The Ecological Implications of Light at Night (LAN)

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Key Words

Light at Night (Light Pollution)

Summary

Light at night (LAN) is now an established environmental problem, not only for astronomers but for the population at large. It has serious ecological effects that are wide ranging, and its environmental effects may be more serious than ever imagined. The ecological and environmental consequences are examined and emphasis is stressed on resolving the problem before it is too late.

Introduction

A casual glance at NASA images of the Earth at night[1] reveals the lights of thousands of cities. The larger cities will contain millions of

street lights, along with commercial, sports and decorative lighting. Most of these lights are on all night, every night, three hundred and sixty-five nights a year, (fig 1), so they must be having a measurable ecological and environmental effect. The most obvious effect of all

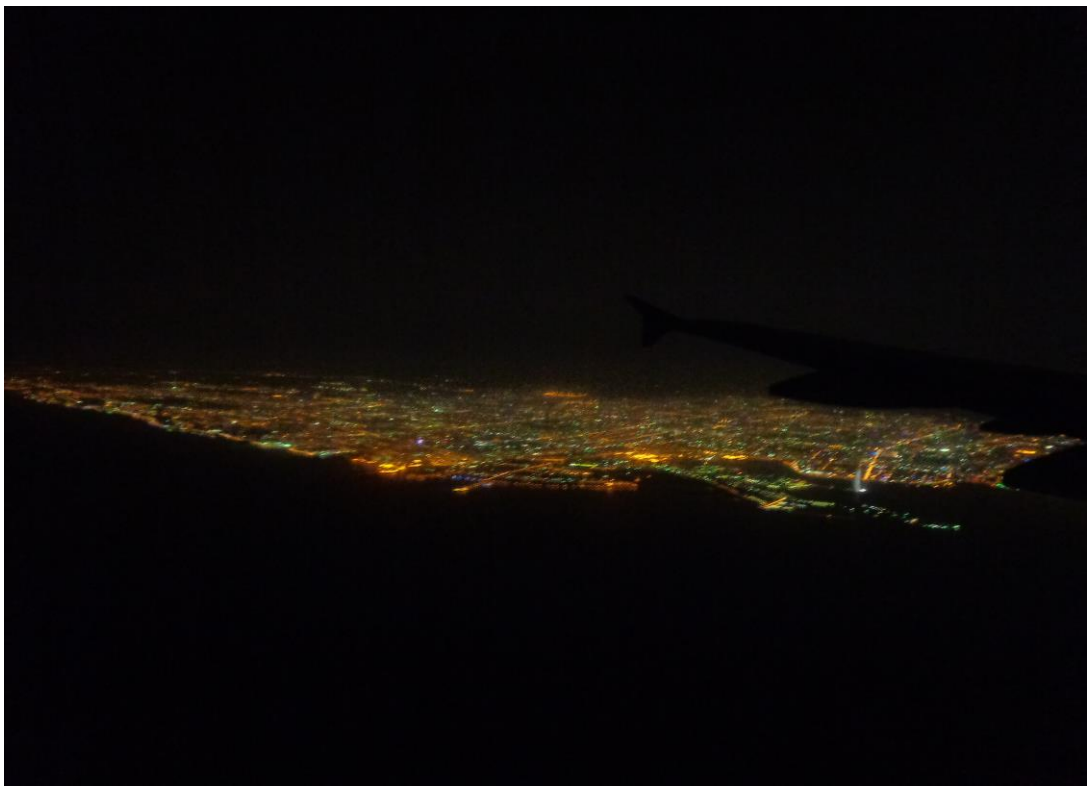

Fig 1. Jeddah, Kingdom of Saudi Arabia, from over the Red Sea, on Turkish Airlines flight TK0094. Image: Colin Henshaw, September 13th, 2013. Such intensive illumination is not a sign of progress or development, but one of human arrogance and lack of respect for the environment.

this excessive lighting is the light pollution suffered by astronomers.

Effects of Light at Night

It's a well known fact that lighting attracts insects, and the environmental threat posed by lighting has been pointed out as early as 1897[2]. Some lights are more attractive to insects than others. Low pressure sodium (SOX) lighting is the least attractive, while the others, such as High Pressure Sodium (HPS), Compact Fluorescent

Lighting and LEDs, are more culpable as they contain light towards the blue end of the spectrum. It has been reported that lighting disrupts the flight patterns of insects, and that this may be more disruptive than their attractiveness to lights[3]. It also affects the migration patterns of birds and bats. Municipal lighting authorities are increasingly turning to LED lighting in order to save energy, but it has now been demonstrated that this kind of lighting attracts 48% more insects[4] than HPS lighting. This can be alleviated by replacing conventional LEDs with lower colour temperature (ideally 2000K and not exceeding 2700K) amber coloured LED lighting. Future research into this kind of technology will have to find ways of minimising its environmental impact. One way in which this can be achieved is for LED lights to be motion operated, so that they only come on when needed.

If not killed outright by the heat of the lights the insects will spiral round them until they are so exhausted they fall to the ground. They will then be too tired either to feed or to procreate[5] and will die as a result. Lighting can be visible from a considerable distance, so lights will suck up insects like a vacuum cleaner[6] over a wide area. Consequently, over a long period of time, insect populations and insect diversity will decline (figs 2 and 3).

Even diurnal insects can be affected. If the lighting is very

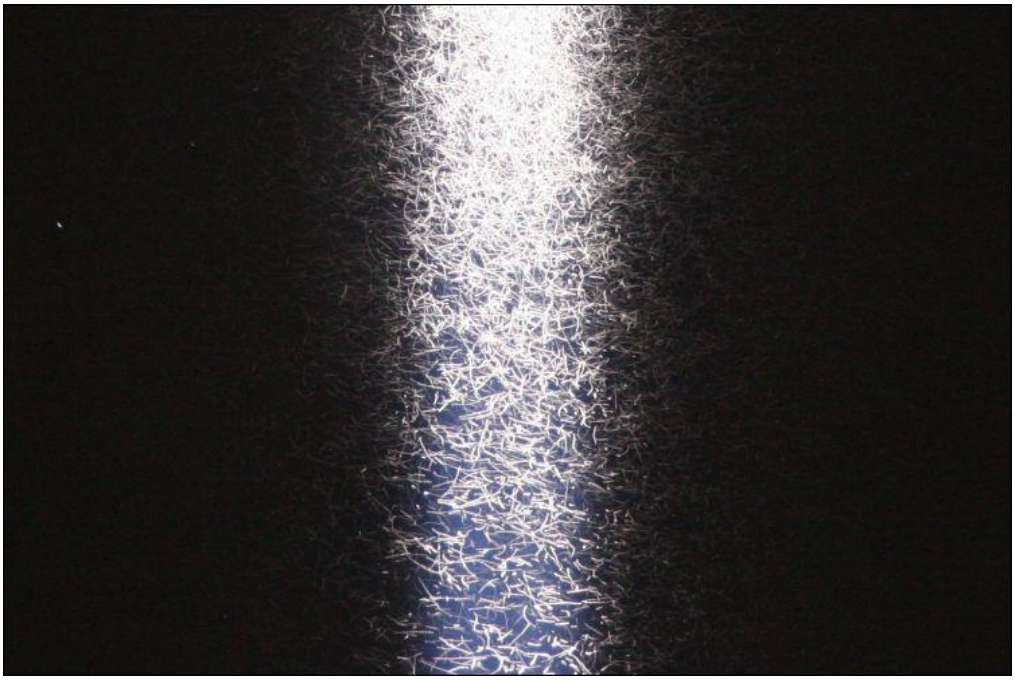

Fig 2: the Luxor Skybeam in Las Vegas, U.S.A. The streaks inside the beam are due to insects attracted by the light. Credit: unknown, but originally on the internet.

intense, they can be tricked into behaving as if it's daylight, and be attracted to lights. This has been seen with butterflies (fig 4), grasshoppers, cicadas, damselflies, dragonflies and bees.

Fig 3 . Insects spiralling around a floodlight located in Briga Township, outside Tabuk, Kingdom of Saudi Arabia. Image: Colin Henshaw, March 2014.

Some insects are repelled by lights, seeking darkness at night, and as urban lighting becomes more widespread, these species find fewer places to hide. They may become more exposed to predation

Fig 4. Diurnal butterflies attracted to a light in the parking bay of an apartment building in Dhaka, Bangladesh. Image: Colin Henshaw, 2006.

and their breeding cycles may be compromised. This can include cockroaches and earwigs. Other invertebrates that are repelled by light include woodlice, scorpions[7] and earthworms. Negative phototaxis in woodlice has often been the subject of many school biology courses[8]. They seek darkness in order to avoid desiccation. In lakes and ponds, planktonic crustaceans such as Daphnia[9] rise to towards the surface at night to feed on phytoplankton and avoid predation by fish. However, light pollution breaks this cycle and prevents them from migrating and this can contribute to algal

blooms in illuminated stretches of water, leading to poorer water quality.

Insect decline is going to have concomitant effects on the higher order consumers that feed on them. Take out the lower trophic levels in any food web, then those organisms that depend on them will have nothing to eat. Declines in insect populations over the past forty or fifty years have been reported by numerous environmental organisations, along with similar declines in spiders, amphibians, reptiles, birds and small mammals. These declines are mirrored by the expansion of urban lighting over the same period.

This has been seen in the case of urban sparrows in the United Kingdom[10]. Sparrows need insects and spiders so they can provide their chicks with sufficient protein with which to grow. If the adult birds cannot find sufficient quantities, then they may fail to raise their broods to maturity. Consequently their numbers decline over time.

A further example of this can be seen with the decline of bat populations. According to Eisenbeis, (2006), as many as one third of all insects attracted to street lights will die as a result. Furthermore a study in Germany recently pointed out that there are about 50,000 street lights in Zürich, Switzerland, that are left on all night and are killing at least 150 insects per night. This means that

in Zürich, about 7,500,000 insects are killed every night[11]. Since bats are known to eat about 3,000 insects per night[12], this could put severe pressure on the local bat population, resulting in bats not being able to find enough to eat. If the bats don't get enough to eat, they are unable to build up the fat reserves necessary to keep them alive over the winter hibernation period. Insufficient food lowers their resistance to disease, and opportunistic infections may take advantage. Outbreaks of white nose syndrome[13], caused by a fungus, Pseudogymnoascus destructans, (fig 5) have been observed in bat populations in the United States where starving bats have been seen foraging over the winter period[14]. Declines in bats can

Fig 5. White Nose Syndrome in North American Bats. Credit: Nancy Heaslip, New York Department of Environmental Conservation.

have an effect on insects that are not attracted to lights. Bats eat large numbers of mosquitoes, and as bat populations decline, mosquito numbers may rise, possibly leading to the spread of mosquito-borne diseases such as malaria, filariasis, dengue fever,

and Japanese encephalitis. It is now known that foraging behaviour in bats declines during bright moonlight[15], probably due to the increased risk of predation. If so, then it can also be expected to decline in areas that are permanently illuminated at night, leading to a concomitant decline in bat populations. The bats will simply move elsewhere. In the United Kingdom it is illegal to harm bats in any way, so this raises the question as to whether our municipalities are culpable by lighting up our environment to the point where they are denying food to bats and reducing their numbers. Light pollution could also affect the regeneration of tropical rain forests[16] by disrupting the seed dispersal behaviour of fruit bats. In Costa Rica it was found that fruit bats avoided foraging in illuminated areas, thereby having a negative impact on ecosystems. Under dark conditions fruit bats would produce a copious rain of seeds that would help rain forests re-colonise land that had previously been cleared. The researchers therefore recommended that dark refuges connected by dark corridors be set up to reduce the impact of light pollution by enabling light-sensitive species such as bats to migrate from one sensitive area to another.

In 2014 it was reported that light pollution adversely affected the reproductive cycle of the grey mouse lemur, Microcebus murinus[17], that lives in the forests of south western Madagascar. Experiments

were carried out in which mouse lemurs were exposed to artificial lighting that mimicked street lighting, and it was found that their reproductive cycles were compromised causing them to become

The Grey Mouse Lemur, Microcebus murinus. Credit: Arjan Haverkamp: http://a-z-animals.com/animals/grey-mouse-lemur/pictures/4167/ No changes were made to this image.

sexually active out of season. This was thought to be due to the effect on melatonin production, which only occurs during darkness. Melatonin is involved in regulating mammalian reproduction. Mouse lemurs breed during the long days of summer, and during winter, with its longer nights, melatonin supresses reproductive behaviour. However, if the animals are exposed to excessive amounts of light at night, this cycle is disrupted. Since both lemurs and humans are primates, this lead the investigators to speculate that chronic light exposure in humans could impact on human

reproduction as well. Excessive exposure to blue light at night is now known to adversely affect male fertility in both mammals and fish[18], so since humans are mammals it is safe to say it will affect us as well. Exposure to light at night in humans is also known to affect menstrual cycles, spontaneous abortions and premature births.

Another effect that has been reported recently is that of polarised light pollution. Artificial lighting may not be directly implicated in this form of light pollution, but it can make it worse. Horváth, Kriska, Malik, and Robertson (2009)[19] have drawn attention to the fact that when light is reflected off smooth surfaces it becomes plane polarised. This happens naturally off water, but now there are numerous man-made substances that are much more efficient at doing this. These include the asphalt road surfaces, motor vehicles, and glass windows that abound in any urban environment and ramify into rural areas. Many animals, especially insects and birds, are sensitive to polarised light and use naturally occurring polarisation to navigate. They cannot differentiate between natural and man-made polarisation, and the effect is now sufficiently widespread for it to have an ecological effect. With so much polarised light being reflected into the sky, these organisms become disorientated and consequently this affects their behaviour. Road surfaces and cars may act as ecological traps for aquatic insects that

are now more attracted to them than they are to water. A possible example of this would be the giant water bugs (Lethocerus spp) seen high and dry in areas as far apart as Zimbabwe, Saudi Arabia and Bangladesh. Mayflies and water beetles are similarly affected. Female insects may actually attempt to lay their eggs on these surfaces where they stand no chance of surviving, and this will further aggravate the existing decline in insect populations. On first sight the impact of polarised light pollution may be reduced by constructing rougher road surfaces, applying matt finish paints on cars, and using less reflective materials in the construction of buildings. Unfortunately, the construction of rougher road surfaces may just set one form of pollution off against another by increasing noise pollution in the neighbourhood of busy roads, and this may be just as damaging. The approach may also have negative effects on vehicle efficiency by accelerating tyre wear and increasing fuel consumption (Ryder, V., 2009)[20], and may not be practicable. A better solution would be to install better lighting in urban areas and avoid the illumination of suburban and rural areas altogether. Another example of this would be the widespread introductions of solar panels in some countries in order to reduce dependency on imported fossil fuels. Though good in principle, such panels are highly polarising and may attract aquatic insects, thereby creating a

new ecological problem while trying to solve another. This problem can be rectified by using patterned or roughened glass in order to reduce their attractiveness to insects[21].

Declines in insects are serious because many of them are important as pollinators. A reduction in insect populations will mean a reduction in successful pollinations, leading further to a reduction in plant diversity (Henshaw, 1994 and Biesmeijer et al, 2006[22]). This has likewise been reported by environmental organisations. Reduced biodiversity in plants may then backfire on insects as many of them are directly or indirectly dependent on them for food. Consequently their decline will accelerate. The rôle of insects as pollinators is very important in crop production, and their absence may jeopardise crops[23]. As much as 35% of all crop production depends on pollinators of one kind or another - insects, birds or bats[24]. In the Netherlands, one of the world's most intensively light polluted areas, flower growers have actually resorted to manual pollination.

Migration patterns in animals is now known to be severely compromised by excessive lighting in our cities. This is now well established in birds that are known to uses starlight[25] as well as the Earth's magnetic field to navigate[26]. Birds can easily become confused by the bright lights of cities and awareness of this has been

raised by the Fatal Light Awareness Programme in Canada[27]. Birds are often confused by the lights of tall buildings during migrations, leading to many avian fatalities. Fledgling seabirds are now known to be fatally attracted to urban lighting on their first flights towards the sea. This has been demonstrated in Australia with short-tailed shearwaters, Ardenna tenuirostris[28], with Cory's shearwater, Calonectris diomedea[29], on the island of Tenerife in the Canary Islands, and Barau's Petrel[30], Pterodroma baraui, on Reunion Island in the Indian Ocean.This mortality inevitably results in declines in the populations of these birds. The problem is obviously widespread and as seen in Canada affects many other bird species as well. Celestial navigation also occurs in insects. It has been reported that dung ball rolling behaviour in African dung beetles is influenced by the visibility of the Milky Way at night[31]. The beetles are no longer able to navigate in straight lines when the sky is overcast. If dung beetles are now known to use the night sky to navigate, it is certain that similar behaviour will also occur in other insects. Since light pollution from cities drowns out the fainter stars and the Milky Way, such behaviour in insects is will inevitably be compromised, leading to their decline in those areas.

Light at Night can also affect germination, flowering and abscission cycles in plants by interfering with phytochrome

production, thereby preventing plants from adjusting to the seasons. Phytochromes are plant hormones that govern photoperiodism in plants enabling them to measure the hours of darkness and anticipate when to bloom, produce seeds, or drop their leaves in autumn[32]. Disruption of phytochrome production will therefore have serious implications for crop production, such as strawberry plants failing to bloom. Deciduous trees exposed to artificial light tend to retain their leaves in winter[33]. If normal photoperiodism is disrupted, then this will lead to further declines in plant diversity and concomitant effects on animals dependant on them for food. This could well include ourselves. Many animals are also dependant on trees for their natural habitat, so if trees are adversely affected they will have nowhere to live and consequently their numbers will decline.

Photoperiodism in plants requires exposure to visible red light (625 to 760nm, and infra-red (760nm to 850nm). Artificial lighting, particularly towards the red end of the spectrum such as sodium lighting will therefore have an effect on photoperiodism in plants. This includes trees[34]. Lighting is now known to advance budburst in deciduous trees in the U.K. by 7.5 days[35]. Earlier budburst may further have an impact on those animal species dependent on the trees for food and habitation. Photosynthesis depends on shorter

wavelength light (blue – 400 – 450nm and red – 625 – 700nm). Green light has little or no effect on plants as this is largely reflected by the green pigment chlorophyll. Artificial light is not intense enough to affect photosynthesis, but orange lighting from street lights extends day-length, affects flowering patterns, and extends the period of growth into winter when the plant can be damaged by frosts and low temperatures. Furthermore continuous lighting is more damaging than part-time lighting.

It was recently reported that lighting from cities was contributing to urban heat engines that have been cooking the atmosphere for decades[36]. These should not be confused with urban heat islands that release heat from road surfaces and buildings that has been absorbed during the day. Formally thought to have only a local effect, heat generated by these urban heat engines is now known to affect jet streams that can change the climate at substantial distances[37]. However, the contribution of lighting is minimal[38] and was not mentioned in the original research. Therefore the effect of lighting has probably been hyped by the media which is not very helpful to those campaigning against its detrimental environmental effects.

Discussion

Our ineptitude in not regarding global Light at Night as a serious

threat will result in massive declines in biodiversity – we may see mass extinctions the likes of which have not been seen for sixty-five million years[39]. This is in addition to the damage caused by other forms of environmental degradation such as habitat loss, pesticides, chemical wastes, and air pollution. The environment has its own inherent system of homeostasis, and will pay us back with our own coin and with compound interest. In this case the imbalance is caused by overpopulation. Current trends in population growth are no longer sustainable, and the planet has already exceeded its human carrying capacity by 200%[40,41]. Sooner or later something has got to give. It is already an established fact that bacteria on a Petri dish will divide once every twenty minutes, following a Malthusian growth curve (Fig 6). After increasing almost exponentially for a while, their numbers will level off and finally decline as they poison their own environment with their waste products. <u>The same law applies to humans, and the Earth is our Petri dish</u>.

The only way of preventing this catastrophe is to tackle the population explosion and eliminate energy wastage including unnecessary lighting. One way in which the former can be achieved is by encouraging same-sex relationships. Those who choose to engage in such relationships have opted out of the reproductive process, so if enough people opt for this life style, then the rate of

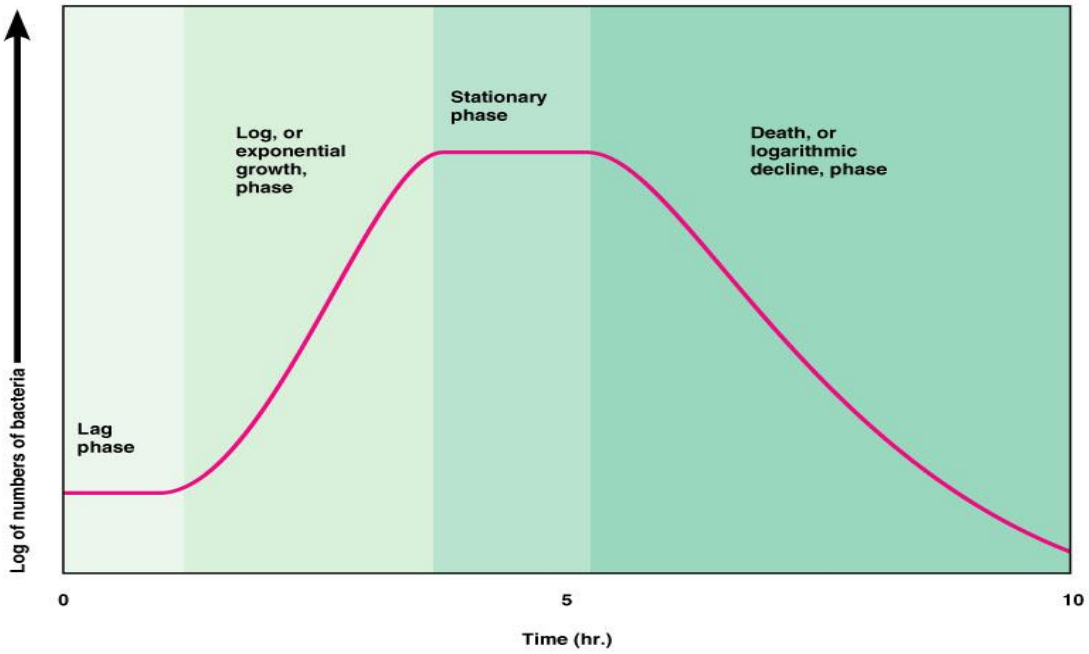

Fig 6. Malthusian Growth Curve for bacteria. Credit: Eliottb80,
http://quizlet.com/18927779/mic-lecture-2-t1-flash-cards/

population increase can be reduced, or even reversed. Such people should be admired and respected instead of being universally reviled. Homosexuality is nature's way of keeping the population down. It can allow us to breed at the rate we are without increasing the population. The latter can be achieved quite easily without suffering loss of amenity. Simply cut back on inappropriate energy use. As much as 38%[42] of a city's energy budget is taken up by street lighting, while one industry source puts lighting at 19%[43] of all global energy production, and a substantial proportion of that is wasted. One unsubstantiated report suggests it may be as high as 50%[44]. This does not include lighting from other sources. It is obvious, therefore, where the first cut-backs should be targeted. Advances have been made in recent years in "green" energy

production, but this is pointless if excessive amounts of energy are wasted. The lighting will still kill insects and other organisms, irrespective of how it is produced. Examples of irresponsible energy wastage include the external illumination of public buildings and folly lighting, some of which has, unfortunately, been endorsed by several eminent scientists[45]. Illuminated Regeneration Follies are illuminated art projects of one kind or another[46] often constructed under the pretext of regenerating depressed areas, or simply by local councillors on an ego trip[47]. Fortunately, some of these projects have been overturned by environmentalist opposition, but others continue to threaten the environment[48]. No-one saw fit to illuminate fifteenth century churches or whatever fifty or one hundred years ago, but now we have an epidemic of illuminated public buildings simply because the technology has become available. This modern fad is no longer acceptable in the current climate of concern about energy wastage and climate change. Commercial premises whose lights are left on all night are another example of inexcusable energy wastage, so any buildings not functional at night should keep their lights switched off.

Just because the energy has been produced by environmentally friendly methods that does not give us the right to squander it on excessive street lighting and vanity projects that don't serve any

useful purpose. Nor should we be turning night into day just because it is technically possible to do so. Darkness at night is normal and is essential to the well-being of both ourselves and the environment . Green energy production, therefore, should go hand-in-glove with efficient and judicious energy usage. Compact fluorescent light (CFL) bulbs may use less energy, and will be cheaper to run on an individual basis, and in that respect they are a good thing. However the danger lies in the fact that the consumer can now afford more and probably brighter light bulbs for the original cost of one. Thus the advantages of more energy efficient lighting are now being negated by the concomitant increase light pollution that will result. Continuing to use excessive amounts of lighting and justifying it by saying that it has been produced by sustainable methods of energy production is simply greenwash - improving efficiency just results in more lighting, so it is counterproductive. Those advocating such usage are totally missing the point as it is the excessive lighting itself that is causing the damage. There is a total disconnect between the need to reduce energy consumption and the environmental effects of excessive lighting, so this needs to be rectified.

Unfortunately, green energy contributes only a small fraction of the total amount of energy consumed. Most energy consumption, including lighting, requires fuel, so will contribute to global warming

through the emission of carbon dioxide. Excessive energy use should therefore be discouraged, and reducing energy wastage by controlling the abuse of Light at Night may make all the difference. Excessive lighting is the easiest form of energy abuse to control as it can simply be switched off. If less energy is used, then less needs to be produced, and that will be beneficial as it will reduce our "carbon footprint." Though improved lighting technology is now available to lessen its impact, exterior lighting should only be applied sparingly, on a needs must basis, where needed, when needed, and in the correct amounts. It should only be applied using appropriate forty-five degree full cut-off smart technology specifically designed for the purpose.

Outdoor lighting should always be aimed downwards, hooded, and, in sensitive areas, motion operated, so the light only goes where it is needed, when it is needed. The luminaire installed should be of the minimum luminosity required for the purpose and not be visible from outside the illuminated area. Motion operated, directional bollard lighting (fig 7) will be more appropriate in residential areas with a low risk of vandalism. The threat of vandalism is always there, so this should be written into the equation at the design stage.

Another solution will be zoning, where all night lighting is permitted in city centres where there are high volumes of vehicular

and pedestrian traffic, and a twenty-four hour society prevails. Suburbs and residential areas should be subject to an 11p.m. till dawn curfew in order to allow the environment to recover, while in rural areas lighting should not be permitted unless it is absolutely necessary. This helps to maintain the distinction between town and country. In winter, schools and businesses can adopt a winter timetable to obviate the need for early morning lighting. In the UK lighting curfews were standard practice until 1969 and no-one complained then about loss of amenity. Some local authorities are now re-introducing them, but only because economic constraints are beginning to bite. Before street lighting is considered planners should first consider alternative methods that might achieve the same objectives but have less of an impact on the environment. Such technology has been around for decades, and includes reflective

Fig 7. Well designed bollard light located at the P.D.O. Recreation Centre, Ras al Hamra, Muscat, Sultanate of Oman. This would be even better if it could be motion operated. Image: C Henshaw, January 2012.

paints and road signs, cat's eyes, and baffles on the central reservations of motorways. One council in northwest England is already advocating the use of reflective signs to replace those that are illuminated[49]. Lighting should only be applied as a last resort.

Conclusions

Light at night is an insidious cancer of the environment that is metastasising at a rate of 6% per anum[50]. Sadly, its negative effects can no longer be denied. Emissions containing light towards the blue end of the spectrum are damaging to insects, having concomitant effects higher up in the food chain, while red lighting is known to affect photoperiodism in plants. Polarisation can interfere with navigation in many living things. The damage caused therefore results in serious declines in biodiversity that may ultimately affect ourselves.

The impact of outdoor lighting can easily be mitigated by stringent legislation and the appropriate application of the kind of lighting technology outlined above. The lighting industry, local authorities and planners should always take this into consideration when developing new lighting technology, applying lighting in any new development, or regenerating old ones. As mentioned earlier, darkness at night is normal, so planners should resist a knee-jerk

reaction against it, especially when new development is planned in a sensitive area. Meanwhile unnecessary and outmoded lighting should be decommissioned with its component parts sent for recycling.

A universal culture-change is needed in our attitudes to lighting, and the importance of this cannot be over-emphasised. Controls on public lighting may be unpopular at first, but the essence of good governance is to know what the people want, and to know what the people need, and to have the wisdom to understand the difference[51]. Similar paradigm shifts have been seen over the past few decades in public attitudes towards such issues as drink-driving, smoking in public places, experimentation on animals and fox-hunting. If we are to protect the planet for future generations, something needs to be done now to combat energy abuse, of which unnecessary public lighting is an obvious example. Our ancestors used to live in harmony with the environment, and if we are to prevent an environmental catastrophe, so must we. It is now well established that Light at Night is a "green" issue that goes way beyond the dark sky concerns of a few astronomers. Environmental organisations should therefore recognise the gravity of the situation and unite with civic and community leaders in order to overcome the problem.

In addition to the issues described above, near-Earth asteroids

pose a major threat to humanity, as was demonstrated recently on February 15th 2013 when a 20m diameter object exploded over Chelyabinsk in Russia, injuring over 1,500 people. Russia is a large target that has been struck three times in just over 100 years, while another object exploded over the Peru-Brazil border in 1930[52]. Yet another object possibly struck China in 1490 resulting large numbers of human casualties[53]. These objects are common in terms of the Earth's history, as is evidenced by the numerous impact craters created by objects far larger than those that have been observed to fall in recent times. The dinosaurs can bear witness to that, having been wiped out by a ten kilometre asteroid that struck the Yucatán Peninsula in Mexico sixty-five million years ago. Next time we might not be so lucky and we could likewise go the way of the dinosaurs. It is not a question of if, but when. Unlike the dinosaurs we are aware of the threat. We will be failing in our responsibilities if we continue to illuminate the night sky to the point where these objects are no longer detectable by the dedicated army of amateur and professional astronomers who continue to monitor the night sky on a regular basis. Consequently we continue to ignore light pollution at our peril. If action is taken now we may be just in time. However, if we are complacent, then we may be just too late.

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