**“Everything under the Sun” - the benefits of full spectrum lighting for our birds.**

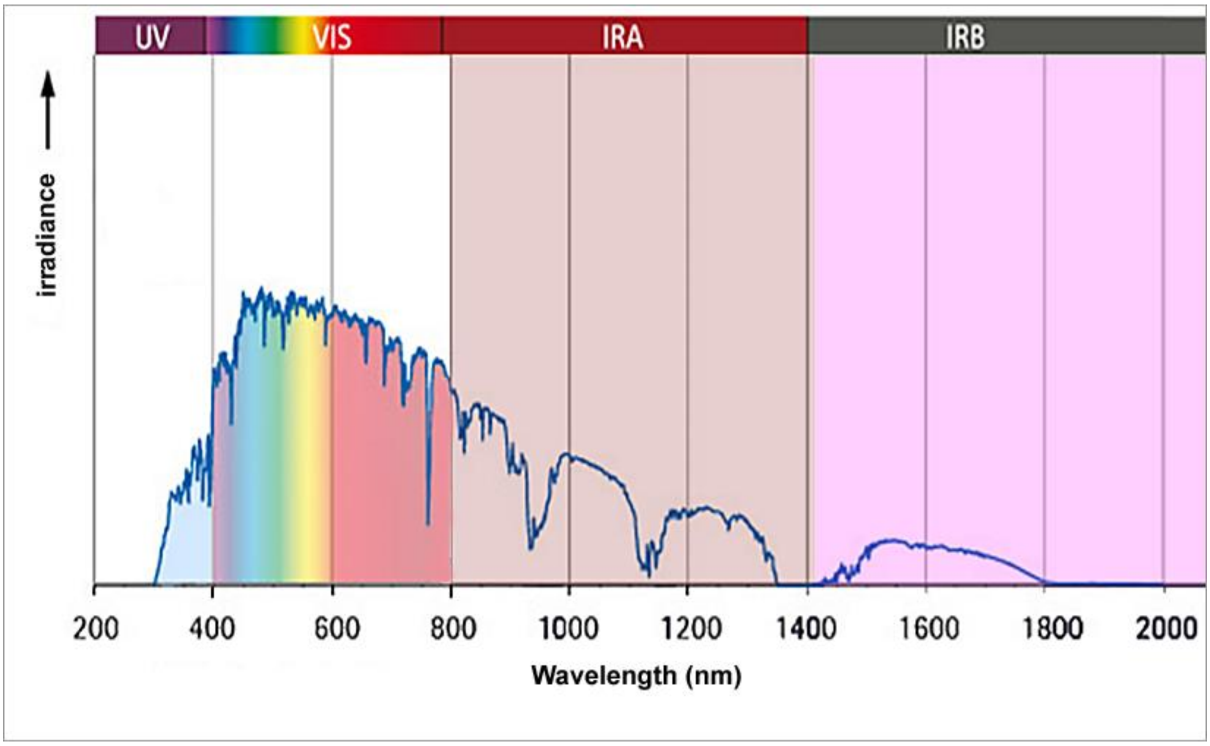
This is the outline of a presentation for the World Pheasant Association Avicultural Weekend, on 11th September 2021, by Dr. Frances Baines MA Vet MB MRCVS.

Introduction

Life on the surface of the earth, wherever it occurs, experiences both day and night in a predictable pattern of light and darkness. Daylight (sunlight) has a very distinctive spectrum (Fig.1) which ranges from UVB (the shortest wavelengths), UVA and visible light to short-wavelength infrared (IR-A and a little IR-B). The amount of daylight available to a bird depends, of course, upon the amount of shade from foliage and the surrounding landscape, and cloud cover, during the day.

Birds evolved in many different microhabitats, ranging from deeply shaded rainforest to wide sun-baked plains or seascapes. All species have adapted to thrive best in the environment available to them in their native habitat. They utilise every part of the sun’s spectrum, in the levels which are available in that place. As keepers, we need to replicate those levels, ideally using natural light as much as possible, although species from warmer climates may need artificial light and warmth to supplement what can be provided in more northern latitudes. The concept then is to create a “patch of sunlight” indoors.

Fig. 1: the Solar Spectrum




Sunlight for warmth

Birds are endotherms (“warm blooded”) so don’t need to bask in sunlight for warmth in the same way as reptiles, but most will readily do so, given opportunity. Additional warmth from artificial sources is often provided inside shelters in outdoor aviaries and in enclosures indoor s. If this warmth is presented as a “patch of sunlight” rather than general ambient warmth, birds will often bask in this, as well. Chicks will normally obtain warmth by direct conduction, when in contact with the hen’s body (or equivalent, such as an electric hen), but will also choose to sit in sunlight (or equivalent, such as a heat lamp) if it is present. The warmth from the sun comes from both the visible light and the short-wavelength infrared (IR-A). These wavelengths do not warm the air; instead they warm solid objects that they illuminate. Red light and IR-A in the sunlight actually pass through keratin (feathers and skin) to warm deeper tissues. Red and IR-A have significant physiological effects. These wavelengths stimulate skin cells to up-regulate genes involved in skin cell repair and replacement, wound healing and strengthening of the immune system.

Red light and IR-A are amply provided by ordinary (white-light) incandescent lamps, such as halogen flood-type bulbs, along with all the other wavelengths used in vision, making them the best type of heat lamps to recreate a “patch of sunlight” during the day.

Ceramic heat emitters (CHE), tube and panel heaters – unlike sunlight - only emit very long wavelength infrared (IR-C) which heats the air and surrounding areas. Since these heaters produce no light, they are ideal for raising ambient temperatures both day and night. However, IR-C does not penetrate feathers or skin, merely heating the surface of the bird and relying upon conduction to warm deeper parts of the body. Since feathers are good insulators this process is very inefficient, so these heaters are much less successful for providing basking warmth. The lack of light renders the heated area hard to detect, as well.

In large enclosures, ceiling-mounted short-wavelength infrared heaters (“patio heaters”) will create huge areas of IR-A and red light for daytime basking warmth, but extra white light is needed to balance out their red glow.

All heaters need thermostatic control. Lamps emitting visible light need dimming thermostats and timers to control the photoperiod. Basking zones must be at least as large as the entire bird, and as evenly illuminated and warmed as possible.

<u>Sunlight for vision</u>

Birds have exceptional colour vision. Their visual range extends well into the UVA, which is a “colour in their rainbow” and which is present in their plumage. White, blue and violet feathers in avian plumage all reflect at least some UVA, as do up to 75% of green feathers, and 40-50% of yellows and reds. 50% of all Galliformes studied have UV-reflecting feathers, which they use to effect in species recognition and mating displays.

Many foods are “UVA-colour” when ripe, and so UV vision also aids foraging. For example, in one trial, black grouse were shown to prefer bilberries with their natural UVA colour, in the same way that birds often identify other ripe berries by the colour red.

Indoor lighting used by humans does not normally include UVA in any significant amounts. However, studies with poultry have demonstrated long-lasting effects on chicks reared without UVA in the spectrum; they show signs of chronic mild stress, explore less, and are more fearful. Domestic chicks reared under UVA and UVB demonstrated better feather condition, had better walking ability and were less fearful. Turkey poults maintained a social hierarchy and showed reduced aggression under light with a UVA component. All these effects may be related to the birds being rendered, in effect, “colour-blind” in the absence of UVA, thereby missing signals from others’ displays and mis-identifying foods.

When choosing indoor lighting for daytime use, the closer the spectrum is to sunlight, the better. Halogen lamps are valuable, but low in UVA and blue content. “Daylight” fluorescent tubes can fill in that part of the spectrum, but are not very bright. If strong light is needed to recreate a “sunbeam” (or to enable good plant growth indoors) metal halide floodlights are ideal; good quality brands also emit high levels of UVA and the spectrum is likely to be the closest possible to that of the sun. LED floodlights can be equally bright in the human visible range, but emit no UVA. None of these lamps emit UVB.

Coloured lamps (such as red “infrared bulbs” and blue “moonlight” bulbs) should be avoided. If all the light is one colour, then everything appears to be in shades of that colour, or black (Fig. 2.). This is bad news for a bird which relies upon full colour vision to make sense of its companions and its food.

Fig. 2: Birds have full colour plumage including UVA. Single colour lamps render the bird “colour-blind”.

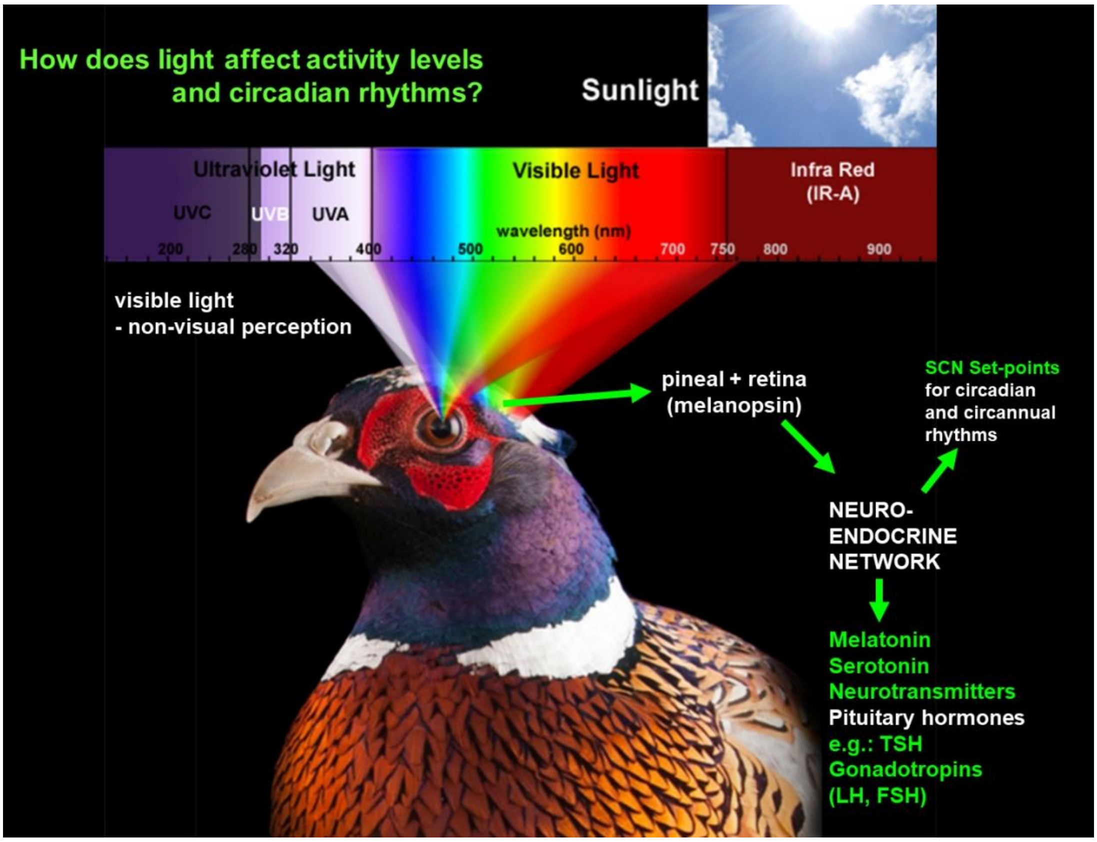
There is one final concern when providing visible light to birds, and that is the ability of many species to perceive flicker in lamps run on an alternating current electricity supply. If a flicker is faster than the brain can process images, no flicker is seen. This is why we can watch movies shown at 30 frames per second. The threshold at which breaks are first seen is the flicker fusion frequency (FFF). It is higher in bright light; for humans this is approximately 60 Hz (cycles per second). Fast-flying birds such as passerines have an FFF over 100Hz. Since 100Hz is the flicker frequency for the UK A/C electrical supply, lamps on magnetic ballasts (old-style fluorescent tubes and some metal halides), self-ballasted mercury vapour lamps and LEDs on some dimmers, will appear to be strobing to these birds. Studies have shown this can cause chronic stress. Ground-dwelling birds usually have a slower FFF, similar to that of mammals. However, a study conducted with *Gammalsvensk dvärghöna* chickens, similar to red jungle fowl, found that their maximum FFF in bright light was 87 Hz. This is a little lower than 100Hz, nevertheless precautions with Galliformes would seem wise. Electronic ballasts flicker at over 20,000 Hz, and solve the problem for all fluorescent tubes and metal halides.

<u>Sunlight for non-visual perception</u>

Our lifestyles often mask our awareness of the passage of time, of the occurrence of dawn and dusk and the changes in light intensity over the course of a day; but birds are extremely sensitive to these cues in their environment. Light enters the eyes of the bird, and a pigment, melanopsin, in retinal ganglion cells responds to the amount of blue in the light. Light also penetrates the skull, to a degree that depends upon its intensity, and directly stimulates light-sensitive cells in the pineal gland and in certain regions of the brain itself. These signals feed into a neuro-endocrine network that sets the bird’s body clocks – circadian and circannual rhythms – and enables production of a whole range of neurotransmitters and hormones, controlling sleep and wakefulness, activity levels and seasonal behaviours, including

reproduction (Fig. 3.)
This is why galliformes benefit from experiencing a natural dawn and dusk, and access to natural light levels outdoors, which on grey overcast days can still exceed tens of thousands of lux, and in full sunlight over 100,000 lux within an hour of dawn. Indoor fluorescent lighting, for example, rarely exceeds 500 – 1,000 lux. When outdoor access is not possible, lighting can be augmented using any good white light sources; metal halides are probably best. Whole enclosures do not need to be illuminated! Forest dwellers inhabit shaded areas with dappled sunlight through the canopy – "patches of sunlight", in fact.

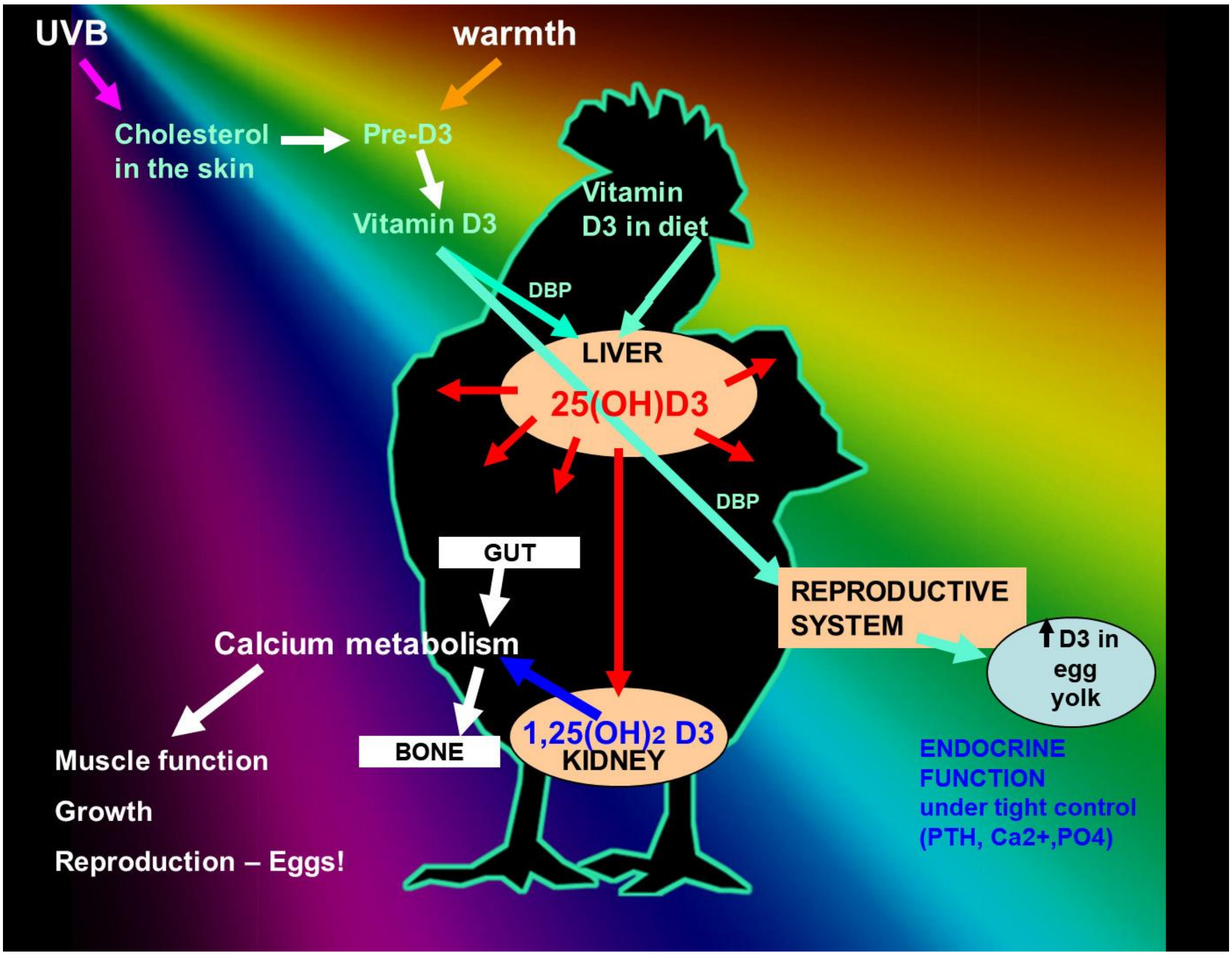
Fig. 3: The neuro-endocrine network.




<u>Sunlight for UVB</u>

Whenever provision of UVB is mentioned, it is often assumed that this is solely to enable vitamin D3 synthesis in the skin. However, natural levels of UVB in daylight and in direct sunlight have beneficial effects of their own. UVB is a powerful disinfectant, killing viruses, bacteria and fungus spores on skin and feather surfaces. It also modulates the immune system, stimulating white blood cells and melanocytes and enabling beta endorphin synthesis (which may explain why sun-basking is pleasant). The formation of vitamin D3 is, nevertheless, a vital function. Fig. 4 shows the basic vitamin D3 pathway. UVB and warmth transforms the cholesterol 7DHC in the bird's skin (in highest concentrations in the most sun-exposed areas – legs and head) into vitamin D3. This has beneficial effects on the immune system of the skin itself, but then is carried into the bloodstream on vitamin D Binding Protein (DBP). When it reaches the liver, it is converted by an enzyme to 25(OH)D3, the storage form, and this is carried in the bloodstream to all the organs of the body. In the kidney, tiny amounts are further converted to the active hormone 1,25$(OH)_2$D3, to control calcium metabolism – promoting calcium uptake from the gut, maintaining calcium levels in bone, and supplying it for muscles, for growth, and for reproduction. 25(OH)D3 is also carried in the bloodstream to many other organs; they convert it to the active hormone inside their cells, where it acts upon more than 2,000 genes involved with protein synthesis and cell maintenance. Its modulation of the immune system is especially important. Insufficient vitamin D3 results firstly in the loss of these functions; only severe deficiency disrupts calcium metabolism, which results in metabolic bone disorder if chronic, but death if acute.

Fig. 4. The basic vitamin D3 pathway.




During egg production in the hen bird, the tremendous transfer of calcium from her bones to the eggs is not the only reason for a high vitamin D3 requirement. Vitamin D3 is carried directly into the yolk of the developing eggs on DBP. Very little 25(OH)D3 enters the egg, so the hen needs to be making plenty of vitamin D3 daily just to go into the yolk. A good yolk store of vitamin D3 is vital, to enable the chick to utilise the calcium from its eggshell for normal development of bones and muscle, which must be strong for the process of hatching. The chick needs to perform a specific set of powerful twisting movements involving head and neck muscles to break into the air sac, followed by leg bracing and turning to cut the shell. Inability to perform these movements due to weakness and hypocalcaemia results in the fully developed chick dying with the head still tucked down, unable to breathe. A study of the condition in chicks from vitamin D3 deficient hens found that treating the embryos with vitamin D3 prevented the high death rate and enabled normal hatching to take place, confirming this is caused by the D3 deficiency rather than a lack of calcium.

Provision of UVB

Very few studies have been carried out on the vitamin D3 requirement of birds, and almost all focus on the use of oral supplementation in poultry feeds. Research is hampered by a lack of knowledge on normal healthy vitamin D levels in wild birds. These do not suffer from vitamin D deficiency, unlike many captive birds, in which metabolic bone disease is not uncommon, manifesting as deformed skeletons (rickets) and failure to thrive in young birds, or reduced fertility and production of thin-shelled eggs by affected hens.

For many species of Galliformes, outdoor housing which allows access to some natural sunlight as well as shade appears sufficient to supply their needs, along with the levels of vitamin D3 provided in the diet. To increase the birds' access to full spectrum light, shelters could have roofs made with special UV-transmitting acrylic panels , since most other transparent plastics block UVB.

Examples include Bay Plastics UV Acrylic Sheet (www.plasticstockist.com/Sunbed-Grade-Acrylic-Sheet/Clear-Sunbed-Grade-Uv-Perspex-Acrylic-Sheet.aspx) and the German product Plexiglas Alltop SDP16 Twin-wall Acrylic by Evonik Industries AG. (www.plexiglas-shop.com/pt/products/plexiglas-alltop/sd29080at-16-0-64-0-2000x.html). These allow approximately 80% transmission of UVB.

New types of UV-transmitting polytunnel sheeting make an inexpensive alternative, allowing about 65% UVB transmission. For example, Lumisol Clear by Bpi.Visqueen is widely available from horticultural firms (e.g. www.northernpolytunnels.co.uk/lumisol-clear.html ).

If natural levels of UVB experienced by wild birds enable them to synthesise all the vitamin D3 they need, then replicating this for those housed entirely indoors should be beneficial. Birds self-regulate their exposure to sunlight, so providing both "sunlight" and shade is required, with the UVB levels regulated to be similar to those the bird would experience in its native microhabitat.

We don't have field recordings from the locations of wild birds, but the UV ranges in different types of habitat have been measured by researchers studying reptiles in the wild. A team led by Dr. Gary Ferguson from Texas published details of the UV Index ranges found in 4 basic microhabitats or "zones": Zone 1 - microhabitats occupied by full shade dwellers, such as a forest understory; Zone 2: microhabitats with partial sun, partial shade, such as forest edges and embankments; Zone 3: open areas where full exposure to sun occurs, but shade is available nearby, such as savannah or open heathland; and Zone 4: microhabitats with little or no shade, such as fully exposed mudflats or arid desert s with little vegetation.

Now known as "Ferguson Zones", these UV ranges have been used to create guidelines for reptile husbandry in zoos and private collections since BIAZA published their "UV-Tool" in 2012. Their application in estimating suitable UV ranges for mammal and bird lighting is still experimental, but these microhabitats are inhabited by all taxa. Full spectrum lighting with UVB is being introduced to increasing numbers of species in indoor aviaries with apparent success.

Figure 5 (below) summarises the Ferguson Zone ranges.

Many Galliformes are "forest edge" birds, living in a sheltered microhabitat with some voluntary exposure to direct sunlight, especially early in the day when UV Index levels are low. These would fall into the Ferguson Zone 2 category, with an estimated maximum of UV Index 3.0 in the "patch of sunlight" available to the birds through the day (typical of early to mid-morning sun in subtropical areas and temperate regions in spring and early summer ).

All guidelines to date are still very experimental, however, especially with mammals and birds, and it is vital to watch the animals' responses and record results. A gradient into shade must always be provided, of course. Ideally, keepers would own a reliable UV Index meter (Solarmeter 6.5 or 6.5R) to check UVI levels themselves, although published charts exist for a number of lighting configurations.

| Typical microhabitat / behaviour | Ferguson Zone | Suggested type of UV provision | Suggested UVI gradient |
|---|---|---|---|
| **Crepuscular or shade dweller**<br>(Daylight with little or no direct sunlight, in very sheltered microhabitat) | 1 | Shade Method – low level, diffused UV resembling "daylight in the shade" across a large area of the enclosure | UVI from zero in full shade to approx. UVI 0.7 in more open areas |
| **Partial sun / occasional basker**<br>(Daylight with some voluntary exposure to direct sunlight, in sheltered microhabitat) | 2 | Shade Method (as above)<br><br>*OR*<br>Sunbeam Method – higher UV irradiance in a brightly lit area resembling "a sunbeam" in a restricted area within the enclosure | UVI from zero in full shade to approx. UVI 1.0 in more open areas<br><br>*OR*<br>UVI with a maximum of UVI 3.0 in the "sunbeam" zone, with a gradient to zero in full shade |
| **Open or partial sun basker**<br>(Daylight with frequent voluntary exposure to direct sunlight, in open habitat) | 3 | Sunbeam Method (as above) | UVI with a maximum between UVI 3.0 – 7.0 (depending upon species' estimated typical sun exposure) in the "sunbeam" zone, with a gradient to zero in full shade |
| **Midday sun basker**<br>(Daylight with near-constant exposure to direct sunlight in exposed habitat) | 4 | Sunbeam Method (as above) | UVI with a maximum between UVI 4.5 – 8.0 (depending upon species' estimated typical sun exposure) in the "sunbeam" zone, with a gradient to zero in full shade |

Fig. 5. The Ferguson Zones

Figure 6 shows the UV Index recordings on clear days close to the solstices and equinoxes in Wales, UK, showing typical changes in UV levels, which are dependent on the sun's altitude in the sky. A UVI of 3.0 is reached by 8am in June, and by 10:30-11am in April and September.

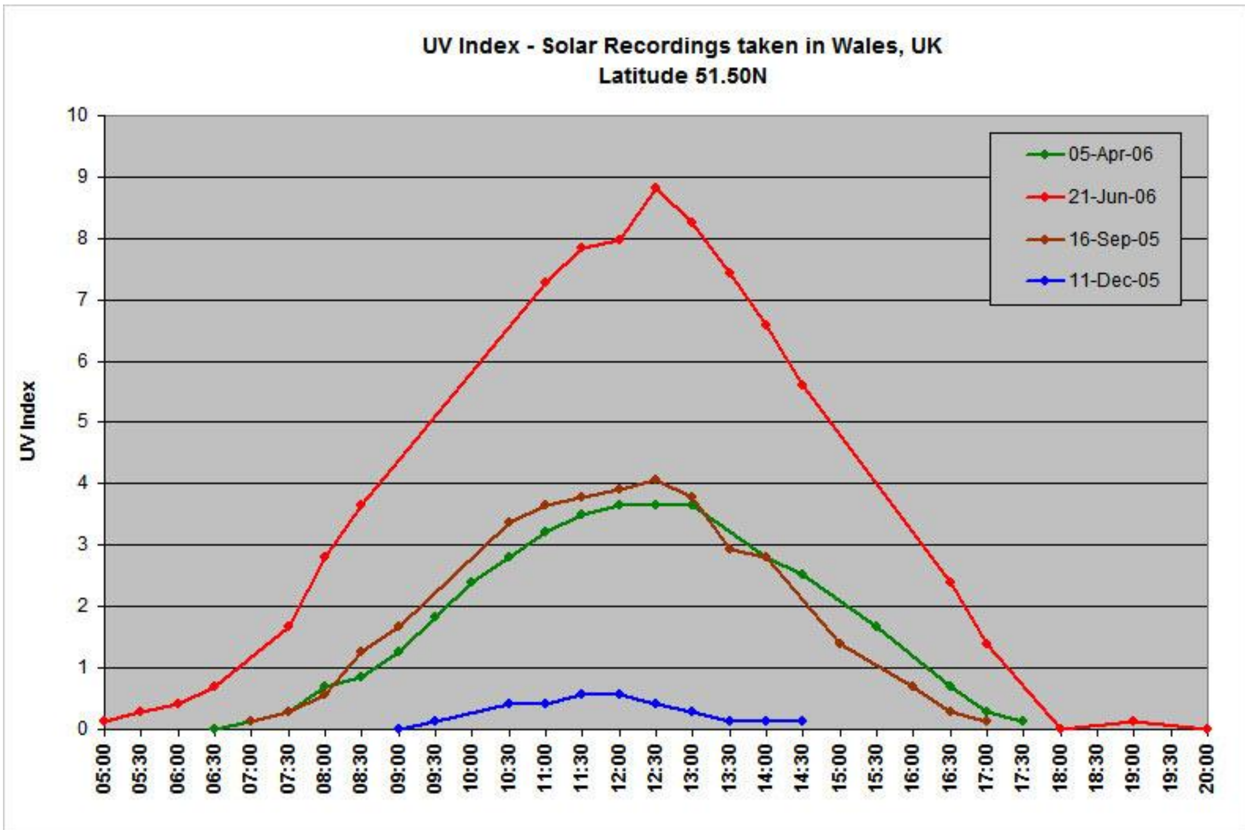



Figure 6: UV Index over the course of a fine day through the year, in Wales, UK.

Full spectrum lighting indoors

A vast choice of UVB-emitting lamps is now available. T5-HO fluorescent tubes appear most suitable for use with terrestrial birds. These produce a wide zone of diffused full spectrum light which, combined with incandescent lamps, can easily create a large patch of "artificial sunlight" below them, for the birds to walk into at will. These lamps are available in different strengths (e.g. 6%UVB, 12%UVB), lengths and wattages, and these factors determine the distance which the lamp needs to be mounted to obtain the desired UV Index at bird level below. Arcadia and ZooMed brands of T5-HO lamps show excellent test results and longevity.

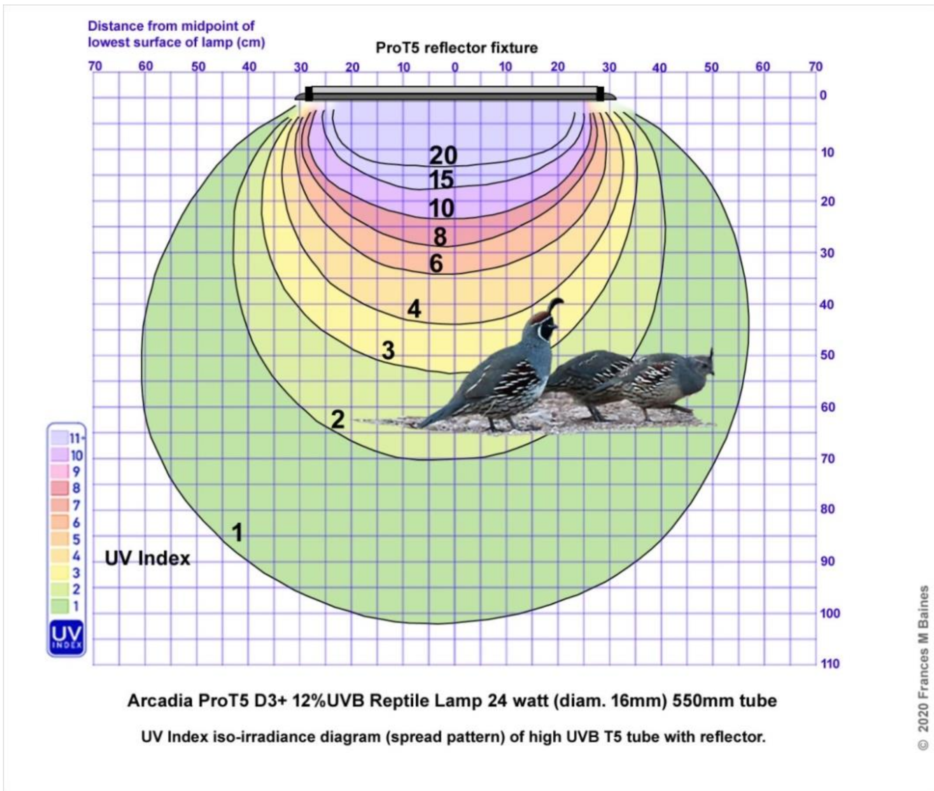



Fig. 7. The UVI gradient beneath a typical T5-HO UVB lamp

Figure 7 is a chart to show the UV gradient obtained directly below a typical 24watt, 22-inch T5-HO tube in a suitable aluminium reflector fixture. (The Gambel's quail are pictured to scale, at a suitable distance below the lamp to obtain UVI 3.0 across an area about 16 inches wide.)

A new 2ft fixture from Arcadia ("Thermal Zoo Pro" - www.arcadiareptile.com/thermalzoopro/ ) has just been launched, combining T5-HO tubes, incandescent lamps and a small infrared heater; this may prove of interest as an all-in-one solution for creating basking zones in medium to large pens.

If even larger areas are to be provided with "sunlight" this is easily done using relatively inexpensive hydroponics fixtures such as Growth Technology Lightwave units, used by many zoos: www.growthtechnology.com/product/lightwave-t5-lw48-ho ). Some or all of the "daylight" T5-HO tubes supplied with these units are replaced with UVB tubes. These fixtures can be hung up to 5-6 feet above the birds. For example, Chester Zoo installed a 4ft long, 8-tube fixture above the birds on a simple wooden gantry along with two halogen floodlights (Figure 8). These fixtures are available in a variety of sizes, and altering the number of UVB tubes used in a fixture adds great flexibility.


Fig. 8. The UVI gradient beneath an 8-tube installation at Chester Zoo