environmental risk assessments. Scientific papers on the environmental impacts of the carcinogenic organophosphate chemical dichlorvos, for example, started to surface in the 1990s—some twenty years after it was first used, and in some cases after it had stopped being used altogether.⁹ Chemicals such as cypermethrin and emamectin benzoate have been in use since the 1990s, but risk assessments are only now being published in peer-reviewed journals.¹⁰

Other environmental risk assessments are deemed so controversial that they remain under lock and key, marked "Private and Confidential" and protected by client confidentiality clauses. For example, despite beginning ecotoxicology work on teflubenzuron in 1995, Nutreco (owners of Marine Harvest—the largest salmon company in the world) had, at time of writing, not published any peer-reviewed environmental risk assessments.¹¹ Other documents are coded so the name of the chemical is unknown.¹²

Where the name of the chemical is given, it is sometimes impossible to penetrate the veil of secrecy. For example, the original documents submitted by Ciba Geigy in the 1980s to secure a licence to use dichlorvos are still out of bounds.¹³ In response to a request to publish the documents, the Secretary of State for Scotland told the UK House of Commons in 1989: "Data has been provided by the manufacturer of Nuvan 500 EC [dichlorvos] to the Veterinary Products Committee in support of the company's application for the product to be licensed for use as a medicine. Information in support of an application for a medicinal product licence is a matter of commercial confidentiality. The publication of such information and the tests on which it is based would be a matter for the company concerned."¹⁴

It is a similar story for all of the chemical case studies considered here—

governments are allowing private companies to hide behind commercial confidentiality clauses against the public interest.¹⁵ Even work carried out by government agencies is either not published at all or is slipped out many years after the event.

Governments have given sometimes salmon farmers immunity from prosecution and virtual *carte blanche* to do as they please.¹⁶ State-sponsored chemical pollution in Scottish salmon farming was such that the UK government ignored a 1994 recommendation by the Oslo and Paris Conventions for the Prevention of Marine Pollution (PARCOM) on best environmental practice for the reduction of inputs of potentially toxic chemicals from aquaculture use.¹⁷ According to the Public Service Employees for Environmental Ethics, the British Columbia government has been in violation of its own Pesticide Control Act since 1995.¹⁸ The Norwegian government breached its international obligations under the 1990 Hague Declaration when salmon farmers were allowed to increase their use of copper-based paints after the ban on TBT,¹⁹ and the Chilean government allowed salmon farmers to use vast quantities of malachite green even after it was banned in 1995.²⁰

Even the “polluter pays” principle has been turned on its head. In a recent case in Canada, the Sierra Legal Defence Fund (a non-profit that provides free legal services for environmentalists in Canada) revealed that salmon farming companies in British Columbia were reimbursed more than \$1.7 million in fines. “Handing the fines back to the industry sends the wrong message,” said Sierra Legal lawyer Tim Howard. “It encourages companies to knowingly violate their licences, and short-changes the taxpayer.”²¹

These are not isolated cases, and they build up a picture of governments around the world bankrolling the expansion of sea cage salmon farming at the expense of both the environment and public health.

Chemical Case Studies

Chemicals used on salmon farms break down into four main groups:

- Antibiotics such as amoxicillin, oxytetracycline, oxolinic acid, sarafloxacin hydrochloride and sulphadiazine
- Artificial colourings such as canthaxanthin and astaxanthin
- Antiparasitics such as azamethiphos, cypermethrin, dichlorvos, emamectin benzoate, ivermectin and teflubenzuron
- Antifoulants such as TBT, copper and zinc-based paints

The use of antibiotics in salmon farming has been prevalent right from the beginning, and their use in aquaculture globally has grown to such an

extent that resistance is now threatening human health as well as other marine species.²² The Norwegian government's Directorate for Nature Management reported in 1999 that "during 1988–92, the mean annual consumption of antibacterial substances in Norwegian aquaculture was 29 tons, while traditional veterinary and human medicine used an average of ten to 25 tons a year in the same period. The aquaculture industry was thus the biggest contributor of antibacterial substances to the environment."²³ The directorate concluded that antibiotic use in salmon farming "may lead to an increasing number of resistant bacteria, and consequent treatment difficulties, in human medicine too."²⁴ Indeed, many of the chemicals used in salmon farming, such as oxytetracycline and amoxicillin, are also prescribed by doctors for flu and other infections.

Chile has taken over Norway's mantle as the world's number one antibiotic addict and is now using 75 times more antibiotics than Norway, which is taking its toll on both the environment and on the lucrative export market in Japan.²⁵ The abuse of antibiotics in aquaculture is a universal problem and not just confined to salmon farms—sea bass and trout farms, for example, are also showing similar signs of antibiotic resistance.²⁶

Antibiotics and vaccines (which are a whole other story) are not considered in detail here, nor are the environmental and public health threats posed by PCBs, dioxins, dieldrin, toxaphene, chlordane, DDT and other organic contaminants that bioaccumulate "accidentally" via the fish feed. Instead, the chemicals considered are those used directly and deliberately on salmon farms. I am focusing on an artificial colouring, several antiparasitics, antifoulants and an antifungal.

- Canthaxanthin (E161g)
- Dichlorvos (Aquaguard and Nuvan)
- Azamethiphos (Salmosan)
- Cypermethrin (Excis)
- Teflubenzuron (Calicide and Ektobann)
- Ivermectin (Ivomec)
- Emamectin benzoate (Slice)
- TBT (along with copper- and zinc-based paints)
- Malachite green

Artificial colourings and antiparasitic chemicals like emamectin benzoate, ivermectin and teflubenzuron are administered to farmed salmon via their feed. Antifoulants such as TBT or copper and zinc-based paints are coated onto salmon nets. For antiparasitic bath treatments like dichlorvos,

azamethiphos and cypermethrin, farmed salmon are quite literally bathed in chemicals. The method of application is unsophisticated and in the bad old days involved leaking buckets and gloves with holes in them. A Scottish government report on fish farming explains: “Some chemicals, particularly antiparasitic and antifungal agents, are used as immersion treatments and the treatment solution is released to the water after use. Cage farmers add these chemicals directly to the cage, which is surrounded by a tarpaulin skirt or complete enclosure during treatment. Once a treatment is finished the skirt is removed and the chemicals are naturally flushed out . . . In most cases, these chemicals are used in such a way that they are directly flushed to the aquatic environment.”²⁷

Bath treatments are time-consuming (it might take as long as a week to treat an entire farm) and so toxic that they can cause stress and mortalities in the farmed salmon themselves²⁸—not to mention their environmental and human health impacts. Consequently, in-feed treatments started to replace bath treatments in the late 1990s. Some farmers are even looking to inject their salmon with sea lice chemicals. A number of injectible anti-parasitics already exist for other species, and chemical companies are considering this form of delivery for salmon farming. Mass injections of farmed fish will cause some headaches. It is “impracticable to inject small fish,” and even in large fish “there is a tendency for some of the injected material to leak back along the track of the needle.” Moreover, “in the case of injection in any food animal, the implications for residues must be taken into account, especially at the site of injection.”²⁹

The following chemical case studies have some recurring themes including commercial confidentiality, political expediency, food safety and environmental impact. The focus is predominantly on Scotland (and to a lesser extent Canada), largely because the information is more accessible. Due to language barriers, the world’s number one and number two salmon farming nations, Chile and Norway, are pretty much out of bounds, although some information is slowly seeping out. Scotland is the third-largest salmon farming country in the world, producing 160,000 tonnes in 2003 (Norway and Chile produce about half a million tonnes each).³⁰ Scotland is also a microcosm of what is happening around the world. Some of the names of the chemicals may be different, but the issues are similar. The situation in the smaller salmon farming nations such as Australia, New Zealand, Ireland, the United States and Iceland may not be as bad as in Chile, Norway, Scotland, Canada and the Faroes (the big five)—but it’s not necessarily much better either.

Before considering each chemical in turn, it is important to get a handle on the global consumption of chemicals by the salmon farming industry. Due to the reluctance of government agencies to divulge details of specific use of chemicals on salmon farms, it is difficult to give actual quantities used. Norway is the only salmon farming country that publishes annual figures.³¹ The Scottish Environmental Protection Agency (SEPA) does “not hold comprehensive records of the total annual tonnages of chemicals used in the fish farming industry,” and if records do exist, “commercial confidentiality” precludes their publication (Andy Rosie, SEPA, pers. comm.). Requests to government authorities in Australia, Chile, Canada, Ireland and New Zealand met with a similar response.

However, an extensive trawl of the literature gives a tantalizing and horrifying glimpse of the global chemical use in salmon farming.³² An international survey published in 2000, for example, revealed that eleven compounds representing five pesticide types were being used on commercial salmon farms to kill sea lice: two organophosphates (dichlorvos and azamethiphos); three pyrethrin/pyrethroid compounds (pyrethrum, cypermethrin, deltamethrin); one oxidizing agent (hydrogen peroxide); three avermectins (ivermectin, emamectin benzoate and doramectin) and two benzoylphenyl ureas (teflubenzuron and diflubenzuron). The number of compounds available in any one country varied from nine (Norway) to six (Chile, United Kingdom) to four (Ireland, the Faroes, Canada) to two (United States). Dichlorvos, azamethiphos and cypermethrin were the most widely used compounds (5 countries) followed by hydrogen peroxide, ivermectin and emamectin benzoate (4 countries each), teflubenzuron (3 countries), diflubenzuron (2 countries), and deltamethrin, pyrethrum and doramectin (1 country each).³³ The situation in 2004 is probably very similar, although more countries have now licensed the use of both emamectin benzoate and teflubenzuron, and dichlorvos has been banned in several countries.

Calculating quantities of chemicals used is much more difficult, but there are some published surveys. Official government figures for annual chemical use by Scottish sea cage salmon farms were published in a private and confidential report in 1992: fourteen tonnes of formalin, 2,400 litres of vaccines, five tonnes of iodophors, 0.2 tonnes of furazolidone, five tonnes of ethoxyquin, 50 tonnes of dichlorvos, 0.3 tonnes of sulphadiazine and trimethoprim, two tonnes of chloramine T, ten tonnes of oxolinic acid, ten tonnes of oxytetracycline, 1.5 tonnes of malachite green, two tonnes of canthaxanthin, two tonnes of astaxanthin and 0.1g of methyltestosterone.³⁴

The use of chemicals on salmon farms increased during the 1990s in line with increases in global salmon farming production. For example, in 1988 there was only one “medicine”—aqualinic powder—licensed by the UK’s Veterinary Medicines Directorate for use on fish farms in the UK. By 2004 the UK government had issued over 30 licences including dichlorvos (1990), sulphatrim (1993), clamoxyl (1994), paramove (1995), azamethiphos (1996), sarafin (1997), cypermethrin (1999), teflubenzuron (1999), emamectin benzoate (2000) and pyceze (2003).³⁵ In Scotland, SEPA opened the floodgates to a wave of new chemicals in 1998 and by March 2004 it had issued over 1000 licences to use the toxic treatments azamethiphos (282), cypermethrin (311), emamectin benzoate (211) and teflubenzuron (212).³⁶ A typical “discharge consent” issued by SEPA permits salmon farms to pump over 30 different chemical formulations including antiparasitics, antibiotics, antifoulants and disinfectants into the sea.

Canthaxanthin (E161g)—An artificial pink dye linked to eye defects

The most eye-catching chemicals used on salmon farms are the artificial pink dye canthaxanthin (E161g) and a related synthetic colouring, astaxanthin, which are added to the feed of farmed salmon for “color finishing.” Several major chemical companies produce canthaxanthin and astaxanthin, including agricultural behemoth Archer Daniels Midland and Swiss pharmaceutical firm Hoffmann-La Roche, which synthetically manufactured canthaxanthin from petrochemicals in its laboratories until 2002, when it sold its “vitamin and specialty chemicals division,” Roche Vitamins, to Dutch chemical company DSM for \$2.2 billion.³⁷

Wild salmon get their pink and red colours naturally, mainly from eating krill, but salmon farmers can choose the colour of their farmed salmon with the help of the “SalmoFan,” much as you pick the right shade of pink for your bathroom wall.³⁸ DSM, which sells canthaxanthin through its “nutritional products” line under the trade name Carophyll Red, now markets the “SalmoFan Lineal”—a colour-by-numbers slide ruler that illustrates every shade of pink from bubble-gum bright to dusty rose.³⁹

Pink dyes can account for up to a third of all feed costs. For salmon farmers, though, it is a price worth paying. Strip farmed salmon of canthaxanthin and it is an unappetizing dirty grey in appearance. A consumer survey conducted by Hoffmann-La Roche found people put a premium on colour and are willing to pay much more for redder salmon. “Consumers perceive that redder salmon is equated to these characteristics: fresher, better flavour, higher

quality and higher price . . . consumers felt that a salmon with a colour of 22–24 [on the “SalmoFan”] should be less expensive and a well coloured salmon, 33–34, would be the most expensive.”⁴⁰

Farmers using artificial colouring are deliberately confusing consumers, making money out of public ignorance, and endangering public health. Canthaxanthin has been liberally applied to farmed salmon since at least the 1980s despite fears that it can cause cancer. In 1990 the *Independent on Sunday* reported that levels of canthaxanthin in farmed salmon on sale in UK supermarkets exceeded safe levels,⁴¹ while in 1992 the Scottish government admitted that “some concern has been expressed over the possible carcinogenicity of canthaxanthin, used to produce coloured flesh in farmed salmon.”⁴²

According to writer Linda Forristal: “There has been one reported death from aplastic anemia (failure of the bone marrow to manufacture red blood cells) attributed to the use of canthaxanthin as an oral tanning agent,”⁴³ and the scientific evidence of canthaxanthin’s impact on the eye is extensive and dates back as early as 1987.⁴⁴ Hoffmann-La Roche knew even earlier than that. In 1986 the company wrote to a customer: “In investigations originally carried out in Canada, and more recently in Germany, a number of people who had been taking Canthaxanthin tanning preparations at high levels, for prolonged periods of time exhibited as a side effect a so far unexplained phenomenon which the authors describe as glistening, apparently crystalline deposits in the inner layer of the retina of the eye, in particular, around the macula. In some of the subjects investigated, sensitive ophthalmological tests revealed, slowing down of light-darkness adaptation of the eye, though the clinical significance of this remains to be fully determined. This functional disturbance is reported to regress on discontinuation of the Canthaxanthin tanning preparation. The deposits in the retina, however, have not been observed to regress, but remain in place without apparent impairment of vision, perception of color or field of vision.”⁴⁵

But while Hoffmann-La Roche considered it unsafe to take canthaxanthin via tanning pills, it still made millions selling canthaxanthin and astaxanthin to salmon farmers throughout the 1980s, 1990s and the current decade. Intense lobbying by Hoffmann-La Roche and the salmon farming industry has ensured that salmon farmers’ “pink poison”⁴⁶ has been protected by the powers that be. In 1987 the UK government acted as a sponsor to Hoffmann-La Roche’s scientific submission on canthaxanthin.⁴⁷ Scientific studies on health impacts of canthaxanthin, submitted by Hoffmann-La Roche to the World Health Organization and the European Commission,

were classified as commercially confidential, and consumers were kept in the dark.⁴⁸

In 1997 the European Commission's Scientific Committee on Food recognized the link between canthaxanthin intake and retinal problems but it was not until the EC's Scientific Committee on Animal Nutrition published a damning scientific opinion in April 2002 that the European Commission ordered Irish and Scottish salmon farmers to reduce levels of canthaxanthin by three to four times by December 2003.⁴⁹ The EC report set out all the scientific evidence linking canthaxanthin to retinal damage in the human eye and also revealed that since 1982 the levels of artificial colourings in the flesh of farmed salmon have more than trebled. Farmed salmon is getting pinker—chemical companies are getting richer.

The industry protested. “You have to consume enormous quantities of canthaxanthin before there is even the potential for damage to your eyesight,” said Julie Edgar, the communications director at Scottish Quality Salmon (formerly the Scottish Salmon Growers Association).⁵⁰ She told the *Financial Times* that sales of Scottish farmed salmon were now threatened in France. “They judge our salmon a lot on its colour.”⁵¹

Scottish and Irish salmon farmers did have the option to switch to astaxanthin, but the crux of the matter is cost: canthaxanthin is much cheaper than astaxanthin. Scottish salmon farmers estimate that the switch to astaxanthin



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Salmon farmers use the Salmofan™ to grade the degree of pink the flesh of their salmon attains through the use of Canthaxanthin. Deeper shades of pink fetch higher prices in the marketplace.



The Institute for Agriculture and Trade Policy's "Go Wild" campaign targets American consumers of farmed fish.

“could increase the cost of finished feed from around £65 per tonne to £80–£85 per tonne”—equivalent to £6 million per year.⁵² Moreover, even the switch to astaxanthin is not without consumer concerns. When the EC’s Scientific Committee on Animal Nutrition gave its opinion on canthaxanthin, it also recommended a food safety risk assessment of alternative artificial colourings, including astaxanthin.⁵³

Of course, salmon farmers outside the European Union—in Norway, Chile, Canada, etc.—are exempt from the EC ruling and can continue to use canthaxanthin as long as they’re not selling product in Europe. But if they do not see the sense of banning artificial colourings from their salmon altogether, they should at least come clean and inform consumers that salmon contain these dyes. The European Commission is now looking into labelling of both canthaxanthin and astaxanthin in farmed salmon (Beate Gminder, pers. comm.). The US already requires labelling, although supermarkets such as Safeway, Albertsons and Kroger have been accused of not following the law.⁵⁴

Labelling would certainly have helped Linda Forristal. “It all started innocently with a delicious salmon dinner after a day’s sightseeing in the Canadian Maritimes,” she explains. “By midnight, I was itching inside and out, as if every blood vessel were dilated. Three days later, another salmon meal provoked an even worse reaction. That’s when I discovered farmed salmon contain food dyes.”⁵⁵

Dichlorvos (Nuvan or Aquagard)—A carcinogenic organophosphate that is the skeleton in salmon farming’s closet.

Dichlorvos (also known as DDVP) is a highly toxic organophosphate originally used by farmers and gardeners to control pests. Like many OP insecticides it disrupts the nervous and muscular system. Related to the military nerve gases developed in the Second World War, dichlorvos is one of the most toxic pesticides in the world. It was first registered in 1948 as an insecticide for use in agriculture and the home (trade names include Doom and Vapona). On salmon farms, the dichlorvos formulation is called either Nuvan or Aquaguard (manufactured by Ciba Geigy—now known as Novartis). It was the first sea lice chemical to be used on salmon farms in the 1970s in Scotland and Norway and was also used extensively in Canada, Ireland, the Faroes and Chile. It is carcinogenic, mutagenic and hormone-disrupting—a so-called gender bender.

The National Poisons Unit describes dichlorvos as “toxic if swallowed,” “very toxic by inhalation” and “toxic in contact with skin.” It is treated as a “Red List” chemical under the European Commission’s Dangerous Substances Directive⁵⁶ and is listed under the UK Poisons Regulations 1982, with harmful effects to humans from acute exposure and cumulative toxicity from repeated exposure to low doses.⁵⁷ The World Health Organization classifies it as “highly hazardous.” Containers of dichlorvos must be labelled with the skull-and-crossbones warning sign and the following instructions for use:

“Wear protective gloves, clean protective clothing goggles, and a respirator of the organic-vapour type when handling this material. Avoid prolonged exposure to fumes. Wash hands and exposed skin after handling and before eating and bathe immediately after work. Keep the material out of the reach of children and well away from foodstuffs, animal feed and their contain-



The makers of Nuvan, a product used to control sea lice, label their product with the skull-and-crossbone symbol for poison. Nuvan is 50% dichlorvos, a nerve toxin.

ers. Ensure that containers are tightly sealed, and stored and disposed of in such a way as to prevent accidental contact.”⁵⁸

Dr. Ted Needham (now boss of Heritage Salmon in Canada) first used Vapona fly-strips against sea lice in trials at Marine Harvest’s Lochailort farm (then owned by Unilever, now by Nutreco) in Loch Ailort, Scotland. He chose dichlorvos because of its wide margin of error in killing sea lice and fish, and because the chemical was readily available for use in the agriculture sector. Needham first applied dichlorvos to salmon by dangling fly-strips in the water of the net pens.⁵⁹ (Nearly 25 years later, the same type of fly-strips Dr. Needham dangled in the water on a salmon farm were banned by the UK government after they were shown to cause cancer.⁶⁰)

Following these experiments in Loch Ailort, reports on slightly more professional experiments using buckets of dichlorvos were published by the Royal Society of Edinburgh in 1982.⁶¹ Gordon Rae, a consultant for Scottish Quality Salmon up until 2003, when he died of cancer, described using dichlorvos in a *Fish Farmer* magazine article in 1979. Alongside is a photo of a fish farm worker pouring the carcinogenic chemicals into a sea pen with a plastic bucket. The worker has no gloves, mask or other safety equipment.⁶²

Dichlorvos baths were a health hazard for the operator, the marine environment and the farmed salmon themselves. According to the Marine Conservation Society in 1988: “Not all farmers use tarpaulins or calculated quantities of Nuvan, resulting in considerable variability in the concentrations and over-use . . . One farm operator described the method of treatment to us as follows: ‘Up to 30 cages can be treated together in an hour. No tarpaulin is used. The Nuvan is poured in at one end of the cage unit and is allowed to flow through with the tide, topping up the concentration at each cage. About 300–400 ml is used per cage. Treatment occurs four or five times per summer’. This would result in approximately 10.5 litres of Nuvan being used in one treatment of a group of 30 cages.”⁶³ Dr. Ron Wootten of the Institute of Aquaculture at the University of Stirling told a House of Commons inquiry (1989–90) that dichlorvos was added to the water at slack tide, “which is frankly unacceptable as there is no containment and the stuff is just poured into the water.”⁶⁴

In 1989 the police, local schools and the Scottish environmental protection agency were alerted after one company lost several litres of dichlorvos in Loch Sunart after they were blown into the water. An SOS went out for the missing bottles and a search party scoured over 90 kilometres of coastline. Dr. Paul Johnston, a toxins expert at London University and a Greenpeace

researcher, said: “[Nuvan] is in fact a nerve poison which could be deadly—especially if a child opened a bottle and took a deep sniff. It is environmental lunacy to keep this substance in a place where it can be blown into the water.”⁶⁵ Following this embarrassing incident, Ciba Geigy, the chemical manufacturer of dichlorvos, was asked to provide better labelling—it was discovered that the Nuvan bottles’ skull-and-crossbones warning labels washed off in salt water.⁶⁶

The casual attitudes for using and storing dichlorvos are reflected in the quantities used. Although a Scottish government report detailing specific use of dichlorvos on each farm is still deemed private and confidential almost a decade after it was written,⁶⁷ it is possible to piece together some numbers from files obtained under the European Union’s Freedom of Environmental Information regulations. Another private and confidential report from 1991 details how just two salmon farms operated by Marine Harvest had been using an average of nearly half a tonne (414 kg) of dichlorvos per year over the previous four years.⁶⁸ By 1989, Marine Harvest was using nearly three tonnes (2,920 kg) of Nuvan (50 percent dichlorvos) in Loch Ailort alone. A 1992 Scottish government report calculated dichlorvos use at a staggering 50 tonnes per year.⁶⁹

Despite its widespread use across Scotland, dichlorvos was not granted a product licence by the UK government until June 1989. Even though the original risk assessments carried out in the 1970s remained private and confidential,⁷⁰ and, according to an article in *New Scientist*, Ciba Geigy admitted in 1988 that dichlorvos was not meant to be used on salmon farms,⁷¹ the government caved in after intense lobbying by the industry, which basically said, “Let us use dichlorvos or we go under.” Dr. Ron Wootten told the House of Commons inquiry into fish farming (1989–1990): “The crucial question as far as the industry is concerned is that without dichlorvos there would not be a salmon farming industry; there is absolutely no question of that.”⁷²

Ali Ross of the Marine Conservation Society argued against licensing at the inquiry. “You have to remember that it is now well over thirteen years since the chemical was first brought into use in the marine environment. It has been widely used and is now universally used by the industry and yet there are still substantial gaps in our knowledge on its environmental fate and potential impacts . . . We still have no published data from the Ciba-Geigy research that they submitted to the VPC [Veterinary Products Committee] and we have no published data from the DAFS research that is quoted in that paper; there has been no evidence that has been open to public scrutiny. As far as we are con-

cerned, nothing has been presented yet that make us doubt the severe reservations we have about the continued and growing use of this chemical . . . What causes great concern to us is that any judgment that is now made on the chemical is not just going to be a reflection of the scientific evidence that is presented supporting the case, but it is also going to be a reflection of the economic or political implications on the industry.”

When the government issued the product licence, Ross’s response was: “To give the impression that this stuff is environmentally friendly is immoral. If it wasn’t for the fact that the substance was already being widely used by fish farmers, I am sure that it would never have been granted a licence. But as it is, environmental concerns have been quashed in favour of economic pressures.”

Once it was legal, Scottish salmon farmers became so liberal in their application of dichlorvos that they used five times more than the combined consumption of the UK farming, pest control and household sectors. According to the Department of the Environment, in 1991 the annual usage of dichlorvos on Scottish salmon farms was ten to twenty tonnes compared to two to three tonnes for the entire terrestrial farming sector.⁷³ This was despite the fact that the UK government was committed to reducing inputs of dangerous chemicals, including dichlorvos, in the sea under international law. Dichlorvos was one of 30 “Red List” dangerous substances that the UK government had agreed to reduce by 50 percent by 1995.⁷⁴

By the late 1980s sea lice had developed a resistance to dichlorvos.⁷⁵ This meant higher and higher doses were required, and it took days to administer a treatment. Mark Jones of the Fish Vet Group describes the cycle: “Nuvan, later known as Aquaguard (dichlorvos) . . . only ever killed the larger, mobile stage pre-adult and adult lice. The safety margin for the fish was low, and with frequent repeated treatments required to remove successive waves of mobile stage lice, resistance developed quickly, necessitating increases in doses and/or exposure times in order to successfully remove the lice. This led to poor treatment success and many cases of repeated overexposure of fish leading to treatment kills. In addition, the concentrated product was dangerous for the handler, who risked long term health consequences in the event of repeated exposure.”⁷⁶ In 1998, Marine Harvest Scotland admitted that a typical year class of farmed salmon could have as many as 22 treatments of dichlorvos.⁷⁷ The *Sunday Herald* reported in January 2002 that “according to some estimates, Scottish salmon farmers used a staggering 500 tonnes of dichlorvos through the 1970s, 1980s and 1990s.”⁷⁸

Dichlorvos was also used extensively across Norway. Trichlorfon (which

breaks down into dichlorvos in seawater) was developed to kill sea lice in the mid-1970s before making way for the more potent Nuvan in the 1980s. Trichlorfon (manufactured by Bayer under the trade name Neguvon) was legally used in Norway until 1995, while dichlorvos was legal between 1987 and 1997.⁷⁹ Norwegian aquaculture used 3,488 kilograms of dichlorvos in 1989 and 3,588 kilograms in 1991, falling to 1,147 kilograms in 1994 and 161 kilograms in 1996.⁸⁰

In the mid-1980s, Norwegian studies began to appear proving how toxic dichlorvos and trichlorfon were to shellfish such as lobsters, crabs, mussels, oysters and even other fish species such as herring.⁸¹ The Canadian government also knew how dangerous dichlorvos was in the 1980s, yet it allowed salmon farmers in British Columbia and New Brunswick to use the substance throughout the 1980s and 1990s.⁸² In 1988, a private and confidential Canadian report stated: “Unpublished work sponsored by Ciba-Geigy, the manufacturers of Nuvan, has shown larval lobsters to be lethally affected by dichlorvos at a concentration of 0.033 ppm after twenty hr.”⁸³ Even farmed salmon can suffer OP poisoning from dichlorvos.⁸⁴

The Canadian government discovered that the dichlorvos formulation Aquaguard, which contains the solvent di-n-butylphthalate (DNP), was even more toxic to Atlantic salmon than dichlorvos alone. DNP is a really nasty piece of work and belongs to a class of compounds called phthalate acid esters (PAEs) that disrupt hormones and are on the priority list of most dangerous pollutants in Canada and the United States.⁸⁵ The industry calculated in 1993 that approximately eight tonnes of DNP had been released into the marine environment through aquaculture.⁸⁶

Unpublished reports showing high levels of toxicity of dichlorvos date back over 40 years.⁸⁷ Information from the UN’s Food and Agriculture Organization, for example, reveals that secret trials conducted since the 1960s detected dichlorvos residues in a wide range of foodstuffs including lettuce, rice, barley, wheat, cocoa beans, milk, cheese and meat.⁸⁸ Given the extensive use of dichlorvos in salmon farming, it is not at all surprising that Norwegian scientists detected dichlorvos in the flesh of farmed salmon in 1990.⁸⁹ Residues of dichlorvos were also found in farmed salmon on sale in supermarkets in the UK in the same year. Tests conducted by a Sunday newspaper made front-page headlines across Britain.⁹⁰

Yet the Scottish, Irish, Norwegian and Canadian governments allowed salmon farmers to use dichlorvos throughout the 1980s and 1990s⁹¹ until a scientific paper published in 1998 linked dichlorvos use on salmon farms to

testicular cancer.⁹² A team of scientists led by Professor Cecily Kelleher of National University of Ireland, Galway, found significant clusters of testicular cancer in salmon farming areas such as County Galway and Mayo. Researchers investigated the incidence of leukemia, lymphoma and testicular tumours in western Ireland between 1980 and 1990 and “found a significant increase in testicular tumours in agricultural workers other than farmers, albeit with very small numbers; this group comprised predominantly those engaged in fish farming.”⁹³ Unfortunately, this Irish study is the only known study of its kind, and there are no plans to conduct further research (Prof. Cecily Kelleher, pers. comm.). Further studies are urgently required in other salmon farming countries where dichlorvos use has been widespread. The German Federal Environment Agency has listed trichlorfon (which breaks down into dichlorvos) as a potential endocrine disrupter that can cause mammary tumours and affect sperm and egg production, while a cluster of Down’s syndrome children in Hungary was associated with consumption of fish excessively contaminated by trichlorfon.⁹⁴

The whole sorry saga should have ended in 1999. Novartis claims it “voluntarily withdrew Aquaguard from the market in November 1999 because it was superseded by Salmosan [active ingredient: azamethiphos], which is a clinically superior product.”⁹⁵ However, the UK Department of Health did not finally ban dichlorvos until April 2002, after a damning report on its carcinogenicity in July 2001.⁹⁶ Yet extensive scientific evidence on the carcinogenicity, mutagenicity, and public health and environmental impact of dichlorvos had been available from the National Cancer Institute, World Health Organization, US National Toxicology Program and US Environmental Protection Agency since the early 1970s.⁹⁷

Despite the UK ban, SEPA admitted in March 2004 that “around 20” Scottish salmon farmers were still permitted to use dichlorvos.⁹⁸ With staggering contempt for both the marine environment and public health, SEPA stated that “the process of going through registers to find all the Dichlorvos consents, so that they could be withdrawn, would deflect scarce manpower from the task of processing applications for the use of the current sea lice treatments.”⁹⁹

As early as 1988, Friends of the Earth Scotland warned of the cancer risk of dichlorvos use on salmon farms. FoE claimed a number of workers had been admitted to hospital with symptoms of Nuvan poisoning, such as severe nausea, headaches, dizziness and pupil dilation; some employees were being denied proper clothing, making the health risk even greater.¹⁰⁰ Reports from

the National Poisons Unit show that between 1983 and 1990, 98 individual cases of poisoning involving dichlorvos were reported in the UK alone. It is not known how many of these cases relate to dichlorvos use on salmon farms, as information previously held by the UK government has been mysteriously “lost over time.”¹⁰¹ However, since salmon farmers used up to five times more dichlorvos than all other sectors, the industry is likely to account for a significant number of the 98 reported cases. The Health and Safety Executive’s Pesticide Incident Appraisal Panel (1987–1993) did record a dichlorvos poisoning incident with the following sketchy details: “A 25 year old male worker became dizzy and nauseous whilst working in a hut used to prepare a sea lice treatment product Nuvan 50 EC.”¹⁰² Requests for further information have been refused by the UK government.

Occupational exposure is one thing, deliberate poisoning is another. In 1998 the Environmental Working Group published a report called “The English Patients,” revealing how students at the University of Manchester had been treated with dichlorvos.¹⁰³ A California pesticide company hired a lab in England to conduct feeding trials using people to test the toxicity of dichlorvos. Hard-up students were actually paid to eat dichlorvos.¹⁰⁴

Unsuspecting consumers of farmed salmon may have been paying for the same privilege for years. Norwegian, Scottish, Canadian, Chilean and Irish salmon farmers have all been unwitting guinea pigs in an authorized and highly irresponsible experiment lasting over three decades. These experiments could be coming back to haunt the salmon farming industry. According to the *Sunday Business Post*, a fish farm worker is suing a west of Ireland fish farm, claiming he developed testicular cancer while working with dichlorvos.¹⁰⁵

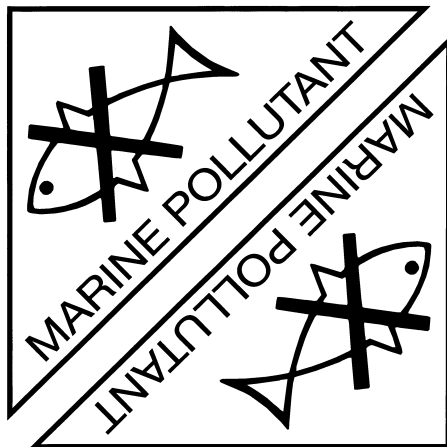
In another legal action in Scotland, an ex-worker is claiming damages for health impacts he claims are related to an incident involving dichlorvos over a decade ago. On May 28, 1990, James Findlay says he was delousing fish, protected only by overalls and a small mask provided by his employer. Aquaguard SLT, much more poisonous than dichlorvos alone, was added to a bucket of water and he was shown how to sluice it over the fish cages. As he did so, the bucket slipped in his hand and its contents went all over his head, face, shoulders and upper body. “I felt an immediate burning sensation and I wrenched the mask off, shoving my head forward to stop anything running into my mouth,” recalled Findlay. “My eyes were burning, my shoulders seemed heavy. I was disorientated, I felt like I was floating. I knew I had to get ashore.”¹⁰⁶ It took over three hours for Findlay to get to a hospital in Inverness, where he was given an antidote.

Azamethiphos is marked as a marine pollutant by its manufacturers. It replaced *dichlorvos* as a treatment for sea lice in the 1990s.

According to Findlay: “The medical prognosis is not exactly cheerful. My once very high IQ has been reduced by neuropsychologists to below average and I appear to have a form of autism when confronted with facts and figures and rapid analysis. I already have creeping paralysis and face total paralysis, further brain deterioration including dementia, numerous potential cancers, rapid ageing of the cells and, of course, early death. I live with depression, irritability, allergies, food intolerances, chronic pain and fatigue alongside tremors, panic attacks—you name it. Most painful of all, I have been told that I am sterile. I will never have the child or children I’d hoped for. It is just as well, because all the evidence suggests that if I did father a child the chances of genetic abnormalities would be incredibly high. Once I had a life of real promise. Is it any wonder that I expect someone, some company, some multinational to apologise and ultimately to pay for this?”

As Fidelma Cook of the *Mail on Sunday* concluded in her article on the case: “If successful in his claim, which could amount to tens of thousands of pounds, Mr. Findlay could open the floodgates to others who, despite worldwide studies backing their claims, have been denied any redress against the chemical industry, government and employees.” Cook also pointed out that “farmers, Gulf War soldiers and even children who have been given head lice treatment have all been potential victims of the powerful pesticide which was first warned about back in the 1950s. Some opponents even suggest that the pesticide could have been responsible for BSE in cattle.”¹⁰⁷

Professor Malcolm Hooper, emeritus professor of medicinal chemistry at the University of Sunderland and chief scientific advisor to the Gulf Veterans Association told the *Mail on Sunday* that he had examined Findlay and was prepared to go to court on his behalf: “James is a victim of government compromise . . . It all comes down to commerce and cash and, as far as I’m concerned, the chemical industry is being protected by government.” This skeleton in the closet looks set to rattle salmon farmers for years to come.



Azamethiphos (Salmosan)—An organophosphate nerve poison

When sea lice built up resistance to dichlorvos in the 1990s, farmers started flooding sea cages with a chemical ten times more toxic—azamethiphos, another organophosphate insecticide that affects the central nervous system.¹⁰⁸ Like dichlorvos, azamethiphos is manufactured by the Swiss-based chemical company Novartis (formerly Ciba Geigy) and sold for use on salmon as “Salmosan.” It is authorized for use in Scotland, Norway, the Faroes, Canada and Chile.¹⁰⁹

Also like dichlorvos, azamethiphos is poured directly into the marine environment, even though the manufacturer clearly warns against such use. For example, Novartis’s safety data sheet for azamethiphos states: “Very toxic to fish.” In capital letters it is marked as a “MARINE POLLUTANT.” Under “Accidental Release Measures” the sheet warns: “Do not contaminate water courses or sewers.”

There is nothing accidental about salmon farming’s use of azamethiphos. The European Agency for the Evaluation of Medicinal Products stated in 1999: “The proposed use of azamethiphos in fish farming means that deliberate contamination of the environment will occur.”¹¹⁰ The Canadian government seemed to anticipate “accidental” releases of azamethiphos when it said: “The nature of the salmon aquaculture industry in southwest New Brunswick is such that many farms are in close proximity to each other and to area of traditional lobster fisheries. Caution must be exercised to avoid an accidental release of significant quantities of these pesticides in sensitive areas.”¹¹¹

Azamethiphos was licensed for use on Norwegian salmon farms in 1994,¹¹² and official figures from Norway show that salmon farmers were using almost twice as much azamethiphos (738 kg) as dichlorvos (395 kg) by 1995.¹¹³ The Norwegian Directorate for Nature Management reported in 1999 that “from 1993 to 1996 the use of the ‘old’ organophosphates dichlorvos and metriphosphate (trichlorfon) plummeted—in excess of 90 percent reduction. In the same period, the consumption of azamethiphos doubled.”¹¹⁴

Canadian salmon farmers were given “emergency authorization” to use azamethiphos in 1996, and it received a marketing authorization for use in Scotland in 1997.¹¹⁵ SEPA started issuing licences for azamethiphos in 1998, despite admitting that “compared to dichlorvos, azamethiphos is more toxic to crustaceans” and that “there has been no short term study of the acute toxicity of azamethiphos to lobster larvae.”¹¹⁶ By March 2004 SEPA had issued 282 licences to use azamethiphos across Scotland.¹¹⁷

As in the case of dichlorvos, reports on the toxicity of azamethiphos were kept confidential by the chemical companies involved. For example, a 1992 report on the environmental assessment of azamethiphos is marked “Confidential to Ciba-Geigy Agriculture.” It noted the chemical’s toxicity to lobster larvae and also reported azamethiphos residues in the flesh of farmed salmon, but concluded bizarrely that: “Exposure of the general population to azamethiphos through treated fish should be negligible and should not constitute a health hazard. In spite of its toxicity, provided that the manufacturer’s instructions are followed, azamethiphos should not constitute an undue hazard to those who are occupationally exposed.”¹¹⁸ Another report on “eco-chemistry and ecotoxicity” of azamethiphos remains the private property of Ciba-Geigy Agriculture and has never been published.¹¹⁹

A risk assessment published in 1999 by the European Agency for the Evaluation of Medicinal Products indicated that “azamethiphos was mutagenic” but “overall, it was concluded that azamethiphos was not carcinogenic.”¹²⁰ A slight improvement on the confirmed carcinogen dichlorvos perhaps, but not for the farmed salmon themselves, as the agency reported azamethiphos has a “very low therapeutic margin of safety in the target species, salmon.” In other words, use too much of it and you end up killing your entire farmed stock. Mass mortalities from overdoses of both dichlorvos and azamethiphos have been reported across the industry—not surprising since farmed salmon are bathed in azamethiphos for up to an hour, and it takes up to a week to treat a whole farm. Nor is it a one-off hit. In 2000, Hydro Seafoods (now called Scottish Seafarms) “anticipated that 6–10 whole site treatments might be required per year.”¹²¹

More recent studies have shown that even tiny concentrations of azamethiphos kill young lobsters.¹²² The Department of Fisheries and Oceans in Canada reported in 2000 that “lobsters exposed to azamethiphos became agitated, often ‘flopping’ erratically around the exposure tank and became aggressive to other lobsters.” Moreover, “they also seemed to lose control of their claws and eventually flipped onto their backs and died within hours.” Signs of distress were recorded in adult lobsters at even ten percent of the recommended treatment concentration.¹²³ Since azamethiphos is a nerve poison, these findings are not altogether surprising.

The Scottish government has also admitted that azamethiphos (and cypermethrin) can cause shellfish poisoning and toxic algal blooms.¹²⁴ The link between chemicals such as azamethiphos and the stimulation of algal blooms was one of the driving forces behind an ongoing UK government

study—“The Post-Authorisation Assessment of the Environmental Impact of Sea-Lice Treatments Used in Farmed Salmon.”¹²⁵ Unfortunately this five-year study, which began in 1999, has still not been published.¹²⁶

As well as the environmental impacts of azamethiphos, the direct human health effects have been investigated by the UK government. According to the Veterinary Products Committee in 1999: “Two areas of potential concern were noted. First, neurotoxicity studies did not meet modern standards. Secondly, no data on operator exposure were available.” The most recent neurotoxicity study was carried out in 1991.¹²⁷ To plug the safety gaps, Ciba Geigy was asked to provide further information to the Advisory Committee on Pesticides in another clear-cut case of conducting risk assessments after the event. In 2001 the UK government recommended additional conditions on the use of azamethiphos.¹²⁸ By the time safety studies had been completed, sea lice were building up resistance to azamethiphos (and cross-resistance with dichlorvos), and though it was still considered a “very useful sealice treatment,”¹²⁹ it was already being phased out in favour of other chemical treatments such as cypermethrin, teflubenzuron and emamectin benzoate.

Cypermethrin (Excis)—A suspected “gender bender” and carcinogenic “neuro poison”

Cypermethrin (along with ivermectin) was the first in a new wave of chemicals replacing the organophosphates dichlorvos and azamethiphos.¹³⁰ It was developed by Shell (now American Cyanamid) in the 1970s to control fleas, ticks, blowflies and lice on chickens, horses, cattle and sheep. Cypermethrin, a synthetic pyrethroid and neuropoison, has been used as a bath treatment on salmon farms since the mid-1990s. By 2002 it had been licensed for use in Norway, Ireland, Scotland, the Faroes, the United States and Chile under the trade name Excis (manufactured by Novartis). Two related compounds, deltamethrin (Alphamax) and high-cis cypermethrin (Betamax), are also available in Norway and the Faroes.¹³¹

There could be few worse replacements for the banned carcinogen dichlorvos. Synthetic pyrethroids are among the most potent pesticides and are hazardous to human health as well as to the environment.¹³² According to the UK government, synthetic pyrethroids are “around 100 times more toxic to some elements of the aquatic environment” than organophosphates.¹³³ In a 1996 incident in Canada’s Bay of Fundy, cypermethrin-contaminated effluent from a salmon farm was alleged to have caused the death of 44 tons of lobsters in a nearby lobster pond.¹³⁴ Pyrethroids have also been shown to be up to

1,000 times more toxic to fish than to mammals and birds.

Cypermethrin is a suspected hormone-disrupting compound—like dichlorvos and TBT—and can even affect reproduction in wild salmon.¹³⁵ Using it in sea cage salmon farms is difficult to defend on either environmental or public health grounds. Perhaps this explains why obtaining information is so difficult. As there was for dichlorvos, there has been a great deal of secrecy and complicity between government and chemical companies in securing the use of cypermethrin. Documents detailing its environmental impacts have either been kept “private and confidential” or were only published years after cypermethrin was first used.¹³⁶

Cypermethrin, deltamethrin and permethrin were used extensively in “field trials” in Norway from as early as 1989 and used commercially across Norway from the mid-1990s.¹³⁷ According to the Norwegian Directorate for Nature Management, “cypermethrin was being increasingly used against salmon lice in 1996.”¹³⁸ Norwegian salmon farmers used 215 kilograms of cypermethrin in 1997, falling to 69 kilograms in 2000 as sea lice became resistant.¹³⁹

Field trials took place in Scotland as early as 1994 but were never published.¹⁴⁰ Trials also took place in Canada in 1996 but were not published until 2001.¹⁴¹ Cypermethrin was not officially permitted in Scotland until 1999, yet in 1998 Wadbister Offshore Ltd. was fined £1,000 under the Control of Pollution Act when residues of cypermethrin were detected in mussels growing near Wadbister’s salmon farms.¹⁴² These incidents prompted the government to launch a program of screening for residues of cypermethrin in mussels and farmed salmon.

The illegal use of cypermethrin spread like a nasty rash across Scotland. “We were spraying this stuff all over the fish and inhaling it,” whistle-blower Jackie Mackenzie told *The Observer* in 2000.¹⁴³ In the first signed testimony by a salmon farm worker alleging the illegal use of chemicals, Mackenzie described to me how Ardesie Salmon, then members of Scottish Quality Salmon, used Deosan Deosect (an illegal cypermethrin-based chemical): “The method used was to raise nets on the sea-cages to three metres and then surround pens with skirts and treat fish for one hour with a top-up after half an hour. When severe head shaking occurred in the fish pen, the treatment had to be aborted. We had a water pump affixed to a tank with sea-water and Deosan Deosect mix. It was then pumped into the cage via a sprinkler hose which dispersed the chemical. When treatment was finished we had to hand-ball the tarpaulin skirts back onto the boat-pontoon.”¹⁴⁴

Deosan Deosect is designed for use on chickens and horses. The manufacturer, Fort Dodge Animal Health (owned by American Home Products), classifies it as a marine pollutant. The label clearly warns: “Dangerous to fish and other aquatic life . . . Do not contaminate ponds, waterways or ditches with the product.” A vet at Fort Dodge Animal Health told *The Observer*: “As far as marine life goes it is as toxic as you can get.”¹⁴⁵ Subsequently a second whistle-blower stepped forward. “We used cypermethrin so many times I lost track,” Jonathan Davis testified live on the BBC evening news.¹⁴⁶

In 2001, empty cypermethrin containers washed up on a Shetland beach close to a salmon farm.¹⁴⁷ These were containers for Barricade, not Excis, the compound authorized for use by salmon farmers. A SEPA spokesperson told the *Shetland Times* that a fish farm could have saved thousands of pounds by using Barricade to treat sea lice instead of an approved product.¹⁴⁸ For salmon farmers wanting to cut costs, Barricade is readily available on the internet or via mail order.¹⁴⁹

Writing in *The Scotsman*, BBC journalist Tom Morton, who lives in Shetland, pulled no punches: “Evidence emerged last week of callous, stupid malpractice within the industry when it comes to the use of illegal toxins. What happened was this: three empty tins of a substance called Barricade were dredged up from the seabed east of Shetland, amid a spread of salmon farms so intense you can barely see the water for cages. Barricade is used in the treatment of lice and fleas, on horses, and contains cypermethrin. It is an open secret that it offers fish farmers a cheap method of treating their stock—in a dangerous and wholly unscientific way—for sea lice. Saving thousands of pounds over approved methods. The Scottish Environmental Protection Agency was, understandably, annoyed. SEPA stipulates that cypermethrin is only used ‘under the strictest conditions’, including the full enclosure of the farm concerned and with monitoring to make sure the chemical disperses properly. But if you pick up some horse lice liquid, you can use as much as you like, where you like, whenever you like. And if it kills a few hundred lobsters and scallops, who cares? Well, I care. I’m sick of this arrogant assumption by salmon farmers that their right to profit comes before the environment I live in. They are poisoning our seas, and they are doing it with impunity. I did learn to like salmon. But, like most fisheries journalists I know, I won’t be eating the farmed version again.”¹⁵⁰

On the other side of the Atlantic, salmon farmers in Maine were using legal and illegal versions of cypermethrin in 1997,¹⁵¹ and SEPA reported in 1998 that “there is some illegal use of cypermethrin in Canada, often at night

using high concentrations and no tarpaulin.”¹⁵²

Even when used legally, cypermethrin can cause fatal and sub-lethal impacts on a wide range of marine species including lobsters, crabs, mussels and salmon. Scientific research in Scotland, for example, has shown that high concentrations of cypermethrin cause valve closing in mussels¹⁵³—not an ideal situation for a mussel farmer trying to earn a living next door to such a noxious neighbour. The same researchers also found impacts of cypermethrin on shore crabs.¹⁵⁴

The environmental impacts of cypermethrin were recognized well before it was authorized for use on salmon farms.¹⁵⁵ Research carried out at the Canadian government biological station in St. Andrews, New Brunswick, during the 1970s, and later experiments on Prince Edward Island in the late 1980s, showed how lethal cypermethrin was to lobsters, shrimp and even salmon themselves.¹⁵⁶ Unfortunately, this research did not fully emerge until the late 1990s.¹⁵⁷ Confidential reports commissioned by Shell in the 1970s but never published also showed how toxic cypermethrin was to shrimp.¹⁵⁸

In a 1996 review of both cypermethrin and azamethiphos, the Canadian Department of Fisheries and Oceans warned: “Unfortunately, these chemicals can be toxic to non-target marine organisms, including commercially valuable crustaceans such as lobster, and to other marine crustaceans that may be important to the coastal ecosystem.” The DFO concluded that: “The distance travelled by a pesticide patch during the first two to four h after release ranges from a few hundred to a few thousand metres, and hence may be carried through an adjacent fish farm . . . These findings have countered the often held belief by some government officials and industry that pesticides released into the marine environment of the Quoddy Region are instantaneously diluted. They have also reinforced the reality that many of the fish farms are sharing the water from adjacent farms on a regular basis and that knowledge of the circulation and dispersal patterns is valuable and necessary information.”¹⁵⁹ A 1997 paper circulated internally by the Canadian government warned that cypermethrin was so toxic it would kill lobsters, crabs, prawns and other commercially important shellfish as well as sea lice.¹⁶⁰

Canadian government researchers also showed that cypermethrin used on salmon farms in the Lower Bay of Fundy, New Brunswick, had “the potential to cause toxic effects over areas of hectares.” Experiments at salmon farms in Deadmans Harbour, Letang Harbour and Black Bay in 1996 and 1997 showed “lethal effects” of cypermethrin at “extremely low concentrations”—some one to three orders of magnitude lower than the intended treatment

concentrations. Nor was cypermethrin quickly diluted—“the plume retained its toxicity for substantial time periods after release.” The researchers from the Department of Fisheries and Oceans and Environment Canada concluded that “since treatment of multiple cages is the operational norm, area-wide effects of cypermethrin on sensitive species cannot be discounted.”¹⁶¹

Sadly, multiple treatments of cypermethrin do seem to be the operational norm, in Scotland at least. Hydro Seafoods (now called Scottish Seafarms), for example, states in a submission to SEPA that there is “a likely maximum of eight treatments per year” at one salmon farm in Scotland. And a private and confidential report reveals that a salmon farm in Loch Sunart used cypermethrin seven times in ten months.¹⁶²

A Scottish scientific study, finally published in 2004 over a decade after the first trials took place, confirms the Canadian research. Copepods, organisms pivotal in virtually all pelagic food webs, died when exposed to cypermethrin at “considerably lower than the recommended sea lice treatment concentration.” The researchers noted “animals showing increased activity in the form of erratic and frantic swimming, often swimming in small circles.” Moreover, “sporadic twitching was also observed in animals prior to complete immobilization and has been reported previously in response to lobsters to cypermethrin exposure.” The study concluded: “Consecutive treatments over several days at a salmon farm will introduce increasing levels of cypermethrin into the water column which may become entrained within a sea loch in localized currents. Thus, a cumulative impact of multiple treatments should not be discounted.”¹⁶³ In other words, lethal plumes of cypermethrin are free to follow the currents, with the potential to kill sensitive species in their wake.

A SEPA survey published in February 2004 also found cypermethrin, teflubenzuron, ivermectin and emamectin benzoate in eleven percent of sediments tested under salmon cages. Cypermethrin was the biggest culprit, found in over a third of all positive samples. The highest concentration of cypermethrin was detected in Busta Voe in Shetland and was so high it exceeded SEPA’s environmental standards. Other sites in Shetland at Collafirth, Bight of Cliffs and Ronas Voe also showed significant sediment contamination, with cypermethrin detected up to 100 metres away from the cages.¹⁶⁴

Cypermethrin has also been shown to have significant effects on the reproduction and sense of smell of wild salmon. “The synthetic pyrethroid pesticide cypermethrin, a known contaminant of tributaries supporting spawning salmonid fish, had a significant sublethal impact upon the

pheromonal mediated endocrine system in mature male Atlantic salmon,” say researchers at the Centre for Environment, Fisheries and Aquaculture Science in England. “The results of the study suggest that low levels of cypermethrin in the aquatic environment may have a significant effect on Atlantic salmon populations through disruption of reproductive functions.”¹⁶⁵

Cypermethrin’s capacity to affect the nervous system has been recorded in farmed salmon themselves. Grampian Pharmaceuticals (now owned by Novartis) warn in the safety data sheet for Excis (cypermethrin) that its use may cause “mild transient headshaking, flashing, increased jumping and uncoordinated swimming” in farmed salmon. Farm worker Jonathan Davis described a farmed salmon with “the shakes” at Ardesie Salmon: “We watched the swimming action of the fish and when we could see them starting to shake their heads, we stopped the treatment.”¹⁶⁶

Human health effects also warrant concern. Cypermethrin has long been considered a possible human carcinogen.¹⁶⁷ Studies on the carcinogenic and co-carcinogenic (tumour initiating and tumour promoting) properties of cypermethrin in mice revealed in 2002 that “cypermethrin possesses complete carcinogenic as well as tumour initiating and promoting potential.”¹⁶⁸ The European Agency for the Evaluation of Medicinal Products warned in 1998 that “human occupational exposure to cypermethrin has been reported to cause transient paraesthesia on the face and other exposed areas of the body. It was considered that the paraesthesia was due to a spontaneous repetitive firing of the local sensory nerve endings, with thresholds temporarily lowered by the substances.”¹⁶⁹ In other words, cypermethrin can cause numbness and a loss of feeling. Other reported symptoms of cypermethrin poisoning include abnormal facial sensations, dizziness, headache, nausea, itching, convulsions, burning and prolonged vomiting.¹⁷⁰

That did not stop some Scottish salmon farmers from failing to provide workers with appropriate health and safety warnings. The safety instructions for the use of Deosan Deosect clearly state “Wear protective gloves, rubber boots and protective clothing,” but Jonathan Davis, former farm worker, recalled that the gloves he and co-workers used “sometimes had holes in them as [the employer] didn’t like to buy any new gloves. Even if the gloves were brand new and didn’t have holes in, our hands got wet hand-balling the tarpaulin when using cypermethrin to treat the fish. The gloves always got soaking and at times my hands at the end of the working day looked like prunes . . . In terms of any health side-effects of using cypermethrin, there was a period of around two to three weeks when my nerve-endings in my fingers tingled

when I had to reach for the rails around the cages. This happened in the period directly after treatment . . . On one occasion [the employer] opened a bottle of Deosect with his mouth. He used his teeth to pull the cap off. He obviously didn't value his own life let alone the health and safety of his employees."¹⁷¹

Davis's former co-worker Jackie Mackenzie is currently taking legal action over the use of cypermethrin, but even without pending legal action and studies confirming carcinogenicity in humans, cypermethrin's time may be up. Sea lice resistance to both cypermethrin and deltamethrin has already been reported in Norway and Scotland.¹⁷² No worries for salmon farmers, though—they have plenty more toxic chemicals in the pipeline.

Teflubenzuron (Calicide)—A hazardous, wasteful and persistent marine pollutant

Teflubenzuron is a highly hazardous marine pollutant, lethal to shellfish in tiny doses, extremely persistent in the sediment under salmon cages and in the flesh of farmed salmon, and a suspected carcinogen. Hardly a suitable candidate for use on sea cage salmon farms, yet that is what salmon farmers reached for when they needed to replace dichlorvos and azamethiphos.

Teflubenzuron is a benzoylphenyl urea insecticide, initially introduced in 1984 to protect fruit, vegetables and cotton. By the 1990s, though, chemical resistance was already being reported in land-based pests,¹⁷³ so Nutreco (owners of Marine Harvest), in conjunction with the US chemical giant American Cyanamid, developed teflubenzuron (trade name Calicide) for aquaculture. Sea cage fish farming is in danger of becoming a dumping ground for chemicals which are past their sell by date on land.

Along with ivermectin and emamectin benzoate, teflubenzuron is administered to farmed salmon in their feed and not via a bath. It is now licensed for use in Norway, Scotland, Ireland and the Faroes and is available in both Canada and Chile on an emergency or trial basis.¹⁷⁴

Norwegian salmon farmers started using both teflubenzuron (under the trade name Ektobann or Ectoban) and diflubenzuron (a related compound manufactured by Ewos [Mainstream] under the trade name Lepsidon) in 1996.¹⁷⁵ Official figures from the Norwegian Medical Depot and Norwegian School of Veterinary Sciences show that 610 kilograms of teflubenzuron were used in 1996, rising to 1,510 kilograms in 1997 and 1,334 kilograms in 1998.¹⁷⁶ Teflubenzuron is also listed by the Norwegian Directorate of Fisheries as equivalent to the chemical praziquantell,¹⁷⁷ which has been used in Norway

since at least 1989. Norwegian salmon farms consumed over 1,500 kilograms throughout the 1990s.¹⁷⁸

In 1998 Kurt Oddekalv of the Norwegian NGO Norges Miljøvernforbund claimed that teflubenzuron (and diflubenzuron) may cause cancer. The Norwegian media widely reported his fears that Norwegian farmed salmon contaminated with teflubenzuron were a health risk and unsafe to eat.¹⁷⁹ Following these revelations, the use of teflubenzuron in Norway plummeted five-fold in a single year to only 231 kilograms in 1999 and then to 28 kilograms in 2001.¹⁸⁰

In Scotland, where teflubenzuron has been approved for use since 1999, fish may not be slaughtered for human consumption within seven days of treatment with the compound. In other countries the “withdrawal period”—the time it takes for drugs to flush out of the fish’s system—is much longer.¹⁸¹ Residues of diflubenzuron were found in Norwegian farmed salmon back in 1991, but it is not clear how widespread teflubenzuron contamination is.¹⁸² There is not a shadow of doubt, however, over teflubenzuron contamination in sediments under salmon cages.¹⁸³

The fundamental problem is that 90 to 95 percent of teflubenzuron ends up in the marine environment, mainly excreted through salmon feces.¹⁸⁴ And as the Scottish government’s Marine Laboratory stated in 2001: “Once in the sediment, teflubenzuron could be available to the benthic community creating a possible passage into the food chain and the possibility of bio-accumulation.”¹⁸⁵

As well as being potentially carcinogenic to humans, teflubenzuron is highly hazardous to the marine environment, especially shellfish. The chemical works by inhibiting the formation of chitin, which is the predominant component of the exoskeleton of insects and crustacean. It is therefore highly toxic to species that undergo moulting at any stage in their life cycle, including lobsters, crabs and some zooplankton species. A safety data sheet from the manufacturers, Cynamid, warned in 1993 that teflubenzuron was “Dangerous for the environment,” “Very toxic to aquatic organisms” and “May cause long term adverse effects in the aquatic environment.” The Scottish Association of Marine Science warned back in 2001 of the lethal effects of teflubenzuron at tiny concentrations and over short periods: “The chemicals used to control sea lice are highly toxic to crustaceans, and are used by the salmon farming industry because of their efficacy at killing certain life stages of the parasitic copepods . . . Exposure of moulting stages to teflubenzuron and emamectin benzoate causes mortality and deformity at very low concentrations. Bioassay

survivors displaying sublethal exposure effects do not generally recover indicating that sea lice chemicals may exert significant ecological effects at concentrations well below indicative LC50 values and after only brief exposures.”¹⁸⁶ Diflubenzuron was also found to be toxic to crabs nearly a decade ago.¹⁸⁷

Shellfish farmers have naturally objected to the use of teflubenzuron, arguing that a chemically dependent salmon farming industry is incompatible with shellfish farming.¹⁸⁸ Nor are we talking about small amounts of chemical. According to a 2003 application for a salmon farm in Loch Fyne, a “pessimistic” figure for the number of teflubenzuron treatments is three, with seven kilograms of Calicide per 100 tonnes of fish treated.¹⁸⁹ If 1,000 tonnes of farmed salmon were treated with Calicide three times a year, 210 kilograms of Calicide would be used, of which 90 percent (some 189 kg) would be discharged directly into the marine environment. Salmon farmers are not the only industry trying to earn a living in Loch Fyne—it is also home to the world renowned Loch Fyne Oysters.

Speaking to the *West Highland Free Press* in August 2000, scallop farmer David Oakes said: “Why was no work done on the effects of the chemical on scallops? The chemical affects the shells of the sea lice and it is likely it will affect shellfish as well, especially in the larval stages. There is evidence to show that the chemical is still to be found in the seabed six months after it was used.”¹⁹⁰ Oakes gained this inside knowledge in 1999 when he was approached by a scientist working at a university in Scotland. The scientist had damning evidence concerning teflubenzuron, but wanted to remain anonymous. “Deep Trout” accused the Scottish government of failing to protect the marine environment and the shellfish farming industry.

Deep Trout’s “Calicide Critique,” widely circulated on the internet and submitted officially to the Scottish government and Nutreco, stated: “The prima facie evidence is that teflubenzuron will be highly toxic to shellfish. SEPA are therefore grossly ignorant of the range of species that will be directly affected by teflubenzuron. The lethal effects are: by prevention of growth in the Arthropoda; prevention of movement in the Annelida and death by starvation and internal damage in the Mollusca. There have been no studies of long term ecological effects of the use of teflubenzuron. They could be immense but have not been considered in its proposed use as Calicide.”¹⁹¹

Deep Trout made a big splash in the Sunday papers. The *Sunday Herald* reported: “David Oakes, who requested the ‘Deep Trout’ report, has been denied access to the scientific evidence which led SEPA to accept that Calicide

was safe. He was told that Trouw's (a subsidiary of Nutreco) commercial interests overrode the need for openness.¹⁹² SEPA's pollution control specialist Andy Rosie told the *Sunday Herald* that "the claims made by Deep Trout are taken seriously." He admitted that SEPA's case was weakened by the fact that studies commissioned by Nutreco were still not available for peer-review. "At the very least the papers we have cited should be available. We will be negotiating with Nutreco to say that these papers should be in the public domain."

SEPA finally persuaded Nutreco to make some of the documents available for public inspection in February 2001, but they came in a straitjacket. In a letter to David Oakes, SEPA explained: "Nutreco retains copyright and intellectual property rights to most of these documents so SEPA is not able to provide you with copies. If you do wish to obtain a copy of any particular document, once you have viewed these, I would recommend you contact Nutreco directly."¹⁹³

Subsequently, I visited SEPA offices to view a mountain of documents marked "Private and Confidential." I was given only a short time to peruse the material and was not allowed to make photocopies, but it soon became obvious why Nutreco might want to keep a lid firmly shut on these ecotoxicological studies. Different reports showed that teflubenzuron can persist in sediment for nearly two years at distances up to one kilometre away from the salmon cages; it can have "significant lethal effect on lobster juveniles fed salmon pellets containing as little as 0.5g feed additive per kg pellets"; 90 to 95 percent of the compound was excreted into the environment via feces"; "the highest concentrations were found 408 days after treatment"; teflubenzuron was still present 654 days after treatment; and it could bioaccumulate up through the food chain via filter-feeders such as scallops and mussels.¹⁹⁴

The day after I viewed these documents, Nutreco's PR adviser Colin Ley rang me up. "How was your visit to SEPA yesterday?" he asked. "If there are any specific queries, please let us know—it would be much better to talk things through with us first before you make any public comments." Needless to say Nutreco read about the reports in the weekend's Sunday papers. "A controversial pesticide approved for use on 61 salmon farms in Scotland is classed as a highly toxic marine pollutant and can still be found in sediment on the sea bed nearly two years after use, according to documents revealed this week," reported the *Sunday Herald*.¹⁹⁵

SEPA's role in authorizing teflubenzuron is typical of the manner in which governments in Norway, Canada, Chile and Ireland have allowed private profit to outweigh the public interest. SEPA's current policy on teflubenzuron

zuron was published in July 1999 and is based almost exclusively on Nutreco's unpublished private and confidential reports. The impact of teflubenzuron on crustacea such as lobsters is of primary concern, and SEPA's policy admits that teflubenzuron "is potentially highly toxic to any species which undergo moulting in their life cycle." As SEPA points out in the "environmental risk assessment": "This will therefore include some commercially important marine animals such as lobster, crab, shrimp and some zooplankton species."¹⁹⁶ In spite of this, SEPA began handing out licences to use teflubenzuron in 2000 and by March 2004 had issued 212.¹⁹⁷

Meanwhile, the case against teflubenzuron is building all the time.¹⁹⁸ Little wonder then that salmon farmers want to bury the evidence. When a secret trial on its environmental impact was conducted in 1996 in the waters around the Isle of Skye, the first the locals knew about it was when their shellfish started dying. "We were unaware of the use of teflubenzuron until massive crab, prawn, squat lobster, and sea urchin deaths were observed in Lochbay," claims Aileen Robertson, who runs a diving centre in the area. "Scallop divers had to move to another sea loch, and the creel fisherman had to stop fishing. Even staff at the fish farm were alarmed to hear what was going on and gave us labels for the medicated food they had been given to use. We got the safety data, worked it out, and called the Scottish Environment Protection Agency. They had given consent for its sea trial with no public notification or advertisement. How do they get away with it?!" (Aileen Robertson, pers. comm.)

Ivermectin (Ivomec)—An illegally used neurotoxin and persistent marine pollutant

Like teflubenzuron, ivermectin is a persistent pollutant and in-feed treatment that seems to me wholly unsuitable for use on a sea cage salmon farm. Scientific studies show that it is acutely toxic to a range of marine life, it persists in the environment and it may potentially bioaccumulate in organisms and even humans. Ivermectin is a member of the avermectin group of chemicals, which are neurotoxins. It acts on the nervous system of invertebrate parasites, inhibiting nerve pulse transmission, resulting in their paralysis and death.

Manufactured by Merck Sharp Dohme as Ivomec, it has been used worldwide since the 1970s as a parasiticide for cattle, sheep, pigs, horses and dogs. Salmon farmers in Canada, Norway, Ireland and Scotland desperately (and illegally) resorted to ivermectin in the late 1980s and throughout the 1990s as

sea lice became resistant to dichlorvos.¹⁹⁹ The Canadian government reported in 2000 that “the anti-parasitic agent ivermectin is prescribed by veterinarians and is used routinely in eastern Canada.”²⁰⁰

However, ivermectin use produces severe side effects in animals. Scientific studies have shown toxicity in collie dogs and acute toxic syndrome in mammals, characterized by depression, mydriasis (excessive dilation of the eye’s pupil), ataxia (loss of control of body movements), coma and death.²⁰¹ Nor is ivermectin a friend of the fish. Studies have shown that it can have direct toxic and pathological effects on farmed fish, causing uncoordinated swimming behaviour and respiratory problems.²⁰² As early as 1987, Irish and Canadian scientists showed that ivermectin caused increased mortality and listless behaviour in farmed salmon.²⁰³ In 1993, researchers showed that Atlantic salmon treated with ivermectin became dark and lost their appetite, and their eyes rolled ventrally so lenses were no longer visible. Intestinal congestion was also recorded.²⁰⁴

That did not stop Canadians from giving thousands of farmed salmon a massive drug overdose. In January 2000 as many as 10,000 farmed salmon were killed at a farm in the Broughton Archipelago, BC, after an ivermectin treatment.²⁰⁵ Dr. Joanne Constantine, fish health veterinarian with the BC Ministry of Agriculture, Fisheries and Food, concedes ivermectin has a “narrow margin of safety [for fish]” when it comes to calculating dosage.²⁰⁶ Use too little and ivermectin does not do its job; use too much and it kills all your farmed stock.

Ivermectin also has fatal consequences for shellfish. Canadian government scientists concluded back in 1993 that ivermectin was lethal to shrimp at tiny concentrations.²⁰⁷ Four nanograms of ivermectin per litre of water kills shrimp—that’s 28 grams per 10,000 Olympic-sized swimming pools.²⁰⁸ Such small doses can have an impact on consumers of contaminated farmed salmon as well. A study in 1995 by the Scottish government found that mussels bathed in a dilute solution of ivermectin accumulated the chemical to a concentration 750 times that in the water column. “In the worst scenarios, levels might be reached which affect the human embryo in the womb, the human baby through breast milk and the aged,” said John Duffus of Heriot Watt University in a report for the Association of Scottish Shellfish Growers. “I have considerable doubts as to the long-term safety of the use of ivermectin in the aquatic environment.”²⁰⁹

The environmental impacts of ivermectin were known in the 1980s.²¹⁰ Like teflubenzuron, it is poorly absorbed by fish; a high percentage of the

chemical is excreted via the feces and escapes to the marine environment. Residues of ivermectin in the flesh of farmed salmon and in the sediment under salmon cages are extremely persistent. The half-life is 90 to 240 days, which means it can take anywhere from three to eight months for half of the chemical in the sediment to decompose. Studies on ivermectin use on cattle have shown that it kills dung beetles in cow pats for up to four years after initial treatment. Professor Jean-Pierre Lumaret, from the University of Montpellier in France, found it produced “toxic and virtually indestructible” cow pats that are capable of killing up to 20,000 dung-eating insects a week.²¹¹

If ivermectin has such a toxic effect on dung beetles on land, it is no surprise to learn that it also kills sediment-dwelling organisms such as infaunal polychaetes living under salmon cages.²¹² Research published in 1998 by Dr. Alistair Grant at the University of East Anglia showed ivermectin to be so toxic to marine life that he recommended a ban on its use on salmon farms. “It is clear that ivermectin is extremely toxic to some marine animals. In view of this, more data are urgently required regarding its toxicity and persistence in the field. It is difficult to justify its continued use until its environmental risks are understood more clearly.”²¹³ Research by the Scottish government also found that ivermectin has a significant impact on lugworms—the marine equivalent of earthworms.²¹⁴ Dr. Ian Davies of the Scottish Office Marine Laboratory told *New Scientist* in 1998 that ivermectin use was so widespread in Scotland that “an area of between 10,000 and 20,000 square metres could be contaminated.”²¹⁵ Dr. Davies later admitted in 2000, over a decade after the UK government knew it was being used, that “ivermectin can reach the marine environment via excretion from the bile, unabsorbed via the fish feces and by uneaten food pellets and has a strong affinity to lipid, soil and organic matter. Risk assessments have shown that ivermectin is likely to accumulate in the sediments and that the species therein would be more at risk than the species in the pelagic environment.”²¹⁶

Ivermectin has certainly left its mark on the Scottish seabed. In their survey of sediment under salmon cages published in February 2004, SEPA researchers found ivermectin residues across Scotland, even though farmers claim they stopped using ivermectin years ago.²¹⁷ Commenting on the findings, SEPA’s lead aquaculture specialist said: “The study has detected low levels of unauthorized and unsuitable formulations, particularly ivermectin, and we are aware that an unscrupulous minority of companies have resorted to this in the past, mainly to save money.”

Ivermectin contamination of sediment is one thing—the contamination

of farmed salmon is another. Ivermectin lingers and leaves unappetizing residues in the flesh of farmed salmon.²¹⁸ So widespread was the illegal use of ivermectin that eleven percent of all Scottish farmed salmon tested in 1994 by the UK's Veterinary Medicines Directorate were contaminated with it.²¹⁹ No wonder supermarkets across Europe became wary of Scottish farmed salmon. In 1996 the German newspaper *Die Zeit* reported that Scottish farmed salmon was contaminated with ivermectin. The Federal German Fish Research Agency "alleged that British salmon farms were getting around restrictions on marine use of the chemical by keeping small herds of sheep."²²⁰ (As with cypermethrin, ivermectin formulations designed for use on terrestrial livestock could be bought cheaply over the counter in hardware stores.) Consumer pressure eventually led to some supermarket chains refusing to accept any salmon treated with ivermectin,²²¹ but as recently as 2001 ivermectin was routinely detected in samples of Scottish farmed salmon on sale in UK supermarkets.²²²

In spite of all the evidence about its toxicity and persistence, ivermectin has been used illegally to control sea lice on salmon farms across Scotland, Canada and Ireland since the 1980s.²²³ In 1991 the manufacturer, Merck Sharp Dohme, wrote to Galway's University College Hospital: "This illegal use of ivermectin is neither encouraged nor condoned by the Company. MSD-AGVET will continue to oppose the use of ivermectin for treatment of louse infestations in salmon until all questions concerning safety and efficacy have been answered and the product is fully licensed."²²⁴

Also in 1991, a salmon farmer in Glencoe on the west coast of Scotland was caught using ivermectin by a filmmaker hiding in the bushes. According to the *Daily Telegraph*: "Fears that the substance is in use in parts of Britain emerged last week when a farm in Kinlochleven was raided by the Highland River Purification Board [later SEPA], after a tip-off by Friends of the Earth (Scotland). Acting on information provided by a farm employee that it was allegedly using ivermectin, Friends of the Earth filmed a fish worker not wearing goggles or protective clothing while feeding salmon. The worker later complained of difficulty with his vision. Users of the pesticide are warned to avoid contact with eyes."²²⁵

Friends of the Earth Scotland's Xanthe Jay said at the time of the incident: "It is difficult to imagine any other industry acting as irresponsibly as this and being so unregulated to get away with it. We accuse: the fish farmers who have been using ivermectin of being dangerously incompetent, the salmon industry who supposedly set quality standards of total negligence, and the statutory

authorities charged with the control of the industry of providing nothing more than token safeguards. This shows the total inadequacy of the system of regulation of fish farming in Scotland. According to our calculations up to 6,000 tons of salmon contaminated with ivermectin could have reached the UK market.”²²⁶

In 1993 another Scottish salmon farm company, Wester Ross Salmon, was fined for the unauthorized use of ivermectin in Loch Glencoul. Following raids by the enforcement agency, farmed salmon was found to be contaminated with ivermectin at a concentration twelve times above the detection limit. Wester Ross Salmon admitted feeding fish pellets containing ivermectin in a trial that ended in the death of thousands of fish. The company pleaded guilty to breach of the Control of Pollution Act and was fined a paltry £500.²²⁷ Despite repeated government warnings, Scottish salmon farmers continued to treat the marine environment and public health with contempt. In 1995 two salmon farmers in Shetland were thrown out of the Shetland Seafood Quality Control scheme for using ivermectin illegally. Far from naming and shaming the companies concerned, however, “client confidentiality prevented the release of the salmon farms’ identities.”²²⁸ According to the *Shetland Times*: “Sea-lice killer ivermectin is the skeleton in the salmon farming industry’s cupboard. Everybody says everybody else is using it. Indeed, if you believe some people, all Shetland salmon farms use it.”²²⁹ Such widespread disdain for the law is by no means confined to the “unscrupulous minority”. In 1996 the Scottish Salmon Growers Association (now Scottish Quality Salmon) issued guidelines on the use of ivermectin “premix for pigs” to treat farmed salmon.²³⁰

Canadian salmon farmers in British Columbia were also caught out using ivermectin illegally. Freedom of information requests by the Sierra Legal Defence Fund revealed that in 1997 alone, 107 kilograms of ivermectin were dumped into the ocean at salmon farms on the west coast of Vancouver Island.²³¹

Scottish salmon farmers’ thirst for this illicit “jungle juice,” as it is known in the trade, led to cattle farmers in Shetland complaining that stocks of ivermectin were running dry (Anon, pers. comm.). For a brief time between 1996 and 1999, SEPA allowed a small number of Scottish salmon farmers (about 30) to use ivermectin legally.²³² But in February 1999 the Secretary of State for Scotland effectively shut the door on the legal use of ivermectin by ordering a public inquiry.²³³ Salmon farmers subsequently pulled the plug on the chemical when they realized such a toxic product would not stand close scrutiny.²³⁴

Some Scottish salmon farmers, however, did not let the law or public health concerns get in their way. One such operator was Ardesie Salmon, which came under the spotlight in a front-page expose published by *The Observer* newspaper in April 2000.²³⁵ Jackie Mackenzie told me in a signed testimony: “I used ivermectin on smolts on numerous occasions. We added ivermectin to smolt food by adding a given amount to water and then, using a knapsack sprayer, we coated the food in a concrete mixer. We then transferred the treated food back into bags and then hand fed over the weekend so the Scottish Environment Protection Agency could not do an unsuspected inspection.”²³⁶ Following the revelations of Mackenzie and another colleague, Ardesie Salmon was thrown out of Scottish Quality Salmon, which also withdrew its Tartan Quality Mark from the farm’s tainted products.²³⁷

As recently as 2002, yet another Scottish salmon farmer was caught using ivermectin, fined a record £6,000 and forced to withdraw from the Shetland Seafood Quality Control scheme.²³⁸ Speaking in court afterwards, SEPA’s water pollution officer in Shetland, Dave Okill, lamented: “I feel disappointed that this part of the industry has seen fit to use an unlicensed and uncontrolled chemical in this way. I am also disappointed that the Shetland Salmon Farmers Association has failed to convince this section of the industry that they have environmental responsibilities, and that they should recognize those responsibilities. This firm has obviously not just broken the law, it also has broken the Code of Best Practice as issued by the Shetland Salmon Farmers’ Association, and agreed to by its members. We have in the last five years taken two reports to the Procurator Fiscal about the illegal use of chemicals in the industry. I think I would be naïve to believe that those two reports related solely to the only two times that illegal chemicals had been used.”²³⁹

Emamectin benzoate (Slice)—A marine pollutant toxic to fish, birds, mammals and aquatic invertebrates

Salmon farmers have merely moved on from one toxic chemical—ivermectin—to another—emamectin. The use of emamectin benzoate is legal, but whether or not it is any better is debatable. Emamectin benzoate is a semi-synthetic avermectin insecticide, closely related to ivermectin. It has been sold for agricultural pest control in edible plant crops since the 1970s, but was only added to salmon farmers’ chemical arsenal in the 1990s. The safety data sheet for Proclaim (active ingredient: emamectin benzoate) warns: “The pesticide is toxic to fish, birds, mammals and aquatic invertebrates. Do not apply directly to water or to areas where surface water is present, or to intertidal areas below

the high water mark.”²⁴⁰

Against this safety advice, emamectin benzoate is now widely used on sea cage salmon farms under the trade name Slice, manufactured by the US pharmaceutical giant Schering Plough. Like teflubenzuron, it is administered to farmed salmon as a premix coated on fish feed. Slice is licensed for use or is being used on a trial basis on salmon farms all over the world including Scotland, Chile, Norway, Ireland, Iceland, the Faroes and Canada.²⁴¹ Secret field trials took place in Scotland as early as 1994 under the code name SCH5844. Further trials in Scotland took place in 1997 but were not published until 2000. Field trials also took place in Canada in 1998.²⁴²

With sea lice resistant to dichlorvos, azamethiphos and cypermethrin, emamectin benzoate is the current chemical weapon of choice in the war on these parasites. However, like ivermectin, emamectin benzoate is no “magic bullet.”²⁴³ And like dichlorvos, azamethiphos or cypermethrin, it can produce after-effects. Schering Plough’s catchy sales slogan is “Slice Kills Lice.” Sadly, Slice may also kill other marine life. Unsurprisingly for a toxic chemical labelled by its manufacturer as a marine pollutant, emamectin benzoate pollutes the marine environment. However, many salmon farmers seem to have been more concerned about its efficacy than its ecotoxicology.²⁴⁴

Field trials on farmed salmon showed “signs that were compatible with toxicosis.” One fish was so drunk on emamectin benzoate that it “swam with its snout out of the water and appeared to be losing equilibrium.” Other conditions reported in the study included scale loss, peritoneal adhesions, visceral melaniation, multi-focal gill lamellar fusion.²⁴⁵ Another study reported lethargy, dark coloration and loss of appetite in both salmon and trout treated with emamectin benzoate. One farmed salmon was so anorexic it died from “focal necrosis, ceroid accumulation in the spleen and melanin accumulation in the kidney.” Other side effects included skin lesions and erosion of the pectoral fins, nose and mandibles. Corneal edema and cataracts were recorded in almost half the salmon treated with medium doses of emamectin benzoate. Another blind-drunk salmon on a high dose of emamectin benzoate “was observed to roll onto its side at intervals, apparently unable to maintain an upright position.”²⁴⁶

Emamectin benzoate is lethal to a wide range of crustacea (not just sea lice) at very low levels. Studies by SEPA show that the small mysid shrimp is poisoned by emamectin benzoate at concentrations equivalent to only half a drop in an Olympic-sized swimming pool.²⁴⁷ Research by the Scottish Association of Marine Science also concluded that both emamectin benzoate

and teflubenzuron cause “mortality and deformities at very low concentrations” in non-target planktonic copepods.²⁴⁸ Another Scottish study reported in 2003 that experiments showed emamectin benzoate significantly reduced moulting success, reduced fecundity and caused deformities in copepods.²⁴⁹ Copepods—the microscopic aquatic equivalent of ladybirds and beetles—are vital to the health of the ecosystem and are an important food supply for wild salmon and other fish species.

Species much larger than copepods are affected by emamectin benzoate as well. Canadian government researchers stated in a paper published in 2002 that emamectin benzoate can cause premature moulting, failure to reproduce and death in lobsters on the east coast of Canada. The studies “confirm the molt-producing effect of emamectin benzoate on female American lobster.” Furthermore, the “results provide conclusive proof that emamectin benzoate is disrupting the endocrine system that controls molting in the American lobster. The results are the first example of a crustacean molting prematurely in response to chemical exposure, the first example of an arthropod molting in response to an avermectin, and the first report that GABAergic pesticides can induce proecysis in crustaceans.”²⁵⁰ Translated into English—those lobsters won’t be raising a family in a hurry. Similar impacts are predicted for species closely related to lobsters including prawns, crabs, and shrimp. Emamectin benzoate is also highly toxic to the northern bobwhite quail and the mallard duck.²⁵¹

Emamectin benzoate, like ivermectin, is hard to shake off and sticks like glue to sediments. Residues have been found in soil, water and crops growing in contaminated soil,²⁵² and it leaches into the marine environment months after a salmon farm treatment.²⁵³ Unsurprisingly, it is appearing in the seabed under salmon cages. In its survey of sediments sampled under salmon cages, mentioned earlier, SEPA detected residues of emamectin benzoate at three times more than the “monitoring trigger value within 25 m of the cage edges,” and also detected it in the flesh of farmed salmon, but “well below the maximum safe limit for human consumption.”²⁵⁴

It is so persistent that in Norway and the Faroes the withdrawal period for farmed salmon treated with Slice is 120 days before harvesting. This does little to prevent contamination of other foodstuffs such as wild shellfish. For example, emamectin benzoate has recently been found in wild scallops near a salmon farm in Maine, USA. Tests carried out by in Cobscook Bay found emamectin benzoate contamination at three times the food safety limit set by the US Environmental Protection Agency. The National Environmental Law

Centre (NELC) says the discovery warrants a warning to harvesters and seafood consumers—the area is a commercial fishery for scallops, lobster and pollock.²⁵⁵

The NELC has also called on the Maine Department of Environmental Protection to conduct rigorous, comprehensive monitoring of non-target marine organisms for residues of drugs and other chemicals used at salmon farms (Josh Kratka, pers. comm.). Sediment scavengers such as prawns, shrimps and crabs are at risk and may be contaminated with emamectin benzoate.

The chemical manufacturer, Schering Plough, has presumably known about the contamination of shellfish for over five years. Confidential research dating back to 1999 but never officially published reveals that emamectin benzoate was detected in mussels up to 100 metres from salmon cages one week after treatment.²⁵⁶ As far as the manufacturers are concerned, Slice is still safe, but Schering Plough has apparently not been anxious to send papers on environmental impact to journals for peer review (John McHenery, pers. comm.), and the vast majority remain private and confidential.²⁵⁷ Some documents on the environmental impacts of Slice are available on the internet, far from any peer-reviewed scientific journals.²⁵⁸

Schering Plough's record in other areas does little to inspire consumer confidence. In 2002 the company was given a whopping US\$500 million fine—the largest ever—by the US Food and Drug Administration for significant violations with respect to their facilities, manufacturing, quality assurance, equipment, laboratories, and packaging and labelling.²⁵⁹ In October 2003 Schering Plough was fined again—this time a US\$1 million civil fine to settle federal regulators' allegations that it illegally revealed financial information. With plummeting sales, Schering Plough is described as “one of the most beleaguered companies in the U.S. pharmaceutical industry.”²⁶⁰

Faced with a mountain of scientific evidence on the dangers of emamectin benzoate, Scottish and Canadian governments worked to approve Slice's use on salmon farms—yet another example of government putting salmon farmers and chemical companies first and shellfish and food safety second.

According to a report on the CTV television network in May 2002, Health Canada had “badly abused” the emergency drug-release program to allow salmon farmers across Canada to use Slice. The chemical had been used “more than 770 times in the past year alone.” The *Globe and Mail* reported that, according to documents obtained by CTV, “several toxicology studies of

Slice (emamectin benzoate) done on rats, dogs and rabbits show that when ingested at high doses the drug can cause side effects such as tremors, spine and brain degeneration and muscle atrophy.”²⁶¹ Earlier, in October 2000, the *Ottawa Citizen* reported that the Canadian government was allowing salmon farmers to “side-step drug ban.”²⁶² In an assessment report in June 2001 the government’s own agency, Health Canada, criticized the Canadian Food Inspection Agency for failing to test for residues of emamectin benzoate in farmed salmon even though it knew full well that the chemical represented over one in three (38 percent) drug prescriptions in the Atlantic area.²⁶³

The organization Public Service Employees for Environmental Ethics (PSE) believes the British Columbia government is guilty of the same chemical corruption with its “aggressive treatment” strategy to kill sea lice. In March 2003 the PSE accused the BC government of being in violation of the provincial Pesticide Control Act since 1995. “Why is the government ignoring their own law?” asked Mike Romaine, executive director of the PSE. “Laws such as the Pesticide Control Act are in place to protect the environment and allow for proper public review. The members of the PSE demand that the provincial government stop allowing the use of these dangerous chemicals in the marine environment without a permit.”²⁶⁴

In a background briefing on emamectin benzoate the PSE stated that BC has “turned a blind eye to emerging concerns” and has been “sympathetic to industry with respect to the enforcement of regulations, monitoring and management . . . Government is now looking to fast-track the use of pesticides or drugs that are known to have environmental concerns and to ignore their own laws with respect to enabling concerns to be aired through a review process. Documents show that when sea lice became a problem in 1995, the industry attempted to use unregistered pesticides to bypass the BC Pesticide Control Act.”²⁶⁵ Speaking on CBC-TV, Romaine accused the Canadian government of ignoring the dangers in its zeal to keep the aquaculture industry afloat. “They’ve got a bad situation and want to find a silver bullet,” he said. “They’re rushing to do everything at the expense of regulation, sound science and democratic decision-making.”²⁶⁶

Canadian salmon farmers have some way to go before they reach the murky depths plumbed in Scotland (illegal chemicals have been used there since 1976), but they are learning fast. Not to be outdone, the Scottish government also allowed salmon farmers to use emamectin benzoate before it had properly dealt with the applications. In February 2002 SEPA fast-tracked a stream of applications to use emamectin benzoate without carrying out

appropriate risk assessments.²⁶⁷ Its decision to short-circuit the regulatory process is yet another example of the government bending over backward for the salmon farming industry. The timing could not have been worse for shellfish farmers—it coincided exactly with the time the free-swimming larval stages of crustacea and other marine life were spawning. SEPA's policy on emamectin benzoate (dated 1999) is now five years out of date and fails to take in much new scientific information.²⁶⁸

Scottish salmon farmers have also been caught using emamectin benzoate contrary to the manufacturer's instructions. The UK's Veterinary Medicines Directorate "is concerned that, if the product becomes less effective, this could in turn lead to more frequent treatments needing to be used, which will increase the overall burden on the environment."²⁶⁹ Misuse may lead to sea lice developing resistance more quickly, and Schering Plough has every reason to worry about this. Resistance to emamectin benzoate in land-based agriculture occurred a decade ago,²⁷⁰ and the company clearly wants to protect its \$10 million investment. Canadian government scientists are already engaged in a study on sea lice resistance to emamectin benzoate, with results to be published in the summer of 2004 in *Pest Management Science* (John Burka, pers. comm.). It is only a matter of time before salmon farmers encounter the same sea lice resistance to emamectin benzoate that they have experienced with dichlorvos, azamethiphos and cypermethrin. Lice may soon be more of a blank than a magic bullet for sea lice.²⁷¹

TBT—A highly toxic antifoulant paint used throughout the 1980s

Tributyltin (TBT), according to Professor Edward Goldberg of the Scripps Institute of Oceanography in the United States, is "one of the most toxic substances deliberately introduced into our natural waters."²⁷² It was first used by ships and yachts as an antifoulant paint in the mid-1960s and was quickly adopted by the salmon farming industry in the 1970s. Despite increasing evidence that TBT caused reproductive failure and growth abnormalities in shellfish, it was used to coat salmon farm nets all over the world. Scottish shellfish farmers complained throughout the 1970s and 1980s that TBT contamination was forcing them out of business. TBT was called "a crime against nature and the shellfish farming industry."²⁷³

Scientific evidence showing the damaging effects of TBT on oysters was published by the Fisheries Research Board of Canada as far back as 1967.²⁷⁴ Further research showed TBT was lethal to mussels, oysters and scallops and was so toxic it could change the sex of dogwhelks and snails.²⁷⁵

The French government banned TBT in 1982 to save its oyster industry, but the Canadian, Norwegian and Scottish governments were prepared to sacrifice the shellfish industry for the sake of salmon farming. The Scottish government continued to sanction the use of TBT on salmon farms even though it knew scallops and oysters on sale to the general public were contaminated with the chemical.²⁷⁶

In Scotland, shellfish farmer Allan Berry launched the “Ban TBT Now” campaign in 1984 after noticing his oyster shells were being affected (there are echoes here of Rachel Carson’s revelations regarding DDT and its impact on birds’ eggshells). “TBT was the most potent molluscicide known and it was wrecking our oyster production,” says Berry. “Instead of being long and thin they had small, very thick shells—a bit like walnuts—and the meat was not developing inside them. Salmon farming poisoned us out of business—not just me, a whole ruddy industry.” But the political might of the Scottish salmon farming industry withheld a ban until 1987. “By this point all the west coast shellfish growers were being affected more or less, but they were small operators, crofters and part-timers who didn’t know how to argue with government. The salmon farmers had suits, degrees, huge Range Rovers and quoted huge sums of earnings,” says Berry.²⁷⁷

It was food safety issues in the economically more important salmon farming sector that finally forced governments to act. Researchers from the US National Marine Fisheries Service in Alaska found that farmed salmon could absorb TBT from the antifoulant paint on the cages.²⁷⁸ Their study showed TBT contamination in eleven out of fifteen samples of farmed Pacific chinook salmon bought from markets in Seattle and Portland—55 to 76 percent of the TBT was still present after cooking.²⁷⁹ Another American study showed that human red blood cells were extremely sensitive to TBT, with tiny concentrations inducing membrane breakdown.²⁸⁰

In 1986 the US Food and Drug Administration declared farmed salmon containing TBT to be unfit for human consumption, but other countries were slower to act. The UK government confirmed in 1986 that farmed Atlantic salmon on sale for human consumption was contaminated with TBT, but did not publish the information until 1987.²⁸¹

Andrew Lees of Friends of the Earth urged the UK government to “ban TBT immediately. The Environment Protection Agency found serious defects in safety tests used to obtain approvals in the United States for products containing TBT. There is mounting evidence of hazards to the environment and potential threats to human health. TBT is on trial and our verdict is guilty. The

Government should arrange for the testing of all seafood products, including oysters and salmon, derived from waters likely to be polluted with TBT. Contaminated products should not be marketed and any products in the supply chain should be withdrawn from sale.”²⁸²

In the wake of the bad publicity surrounding TBT contamination of farmed salmon, major supermarkets issued an ultimatum to salmon farmers—stop using TBT or we stop selling farmed salmon.²⁸³ Less than a week later, on February 25, 1987, the UK government finally banned TBT use on salmon farms.²⁸⁴ It took another year for the Scottish government to publish studies on the effects of TBT on oysters.²⁸⁵ Norway was even slower to act and banned TBT in 1990. In 1992 the Scottish government also conceded that TBT was “implicated as growth stimulants for toxic ‘red tide’ producing dinoflagellates in studies elsewhere in Europe,”²⁸⁶ joining dichlorvos, azamethiphos and cypermethrin as implicated in the stimulation of toxic algal blooms.²⁸⁷

Some Scottish salmon farmers simply stockpiled TBT before the ban came into force. The *West Highland Free Press* reported in April 1987 that “one large-scale salmon farmer in the north-west mainland is at present stockpiling supplies of anti-fouling substances which contain TBT, possibly with a view to offering them for future use.”²⁸⁸ In May the *Shetland Times* also reported “quite a rush” on TBT before it became illegal. Commenting on a sign in a local shop urging salmon farmers to stock up before the ban, Douglas Smith, director of environmental health at Shetland Isles Council, said: “Considering what’s happened in the recent past and considering that the ban takes effect very shortly this does seem slightly less than responsible.”²⁸⁹

The ban on TBT left other salmon farmers with a toxic waste disposal problem. One of them, Laurence Anderson of Sunnyside in the Shetland Islands, “dumped three barrels of toxic anti-fouling compound over a cliff and ordered three more barrels to be dumped in the sea.” After Anderson was fined £600, defence agent Steve Leeman said that his client had wanted to dispose of TBT “because it was about to be banned but he had not realised how dangerous it was.”²⁹⁰ A subsequent scientific assessment by the Scottish government reported on this illegal dumping’s impact on dogwhelks and limpets.²⁹¹

A decade after it was banned in Scotland, the government eventually “published” a report on the effects of TBT, but it is marked “Private and Confidential.”²⁹² Nearly twenty years after TBT was found in farmed Scottish

salmon, the European Commission's Scientific Committee on Food is still preparing a scientific opinion on the risk assessment of TBT in fishery products. The TBT issue also raises questions about all the other chemicals licensed for use on salmon farms. Just after the TBT ban on Scottish salmon farms in 1987, an editorial in the *Glasgow Herald* asked: "The remaining worry about TBT is this: if it was examined, as it presumably was, and passed fit for introduction to the environment by the appropriate Government agency, how many other substances of a similarly powerful toxicity have received the same approval?"²⁹³

For a start you can add copper- and zinc-based paints—the less-effective biocides that replaced TBT—to the long list that already includes canthaxanthin, dichlorvos, azamethiphos, cypermethrin, teflubenzuron, ivermectin and emamectin benzoate. The salmon farming industry saw copper as "safer than tin," but safety is all relative.²⁹⁴ Research by the Norwegian government as far back as 1985 (even before the ban on TBT) shows that copper is acutely poisonous to many marine organisms and that bioaccumulation occurs in algae, oysters, mussels and crabs.²⁹⁵

The safety data sheet for Aqua Net, one of the copper-based paints used by salmon farms, states: "Do not empty in sewers or other water drains" as it contains a substance classified as "toxic for water-living organisms" and "may cause unwanted long-term effects in the water environment." Canadian marine biologist Alexandra Morton reports that many of the netpens in the Broughton Archipelago of British Columbia are daubed red with copper. They have been painted with Flexgard XI—active ingredient: 26.5 percent cuprous oxide. The label for this paint sports a skull and crossbones and a "notice to user" that says: "Product to be used only in accordance with the directions. Toxic to aquatic organisms. Do not contaminate water. Do not allow chips or dust generated during paint removal to enter water."²⁹⁶

According to the Norwegian Directorate for Nature Management, most of the copper emissions from salmon farming (80 to 90 percent) take place as diffuse releases from the actual nets as the copper dissolves in the water.²⁹⁷ The way salmon farmers clean their cages accounts for the rest. Nets are often washed on beaches. Washing not only removes fouling organisms such as barnacles, mussels and seaweed, but also copper and zinc (and TBT when it was used), which are then flushed into the sea. Fisheries Information news service has reported that "local copper pollution has occurred near fish cage maintenance facilities in Norway. Discoloration of beaches has been noted and increased copper concentrations in sediments have been found several places."²⁹⁸

The quantities of antifoulant used on salmon farms are alarming. For example, an Irish salmon farm predicts that it will use “7,364 litres of copper-based antifoulant per year” for 1,500 tonnes of farmed salmon.²⁹⁹ In Norway, 529 tonnes of copper were released to water by the boating, mining, industrial and salmon farming sectors in 1985, rising to 647 tonnes in 1996. But while the industrial sector’s copper use fell six-fold during that time, the salmon farming industry’s use increased four-fold. Such increases were in contravention of the 1990 Hague Declaration and the 1995 Esbjerg Declaration, which committed the Norwegian government to reduce and then cease emissions of copper by 2020. In 1997 the Norwegian Parliament ordered that “emissions should be substantially reduced by 2010,”³⁰⁰ and in 2001 the Norwegian Pollution Control Authority finally put forward a proposal to ban emissions of copper-based paints from salmon cages,³⁰¹ though the ban may come too late to save some beaches.

Some of the copper released by salmon farms is bound in organic or inorganic compounds that gradually sink to the sea floor. Over time this leads to a rise in the copper content in the seawater and sediments surrounding the salmon farm.³⁰² Scientific studies in Norway have shown elevated concentrations of copper in sediments and in marine life around salmon farms and net washing stations.³⁰³

Scottish studies have found similar results. In 1995 the Highland River Purification Board (later SEPA), described how 4.5 kilograms of copper leached from a single salmon net in just three days.³⁰⁴ A secret survey carried out by SEPA in 1996–97 found that sediments directly beneath cages and within 30 metres of the farms were “severely contaminated” by both copper and zinc at seven out of the ten farms surveyed. Copper concentrations were elevated by up to 25 times and zinc by up to six times. The report concluded: “It is likely that the high concentrations of metals, together with high levels of toxic substances such as sulphides and ammonia, will represent a significant barrier to the re-colonization of the benthic sediments at the affected stations in the various sea lochs visited.”³⁰⁵

Scientists have also found zinc contamination under salmon farms in New Zealand,³⁰⁶ and salmon farmers in Australia use copper-based paints to reduce the threat posed by predators. “The industry has in the past avoided the use of conventional anti-foulants on net cages, but has recently obtained a permit from the National Registration Authority to use copper-based antifoulant nets in an attempt to combat seal attacks during frequent net changes of unprotected use,” explains Darby Ross of the Department of Primary

Industries, Water and Environment in Tasmania.³⁰⁷ Fish farmers in Australia have more excuse than most, as seals are the least of their worries. Attacks by great white sharks are now commonplace throughout southern Australia (in northern Australia it is crocodiles).

It is difficult to feel sympathy for sea cage salmon farmers, though. If salmon farms were on land there would be no need for antifouling paints or many of the other toxic chemicals pumped into the sharks' swimming pool, predator attacks would not happen at all, and, perhaps more seriously, copper and zinc contamination of farmed salmon would not be a consumer health problem. The Australian government's "National Residue Survey Results for 2001–2002" detected copper and zinc contamination in 100 percent of farmed salmon tested (60 out of 60 samples).³⁰⁸ By discharging hazardous chemicals into the sea and by causing contamination of farmed salmon, salmon farmers appear to pose inherently more danger than the great white shark any day of the week.

Malachite Green—A carcinogenic chemical contaminating one in seven farmed salmon tested in Europe in 2002

The only thing green about this chemical is its colour. Malachite green is a synthetic triphenylmethane dye that was spawned in the laboratory. It is one of the industry's longest serving chemical weapons, and its use in fisheries dates back to the time of Rachel Carson's *Silent Spring*.³⁰⁹ Salmon and trout farmers have used malachite green since the 1970s³¹⁰ because it is so effective at killing the fungi and parasites that plague farmed salmon. However, now it threatens to blow Chilean and Scottish salmon farming out of the water.

Health agencies in the Netherlands, Spain and the UK have all refused entry to Chilean farmed salmon contaminated with malachite green, and during 2003 the European Commission's Health and Consumer Protection Directorate issued about a dozen "Rapid Food Alerts" warning consumers that Chilean farmed salmon could be contaminated with the chemical.³¹¹ These are not isolated incidents but involve the entire industry, including some of the largest salmon companies in the world. In 2003 Nutreco, for example, was fined for the illegal use of malachite green.³¹²

Scottish farmed salmon is so contaminated that ten to twenty percent tested positive between 2001, when monitoring first began, and 2003.³¹³ As a result, the European Commission has threatened to ban imports of farmed Scottish salmon to the European Union.³¹⁴ (The UK banned use of malachite green on fish farms in 2002.) Ireland, New Zealand, the Faroe Islands and

Norway have all been guilty of using malachite green illegally. For example, malachite green has been widely used in Norwegian salmon farming since at least 1989, when 26 kilograms were consumed. Official figures show that its use peaked in 1991 at 114 kilograms, falling to 47 kilograms in 1995 and 27 kilograms in 2000.³¹⁵ Svanhild Vaskinn of the Norwegian State Food and Beverage Inspectorate told Intrafish in 2001 that “Malachite has not been assessed and is therefore prohibited from use on fish that will be consumed.”³¹⁶

Unfortunately that has not deterred some salmon farmers, who have shamelessly cut costs by using malachite green, which is twenty times cheaper than the less effective alternative. As Professor Ron Roberts, vice-chairman of the Animal Health and Welfare Committee of the new European Food Safety Authority, said in 2003: “There is a licensed product available for use in salmon egg hatcheries, called Pyceze. It works to some extent but is some twenty times as expensive as malachite and has no residual effect in protecting the eggs between usage, so has to be used daily, at full therapeutic dose level.”³¹⁷ Bronopol (trade name Pyceze) is manufactured by Novartis and has been used in Norway since 1999. It was available for use in the UK in 2001.

Malachite green has long been suspected of causing genetic mutations that can lead to malignant tumours in humans. These cancer-causing properties were addressed in reports published in 1999 by the UK Department of Health’s Committee on Mutagenicity and Committee on Toxicity.³¹⁸ However, salmon farmers, the chemical industry and the government must have been well aware of the toxic and carcinogenic effects of malachite green since the 1960s.³¹⁹

In January 2001, the US National Toxicology Program issued the following warning about malachite green: “Because of its effectiveness this chemical is considered to have a high probability of abuse . . . the use of this product could result in significant worker exposure and the effluent from the aquaculture facility could enter the water supply resulting in exposure of the general public through recreational activities and drinking water. Finally, the use of malachite green in food fish could result in human consumption of malachite green residues.”³²⁰

In January 2003 a European Commission science panel recommended classifying malachite green as a toxin that poses a risk of birth defects and harm to public health.³²¹ It has been reported to be injurious to the human eye, it caused skin problems in six of eleven eczema patients,³²² and in 2004 the US Food and Drug Administration received information from the US Fish

and Wildlife Service and the Centre for Diseases Control and Prevention about a possible correlation between hatchery workers' exposure to malachite green and the formation of acoustic neuromas (tumours that can lead to hearing loss, imbalance and brain stem compression).³²³

Two recent initiatives on either side of the Atlantic could be the final nails in the coffin for malachite green use in fish farming. A meeting of the US Department of Health and Human Services National Toxicology Program in February 2004 brought official confirmation of malachite green as a carcinogen a step closer. Malachite green was "nominated for toxicity and carcinogenicity studies due to the potential for consumer exposure through the consumption of treated fish."³²⁴ And in October 2003 a meeting of the World Trade Organization's Committee on Sanitary and Phytosanitary Measures agreed to the European Commission proposal to set minimum required performance limits (MRPLs) for malachite green in farmed fish. MRPLs for malachite green were formally adopted in November 2003 and are due to come into force in December 2004.³²⁵

Whether the new measures on malachite green are successful or not is somewhat irrelevant. The UK's Veterinary Medicines Directorate has said that "although the use of malachite green was banned in the UK [in 2002], estimates indicate that we can expect to see residues up to around June 2006, and possibly for longer."³²⁶ Malachite green, like teflubenzuron, ivermectin and emamectin benzoate, is so persistent that even if salmon farmers clean up their act right now, its "lingering legacy" will still be found in food for a long time to come.³²⁷

Shutting the Cage Door after the Salmon Have Bolted

It is clear from these chemical case studies that salmon farms are slipping through the net. In a complete reversal of the precautionary principle, the policy of governments has been to issue licences for toxic chemicals first and ask questions second (and then only if they have to).³²⁸ So instead of completing a risk assessment before a chemical is approved for use, we have the unsatisfactory situation of assessments taking place after the event, if they occur at all, far too late to ensure either environmental or human safety.³²⁹

The UK government's Post-Authorisation Assessment Programme illustrates all that is wrong with the current chemicals licensing system. This £4 million pesticide probe was first mooted in 1994, but the salmon farming industry successfully delayed it until 1999. Since then it has suffered a series of setbacks and faces an uncooperative attitude from the industry. The five-year

study has taken so long to publish its findings that many of the chemicals being assessed will have been phased out in favour of a new generation of chemicals.³³⁰

Plugging the research gap in the environmental assessment of chemicals is of primary importance. A report published in 2002 by the Scottish government concluded that a great deal of research needed to be carried out “on the toxicity of emamectin benzoate, teflubenzuron, copper and zinc to benthic organisms commonly found in Scottish sea lochs; more information is required on the long-term effects of cypermethrin, emamectin benzoate, copper and zinc on sediment associated organisms; more information is required on the dispersion, fate, and potential long-term effects of multiple cypermethrin treatments (at single and multiple farm sites) within a loch system; more information is required on the potential effects of concurrent emamectin benzoate treatments at several farm sites within a loch system.”³³¹

For chemical companies, less is more. The less public scrutiny, the more chemicals will be sold and the more profit. It is clear that there is a great deal of money at stake here. The worldwide parasiticide market for terrestrial livestock was worth US\$3 billion in 2000,³³² and companies such as Novartis and Schering Plough apparently see oceans of opportunity in the sea cage fish farming sector. The market for chemical products for sea louse control currently accounts for less than one percent of global parasiticide sales, but it is an emerging one.³³³

Sea lice infestations can reduce the yearly market value of farmed salmon by up to twenty percent due to cosmetic effects, poor growth and fish mortalities.³³⁴ In 2002 the Scottish Salmon Growers Association estimated the costs of stress on infected fish and loss of growth due to sea lice infestation alone cost the Scottish salmon farming industry £13 million per annum. Big bucks are involved: “Discussions with pharmaceutical companies reveal that there is a market of £4-£5 million for medicines, and when this is added to the costs of administering medicines including hardware and labour, the costs of accidental treatment mortalities during bath administration, and the costs of down-graded product at harvest, a total cost per annum of £20-£30 million is acceptable to most in the industry.”³³⁵ If you extrapolate that figure around the world and take into account inflation, you have a conservative estimate of £200 to £300 million per year to be spent on parasiticides. Acceptable costs to the salmon farming industry perhaps, but the marine environment, shellfish, wild salmon and consumer health bear the brunt of these savings—a heavy price to pay for cheaper salmon.

A War with No Winners, a War with No End

In this warped chemical weapons race there is a recurring nightmare: Government authorities license a chemical knowing full well it is toxic, protect the chemical company from public scrutiny, and when a risk assessment is finally published years later (after the target's resistance to the chemical has made its use redundant anyway), a new chemical takes its place.

Salmon farmers are fighting a losing battle against their nemesis, the sea louse. As Craig Orr of Watershed Watch says: "Lice rapidly develop resistance to all chemical therapeutants (three to five years) and, as long as we practice open-net-cage aquaculture, we'll always need newer, better and more expensive drug and lice treatments."³³⁶ So concerned are salmon farming nations that an international European Union-funded project named SEARCH (SEALice Resistance to CHemotherapeutants) involving Norway, Scotland, Ireland and Canada has been set up to combat the problem of sea lice resistance.³³⁷

In the absence of new treatments, salmon farmers use existing chemicals in greater quantities³³⁸ or in combination. "Integrated Sea Lice Management"—a phrase often used by the salmon farming industry—merely means using several different chemicals instead of just one.³³⁹ This is done without taking into account their synergistic effects—the so-called cocktail effect.

The chemical industry continues to put new and dangerous chemicals on the market and is attempting to "harmonize" the use of chemicals worldwide. This would mean that chemicals available in one country are also available in others.³⁴⁰ The Veterinary International Co-operation on Harmonisation, launched in 1996, is "aimed at consolidating technical requirements for veterinary product registration."³⁴¹ A September 1997 roundtable discussion in Edinburgh on "Progress with Registration of Drugs and Vaccines for Aquaculture" sought "world-wide co-operation to gain approvals of drugs." Similar initiatives have been developed around the world. Salmon Health, for example, was developed in Canada "to assist pharmaceutical companies to compile data submission dossiers to meet the requirements of regulatory and licensing agencies." It is run by the Canadian Aquaculture Industry Alliance and is funded by the aquaculture and manufacturing sectors (pharmaceutical and feed) and by government agencies. Over five years the number of approved therapeutants for salmon farmers in Canada increased from three to six, with temporary registration of three additional compounds.³⁴² A cynic might see this initiative as nothing more than an attempt by the chemical

lobby to short-circuit the chemicals registration process and fast-track chemicals globally.

There is an eerily familiar sense of déjà vu as the same mistakes are repeated over and over again: the name of the chemical may be different but the problem remains the same be it canthaxanthin, dichlorvos, azamethiphos, cypermethrin, teflubenzuron, ivermectin, emamectin benzoate, TBT or malachite green.

Closing the Net

To avoid a “Silent Spring” of the sea we must curb chemical use in the entire sea cage fish farming sector now (sea bass, bream, barramundi, kingfish and tuna farmers are already using similar chemicals). Even then the lethal legacy of sea cage salmon farming will be with us and our children (if we don’t become too impotent to have them) for a long time to come. Over 40 years after *Silent Spring* was published, the chemical Carson exposed, DDT (widely banned in the early 1970s), is still being found in farmed salmon along with PCBs, dioxins and other contaminants. It is a dreadful prospect to think what we will be finding in 2044.

The salmon farming industry must tackle the causes, not the symptoms of addiction. For the long-term health of the marine environment and consumers, the industry must stop discharging contaminated wastes directly into the sea and start ripping out sea cage salmon farms. If salmon farmers adopted closed containment technology to treat their chemical wastes, environmental impacts would be reduced at a stroke, yet closed containment systems are dismissed as too costly. A SEPA report in 1998 concluded: “Capital costs are likely to be prohibitively expensive for all but the

Average PCB levels found in BC salmon



largest producers. Although land-based systems currently offer the greatest potential for containment and treatment of wastes following chemotherapeutant use, the systems are not viable for commercial salmon production under present economic conditions.”³⁴³ Similar studies on wastewater treatments and closed containment technology have been conducted in British Columbia but, all too predictably, are considered “uneconomic.”³⁴⁴

Even for in-feed treatments there is a solution other than dilution. “What we’re developing is a carrier for medicines that will allow medicine to be added to the fish food and then come out in the stomach of the fish,” says Lynne Wallace of Ensolv Ltd. in Scotland. “From an environmental point of view, this will reduce the amount of waste going into the water column. What’ll happen is that if the product goes into the environment, the therapeutant chemical won’t leak into the water, and it’ll be able to be collected, as opposed to having the waste discharged into the water. We need to get fish farmers on board. If they could reduce the amount of environmental waste, that would improve their position with respect to licensing, and how much of a product they could use. At the same time, we need the pharmaceutical companies because obviously it’s their medicines that would go into the carrier.”³⁴⁵

It is far too late for the hundreds of thousands of tonnes of chemical wastes dumped into the sea by salmon farmers since the 1970s, but it is at least a step in the right direction. Other sensible solutions include reducing stocking densities, increasing fallowing periods or using biological controls such as cleaner fish, which work in harmony with nature. As Rachel Carson said on CBS television shortly before her death in 1964 from breast cancer: “Man is a part of nature, and his war against nature is inevitably a war against himself.”³⁴⁶