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Extract from an article by CR Brightwell-Marine Scientist

It is without question that the topic of proper reef aquarium lighting has been a source of some controversy for at least the last 10 years. Opinions abound, making it nearly impossible, and hence extremely frustrating, to decide upon the most beneficial lighting “package” for a given aquarium. I will go so far as to say that many lighting concepts, in general, are not firmly grasped by the majority of interested marine aquarists due to the hodgepodge of information circulating throughout the hobby. It’s not the fault of the aquarists, by any means. There’s simply too much misinformation on this subject to be able to make an informed decision about which lights are best, what intensity is most desirable, what intensity really is, duration of photoperiod (the length of time the lights are operating each day), etc. With all of this in mind, allow me to make a general disclaimer statement: The following series of articles are not an attempt to summarize every aspect of lighting in accordance with actual theories of Physics. They are, however, composed in a way that I feel will be easily understood by all who read them.

The subject of energy as visible light, in general, is extremely in-depth and technical, with various theories describing the behavior and characteristics of light. It’s not easy to correctly simplify the most important points of light concepts, which may explain the lack of understanding in the aquarium hobby. For example, “watts per gallon” has little relevant meaning in the area of aquarium lighting, because watts do not equate to light intensity. So, let’s try and sort it all out. I’ll stick to easy, concise explanations where I can; some things can’t be simplified, however, so be prepared. I will attempt to cover the entire subject in way that enables every aquarist to better understand reef lighting armed with the information readily available from lamp and ballast manufacturers. Because manufacturer’s information is of limited use to individuals seeking “exact” answers, because few aquarists will want to go through the rigor moral of calculating such answers, and because an intricate knowledge of lighting parameters doesn’t necessarily mean increased success with a reef aquarium, I’ll keep the discussion limited to “applicable” aspects of reef lighting. Of the various terms and concepts associated with lighting, those of main importance that are usually available from a lamp manufacturer are lumens, CRI, Kelvin temperature, and the bulb’s life-span. PAR is important, but few manufacturers have data on it readily available. Allow me to make one more statement regarding “proper” aquarium lighting as it pertains to photosynthetic organisms: An impressive reef system does not revolve around the lighting regime alone! Water quality, water temperature, and proper lighting are all equally important aspects of keeping a successful reef aquarium. Without close attention to water parameters, even the most spectacularly illuminated reef

aquarium will not sustain the lives of desirable marine organisms!

Let's discuss the importance of proper lighting in the reef aquarium. Tropical reefs are predominantly composed of corals, the majority of which contain symbiotic dinoflagellates (known as zooxanthellae) within their tissue. These corals are classified as "hermatypic"(corals lacking zooxanthellae are termed "ahermatypic"). Corals and other hermatypic tropical reef organisms, as well as algae, have been evolving over the past several million years in conditions that vary little from day to day. Those organisms living in tide pools may experience fairly rapid changes in sea level, temperature, and light intensity; however they are used to these cycles, and are physiologically prepared to deal with brief periods of exposure to air and direct sunlight. The rest of the organisms that remain submersed 365 days a year, likewise, are "engineered" to survive in the relatively unchanging conditions found at the location they reside in. Leaving a discussion on water parameters for another section of Kent UniversityÔ, let's focus on the issue of lighting and it's importance to zooxanthellae, and hence the host organisms.

Zooxanthellae are a type of algae; more specifically they are dinoflagellates. Algae, in turn, are photosynthetic organisms, reliant upon three things for proper functioning: an appropriate source of light, carbon dioxide, and the proper nutrients. Nutrient sources are not hard to find in most reef aquariums, which typically have more than enough for all concerned parties. Carbon dioxide is produced by respiration of the host organism. Lighting is the critical factor. If the intensity is too low, the zooxanthellae suffer. If the intensity is too high, the zooxanthellae can damage the tissues of the host by producing copious amounts of oxygen. If the spectral composition of the light is "abnormal" to the zooxanthellae, they must change pigmentation to make proper use of the available light.

There are other reef inhabitants that rely at least partially on the metabolic products of zooxanthellae for nutrients. Most reef-associated anemones, clams belonging to the genus Tridacna, and some belonging to the genus Hippopus, harbor zooxanthellae in their tissues and mantles, respectively, where light can readily strike them.

General Guidelines for Providing the Correct Light Regime for Your Reef Aquarium:

Purchase daylight lamps with the highest possible CRI
Provide a wide variety of Kelvin temperatures to satisfy the needs of all photosynthetic organisms in the system
Use electronic ballasts whenever possible
Provide 10-12 hours of illumination daily, preferably on a fixed schedule (use a timer)
Keep lights close enough to the aquarium to easily satisfy the light needs of organisms living on the aquarium bottom
Use one or more vent fans to cool the aquarium hood
Install all lights on a ground fault circuit interrupt
Provide enough intensity of the correct wavelength proportions to satisfy the

needs of all photosynthetic organisms in the aquarium
Replace metal halide bulbs every 6 months or so, and fluorescents every 12 months
Do not replace all lights of the same kind at once; replace one at a time in 1-2 week intervals
Use waterproof fixtures and endcaps whenever possible
Stony corals and giant clams often seem to require greater intensities of light than do the majority of leather corals, polyps, and anemones, so plan the lighting profile and location of each type of specimen in the aquarium accordingly
Based on these guidelines, a few of which may seem arbitrary, a reef aquarium can be maintained successfully as far as lighting is concerned. Please don't be discouraged by my abruptness in detailing the correct ways to "properly" illuminate a reef aquarium, since the entire section of lighting terms and definitions will provide you with much of the information you'll need to make judgments about your own aquarium. The "standard" for quite a few years has been to place a combination of daylight and actinic lights over the aquarium. When using fluorescent lights only, it's a good idea to place as many aquarium-length tubes over the aquarium as will fit in the canopy. The use of halide bulbs typically means one to three halides (depending on tank length and depth), and a pair of actinic bulbs that are as long as the aquarium. Recent introductions of 10,000 and 20,000K lamps are getting some attention, and are more beneficial to organisms originating from relatively deep areas of the photic zone than they are to "shallow-water" inhabitants. If you have researched the depths of the reefs from whence your corals are likely to have originated, and feel that these newer bulbs may be of some use to you, then by all means try them out. Otherwise the daylight/actinic combination is generally adequate for the vast majority of aquarium inhabitants.

I will wrap this up by stating that aquarists and research facilities have been successfully maintaining corals and other photosynthetic reef organisms for decades using the type of information presented throughout the entirety of this discussion. Reef lighting doesn't need to be as complicated and frustrating as it has gained the reputation for. So when your blood pressure begins to rise the next time you're thinking about setting up a new reef aquarium and the associated lighting system, take a deep breath and refer to this discussion. Then, filter all of the lighting conjecture and nonsense out of your mind and realize that nine times out of ten, poor appearance of corals and other photosynthetic reef organisms is due to deteriorating water quality, not a lighting problem.

Part II: Intensity and Lumens
Intensity refers to the relative instantaneous "strength" or brightness of the light source. It does not equate to the commonly used "unit" of watts/gallon. Imagine the difference in light strength, relative to the observer, between a 100-watt light bulb 6 inches away, and an identical bulb 100 feet away. Although the wattage of the bulbs remains the same, the perceived light intensity is much different. Likewise, a 40-watt fluorescent bulb positioned 2" above the aquarium water surface may seem more intense, when viewed from within the aquarium, than a pair of 40-watt bulbs positioned 8" above the aquarium. The explanation to all of

this is that light intensity drops tremendously with increasing distance from the light source. To be precise, it can be said that illuminance of a surface changes inversely with the square of the distance from the source.

Lumens, or luminous flux, is the unit of light intensity. The number of lumens produced by a “general-purpose” light bulb is often found on the bulb package, though few “aquarium” lights list this information. A phone call or e-mail to the bulb manufacturer can usually supply all of the technical information you really need.

The following equation describes the illuminance of a surface, ‘E’, which equals the lumens, ‘F’, per unit area, ‘A’. ‘I’ is the luminous intensity.

E = F / A

and

F = 4pI

Calculating the change in ‘E’ with distance from source to destination is as follows:

E = I / d2

Where ‘d’ is the distance from the light source to the destination (or the distance from the light bulb to a given point in the aquarium). We are assuming that the light beam is perpendicular (directly above with light emanating at a 90º angle) to the water surface, in order to simplify the calculations. So, the value we get from the final calculation is representative of intensity directly below the light source.

One problem with the overall equation of calculating the change of intensity with distance is that the relationship between ‘E’ and the luminous intensity, ‘I’, requires that the light be emitted from a point source (like from an incandescent or halogen bulb), which fluorescent bulbs do not provide. We can somewhat standardize the equation if we are comparing like fluorescents with each other, like halides with each other, and so on. In that case, when comparing two bulbs of the same spectral output and age, intensity of the bulbs should be approximately the same; in other words, ‘I’ is approximately the same for both bulbs, so if the luminous intensity of the bulbs isn’t known we can give them an equal, arbitrary value in order to produce a numerical final answer. Again, a problem arises with bulbs that are supposed to be the same intensity, but obviously differ right out of the box. At any rate, the difference in surface illumination with changing distance can be measured in relative terms when comparing like bulbs. For example, the surface illumination provided by a pair of brand-new, 6500K bulbs can be calculated in terms relative to each other. If one bulb (a) is 24 inches, or 2 feet, from the aquarium substrate, and the other (is 36 inches, or three feet, from it, and we assume ‘I’ to equal 100,000 lumens, the “calculation” is as follows:

(a) Ea = I / d2 ® Ea = 100,000 lumens / (2.0 ft)2 ® Ea = 25,000 lumens / ft2

(Eb = I / d2 ® Eb = 100,000 lumens / (3.0 ft) 2 ® Eb = 11,111 lumens / ft2

Ea / Eb = 25,000 / 11,111 » 2.25

So, bulb (a) is approximately 2.25 times more intense than bulb (at these distances. As long as ‘I’ is the same for both bulbs, this difference in intensity will hold for all bulbs 2 and 3 feet from the substrate.

Now, if you are comparing the light intensity at the substrate, 3 feet from the bulb, and that of a point 2 feet from the bulb, where you may have placed a coral, you know how to go about the calculation. ‘I’ is obviously the same number, since the light is collectively emitted from the same bulb, or bulbs.

Let’s say you’re comparing the difference in intensity between using one and two “like” bulbs over an aquarium. Now, the value of ‘I’ for the set of bulbs is two times the value for the single bulb. Simple enough, right?

One thing that needs to be taken into consideration is that water reflects light of decreasing wavelengths with increasing depth, a process known as refraction. Water molecules, dissolved organic substances, and surface agitation are a few of the culprits that scatter light. Refer to the section on refraction for an explanation. I see no point in deriving the values for intensity when taking turbidity into account, since most aquarists aren’t taking the hobby to this extreme. Let’s just say that it’s very important to skim the water efficiently as a means of dissolved organic matter (DOM) removal. Excess DOM discolors the water, effectively changing the characteristics of light reaching the aquarium inhabitants. Fortunately, marine aquarium enthusiasts tend to overskim their systems, thus keeping the water practically crystal clear. This practice not only increases the ORP and overall health of the system, but it makes for more efficient light penetration.

Part III: Wavelength and Spectral Composition

Wavelength refers to the distance between two successive peaks in a light wave. According to quantum mechanics, light can be thought of as acting as a particle, called a photon. Simply put, photons can be thought to behave as waves, similar to waves in water. The differences in wavelengths dictate the portion of the spectrum that we perceive the light to be, if it’s indeed visible. At the violet end of the visible spectrum, the wavelengths are very short. As wavelength increases, the perceived color shifts progressively to blue, green, yellow, orange, and red. Ultraviolet and infrared light are not visible to the unaided human eye, being just outside the range of the visible short and long wavelengths, respectively.

Wavelength is measured in units known as nanometers (nm) and angstroms (Å). One nm is equal to one billionth of meter, whereas one Å is equal to one ten-billionth of a meter, so it’s apparent that we’re talking in very small terms with wavelength. The visible portion of the electromagnetic spectrum for humans is roughly between 400 and 700 nm, with violet and red making up the low and high

visible ends, respectively. Water refracts light, changing the characteristics of light as depth increases. There is an inverse relationship between the water depth and the wavelengths of light that are refracted out. Red, being the longest wavelength, is refracted first (in “shallow” water), followed by orange, yellow, green, blue, and violet with increasing depth. This is easily observed by watching a nature documentary on reefs, or the ocean, in general. Many deepwater and nocturnal fishes exhibit red coloration, because there is no red light present at depth or at night. When a diver shines a flashlight on the red fish (or other organism), the red wavelengths are added back the water, and the true coloration of the fish is visible. This is an evolutionary tactic of deepwater and nocturnal organisms that provides them with camouflage, because they appear brown or black in the absence of red light. They are therefore hidden from would-be predators and prey items.

Spectral Composition of a light source refers to the various “colors” of light that make up the overall light emission. Most, if not all, artificial sources of light used in aquariums contain at least some portion of every wavelength from 400 to 700 nm. The relative strength of the independent wavelengths are what give a light an appearance of being more blue than red (otherwise known as “cooler” vs. “warmer”). For example, actinic bulbs have a far greater emission in the 420 nm “area” than they do in longer wavelengths, giving them a distinctly blue appearance. By comparison, a bulb with a greater emission in wavelengths around 650-700 nm would appear very red.

Part IV: Kelvin and CRI

Kelvin temperature of light, for our purposes*, refers to the relative blue vs. red appearance of the light being emitted. The redder a light source appears, the lower the Kelvin temperature. Conversely, the bluer a light source appears to be, the higher the Kelvin temperature. Most quality lights sold specifically for freshwater aquariums have a Kelvin temperature of 5,000 to 6,500K, and produce a relatively “warm” white light that is said to simulate sunlight. Bulbs sold for marine aquaria have Kelvin temperatures ranging roughly from 6,500 to 20,000K. The greater relative intensities of blue wavelengths in the light emission are thought to be more beneficial to photosynthetic marine organisms that often live at depths in which very little red light is able to reach. Actually, the higher Kelvin temps may be more for display than practicality. Although sunlight is progressively filtered with increasing depth in ocean water, 6,500K lights are still a no-nonsense approach to providing a reef system with an appropriate source of light. Even so, 10,000K lamps seem to have a more aesthetic appeal to them. Not too blue, not too yellow.

It should be noted that the actual Kelvin temperature of a new bulb sometimes varies quite markedly from the manufacturer’s stated Kelvin temperature. Unfortunately for the vast majority of consumers, there is no inexpensive means to get the actual Kelvin of a bulb, so in a sense you’re at the mercy of the manufacturer’s “word”. This is one explanation for the difference in apparent color of two “same Kelvin” bulbs produced by different manufacturers. There’s no

reason to panic, however. Corals don't care if a light is exactly 6,500K, 7,100K, 10,000K, etc. All they are interested in is a light source that is of high enough intensity, while simultaneously providing the correct wavelengths at the correct relative levels. So if a "10,000K" bulb has an actual temperature of 9,000 or 11,000K, it won't matter much to the corals.

I will briefly touch on the extremely controversial topic of "which bulb is best". There is no correct answer to that subject that suits every aquarium. Organisms originate from various depths of the reef, some are in full sunlight, some are shaded beneath other organisms or in caves, some live in water with high turbidity, etc. If your aquarium houses animals that are all found in the same section of the reef in the same "light" conditions, then you can choose a general Kelvin temperature that will replicate the organism's "natural habitat". Cases such as this are extremely rare. Practically every reef tank will have a mix of animals that originate in various conditions. Therefore, a wide approach to lighting the aquarium may prove most beneficial. A mix of 6,500K, actinic, 10,000K, and 20,000K bulbs will probably satisfy the light needs of all photosynthetic organisms, provided the intensity of light is high enough. Actually, a combination of 6,500K and actinic bulbs has been a "reef standard" for quite some time, and with good results. Aside from providing the correct light regime for corals, the observer also needs to be satisfied with the entire reef scene. This is one reason that you see few aquariums illuminated entirely with actinic lights. All in all, most photosynthetic reef organisms will successfully adapt to "foreign" light conditions, given enough time.

*There is a little more to Kelvin temperature than my simple explanation above, but it's more applicable to Physics than to aquariums. When an object is heated to high enough temperatures, it begins to glow (incandescence). The radiation emitted has different characteristics according to the temperature of the object. At relatively "low" temperatures, the object gives off more of a red glow. The hotter the object becomes, the more blue and less red it becomes. This behavior is tested in Physics with an object known as a "blackbody", which reflects no light, yet radiates light as it's heated.

CRI or Color Rendering Index is a relative measurement of the light source as it compares to sunlight over the equator at sea level at noon. The higher a CRI is, the more closely that light source resembles the sun in those conditions. CRI is an important factor when selecting so-called "daylight" lamps (5000-6500K), but is of little importance to bulbs emitting a lower or higher Kelvin temperature. If a daylight bulb has a CRI over 90, it approximates the "color" of the sun fairly well, while a bulb with a CRI around 80 is not as desirable. Only a few lamp manufacturers readily advertise information about the CRI of their products, and as expected, these are some of the better CRI ratings to be found in the hobby. Information on CRI of a lamp should be available from its manufacturer. If they don't have the lamp specs available for some reason, that's an indication that you're not speaking to the original manufacturer of the lamp.

By the way, the "standard" actual daylight Kelvin temperature is roughly 6000K.

Part V: Color Shift, Actinic, and Full-Spectrum
Color Shift refers to the change in overall light-emission characteristics of a lamp as time progresses. As a bulb ages, the Kelvin temperature of light emitted will gradually shift towards the red end of the spectrum. Bulbs of poor quality will undergo this change very rapidly within one to two months of first use. Better bulbs will take longer, from six to twelve months, to degrade to the point of no longer being useful. Let me add a brief disclaimer: brand-new halide bulbs must be “broken-in” for a period of several hours, during which time there is a significant color shift. Then, after the bulb has conditioned, it should retain it’s spectral output for several months before it degrades to the point of needing replacement.

Metal halide bulbs tend to shift much more quickly than fluorescent lamps, which can usually last up to 12 months before needing replacement. Of course, all of the times involved are dependant on the number of hours that the lamps are burned daily, and the efficiency of the ballast or transformer employed.

The color shift process is, for the most part, quite gradual. Therefore, the photosynthetic organisms in the aquarium are also gradually acclimating themselves to living under the ever-changing color temperature. In aquarium hoods housing more than one lamp of the same original Kelvin temperature, it’s important to replace the bulbs one at a time, allowing at least a week between changing each bulb. This allows the photosynthetic organisms time to adjust to the different light characteristics. Replacing all of the lamps at once can cause organisms to not open, increase oxygen production by zooxanthellae that may oxidize the coral tissue in the absence of enough iodide, and can be the catalyst for eventually killing the organism.

Actinic or Actinic 03 lamps produce a relatively high intensity of 420 nm wavelength light. This light stimulates many pigments in zooxanthellae, causing them to fluoresce almost as if the coral itself is glowing.

The advent of actinic lighting actually belongs to the paper printing industry. The “actinic 03” lamp is a refined version of the earlier lamps. It has a strong peak in the 420 nm “area” of the spectrum, and so is predominantly a deep blue color. While the fluorescing effect it has on corals is intriguing, illuminating an aquarium with nothing but actinic lamps doesn’t usually satisfy the needs of the corals or the aesthetical needs of the aquarist. The light simply doesn’t have the right characteristics to show the actual colors of the aquarium residents. In addition, it’s not likely to provide enough intensity of the correct wavelengths to keep corals and clams happy.

Generally, actinic lamps have a Kelvin temperature somewhere near 7,100K. The difference in appearance of same-wattage actinic lamps produced by different manufacturers is attributable to variations in Kelvin.

Full-Spectrum refers to lamps providing the full range of wavelengths from roughly 400-700 nm (the visible portion of the electromagnetic spectrum). Interestingly, the

only lights that are not truly full-spectrum are those in which the glass is colored, such as the small, colored incandescent lamps used in very small aquaria. In cases such as these, the color of the glass acts as a filter to all wavelengths other than that color, and so the lamp appears to be red, blue, green, or whatever the case may be.

Most fluorescent lamps and metal halide bulbs emit the full visible spectrum. Even actinic bulbs are emitting all (or nearly all) of the colors of the rainbow. They're simply emitting more blue light than anything else, giving them a characteristic blue appearance during operation. Lamp manufacturers have gotten into the habit of calling "daylight" replicating bulbs full-spectrum, but this characterization has little relevance when you consider that 99% of the lamps used with aquariums are full-spectrum. The tricky part is that the relative intensities of the wavelengths of two 6,500 bulbs (for example) may be different. Although hobbyists may be searching for a way to economize lighting, it's advisable to avoid cheap light bulbs from home improvement centers when it comes to caring for a system loaded with very expensive corals or plants! My advice is to forego saving money by shopping at home improvement stores for inexpensive bulbs; spend the extra money and buy lights marketed specifically for saltwater aquariums. The peaks of blue, green and red wavelengths in these lights are more appropriate for use with photosynthetic organisms than are the peaks in lights intended to illuminate kitchens and bathrooms.

Part VI: Reflection and Refraction

Reflection in this case refers to the "bouncing" of light rays as they come into contact with a surface.

Refraction is, in very simple terms, the bending of light that occurs when light passes from a medium with a density, x, into a medium with a different density, y. The amount of bending depends upon the angle that the light hits the surface interface, otherwise known as the angle of incidence. Let's try to make sense of this all with a general example that discusses overhead reef lighting while not including ambient room lighting…

Over your 40-gallon aquarium, you have a hood with one halide bulb. We'll further simplify by saying that the light is mounted on a reflector, focusing the light downward towards the water. When there is no water-surface agitation, such as that created by powerheads and return pumps, the water surface is "smooth" or flat, with no ripples. Assuming that the light is coming from directly above the aquarium, the path of light is perpendicular, or "normal", to the water surface. There is no discernable distortion of light as it passes through the water column towards the aquarium bottom. When there is surface agitation, such as that produced by a pump or powerhead, the light is refracted among the ripples and broken up as it reaches the bottom of the aquarium. This creates the appearance of water ripples on sand and rock

For all intents and purposes, reflection and refraction play a very small role in decreasing light intensity in the typical reef aquarium. For one thing, reflection and refraction are the cause of the “rippling light” affect on the bottom of aquariums illuminated by metal halide bulbs, or other point sources of light. For the majority of aquarists, this is a pleasing affect, looking a little more “reef-like” than the ambient light produced by diffuse light sources such as fluorescent bulbs. Additionally, the water in most well-kept reef aquariums is nearly crystal clear, so it’s not as though light is being bounced out of the aquarium by particulate matter (such as that found in productive estuaries, in which underwater visibility may often be less than 6”). In actuality, bubbles that form from skimmer exhaust and general surface water agitation reflect more light than the dissolved and particulate organic matter floating around in the aquarium (which should be minimal anyway). Concurrently, ripples in the water surface may focus beams of light and create short-term increases in light intensity.

Part VII: Ultraviolet Light and Photoperiod

Ultraviolet (or UV) light is that which has wavelengths shorter than violet light and greater than x-rays and gamma rays, and is not visible to the unaided human eye. Collectively, it is high in energy relative to other wavelengths of light within the visible spectrum. There are three types of UV light; UV-A, UV-B, and UV-C, with the latter being the most energetic of the three and commonly used in ultraviolet sterilizing systems. Overexposure to UV-A and UV-B causes sunburn, both in humans and other organisms (including clams and corals containing zooxanthellae). If a light source is emitting a high intensity of these UV types, coral and clam tissue can become damaged.

Metal halide bulbs, for the most part, employ the use of glass that filters UV light out of the emission, though there are still some lamps (typically the imported double-ended bulbs) that must be retrofitted with a glass UV-filter. Very High Output (VHO) bulbs also emit relatively large intensities of UV light, and so must either be shielded or placed further away from the aquarium, or organisms sensitive to UV light must be placed further down in the aquarium in order to protect them from the harmful radiation. Organisms originating in shallow or intertidal water are somewhat accustomed to, and can typically tolerate, a greater intensity of UV light than can “deep water” organisms, which lack enough UV-blocking pigments to protect the specimen from damage.

It is not recommended that you look directly at any metal halide, VHO, or power compact lights while they are operating. The high intensity of light is almost certain to “leave spots in front of your eyes”, and may also damage retinal tissue.

Photoperiod refers to the amount of time each day that the lights are burning over the aquarium. In the tropics, the day is said to be 12 hours long, with an hour each allotted to the period prior to/post sunrise and sunset, respectively. Therefore, light over the reefs has reached a substantial intensity one hour after sunrise. This equates to a 12-hour photoperiod, more or less depending on the preferences of the aquarist. Assuming that sunrise is at 6 a.m., and sunset is at 6 p.m., the

intensity of light is strongest during the period from 10 a.m. to 2 p.m.

It should be remembered that there is light before the sun comes over the horizon, as well as after the sun has set. Actinic lights are generally used to simulate sunrise and sunset, and so come on first and go off last each day. Using the above guidelines, the actinics would come on at 6 a.m. and would turn off at 6 p.m. Normal daylight replicating lamps could come on around 7 a.m. and turn off at 5 p.m., and metal halides would burn from 10 a.m. to 2 p.m. In general, this is an effective way to simulate the “natural” photoperiod.

Of course, if you don’t return home from work everyday until 6 p.m., you won’t see the aquarium illuminated at all. For this reason, you can adjust the photoperiod times to suit your personal needs. Many people will set the timers on each set of different lamps so that the halides come on during the early evening, with lights turning off around midnight. This allows them to observe the aquarium fully illuminated each day.

Twelve hours is generally a long enough photoperiod. Increasing the photoperiod by a few minutes up to an hour probably won’t harm the system, but it won’t do it much good, either. A longer photoperiod sometimes provides the right conditions (in the presence of the proper nutrient concentrations) to fuel a nuisance algae plague. Conversely, a somewhat shorter photoperiod won’t do much harm to aquarium inhabitants. If you were to cut the photoperiod down to 8 hours, however, the appearance and health of the photosynthetic organisms would likely decrease over time.

Part VIII: Ballasts, Metal Halides, and Incandescents

A Ballast is the piece of equipment that “runs” the bulb or bulbs. Electricity enters the ballast, where it is transformed into the proper voltage to power the bulbs. As electricity flows, it heats the ballast and lowers the overall efficiency and life span of both the unit and the bulbs. The “old-style” ballasts use tar as a heat sink, and are quite inefficient. These ballasts are typically found in commercial lighting fixtures and shop lights, and have a life-span of roughly 1 year before they burn out and must be replaced. The build up of heat in an enclosed space, such as in a ceiling or aquarium hood, speeds up the failure of the ballast. A somewhat recent advancement in lighting technology is the use of electronic “cooling” systems. Electronic ballasts run much cooler and increase the efficiency of the system and intensity of the bulbs relative to a system driven by a tar-cooled ballast. Electronic ballasts are also, of course, more expensive than tar-cooled units. However, their advantages heavily outweigh the higher price.

It’s important to purchase a ballast manufactured by a company that makes lighting and/or electronic equipment only. Ballasts marketed by companies that sell everything from fish food to light bulbs are not as reliable, have more relaxed safety standards, and could pose a hazard. Electronic ballasts typically have a life span of 5 to 10 years, depending on factors such as manufacturer, number of hours run on a daily basis, and ambient temperature of the area immediately

surrounding the ballast. Bulbs tend to burn brighter and last longer than when used with tar-cooled ballasts. Electronic ballasts create less heat than their tar-cooled counterparts, which is of concern if the ballast is mounted in a location in which it may influence the temperature of the aquarium water.

Metal Halide bulbs are somewhat similar to incandescent bulbs used in home applications. Like incandescents, light is produced when an electrical current heats a filament inside the glass. The major difference between the two types of bulbs is that in metal halides, the filament is typically coated with tungsten, and the filament itself resides within a pressurized capsule within the bulb. The resultant light is very intense compared to most other types of lighting. The idea is to simulate actual sunlight intensity as closely as is possible, which of course varies with water depth. Bulbs of greater wattage can illuminate deeper aquariums better than lower-wattage bulbs, and they also illuminate a greater surface area. So, if the aquarium is particularly large, the aquarist can either use a fewer number of greater wattage bulbs, or a greater number of lower wattage ones. The super intensity produced by metal halide lighting is thought by some to bring out (i.e. intensify) the colors of corals and clams more than when fluorescent lighting is used alone. This is only the case in organisms that have been conditioned to the high light intensities. If the organism is not acclimated to the lamp, zooxanthellae often replace blue, pink, and purple pigments with brown or green ones. This is in response to a greater intensity of light in wavelengths that require different pigments to maximize photosynthesis and/or block harmful radiation.

Just like their incandescent cousins, metal halide bulbs are not efficient in the very least, for while they produce very intense light, the majority of electricity consumed by the bulbs goes to heat production. This high heat output can create problems with aquarium water temperature. If bulbs are placed too near the aquarium surface, they can heat the water to temperatures that stress the organisms in several ways. First, as the water temperature rises, less oxygen is able to stay in solution, and so the dissolved oxygen concentration in the aquarium water decreases. Second, the increase in temperature speeds up the metabolism of all organisms present in the system, which can lead to illness and other secondary complications. Third, if the temperature rises too high (in extreme cases), proteins that make up the cells of organisms can actually begin to denature, or “unravel”, which should be inherently avoided (obviously).

In addition to the dangers of water temperature increase, bulbs placed too near the aquarium surface can give photosynthetic organisms “sunburn” if they’re overexposed to the light. They must therefore be gradually acclimated to the light. “Too much” light will cause zooxanthellae to produce a relative overabundance of oxygen in the epithelial cell tissues of their host corals, anemones, and clams. The excess oxygen damages the tissue, unless it is “detoxified” by iodide (though the effects of iodide have been hotly debated as of late, many, many long-time hobbyists have noted that iodine supplements appear to help corals and other hermatypic invertebrates acclimate to higher intensities of light). This is one of the many reasons that iodide supplementation in reef aquariums is very important, especially when changing lights or adding more to the system. The point is to keep the lights elevated 4-8” off the aquarium surface. Some people may be concerned

with the loss of intensity, but that's the whole point of keeping the bulbs elevated above the aquarium, isn't it?

In spite of these potential drawbacks, metal halide lighting remains one of the most popular ways of delivering high intensity light to a reef aquarium. The bulbs typically used in aquarium applications are available in 100, 175, 250, 400, and 1000-watt models, and in various Kelvin ratings ranging from 3,500-20,000K (of which only bulbs of 6,500K or greater have any use in a reef aquarium). There are two niche-types, one being the standard "screw-in", and the other being double-ended. There is no obvious advantage to the use of one or the other. The major thing to keep in mind is that the reputation of the bulb manufacturer plays a very large role in the over-all quality of the bulb. Experience has shown us that European and Japanese-made metal halide bulbs typically last longer, undergo a much slower Kelvin shift, and are more reliable than the majority of American-made bulbs.

This brings us to another point. The average useful life-span of a metal halide bulb is typically between 6 and 8 months. After this length of time, the intensity of the bulb has degraded quite a bit, and the color temperature has probably undergone a substantial red shift. Unless you plan on utilizing a lux meter and can gauge the color temperature of the bulbs on your system, it's recommended that you replace them every six months as a general precaution. It is very important that should the system have more than one halide, in this case, bulb that needs replacing, change them one at a time with at least one week between. Actually, I recommend three to four weeks between changing bulbs. This enables the organisms to gradually acclimate to the changing light characteristics, and will minimize the stress associated with the sudden change in light conditions. Should the color temperature shift too far into the red end of the spectrum, conditions will be more suitable for microalgae to proliferate than when the corals and other photosynthetic organisms are "operating under maximum efficiency". Think of it as a see-saw, with microalgae on the left side of the pivot, and "desirable" photosynthetic organisms on the right. The pivot is the Kelvin temperature of the bulbs, and at the exact center of the balance it measures roughly 6,500K. To the right are temperatures above 6,500K, and to the left are the temperatures below. Under optimal water conditions, when the Kelvin temperature is 6,500 or greater (more to the right), the corals, etc., are able to take up nutrients faster than the microalgae, and so the desirable organisms proliferate. However, as the Kelvin temperature drops below 6,500K and the balance is shifted, the microalgae are able to assimilate nutrients faster than other organisms. Make sense? This is why it's necessary to replace bulbs every six months or so. Yes, the "final" color temperature does depend on the initial Kelvin temp, but if your intent is to run a system using, for example, a pair of 10,000K metal halides, you'll need to replace them periodically to keep the lighting conditions consistent. The old argument is that the cost of all of the corals and clams in a well-stocked reef system is worth the cost of replacing the bulbs twice a year. It seems to make sense that if you're willing to invest in a metal halide system, you do it "the right way" and maintain it for the sake of the organisms in the system.

For the sake of being complete in this topic, I should mention that brand new bulbs

often increase in Kelvin temperature up to the first 100 hours of operation, which is why many aquarists will run new bulbs for several hours a day in a location away from their aquarium until the bulbs have been “broken in”.

Ballasts are specific as to which wattage bulbs they can power. For instance, don’t try running a 1000-watt bulb on a ballast rated for 400-watts. Electronic ballasts are now available for use with metal halide bulbs. The heat production of the bulbs is decreased, and the intensity increased, when using these types of ballasts. In any case, a major part of the initial investment into a metal halide system is the ballast itself, which can range anywhere from $75 to over $300. This is not including the fan(s) used to cool the bulbs/remove heat from the hood, the bulbs themselves, or the timer(s) that will control the photoperiod.

Unfortunately, the quality of a bulb can’t be judged by its price. Many of the low-quality bulbs I spoke of earlier are often more expensive than “better” bulbs of the same wattage. Therefore it’s a good idea to research the bulbs very carefully before you shell $60 to $300 out for each metal halide bulb. You are interested in approximate values for useful life-span of the bulb, actual closeness to the manufacturer’s “claimed” Kelvin temperature, and rate of failure before six-months of operation have passed.

Incandescent lighting is probably familiar with everyone reading this right now. It is represented by the “standard light bulb” that’s screwed in to overhead lighting, table lamps, many flashlights, nightlights, and the like. Light is produced when current flows through the filament located inside the glass vacuum. In any case, when two bulbs, one incandescent and the other fluorescent, of the same wattage are compared in terms of light intensity produced, the incandescent produces far less intensity. This is because more energy is consumed by heat in incandescent lights than is by fluorescents.

In addition to the relatively low light intensity produced by incandescent bulbs, they burn very hot and typically produce light with a Kelvin temperature less than 4,000, making them unsuitable for reef aquariums. There are a few specialty bulbs produced, such as the so-called “black light” incandescents that are used by reef hobbyists to simulate moonlight, but brighter, more efficient power compact actinic bulbs can replace even these. There is less resultant heat production, less chance of an exploded bulb if water happens to splash up on a power compact than if it hits a hot incandescent light bulb, and the increased light makes it easier to view the nocturnal behavior of many organisms.

Part IX: Types of Fluorescent Lighting

Fluorescent light is produced when an electrical current excites mercury gas inside a glass tube internally coated with fluorescent material. Part of the radiation emitted by the “charged” mercury vapor extends into the ultraviolet range. This ultraviolet light is absorbed by the fluorescent material, and is then emitted as visible radiation (light). The light emitted is broad band; that is to say that peaks in intensity are observed in a close range of wavelengths, not in sharply defined

wavelengths. The characteristics of the light emitted from a fluorescent lamp depend on the composition of the internal coating.

The efficiency of fluorescent lamps is high relative to that of incandescent and metal halide bulbs. Whereas less than 5% of the electricity that goes into powering an incandescent bulb may be converted to light (the rest goes to heat production), modern fluorescent lamps convert over 40% of electricity to light. Electronic ballasts, which run cooler than older tar-cooled ballasts, provide the greatest efficiency.

There are many types of fluorescent lamps. Most people are familiar with the tube-style lamps used in home lighting applications and aquariums. These lamps are available in energy saver, standard, and very high outputs (high output lamps are very seldom seen in the aquarium hobby in the US, so we'll skip them in our discussion). The number of milliamps used to power each type is the distinction between each category. Please see the table below for the lengths and associated wattages of these lamp types. Power compact lamps are a fairly introduction to the aquarium hobby, and will be discussed shortly.

Lamp Type				
Tube Length	Energy Saver	Standard	VHO	Power Compact
15"	n/a	n/a	n/a	28 watts
18"	15 watts	15 watts	n/a	n/a
24"	17 watts	20 watts	75 watts	

55 watts

36"
25 watts
30 watts
95 watts
96 watts

48"
32-36 watts
40 watts
110 watts
n/a

60"
n/a
n/a
140 watts
n/a

72"
n/a
n/a
160-165 watts
n/a

Table 1. Fluorescent Lamp Length and Associated Wattages Consumed.

Lamps designated with ‘n/a’ don’t mean that they aren’t in production, simply that they are rarely used in applications with aquariums. As you can see, the energy consumption of same-length lamps varies quite a bit from type to type. Generally speaking, the intensity of “higher-wattage” lamps is greater than that of same-size lamps using less power.

The topic of standard vs. VHO lamps for use on reef systems has been argued for years. So many aquarists using VHO swear by them, making other aquarists take a long, hard look at purchasing a VHO system. An impressive reef system does not revolve around the lighting regime alone! Water quality is the first and foremost important aspect of keeping a successful reef aquarium, followed by water temperature and then lighting. Without close attention to water parameters, even the most spectacularly illuminated reef aquarium will not sustain the lives of desirable marine organisms! In reality, the kind of lighting used (standard vs. VHO or power compact) depends on the needs of the photosynthetic organisms in the aquarium. Stony corals and tridacnid clams require relatively high intensities of light, compared with the intensity produced by a standard fluorescent lamp. Therefore, many aquarists have greater success with VHO or power compact

lamps in systems containing these organisms. Aquariums that are 20” or more in depth are better illuminated with VHO/PC lamps, as their greater intensity easily satisfies the light requirements of photosynthetic organisms placed at the bottom of the tank (assuming enough lamps are used). I prefer to use power compact lighting on all reef applications.

Aquariums housing soft or leather corals and various polyps can get by with standard fluorescent lighting, provided enough bulbs are used to produce the required intensity. Using bulbs of differing Kelvin temperatures will usually satisfy the needs of the photosynthetic aquarium inhabitants, and is pleasing to the observer (depending on your personal taste).

Power Compact lighting has been available to aquarists for a few years now. While they provide high light intensity, power compact lamps burn somewhat cooler than similarly sized VHO systems. They’re still very hot to touch after having “run” for a couple of hours, so please don’t misunderstand. Each bulb has a ballast built into the end, which then plugs into a rubber boot connected to a transformer. Power compact lamps have a very small diameter, which gives them a far greater intensity than same-length, non-power compact fluorescent lamps. Similarly priced with VHO and metal halide lighting systems, in time perhaps the cost of PC systems will decrease. However, since they provide high light intensity and consume little electricity (relative to metal halides and VHO bulbs), they present the aquarist desiring the best fluorescent lighting system with some interesting options.

Very High Output or VHO bulbs have been the mainstay of reef hobbyists for years, although power compact lighting stands a very good chance of completely eradicating them from the aquarium hobby. Instead of drawing 425 milliamps (mA) as standard output fluorescent lamps do, VHO bulbs draw 1500 mA. This makes them very bright in relation to standard output bulbs. It also means that they produce more heat than do standard fluorescents. Because of the increase in current needed to power the bulbs, a special ballast is required to drive them. Of course, this means more expense, but the benefits of high intensity of VHO bulbs coupled with their low operating temperatures (relative to metal halide bulbs) generally outweigh the price drawbacks. In addition, VHO bulbs can often last up to a year before their intensity and color temperature have deteriorated to the point of needing replacement. Considering that they cost a fraction of what metal halide bulbs do, and can last two to three times as long, VHO bulbs can be thought of as a more economical way of providing high intensity light to your reef aquarium. It is for reasons such as these that VHO bulbs have had such a prominent place in the reef aquarium hobby for the past several years.

Posted by: pospeh Aug 29 2003, 01:12 PM

Hey boss, do you expect anyone to actually read through this thing.

I think you need a PhD in Physics to understand all this.

Posted by: Achilles Tang Aug 29 2003, 01:30 PM

READ IT!! IT'S AN ORDER!!!!

Well, this article is quite old but relevant. I think T5s were not even born yet.

Posted by: jsoon Aug 29 2003, 02:00 PM

Well, let give him the credit. He did a good job to locate this info.

I read it all YES SIR !!!!!

Posted by: ReeF_LoVeR Aug 30 2003, 12:55 AM

I read it too..
but still dun understand

Posted by: hghflyer Aug 30 2003, 03:04 AM

Read halfway...then dozed off...will continue tmrow...

Posted by: ReDDeviLs Aug 30 2003, 03:54 AM

wow,after mucch reading(not eveerything) guess i need to brush up my english,dont really understand

Posted by: Razo Aug 30 2003, 10:26 AM

> **QUOTE** (Achilles Tang @ Aug 29 2003, 01:30 PM)
> READ IT!! IT'S AN ORDER!!!!
>
> Well, this article is quite old but relevant. I think T5s were not even born yet.

hehhe i read half.. skip half... maybe some pic attached will make reading more interesting.. too much words..hehhee

Posted by: seareefer Sep 1 2003, 11:07 PM

i have read about this article its from kentmarine website right.

Posted by: DeepBlue Sep 1 2003, 11:23 PM

good stuff..the more I read the more I find out how much I dun know....seriously....have to re-read again tomorrow to let everything sink in... Thanks for surfacing the doc, AT....really good.

Posted by: Fireclown Sep 2 2003, 12:02 AM

Ouch! Headache! This is worst then my electrical notes!

Posted by: Lawrence Nov 27 2003, 01:27 PM

Hi Achilles Tang,

Thanks for all the helpful advices & posting! Appreciate your hard work even all this you do it on your free will, glad to be a member in this website!

You sure be awarded with a Marine Aquarium Medal of Honor!

Yours truly,
Lawrence

Posted by: sinner Nov 28 2003, 11:34 PM

wahahahhaa read it twice!!! dun understand abit mind simplfy it?

Posted by: kschew1498 Dec 31 2003, 11:57 PM

Hi this article mentioned about Power Compact light and VHO light bulb....what are those? Are they T5??? Can anybody advise?

Very interesting article but I have to say it is a article compulsory for newbie reefer!!!

Posted by: hazkha Jan 14 2004, 11:41 PM

erm.....i got a 2 feet tank...and i want to keep corals..but im not sure which light to buy?can i use 1 PL light?

Posted by: ryz Jan 14 2004, 11:57 PM

I would say 2 PL lights would suffice for most corals.
Powercompacts or PCs = PL light
VHO(Very High Output) bulbs = t5 bulbs

Posted by: hazkha Jan 15 2004, 12:03 AM

oh okay.....does da light have to be atnic blue and white?

Posted by: ryz Jan 15 2004, 12:05 AM

no need. just need to be bright enough. But actinics make the zooxanthelle (present in many corals) algae fluorescence so very nice. But no need one.

Posted by: Jewel Tang Jan 15 2004, 12:30 AM

read until 3 paragraph have not finished yet, and go back to 1st again coz don ustand, must digest slowly.
tomolo will read again lar.. good info article.

Posted by: kschew1498 Jan 15 2004, 09:51 AM

Hi Hazkha and Jewel Tang....my 25cents advise.....go for PL light straight away.....the more the merrier.....and you can affort go for T5 or MH.....

I check out the price already.....2ft T5 cost around $300, (oxford road LFS selling...forgot the LFS name) advantage...not too hot. Use a fan will do.

As for MH, 2ft 400+ but will need a chiller!! (saw ML selling)

Sigh! Didnt read enough and went for FL.....now very regret and hesitate to upgrade to T5 or MH!!!! because I was thinking to rather spent on my upgrade to a 5 footer in the near future!

Posted by: Hon Jan 15 2004, 10:17 AM

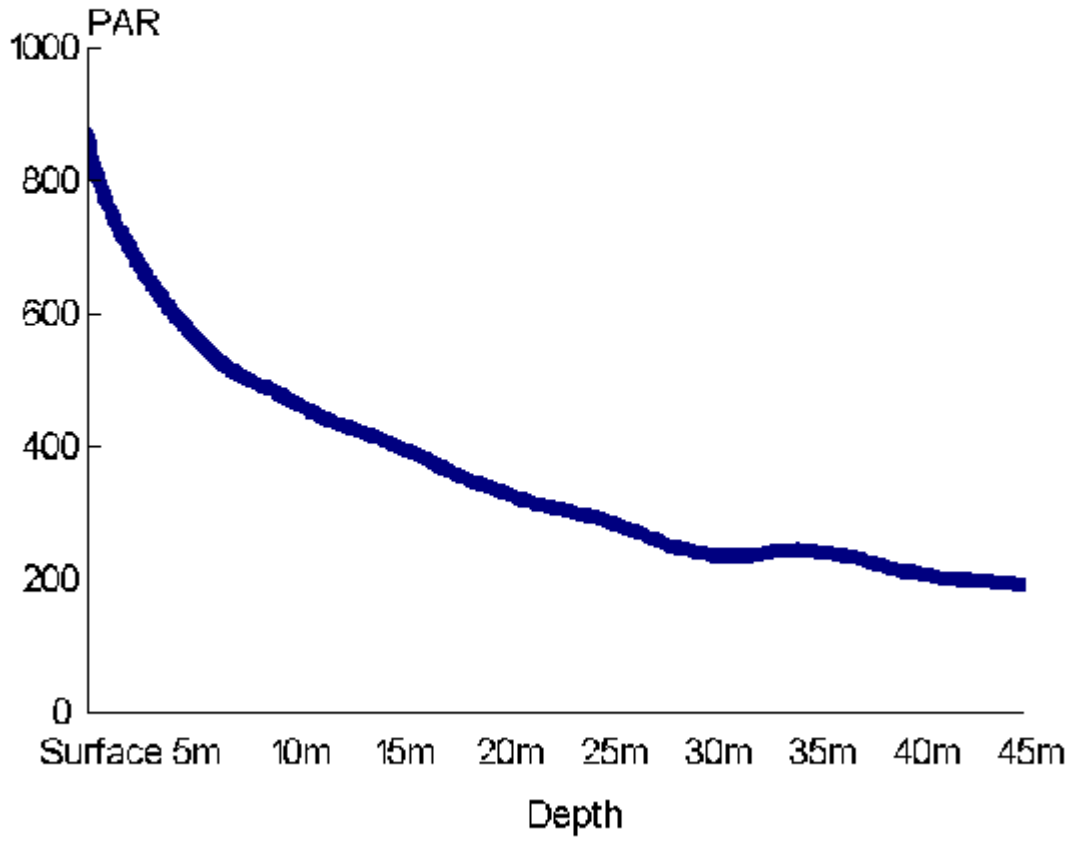
Can somebody summerise it?? I read 1st paragraph give up liao ... light = light lor...pengz

Posted by: jc85 May 12 2004, 01:49 PM

May I add a link that I found on lightings?

http://web.archive.org/web/20020612040241/www.animalnetwork.com/fish2/aqfm/1999/july/fe

A chart from the article.



Posted by: cowgum Jul 26 2004, 10:07 PM

Very cool site that shows effects of diff bulbs/combi on same tank
http://www.coralreefecosystems.com
Look under lighting

Posted by: Tiny Tears Jul 27 2004, 01:07 PM

oooo..that was quite cool seeing all the different types of lighting.

I have read that article at the beginning, very interesting.

I took his conclusion at the end to mean that he is favors compact lighting above all others?

MH, are expensive to buy, expensive to run, create a lot of heat and have to be replaced after 6-9 months. However, it seems most folks here still favor the MH.

I also read AT's lighting post under the DIY section. I notice that is now a 2 year old thread, but wondered if since that was written there is any change on opinion, that NO MATTER WHAT, Metal Halides are considered the best.

Posted by: AlfaRomeo Jul 27 2004, 02:20 PM

Nowadays, for shallower tanks, you can get away with a bunch of Ts for SPS. Look at Danano's/Joe_p thread and also some others which are using T5 exclusively.

MHs are the be all and end all for deeper tanks cos of the capability to punch thru the water rite to the sandbed... critical for SPS tanks

Posted by: yongwil Jul 27 2004, 11:50 PM

Hi

A more readable site about light

http://www.liveaquaria.com/general/general.cfm?general_pagesid=149

http://www.liveaquaria.com/general/general.cfm?general_pagesid=152

Posted by: Tiny Tears Jul 28 2004, 02:30 PM

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