# The physical and chemical environment of gardens

**By Steve Head** **Reviewed by Ken Thompson**

In Britain, people garden from the frost-free oceanic bliss of the Scilly Isles, to the dry plains of East Anglia, or the wind-blown and cold uplands. There is no shortage of literature on how climate affects what gardeners can grow, but how does the physical environment in general affect garden wildlife?

## Climate and geography

The north-south gradient has a great impact on which species can survive in an area, mainly through the impact of climate. There are, for example, 58 butterfly species in Britain, and numbers are greater in the south. There are 46 butterfly species in Hampshire[1] and only 29 species in the Scottish Highlands[2] (but including several northern species like the mountain ringlet and scotch argus which are never seen in the south). In the extreme environment of the Shetlands, only 14 butterfly species are recorded, mostly rare vagrants[3]. This geographical trend naturally reflects on what can be found in gardens, and we can expect climate change to have an impact; already some butterfly species like the comma butterfly are extending their range north, while there is concern that some of the northern species may be squeezed out[4].

There are also gradients in climate from west to east in Britain. In general, western areas, especially the high ground, receive much more rainfall than eastern coastal areas. Much of the western seaboard gets over 1,500 mm rain per year, while most of East Anglia gets less than 800 mm[5]. High altitude increases rainfall on windward hills, but can result in less rain over rain-shadow areas. Higher set gardens (and coastal gardens) are more likely to be afflicted by high winds, and average temperature drops by about 5°C per kilometre (0.5°C per 100 metres) altitude[6]. Although the relationship is complex, higher ground is more likely to experience frost, and frosts are particularly rare on south western sites where the prevailing wind brings warm air off the sea. People living close to the coast in Cornwall can grow many plants outside in the garden that need greenhouse protection in the rest of Britain.

## Temperature and gardens

Although gardens broadly share the climate of the region in which they are set, large urban areas experience the “heat-island” effect. This is defined as the rise in temperature of any man-made area, resulting in a well-defined, distinct "warm island", contrasting with the lower temperature of the nearby natural landscape[7]. Cities heat up for several reasons. Buildings increase the surface area for the sun’s rays, and heat up noticeably in the daytime, releasing the stored heat at night. Human activity, business and transport generate waste heat, as do air conditioning in summer, and central heating in winter. Where vegetation is minimal, cooling by transpiring leaves is prevented. Generally inner cities are hottest, with cool areas over parks. Suburban areas, with a high proportion of garden space, heat up less than more built up areas. As buildings retain heat, the difference in temperature is often more marked at night than in the daytime, and in still conditions rather than windy.

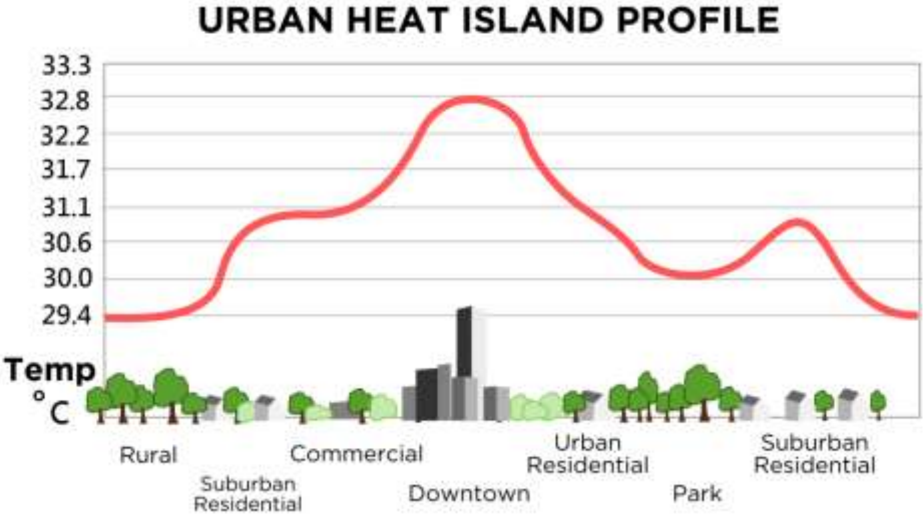


**Diagram illustrating the heat-island effect in a US context.**[8]

In hot summers the heat island effect can make city life for people nearly intolerable or positively dangerous, causing respiratory distress, heat stroke, heat exhaustion, fainting, and cramps[9]. During the 2003 heat wave in France, almost 15,000 excess deaths were recorded, and Paris was severely affected, with an excess death rate of 141% over normal rates for the same period. People over 75 were most likely to be affected[10].

Warm urban environments affect wildlife in gardens mainly through the comparative rarity of frosts. There is a marked heat-island effect in London when overnight temperatures, from late autumn to early spring, can be over 5 °C higher than in the outer suburbs and surrounding rural areas. London gets less than 30 air-frost days per year. This effect is less marked in smaller urban areas, and can be negated by topographic "frost pockets" like Benson near Wallingford, which has 55 air frosts and 110 ground frosts per year, and only July and August are historically free of air frosts[11]. City gardeners, and their wildlife, experience longer, warmer growing seasons, and can grow tender exotic plants like *Echium pininana* out of doors.

***Echium pininana*, native to the Canary Islands, growing superbly at Roots and Shoots, Lambeth London. Photo David Perkins**

We don't know much about how animal wildlife responds to the higher temperatures in cities, but it could be beneficial for cold-blooded insects and vertebrates. One American study found the scale insect pest *Parthenolecanium quercifex* was 13 times more abundant on willow oak trees in the hottest parts of Raleigh, NC, in the south-eastern United States, than in cooler areas, and this related to adaptation, and was not due to stressed plants or reduced numbers of parasites or predators[12]

Further evidence for an effect of local climate on garden biodiversity is provided by the species composition of garden lawns in Sheffield where there are substantial differences in altitude between districts. Altitude related temperature differences were found to have a detectable influence. Most of the variation in the vascular plant flora of lawns in Sheffield was explained by factors correlated with the 200 m decline in altitude from west to east in the samples, with plants of woodland or damp habitats more common in the west, while weeds of waste ground were more common in the east[13]. In a further study within the BUGS project, malaise traps in the higher gardens caught significantly fewer beetles, spiders and social wasps, but significantly more craneflies, which are a classically upland group[14].

It is important to note that establishing green roofs or walls for amenity and to help reduce the heat island-effect for people, can produce additional valuable habitat for urban wildlife. See our Green roofs page for more information.

## Water and gardens

One of the more important ways in which gardens can differ from the countryside is in their availability of water. Areas down-wind of major cities can experience additional rainfall. Hot city air rises, and buildings displace incoming warm air upwards. As the rising air cools, it forms clouds which rain on the downwind suburbs[15]. This effect is of course minor to that of gardeners being able to manage water in their gardens.

**One water butt won't make a lot of difference in even a small garden, but they can be linked together to catch a large volume. In chalky areas, the rain water collected is ideal for watering lime-hating plants like azaleas in tubs.**

When rainfall is reduced during periods of drought, gardeners can water their plants and maintain a healthy level of moisture, without which their flowers and vegetables would wilt and reduce their growth rates. One study on resources available for wildlife estimated 86% of gardeners watered their gardens[16], although another study in the south of England found only 49% of householders with gardens or outdoor plants do water them, the rest wait for rain. Only a third of those who water use hosepipes, and about a quarter save water in butts[17]. It would be very interesting to estimate the impact that watering has on urban wildlife. Sound advice is available from the RHS website[18].

Another way that gardens differ from their surrounds is that some people provide water for birds, or create amenity garden ponds. Overall 15.7% of gardens in five UK cities had birdbaths, but the frequency varied from 4.9% in inner cities to 27.3% in the outer suburbs. The same study found an average of 8.2% of gardens with ponds; 2.6 in the inner city and 13.0% in the suburbs[19]. Water in any form benefits wildlife. Honeybees, for example, need litres per day in hot weather to cool their hives. Maintained garden ponds, particularly with associated bog gardens, maintain a moist habitat throughout the driest summer.

**Disturbance**

One worrying aspect about gardens as places for wildlife is the relatively high level of disturbance in urban areas. This is in the form of people and their pets, noise, and excess light at night. Many birds in particular are very sensitive to disturbance, especially during the breeding season. Minimum disturbance distances for key Scottish birds were reviewed recently, suggesting of the order of 300-600m for red kite *Milvus milvus*, 400m for peregrine , *Falco peregrinus* 100m for crossbill *Loxia pytyopsittacus* and *L. scotica*, and 50m for barn owl *Tyto alba*[20]. This pretty much precludes garden nesting for these species, although red kite in particular now commonly patrol and hunt over gardens as populations expand from their reintroduction areas. Cats are a particular issue with songbirds, and this is discussed in our page on Cats and Predators.

Noise levels are higher in urban areas than the countryside, and this does impact on some species. Many male birds sing to advertise and defend their territories, and too much competing noise could result in smaller and less viable territories. Nightingales in noisy parts of Berlin were found to sing louder that birds in quiet areas[21]. This may seem a simple response, but requires a greater expenditure of energy which could reduce efficiency of foraging for nestlings.

Urban robins have adapted by switching their territorial singing to the night time when there is less competition from high levels of daytime noise. Robins commonly singing at night experienced an average of 10db louder daytime noise than those that did not[22].

Studies in the Netherlands[23] and Spain[24] have shown that urban great tits *Parus major* overcome high ambient noise by singing at a higher frequency, which allows their song to be heard at a greater distance. This might seem a clever adaptation, but a subsequent study showed that male birds forced to sing higher were less attractive to females that seem to prefer lower pitched song, and proved less likely to mate successfully[25]. A similar adaptation has been found in the southern brown tree frog *Litoria ewingii* which calls at a higher pitch when competing with traffic noise, with an average increase in call frequency of 4.1 Hz for every extra decibel of noise, up to an extra 123 Hz[26].

**Light pollution**

Spill-over of artificial light in built-up areas is a major aspect of urban life, encouraging the creation of dark sky reserves so people can have the chance to see stars that are invisible from cities[27]. The impacts on wildlife are considerable, creating a "night light niche" for some predators which clearly helps them, but not their prey. Light causes mortality in nocturnally migrating birds, and influences many other aspects of their behaviour[28].

**Few people nowadays can see the stars from their homes as clearly as this. Artificial night light is a problem for many creatures.**
*Picture Michael J. Bennett Wikimedia Commons*

Male blackbirds (*Turdus merula*) exposed to night-time light intensities typical of cities develop their reproductive system earlier. Their testosterone levels rise, their testes mature, and they begin to sing and to moult earlier in the year[29]. The present levels of light pollution in cities may therefore exert a major influence on the seasonal rhythm of urban animals, but it is not clear what actual impact this could have, because the main control of breeding success is availability of food for the young.

The effect of artificial light on invertebrates recently reviewed by Buglife[30], has long been of concern to conservationists. Some insects, such as moths, are attracted to artificial lights at night, disrupting their normal behaviour and making them more vulnerable to predation by bats. Moths can be attracted to light from over 100m, and as many as one third of attracted insects die from collision with hot lamps, exhaustion or predation. The change in apparent day-length, which is often a trigger for insect behaviour, has more subtle effects which are not fully evaluated, causing changes to dormancy, migration and activity levels. Light pollution may be a factor in the decline of glow-worms in Britain.

## Chemistry - Pollution

Air pollution was once a major issue in many British cities when most heating was by coal burning producing soot and sulphur emissions which resulted in smogs and large annual deaths from respiratory problems. The Great Fog of 1952 caused the death of at least 4,000 people and resulted in the Clean Air Acts of 1956 and 1968[31]. We can assume that there was a corresponding impact on urban biodiversity, but there seem to be no data to estimate this. Since then the position has greatly improved, and the soot-adapted black (melanistic) forms of insects like the peppered moth, once dominant in cities, have become scarce again[32].

There is evidence that even lower current exposure levels to pollution such as nitrogen oxides ($NO_x$), volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), metals and particulates from vehicle exhausts can have damaging effects on local ecology[33]. A recent study showed realistic levels of exposure to diesel smoke resulted in changes in growth and phenology in some plant species, with a consistent trend for accelerated ageing, delayed flowering and changes in surface wax structure following pollutant exposure[34]. The study demonstrated clearly the potential for adverse effects on urban vegetation, but what ecological significance this has on typical gardens and their wildlife remains unknown.

**Chemistry: Nutrients**

A recent British review found that 58% of gardeners used fertilisers[35]. A study in Belgium found a similar proportion of gardeners using fertilisers, while soil analysis revealed that garden soils were generally of high pH and contained high or very high levels of phosphorus[36]. Almost half had more than 30 mg P per 100 g soil, and over a fifth had more than 50 mg, which is practically off the scale even for a fertile agricultural soil. As the researchers themselves put it, "*These (very) high concentrations of phosphorus are probably due to excessive fertilization*", and *"they do indicate that gardeners on average could do with less phosphorus fertilization"*.

This high garden fertility probably translates to high net primary productivity, and plenty of food for the rest of the food chain. Insect herbivores are generally favoured by the use of fertilisers, although not all to the same extent[37]; sucking insects show a much stronger positive response to fertilisers than chewing insects, while Lepidoptera and Hemiptera seem to be most favoured. Nitrogen fertilisers seem to be more beneficial for insects than phosphorus.

Runoff from highly fertile garden soil (and fish feeding) accounts for the generally high level of nutrient pollution in most garden ponds[38].

**Conclusion**

The physical and chemical environment of gardens is not the same as that in pristine country habitat, although not always as altered as in modern intensive agriculture. Some aspects, such as warmer conditions, watering and high fertility are probably largely beneficial to wildlife, while others, particularly pollution and disturbance are probably negative. It must be noted however, that there is generally a lack of published information, so with the probable exception of disturbance and birds, we can't be sure to what real extent urban biodiversity is affected by these differences.

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