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5.6 Pollution

Pollution presents a wide range of pressures and risks to the natural environment. This section considers two of the more significant areas of risk: nutrient enrichment and toxic chemicals.

5.6.1 Current situation

5.6.1.1 Nutrient enrichment of terrestrial and aquatic habitats

Nutrient enrichment can lead to excessive growth of plant life in aquatic and terrestrial habitats, adversely affecting species and ecosystems – this process is known as eutrophication. Nutrient enrichment can arise from diffuse or specific point sources. The two principal sources of nutrient enrichment causing concern are phosphorus and nitrogen compounds entering freshwater and coastal water systems, and atmospheric nitrogen deposition which affects terrestrial as well as aquatic habitats.

In the freshwater environment, phosphorus loads in heavily populated catchments come largely from domestic and industrial sources (for example sewage treatment works). In contrast, in more rural areas loads come mainly from diffuse agricultural sources (particularly run-off from fields and also leaching through soils), although small point sources (such as septic tanks) can have significant local effects (Carvalho *et al*. 2005). Agriculture's contribution to phosphorus loading varies regionally from almost 50% in the West Midlands to less than 20% in the Thames catchment (White and Hammond 2007). In terms of the nitrogen load in freshwater systems, nationally diffuse agricultural pollution accounts for 60% and sewage treatment for another 32% (ADAS 2007). Coastal waters are subsequently influenced by these freshwater sources when they enter the sea, as well as by direct point and offshore sources.

Phosphorus and nitrogen loads have been reduced through improved treatment at major sewage works under the Urban Waste Water Treatment Directive and (for SACs and SSSIs) under the Habitats Directive and national legislation. There has been a decline nationally in direct inputs (from point sources such as sewage outfalls) of phosphorus by 50% and nitrogen by 35% to coasts and estuaries since 1990 (Defra 2005a). However, riverine inputs to coasts and estuaries, mostly dominated by diffuse sources, have not decreased and there is growing recognition of the need to tackle such sources (for example Johnes, 2000, Mainstone *et al*. 2008).

The main atmospheric sources of eutrophication are oxides of nitrogen (NO_x) from industry and transport and ammonia, principally from agriculture. Ammonia forms an increasing proportion of nitrogen deposition in the UK, now accounting for 47% of the total (RI Smith, pers comm., Hall *et al*. 2006b). These ammonia emissions come chiefly from livestock production and have increased substantially in the latter half of the 20th century due to agricultural intensification. Emissions of the other main source, oxides of nitrogen, have decreased by 48% since their peak in the 1970s and the main source is now the transport sector, which contributes 39% of total emissions (National Atmospheric Emissions Inventory, 2008). Natural soil processes also emit NO_x. This may account for 2-23% of the total in Europe (NEGTAP 2001), and is likely to increase under climate change.

Across the UK, the average atmospheric nitrogen deposition (to 2001) of 14.5 kg N ha^{-1} y^{-1} is around ten times higher than in the 19th century (NEGTAP 2001). The greatest deposition is in upland areas and parts of south west England and East Anglia where it may be more than double the average, reflecting patterns of rainfall, and road transport and agricultural emissions.

Nitrogen deposition also plays a role in acidification and is now proportionately more important than sulphur compounds (SO_x) in causing the acidification of upland soils and freshwaters. Background sulphate levels in air from the Atlantic, largely due to emissions from shipping, have recently formed an increasing proportion of UK sources.

5.6.1.2 Toxic chemicals

The toxic chemicals that enter the natural environment on a daily basis include pesticides, herbicides and veterinary medicines, and industrial and other chemicals. In addition, accidental releases can result in major pollution incidents (Environment Agency 2006a), and pesticides and other biocides are still deliberately used in illegal poisonings of wildlife (Barnett *et al*. 2007).

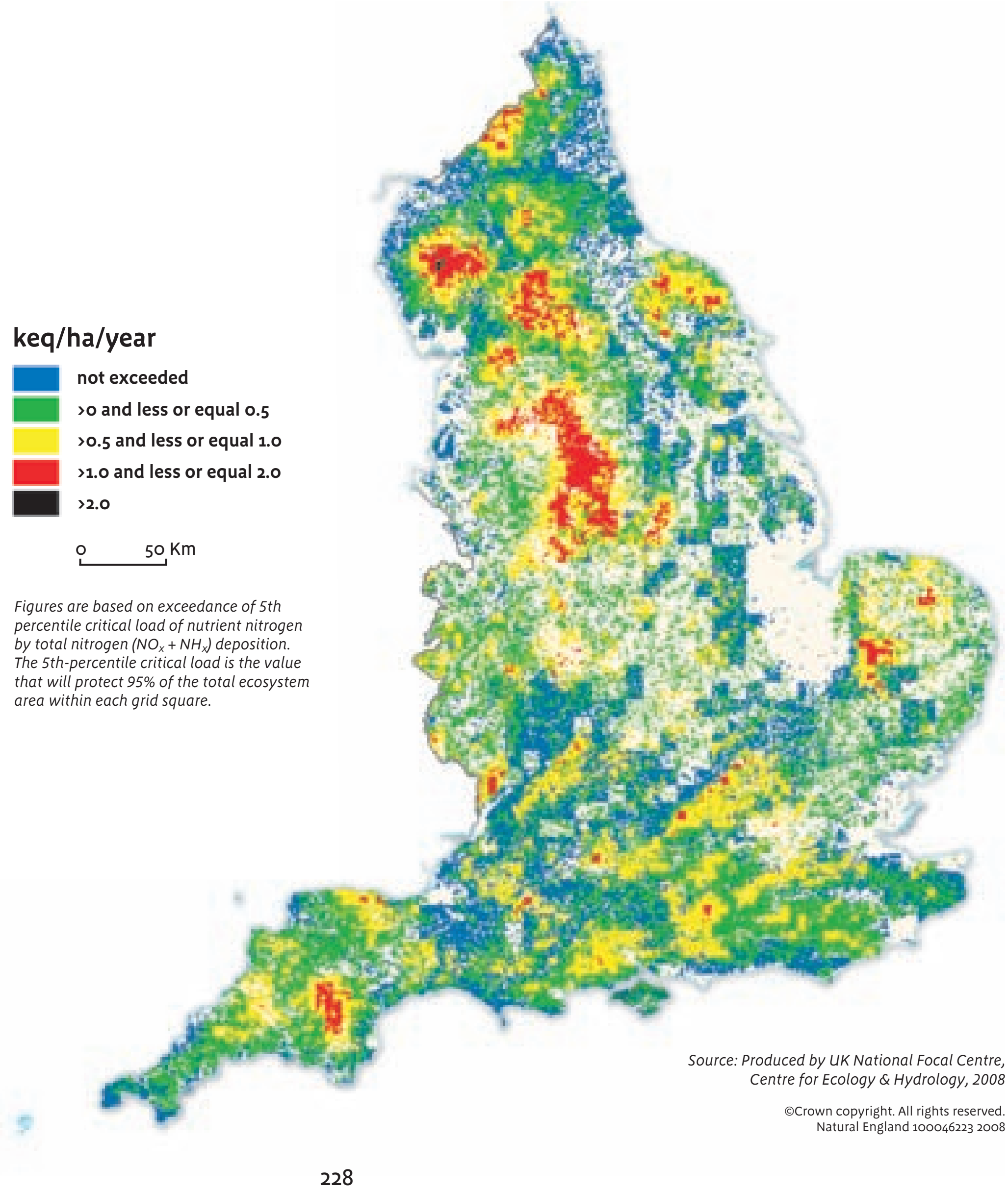
Ground level ozone is a global toxic atmospheric pollutant of growing concern, with potentially harmful effects on plant communities and agricultural crops (Morrissey *et al*. 2007). It is formed in the lower atmosphere by complex photochemical reactions between nitrogen oxides (NO_x) and reactive volatile organic compounds in the presence of sunlight. Highest levels tend to occur in the summer and there is large geographical variation across England with the highest concentrations in the South East.

5.6.2 Implications for the natural environment

5.6.2.1 Eutrophication

Eutrophication from atmospheric nitrogen deposition is now one of the major threats to ecosystems at a global level alongside climate change and biodiversity loss (eg the GANE programme (NERC 2005)). The effects of atmospheric nitrogen deposition are usually assessed in terms of exceedence of the 'critical load' (the level of exposure below which there will be no known significant harmful effects on sensitive elements of the natural environment). Critical loads for nutrient nitrogen (combined ammonia and NO_x deposition) are currently exceeded in about 89% of the area of sensitive habitats in England (J Hall pers. comm.; Hall *et al.* 2006b) (Table 5.7) with the uplands being particulary sensitive (Figure 5.9).

Figure: 5.9 Exceedance of nutrient nitrogen critical loads by total nitrogen deposition 2003-2005



Figures are based on exceedance of 5th percentile critical load of nutrient nitrogen by total nitrogen ($NO_x + NH_x$) deposition. The 5th-percentile critical load is the value that will protect 95% of the total ecosystem area within each grid square.

Source: Produced by UK National Focal Centre, Centre for Ecology & Hydrology, 2008

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Evidence exists for broad-scale vegetation changes due to nutrient deposition (Leith *et al*. 2005, Stevens *et al*. 2004). Studies have shown a general shift toward more nitrogen-tolerant plant species (Preston *et al*. 2003, Countryside Survey 2000, Braithwaite *et al*. 2006), with increases in those characteristic of more nutrient-rich soils and decreases in those characteristic of less fertile habitats. Increased dominance by grasses, especially species tolerant of higher nutrient conditions, has also been observed in the Brecklands, northern England, and the chalk grasslands in southern England. There have also been losses of lower plants, especially in upland areas (NEGTAP 2001).

Atmospheric nitrogen has further effects on plant communities, including through its contribution to acid deposition; direct toxicity of ammonia to sensitive plants; greater susceptibility of plants to feeding by invertebrates; changes in frost and drought tolerance; and changes to mycorrhizal infection rates (Achermann and Bobbink 2003;. Hall *et al*. 2006a). Close to intensive livestock units, concentrations of ammonia can be very high, with serious impacts on designated sites (Pitcairn *et al*. 1998).

Acid deposition (resulting from emissions of sulphur and nitrogen) has caused widespread acidification of acid sensitive soils and waters in the UK, as well as direct damage to sensitive plant species. According to the UK National Focal Centre for critical loads modelling and mapping, critical loads for acidity are exceeded in 71% of the area of sensitive terrestrial ecosystems in England (2003-2005 estimates) (J Hall pers. comm.). Reductions in emissions have resulted in chemical recovery in some acidified freshwaters though biological recovery has been less evident. Large areas of semi-natural habitat are likely to continue to exceed critical loads as diffuse sources of nitrogen contribute to acidity.

Routine monitoring of protected site condition is not specifically designed to assess air pollution and so the impacts of nitrogen deposition on SSSIs are underreported (JNCC 2007a). It is currently reported that air pollution is a reason for 7.8% (16,804 ha) of SSSI area in England being in adverse condition, but this is likely to be a significant underestimate. Table 5.8 sets out the extent of designated sites exceeding critical loads for nutrient nitrogen (Hall *et al*. 2006a).

Table 5.8 Designated sites in the UK exceeding critical loads for nutrient nitrogen

Site type	Area (km^2)*	Exceeded area (km^2)	Percentage exceeded area
SSSIs	21,061	14,191	67.4
SACs	14,625	9,144	62.5
SPAs	12,119	7,081	58.4

* This is the area of designated sites that occur in 1 km grid squares of the UK for which critical loads for terrestrial habitats are mapped
(Source: Hall *et al*., 2006a)

Table 5.7 Habitats exceeding critical loads for nutrient nitrogen in England 2003-2005

Broad habitat	Habitat area (km^2)	Exceeded area (km^2)	Percentage area exceeded	Accumulated exceedance (keq/year)
Acid grassland	2,620	2,537	96.8	144,845
Calcareous grassland	3,312	2,181	65.9	68,989
Heathland	2,466	2,373	96.2	125,829
Bog	1,007	1,007	100	91,898
Montane	2	2	100	224
Coniferous woodland (managed)	1,719	1,719	100	305,765
Broadleaved woodland (managed)	5,588	5,588	100	1,123,423
Unmanaged woods (ground flora)	2,252	2,252	100	437,381
Atlantic oak (epiphytic lichens)	150	150	100	28,794
Supralittoral sediment	1,183	269	23.1	5,247
All habitats	**20,299**	**18,078**	**89.1**	**2,332,395**

(Source: CEH (J Hall pers comm), 2007)

Major risks to aquatic ecosystems arise from eutrophication due to nutrient enrichment, organic enrichment and increased fine sediment loading. Eutrophication alters the relative rates of plant growth, especially by stimulating algae, with consequences for plant communities and for overall food webs affecting invertebrates, fish, birds and mammals. Indirect impacts include oxygen depletion in the water column and in sediment, and increased turbidity; these indirect impacts often exacerbate eutrophication symptoms.

Most freshwaters in England are affected by nutrient enrichment from human activities with only a few remote upland water bodies remaining near pristine. Through a national assessment programme, the Environment Agency has made a preliminary assessment of areas of highest diffuse pollution risk. About 50% of river stretches (by length) may be at risk of failing Water Framework Directive quality objectives due to diffuse phosphate pollution (Environment Agency 2004c). Seventy per cent of the area of river SSSIs considered to be in unfavourable condition is due to diffuse pollution, mainly from nutrient enrichment due to factors such as run-off and leaching from agricultural land, and 41% is unfavourable due to a range of point-source pollutants, including nutrients. Agriculture is also a significant source of fine sediment which smothers river plants and gravels important for invertebrates and fish spawning. The England Catchment Sensitive Farming Delivery Initiative has begun to reduce agricultural diffuse pollution affecting SSSIs within priority catchments (see Section 6.6.1).

In contrast to rivers, there is less widespread quality monitoring of lakes under the Environment Agency's risk-based monitoring programme. The *Water Framework Directive River Basin Characterisation* report for England and Wales (Environment Agency 2004a) indicated that up to 53% of lakes were at risk of failing to meet good ecological status due to diffuse water pollution. The 1996 Lowland Pond Survey (DETR 1999) showed that at least 50% of ponds are highly degraded and that there is widespread evidence of enrichment and other diffuse pollution impacts. Approximately 80% of a sample of lake SSSIs were affected by eutrophication in 1998 (Carvalho and Moss 1998). This is mainly from phosphorus enrichment, but there is emerging evidence that increased nitrogen may also be having an effect in reducing submerged plant diversity (eg James *et al*. 2005). Other factors such as overstocking with bottom-feeding fish can interact with nutrient loads to cause greater problems.

Extensive areas of the coastal waters of England are enriched by nutrients from land-based sources (Defra 2005b). The risk of eutrophication to these waters depends on their vulnerability to nutrient enrichment. Defra has identified 11 sensitive English coastal areas under the requirements of the EC Urban Waste Water Treatment Directive where there are eutrophication risks (partly from point sources) or impacts (Defra 2007h). The largest concentration is in southern England. The Environment Agency's review of Consents programme currently shows that 11 SACs and SPAs, with marine components, (approximately 15% of the England total) are impacted by or at risk from eutrophication.

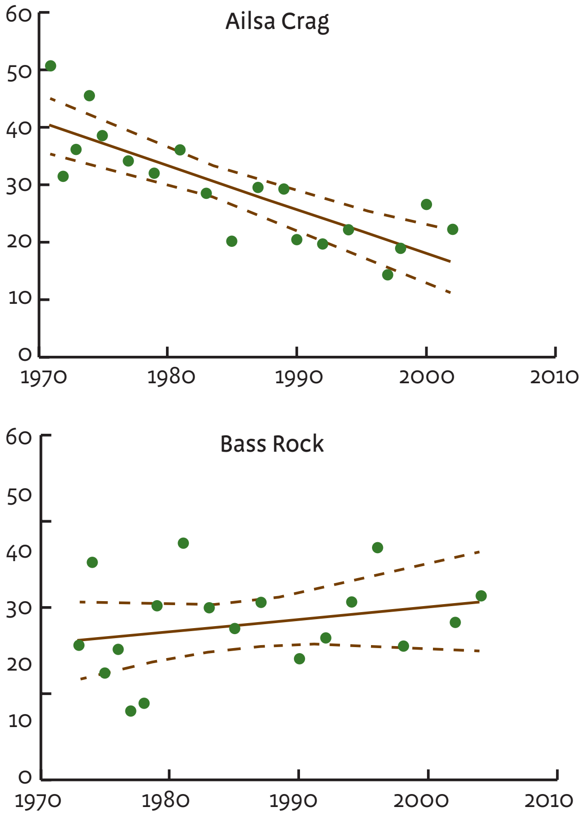
5.6.2.2 Toxic chemicals

A range of chemicals affect wildlife populations. This can be via direct lethal effects (for example cypermethrin-based sheep dip pollution incidents have impacted upon populations of white clawed crayfish) (Environment Agency 2006a); endocrine-disrupting effects (such as effects on dog whelk due to exposure to tributyl tin; see also below) (Bryan *et al*. 1986, Sayer *et al*. 2006); or indirect food web effects such as pesticide impacts on farmland birds (Boatman *et al*. 2004). However, the risks to biodiversity from some 30,000 chemicals currently in use in the EU (European Commission 2007) are largely unknown.

Despite regulatory actions that have reduced emissions, some persistent, bioaccumulating and toxic substances remain a risk to the natural environment. For example, concentrations of tributyl tin (TBT, an antifoulant used to reduce the build-up of invertebrates such as barnacles on underwater surfaces) are still unacceptably high in some parts of the UK (Environment Agency 2006a), partly due to its persistence in sediments. Risks also remain due to uncertainties in chemicals authorisation processes, which largely involve evaluations of single substances and do not adequately assess the risks from chemical interactions in the natural environment, sublethal effects and their consequences for wildlife populations, or indirect effects such as those on the food chain.

As it is not practicable to monitor all chemicals, monitoring in the environment relies in part on a risk-based targeting approach and using indicators. The Predatory Bird Monitoring Scheme (PBMS 2006) monitors toxic chemicals of concern in predatory birds and their eggs. The PBMS has revealed that, despite controls over industrial and agricultural releases, mercury contamination in gannet eggs has failed to decrease across all UK colonies (Figure 5.10). It has also provided evidence of widespread exposure of predators to second-generation anticoagulant rodenticides (Figure 5.11), thereby highlighting the risk to wildlife from these compounds.

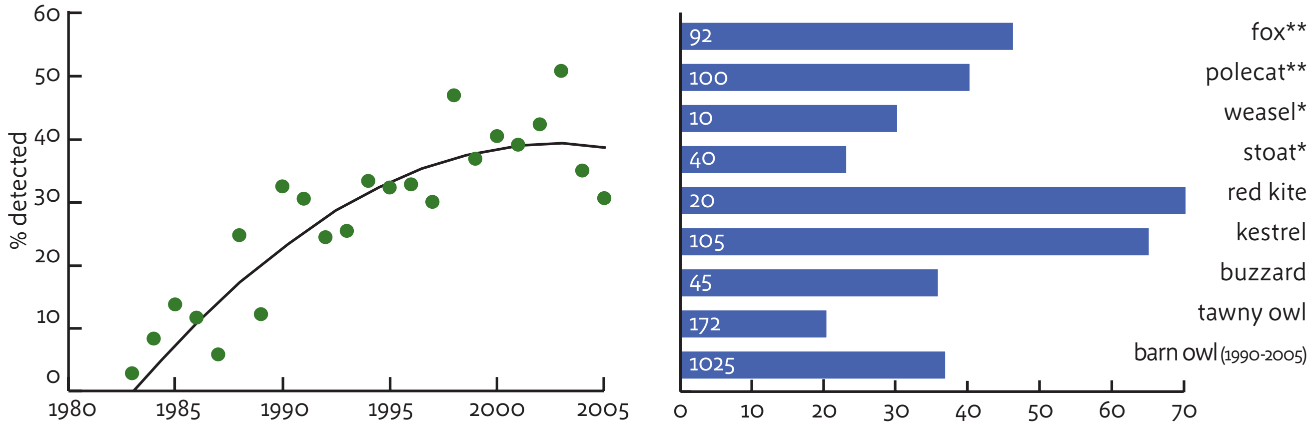
Figure 5.10 Long-term trends in mercury residues in gannet eggs (1970-2002)



Data are derived from Scottish colonies at Ailsa Craig (west coast) and Bass Rock (east coast). Lines shown are linear relationship (with 95% confidence intervals) between mercury concentration and collection year.

(Source: Shore *et al*. 2006)

Figure 5.11 Changes in exposure of barn owls to second generation anticoagulant rodenticides (SGARs) and exposure footprint for SGARs in predators in the UK



% of barn owls with detectable liver concentrations of one SGAR. Number of barn owls analysed each year is approximately 50. Data from PBMS

% of individuals tested that had detectable liver concentrations of one or more SGAR. Numbers in white indicate number of animals tested

(Sources: PBMS-CEH, 2008, McDonald *et al.* 1998*, Shore *et al.* 2003a, 2003b**)

5.6.3 Forward look

Although significant reductions in emissions of many of the major pollutants have taken place or are planned, risks remain in certain areas. The reductions so far may not sufficiently lower the risk to sensitive habitats and species or to designated sites. For atmospheric pollutants, reductions in point source emissions by 2010 are expected under the EC National Emissions Ceiling Directive. There is no equivalent programme to tackle diffuse atmospheric sources (Fraser and Stevens 2007), although the European Commission is likely to set tighter limits for a range of atmospheric pollutants to be met by 2020. Even with these reductions, critical loads for acidity and eutrophication are likely to continue to be widely exceeded (Hall *et al.* 2006b).

Changes to regulation such as the Water Framework Directive and REACH (Regulation, Evaluation, Authorisation and Restriction of Chemical substances) will improve our understanding of the risks associated with a number of toxic chemicals, and will also aim to phase out, reduce or substitute the most hazardous (European Commission 2007). However, it is likely that most effort will continue to be aimed at controlling single substances, and the environmental risks of complex mixtures will remain unclear.

Population pressure and climate change will affect future pollution risks to the natural environment. Population increase will place further pressures on sewage infrastructure. Likely increased demand for water may result in reduced river flows and water levels, exacerbating the impact of higher nutrient levels in the aquatic environment (Environment Agency 2007a). Climate change projections suggest an increase in intense rainfall events, generating greater surface run-off with associated increased loads of phosphorus and fine sediment. Decreased river flows in hotter, drier summers would reduce flushing capacity and exacerbate the impacts of higher nutrient levels, with increased temperatures stimulating plant growth, and algal build-up resulting in impacts on biodiversity.

The impacts of toxic chemicals on the natural environment are likely to be affected by climate change in a number of ways, both directly (for example higher temperature changing chemical behaviour) and indirectly through changes in use, availability and management of land and water. For example, changes in the occurrence and spread of plant pests and diseases are likely to result in alterations in pesticide usage. Increased storm events and management of water bodies could increase disturbance of historically contaminated sediment in estuaries, increasing risks to aquatic wildlife. The impacts of air pollutants on ecosystems may be modified through climate change in a number of ways, for example, via changes in plant uptake of pollutants, effects on soil microbial activity, and on soil mineralization rates (Defra 2007b). Critical levels for ozone effects on vegetation are already widely exceeded (Coyle *et al.* 2002), and background emissions of precursors in the northern hemisphere are increasing. Ground level ozone concentrations are expected to change in complex ways in response to emission controls and to climate change. Hotter summers may increase the frequency of high ozone episodes (Morrissey *et al.* 2007).