Air pollution and biodiversity

Introduction

Air pollution is a serious threat to the diversity of life. This factsheet deals primarily with the effects of acidification, nitrogen fallout, and ground-level ozone – where the specific pollutants are sulphur dioxide, compounds of nitrogen and volatile organic substances.

Another potentially serious threat is climate change, only touched upon here, resulting from anthropogenic emissions to the atmosphere of greenhouse gases.

In general it can be said of the effects of air pollutants on biological diversity that:

Lower life forms are usually more affected than higher forms. Whereas the effects on larger organisms may be more noticeable, those that can be seen on lower forms of life are far more extensive, as regards both the number of species that are affected and sensitivity of individual species. Especially hard hit are lichens, bryophytes, fungi, and soft bodied aquatic invertebrates.

On land, plants are more affected than animals, but not in freshwater. By nature plants are less able to adapt to sudden changes in pollution levels and climate than animals, which can often migrate or change their source of food. A wide survey of the literature (Tickle et al. 1995) gave evidence of more than three times as many terrestrial plants being affected by pollution as animals. In freshwater ecosystems on the other hand the decline is greater among animal species than among plants. It has been found in studies of benthic fauna in Sweden that the diversity of animal species declined by 40 per cent with a reduction of the water's pH value by one unit, as against a decline of only 25 per cent for plant species.

While most affected species decline as a result of air pollution, some increase. A great majority of species are adversely affected by air pollutants. There are some however that benefit. Many aphids, for instance, appear to be stimulated by air pollutants. Other species are resistant to them and expand to fill the space left by the disappearance of more sensitive kinds.

Effects on different groups

Most of the studies of the effects of air pollutants on animals and plants have been confined to single species or groups of species. In the study mentioned (Tickle et. al 1995), there were found to have been documented effects on some 1300 species in Europe, including 11 mammal, 29 bird, 10 amphibian, 398 higher plant, 305 fungi, 238 lichen, and 65 invertebrate.

Sensitivity varies, generally speaking, from species to species within each group of organisms and according to such things as the pollution load, the stage of life at which the individual is exposed, and the way competition becomes changed within a particular ecosystem.

The effects found on plants were mostly among lichens, bryophytes, fungi, herbaceous flowering species, and trees. The sensitive examples include blue-green algae of the Nostoc and Scytonema genera (endangered all over Europe because of air pollution), lichens of the Usnea and Ramalina genera (decline due to gaseous sulphur dioxide), and Lobaria (reduced by wet acid deposition), mycorrhizal fungi (affected by nitrogen deposition on acid soils), some species of herbaceous flow¬ering plants, including Primula veris, Vicia sepium, Trifolium medium, and Melica nutans (cause of decline: soil acidification).

Although the effect on invertebrates has been poorly researched, the fact of their being affected has been statistically proved. Among the species that decline in acidified water are all kinds of zooplankton (number of species more than halved), flatworms, leeches, snails, bivalves, small crustaceans, freshwater crayfish, and some mayfly and stonefly larvae (although a few are more tolerant). Some species of insect, such as water boatmen and dragonflies, actually increase in acidified water because of the predatory pattern having changed with the disappearance of fish. Terrestrial invertebrates are also affected, although in their case knowledge is still more limited. Particularly sensitive groups are earthworms, slugs and snails, but effects have also been proved on certain kinds of spider, butterflies, and beetles.

Relatively few examples are known of higher animals suffering direct toxic effects either from acidity or gaseous air pollution. The effect tends rather to be indirect, mainly through loss of food sources and the disturbance of reproductive systems. The connection is clearest as regards food loss in acidified waters, which has hit for instance otters, dippers, and ospreys. Amongst animals of slightly lower orders, particularly amphibians and fish, the effects are more commonly related to loss of reproductive capacity - as in the case of Atlantic salmon, brown trout, the common frog and natterjack toad. Usually it is not acidity itself that appears to be the problem, but the effect of acidification in releasing metals such as aluminium into the water.

Research has also indicated that high levels of aluminium, arising from acidification, have contributed to a thinning of the shells on the eggs of some bird species, such as the great tit and pied flycatcher.

Ecosystem responses

Whether and in what way ecosystems are affected by air pollutants depends especially on the nature, concentration and time of arrival of the pollution, but also on the existing status and nature of the particular habitat. In general it can be said that:

Some environments are particularly susceptible. Ecosystems are likely to be most at risk if they are on substrates with a low buffering capacity, and/or receive occasional, heavy doses of pollution, and/or contain key species that are vulnerable. Examples of the last are bark-living communities dependent on foliar lichens and epiphyte mosses. Details of some of the most sensitive European ecosystems appear in the next section.

Air pollution tends to reduce biodiversity, but not necessarily biomass or primary production. The effects on biodiversity are summarized on page 4. The losses usually represent a decline in rarer, more sensitive species, their places being taken over by commoner and more robust species. In the case of plants, these may be many successful weed species that are adapted to a wide range of soil and climatic conditions.

Air pollution does not respect the boundaries of nature reserves and conservation areas. Because loss of habitat has long been the greatest threat to biodiversity all over the world, much conservation effort has been directed to the creation of protected areas which, however, give little protection against air pollution. There are even studies suggesting that the protected areas of Europe are especially at risk from acidifying air pollutants, since they have often been set up on low-productive ground of little commercial value - which in many cases offers little resistance to acid fallout.

Liming is not the solution

There are few possibilities, apart from reducing emissions, of getting to grips with the effects of air pollution. In Scandinavia, liming has been used for decades as a means of counteracting acidification. This has saved sensitive freshwater ecosystems, and restored damaged ones. Liming does however leave obvious problems in its trail: disruption of ecosystems, long-term changes in water chemistry, and the risk of causing further damage by the shock of sudden changes in pH value. A similar mixture of benefits and problems occurs with liming of forest soils. Fundamental in both cases is the fact that as long as pollution continues, any gains will be both partial and temporary.

Air pollution is a significant contributory factor to the global decline in biodiversity
To date, research suggests that air pollution has been involved in the decline and attenuation of species, rather than their extinction. It is likely, however, that if the trend continues, particularly sensitive groups in temperate regions will continue to decline until they have become extinct. This is, for example, a real possibility for some lichens. Pollution effects in some areas of the tropics, which are now becoming ever more widespread, can also lead to extinction of species, since both biodiversity and ecosystems are more fragile there than in temperate regions.

Sensitive ecosystems

Among the ecosystems of Europe that are most affected by air pollution are the following:

Freshwater systems in base-poor areas. The surface waters are sensitive to acid deposition in areas where the bedrock does not easily weather. They have become acidified in many parts of Europe, including Scandinavia, Belgium, mid-Wales, and Scotland, as well as in parts of eastern North America. The effects on freshwater life increase with the level of acidity. Some species and groups disappear quickly at the onset of acidification, while others remain resistant to damage, and in the absence of competition may even increase. Estimates indicate that at least 20 per cent of plant and animal species have died out in the 15,000-25,000 European lakes where the pH has fallen by more than 0.5 unit as a result of anthropogenic acid deposition.

Forest ecosystems in polluted environments. From the European survey of 1995 it appears that 25 per cent of the sample trees could be classified as damaged, in equal proportion for broadleaved and coniferous species. The worst damaged were oak (Quercus spp.) and fir (Abies spp.), 31 and 32 per cent respectively. (To be classified as damaged, trees must show a loss of leaves or needles of at least 25 per cent, compared with a reference tree of the same species.) Damage was particularly severe in the Czech Republic and Poland, were 60 and 53 per cent of the trees showed a defoliation of more than 25 per cent.

Most researchers now agree that air pollution plays an important role in this decline, along with a mixture of other factors such as climate change, forestry practices, and attacks of pests and diseases - the so-called multiple stress hypothesis. Some of these factors are interrelated; trees may for instance be so weakened by air pollution as to be especially susceptible to disease.

Mountain sites. High altitude environments will be among the first to show the effects of acidification. Although pollution often decreases with altitude, deposition can remain high because precipitation will increase. Harsh climatic conditions also make plants unable to absorb additional atmospheric nitrogen, which instead leaks into steams. From measurements in the Bavaêian Alps, it appears that ozone also increases with altitude.

Peat ecosystems. Since most peat bogs and mires are already acid or neutral, an additional load of acid can cause serious changes in the ecosystem. Peat ecosystems are also sensitive to additional inputs of nitrogen.

Heathlands. Air pollution can cause major changes in acidic or base-poor heathlands. Excess inputs of nitrogen to unmanaged heathland in the Netherlands, for instance, has resulted in nitrophilous grasses replacing slower-growing heath species.

Microhabitats on acid tree bark. Lichens are likely to decline more rapidly on acid than alkaline bark.

Plankton communities in the ocean. Research suggests that increased nutrient load, and so eutrophication, is having an important effect on plankton in some areas. Part of the loading is from atmospheric pollution.

References and further information

The information in this factsheet comes mostly from Air Pollution and Biodiversity by Nigel Dudley and Sue Stolton, WWF International 1996. Also recommended is Acid Rain and Nature Conservation in Europe by Andrew Tickle et al., WWF International 1995.

The biodiversity - climate change complex is treated at length in Some like it hot: Climate change, biodiversity and the survival of species by Adam Markham, Nigel Dudley and Sue Stolton, WWF International 1993. All three can be ordered from WWF International, CH-1196 Gland, Switzerland.

FACTFILE 1: Not so simple

It is far from simple to determine the extent to which air pollutants affect biodiversity:

Different pollutants will affect any one species in a variety of ways. The mixture of airborne pollutants to which organisms are exposed can vary in composition, and each combination will have a slightly different effect. Different substances in combination can sometimes have a greater effect than the sum of the effects each one of them would have separately, while in other combinations they can cancel each other out. Although our knowledge of pollutant interactions is still limited, there can be no doubt that certain lichens, for instance, are more sensitive to gaseous sulphur dioxide than to wet deposition of acid, while for other species the reverse is true. Several species of sphagnum mosses decline where there is high sulphur-dioxide pollution, and a few are susceptible to nitrogen oxides too. But in acidified waters many of them increase.

Initially, some pollutants appear to be beneficial, only later to become harmful. Air pollution can benefit some species at the expense of others, either because they are especially resistant, or because the surrounding habitat changes in a way that favours them more than other species. Studies in Germany, for example, suggest that forest decline can result in a temporary increase in some endangered species, such as the three-toed woodpecker, citril finch, crossbill, and rock bunting -- by increasing the number of dead trees and the herb and scrub layer in managed forests. On the other hand research also suggests that a still greater number of species will suffer as a result of forest decline.

Air pollution poses both threats and opportunities. The effects of air pollution interact with natural and other anthropogenic factors to alter ecosystems. A number of changes occur, for instance, when a lake becomes acidified: more metals come into circulation, some insect species increase their numbers, fish disappear. This affects aquatic bird species in various ways. Fish-eating species such as divers will gain from the increased transparency of the water but lose because there will be fewer fish. Reproduction may improve because fewer young birds will be eaten by predator fishes, but be set back by an increased content of metals in the food.

Interaction with ozone depletion and climate change. Biodiversity will be affected both by ultra-violet radiation and climate change. Most threatened by climate change are boreal forests, the ecosystems of mangrove swamps, cloud forests, and some wetland and peatland habitats. Either or both of the above factors may interact with acid deposition.

Interaction of air pollution with natural and other anthropogenic factors. The effects of air pollution are further complicated by the fact that the pollutants are usually acting in the presence of other factors which themselves have an influence on ecosystems, such as forest management practices, soil types, and introduced plant diseases. Sorting out the most important factors is often difficult and sometimes impossible.

FACTFILE 2: A summary of the effects of air pollutants on biodiversity

ALGAE. Blue-green algae are particularly susceptible to a whole range of air pollutants. Some species risk extinction in polluted areas.

LICHENS. Probably the one group that shows the strongest responses to pollution, in the form both of dry-deposited sulphur dioxide and wet acid deposition. Sensitive species extinct in many localities and in some cases nationwide.

BRYOPHYTES. Also highly sensitive to many air pollutants, tree-living and bog mosses being especially susceptible.

FUNGI. Many mycorrhizal fungi decline in acidified environments.

PTERIODYOPHYTES. Evidence for the decline of some fern and many club moss species in polluted air.

HERBACEOUS FLOWERING PLANTS. Increasing evidence of decline, both from sulphur dioxide in the air and acidified soils.

TREES. Many species decrease in polluted environments on the account of air pollution and other stress factors.

MICROORGANISMS. Zooplankton decline in diversity in acidified waters, as do soil microorganisms generally in acid soils.

SOFT-BODIED INVERTEBRATES. Almost all lower invertebrates decline in acid waters, and many species, including earthworms, are known to do so in acid soils. There is increasing evidence of molluscs and other species being directly or indirectly affected by air pollution on land.

ARTHROPODS. Many crustaceans and insects decline in acid waters, although some insects thrive in the absence of competition. Fragmentary information suggests that air pollution is likely to cause many species to decline on land, although some, particularly aphids, thrive and increase in environments with high concentrations of sulphur dioxide.

FISH show a range of responses to acidification. Some species disappear in slightly acid waters, while others are able to withstand even fairly severe acidification. Decline has occurred widely in Europe and North America.

AMPHIBIANS. Many species decline in acidified waters, primarily because of reproductive failure. A few resistant species thrive in the absence of competition.

REPTILES. Information is lacking.

BIRDS. While a minority of species have declined because of losses in the food chain, especially in acidified waters, others have proved adaptable enough to cope with any changes.

MAMMALS. Despite much evidence of a build-up of heavy metals and sulphur in mammals in polluted areas, the main effects have been due to disturbances in the food chain for species such as otter and elk.

Source: Dudley & Stolton, 1996.