

# Lighting Your Reef Aquarium

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Lighting your reef tank is an important and expensive part of your aquaculture experience. There is quite a bit of information and certainly misinformation available on this subject. It behooves us all to understand some key concepts of lighting so we are able to make informed decisions on how to provide the best environment for our aquatic animals. As important as lighting is NOTHING is as important as water quality in maintaining a healthy tank.

The conventional wisdom for reef lighting simply is to provide 3-8 watts of light per gallon of tank. This is about as useful and helpful a measure as selecting an automobile based upon the size of the gas tank. Watts are a measure of how much power the lighting system consumes. It does not tell you how much light it produces or the type of light it produces, which is the important information. In addition there are two different masters with different requirements that the lighting must satisfy – the animals in the tank and the animal that is aqua farming - you. This paper will shed some light on what you should consider when determining the lighting requirements for your reef tank to satisfy both parties.

Before we get to the lighting itself, we need to establish a common language and understand some basic lighting concepts.

## Light

Light is a part of the electromagnetic spectrum. This spectrum is made up of energy of many different wavelengths. What we humans see is known as visible light. Energy in the visible light region has wavelengths between 700 nm(nanometers – 1 billionth of a meter) and 400 nm. Red light is the longest wavelength at 700 nm between wave crests progressing to the shorter violet wavelength at 400 nm.

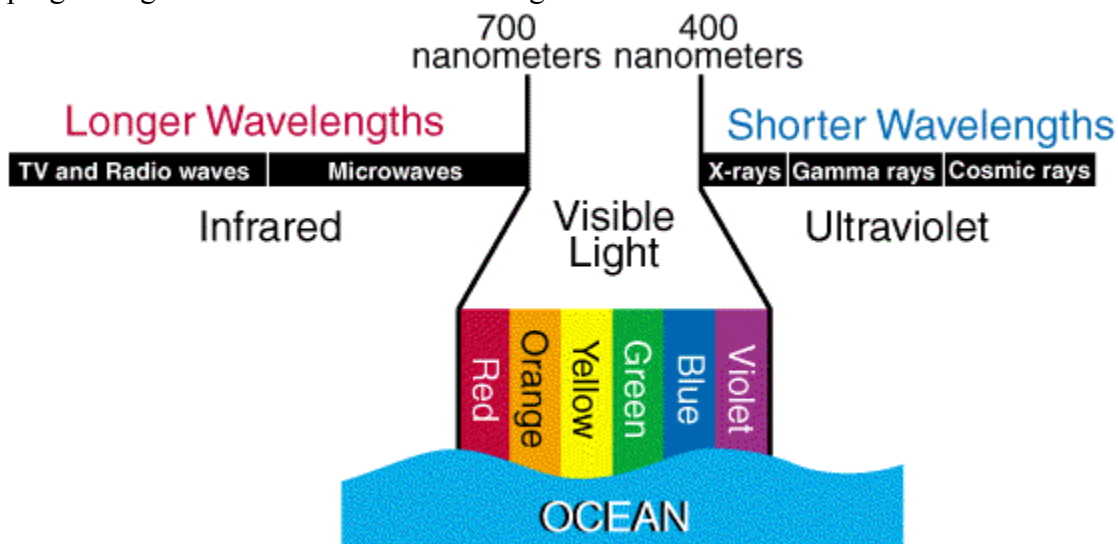


Figure 1. Drawing from <http://punaridge.org/doc/factoids/light/default.htm>

Wavelength nm	Color	other
320		UV B
		UV A
400	Violet	
	Indigo	Actinic lights
	Blue	
500	Green	Human eye most sensitive
	Yellow	
600	Orange	
	Red	630 nm chlorophyll absorbs the most light
700		Infrared

Actinic lights have a great deal of their emission around 420 nm, producing a distinctive blue- violet appearance. Ultraviolet light is divided into three types: UV A, UV B and UV C. The A type has a wavelength of 320-400nm, the B type wavelength is 280-320nm and the C type is 200-280nm. UV A light is useful, B & C are dangerous. UV B is destructive to nucleic acids and photosynthesis, while UV C @ 275nm is used in UV sterilizers. Chlorophyll absorbs the most light at 630 nm.

White light is a combination of all these wavelengths; black is the absence of light. Light from the sun or other sources reflects some of the light off the objects to our eyes, which gives the objects the color we see. When white light strikes a leaf, it absorbs most of the colors and reflects only the green wavelengths to our eyes. The light that is not reflected to our eyes is absorbed or scattered. Many of the absorbed wavelengths are used by the chlorophyll inside the leaf cells to generate energy for the plant in converting CO<sub>2</sub> to O<sub>2</sub>. This same conversion takes place in the zooxanthellae of the corals we keep in our reef tanks. Zooxanthellae are a type of algae or more exactly dinoflagellates. These algae have multiple forms of pigments that absorb different wavelengths of light. There is growing evidence that corals can actually change the type of algae depending upon the lighting condition they have.

### Quantum theory and light

Another way to measure light is how much it illuminates an object. This how much energy is provided by the light source at specific distances. Light loses energy very rapidly as it travels; it follows the Inverse Square Law -

$$E = I/d^2 .$$

Using this relationship we define light energy at 1 foot to be 1, then at 2 feet is only ¼ strength and at 3 feet is 1/9 as bright as at 1 foot.

Remember this, because the distance that your light source is above the water greatly affects the amount of light that reaches the animals in your tank.

We measure the amount of light that illuminates an object in **lumens**.

Let's look at a practical example of energy loss using a new 6500K Metal Halide bulb that produces 100,000 lumens.

$$E = I/d^2 = 100,000 / (1.5)^2 = 44,444 \text{ lumens}$$

- 100,000 lumens @ 1 foot
- 44,444 lumens @ 1.5 feet, already less than half the intensity
- 25,000 lumens @ 2.0 feet, ¼ the intensity
- 16,000 lumens @ 2.5 feet
- 11,111 lumens @ 3.0 feet 1/9 the intensity

Light source	Lumens	Lifetime
100 watt incandescent light bulb	1690	750 hours
40 watt incandescent light bulb	490	1000 hours
28 watt compact fluorescent bulb	1750	10,000 hours
96 watt compact fluorescent tube		
96 watt VHO fluorescent tube		
40 watt fluorescent tube	1650?	

Other light terms we need to define are Kelvin, PAR and CRI.

**Kelvin temperature** is an astronomical term that has been adapted to characterize aquarium lighting. Sometimes you will see Kelvin referred to as Color temperature. Lights with a Kelvin temperature range of 5,000 to 6,500K is referred to as white lighting and are only useful for freshwater aquariums. Reef lighting generally runs from 6,500 K to 20,000 K. A 6,000 K light best mimics the noon sun, but generally a 10,000 K light gives a more pleasing light to humans. The 12,000 to 20,000 K lamps are known as cool lights and highlight the phosphorescence in many corals.

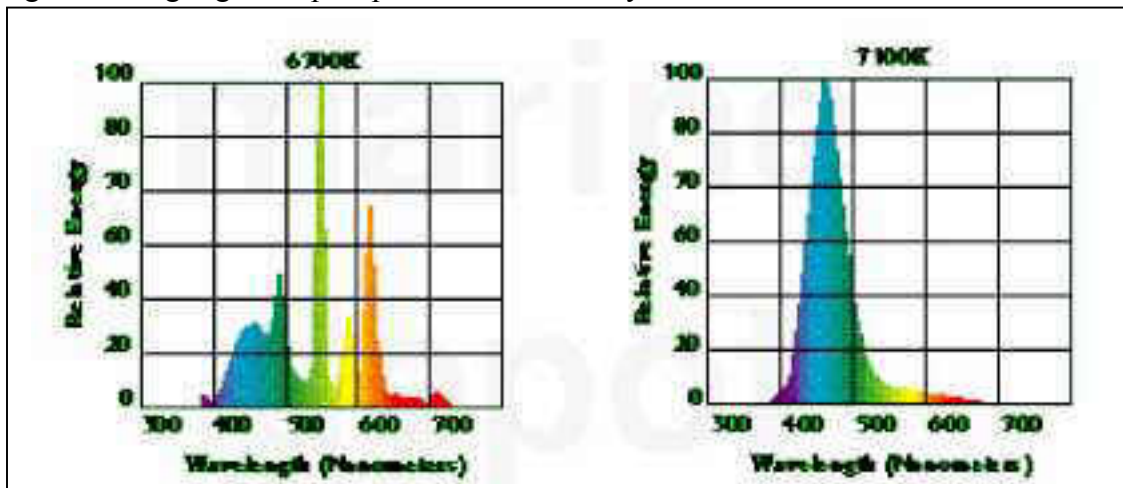


Figure 3. 6700 K and 7100 K Power Compact Lamp spectrums

3000 K	yellowish	- Warm lighting
6000 K	noon sun	
10000 K	white with blue	
20000 K	blue	- Cool lighting

**PAR** (Photosynthetically Active Radiation) this is a new, but important measure of light intensity. Most light intensity measurements are made in Lux or lumens, these measurements are centered on the human eye range that peaks in the green part of the spectrum - photometric. This is the least used part of the spectrum for photosynthesis – remember most of the green light is reflected. These photometric measurements are great for picture taking, but not very useful for plant and photosynthetic animal lighting determinations. The PAR measurements record the light intensity in the useful part of the spectrum for photosynthesis – the violet, blue and red areas. You should look for and request measurements using this standard since this is the range we are most concerned with for our corals.

**CRI** (Color Rendering Index) describes the light's ability to accurately render the colors of objects. You want to see the coral in the colors they really are. Representative images as seen in different light taken from the Dorling Kindersley book on "Light" can be found at: <http://webexhibits.org/causesofcolor/1H.html> . There are images of a multicolored box illuminated by different lights that show how the colors change with different lighting. Also in the section on Metal Halide lamps is a link that shows photographs of different MH bulbs lighting the same reef aquarium side by side and the vast difference they produce. Look for CRI of 90+ to get accurate color from your light.

### **Light and Saltwater**

Saltwater absorbs/refracts light just like the leaf, but to a much lesser degree. Ocean water absorbs the long wavelength red light most easily and the longer wavelength IR wavelength even more readily. This IR energy is what heats the water and generates most of the world's weather. Your home saltwater tank absorbs the IR just as readily, which has implications for your water temperature. The shorter wavelength violet light is absorbed least. An interesting experiment with sunlight and the ocean is to drop some M&Ms into the water and follow them as they sink.

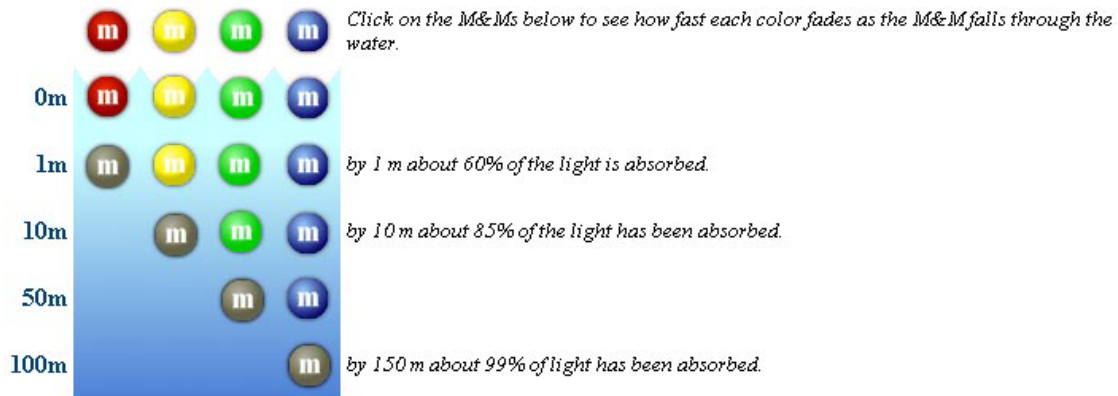


Figure 2. Drawing from <http://punaridge.org/doc/factoids/light/default.htm>

As you can see in Figure 2, if you were to go down to 1m the red M&M would appear gray because there is no more red light to reflect off the red M&M. Remember, the M&M is red because the red light is reflected off the M&M, no red light, no red color. At 10m the yellow light is absorbed and the yellow M&M will be gray, at 50m the green M&M will be gray and at 100m the blue M&M will be gray. At 1m (39.37 inches) about 60% of all the light is absorbed, at 10m this is up to 85%. So organisms that need red light for photosynthesis cannot receive it below 1m. Fish and other marine creatures that have red coloring benefit because they appear gray and now blend into the background. Who would think that red coloring would provide protective coloration.

### Light and the Aquarium Corals

According to Dr. Sanjay Joshi, “As a frame of reference, the amount of light on a coral reef is around  $2000 \mu\text{E}/\text{m}^2/\text{sec}$ , while that from a 175 Watt metal halide is about  $200 \mu\text{E}/\text{m}^2/\text{sec}$ ”. Ten times the amount generated by the metal halide! In addition to light levels we need to consider some of the other things that affect the light the corals receive. These include environmental and biological changes like the movement of the sun, clouds, storms, turbid water, plankton blooms. We tend to have fixed lighting from one location, it is impressive that the corals are able to adapt to these radical lack of changes in its environment.

It is extremely important to know your corals and what depth they came from. You want to provide them with the same lighting conditions, as they would naturally have. By the same token it is difficult to mix many different types of corals and responsibly and adequately provide correct lighting for them all. It is highly recommended that you select coral species from the same reef zones and build your tank around this particular environment.

### Duration of the light

Most corals come from the tropical regions of the world that have around a 12 hour photoperiod. These animals need light to live and grow as well as enough darkness to rest, or vice versa for the night scavengers. So a good choice is to select the photoperiod and intensity level for your tank to satisfy both you and the inhabitants. Many people use a 12 hour lighting period beginning at 9am or 10am, with the lights staged by timers. To

better simulate the natural lighting levels a 3,6,3 pattern is common. The actinics or 50/50 lamps come on first for about 3 hours, then the full spectrum lamps plus the first set for the next 6 hours, then the actinics or 50/50 lamps finish out the last 3 hours.

Sample schedules:

10 am	9 am	actinics or 50/50 lamps on
1 pm	Noon	full spectrum lamps + actinics or 50/50 lamps on
7 pm	6 pm	full spectrum lamps off
10 pm	9 pm	actinics or 50/50 lamps off (moonlights on?)
5 am	4 am	moonlights off?

### **Types of Aquarium Lighting**

Since this paper is about reef aquariums, I will cover just fluorescent and metal halide lights. **All current reef lighting schemes begin to deteriorate as soon as they are plugged in.** Some important lighting rules:

- Your eyes adjust to the changing output of your aquarium lights, don't wait for the lights to quit before replacing them.
- Write the date you replaced the lamp on the lamp base with a Sharpie.
- Your reef lamps change spectral output over their lifetime
- Record the date to change your lamps in your aquarium notebook.
- When changing your lamps reduce the time that they are on to help your animals adjust to the increased lighting.
- Never replace more than one lamp every 3 or 4 weeks
- Your interests will change; consider the ability to upgrade your lighting when choosing a system
- Don't use the rated lifetime of a bulb, change them on a fixed schedule

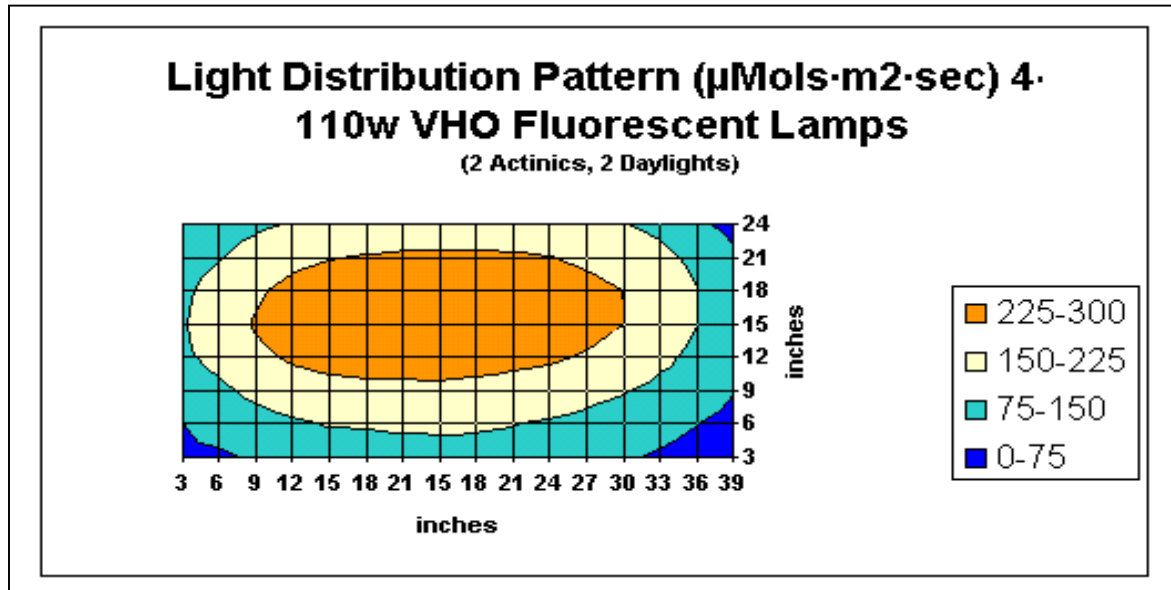
### **Fluorescent**

Fluorescent Lighting comes in many different flavors. There are NO (Normal Output – your standard 4' 40 Watt bulb); HO (High Output); VHO (Very High Output) and PC (Power Compact). You will see a T value associated with Fluorescent lighting; this is used to describe the size of the bulb. T are stated in 1/8" units, times the number to give you the circumference. T12 is 1/8" \* 12 = 1.5" bulb, T5 are associated with HO lights and are small lamps at 5/8" around. All these fluorescent lamps need a ballast to provide the startup and operating voltage for the lamps. The higher output lamps need more expensive and specialized ballasts. A special ballast is required for the different wattage versions of these lamps, make sure you are using the correct ballast. Many ballasts will power your lamps, but this will shorten their lifetime and not provide the specified output spectrum. The Icecap 660 ballast gives you the most flexibility in that it can power both VHO and PC lamps and up to 4 of them in any combination.

**HO Fluorescent** – not found very often anymore.

**VHO Fluorescent** – signaled the next step up from NO and HO light. These lamps come in 36-60” lengths with the power tied to the length. 36” = 95 Watts; 48” = 110 Watts and 60” for 140 Watts. These lamps are cheaper than the PC and MH lamps, but have a shorter lifespan of rated lighting. See the graph below for measured light output and the area it illuminates.

**Usable lifetime – 4-6 months**



Graph from VHO information

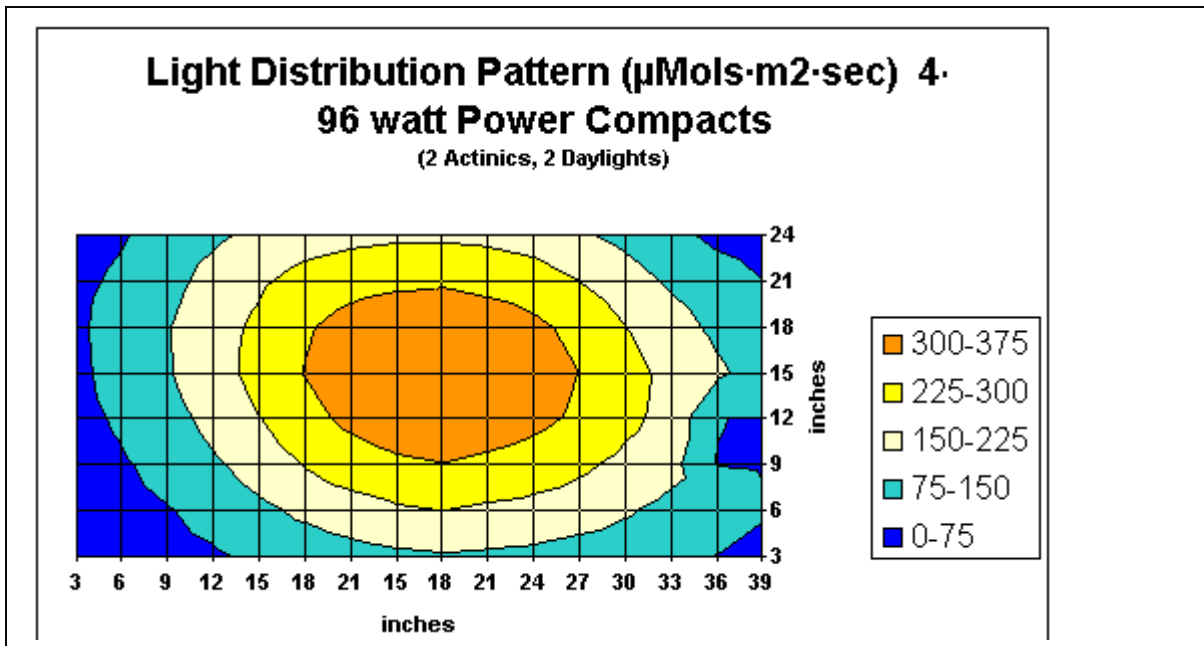
Head to head comparison of lighting coverage of VHO vs PC lights

**4- 110 Watt VHO coverage**

150-400  $\mu\text{mol}/\text{m}^2/\text{sec}$  area 33” x 21”  
 200-300  $\mu\text{mol}/\text{m}^2/\text{sec}$  area 21” x 12”  
 300-375  $\mu\text{mol}/\text{m}^2/\text{sec}$  area *none*

**4- 96 Watt PC coverage**

150-400  $\mu\text{mol}/\text{m}^2/\text{sec}$  area 27” x 24”  
 200-300  $\mu\text{mol}/\text{m}^2/\text{sec}$  area 18” x 18”  
 300-375  $\mu\text{mol}/\text{m}^2/\text{sec}$  area 12” x 9”



**Power Compact Fluorescent**  
Usable Lifetime – 8-12 months

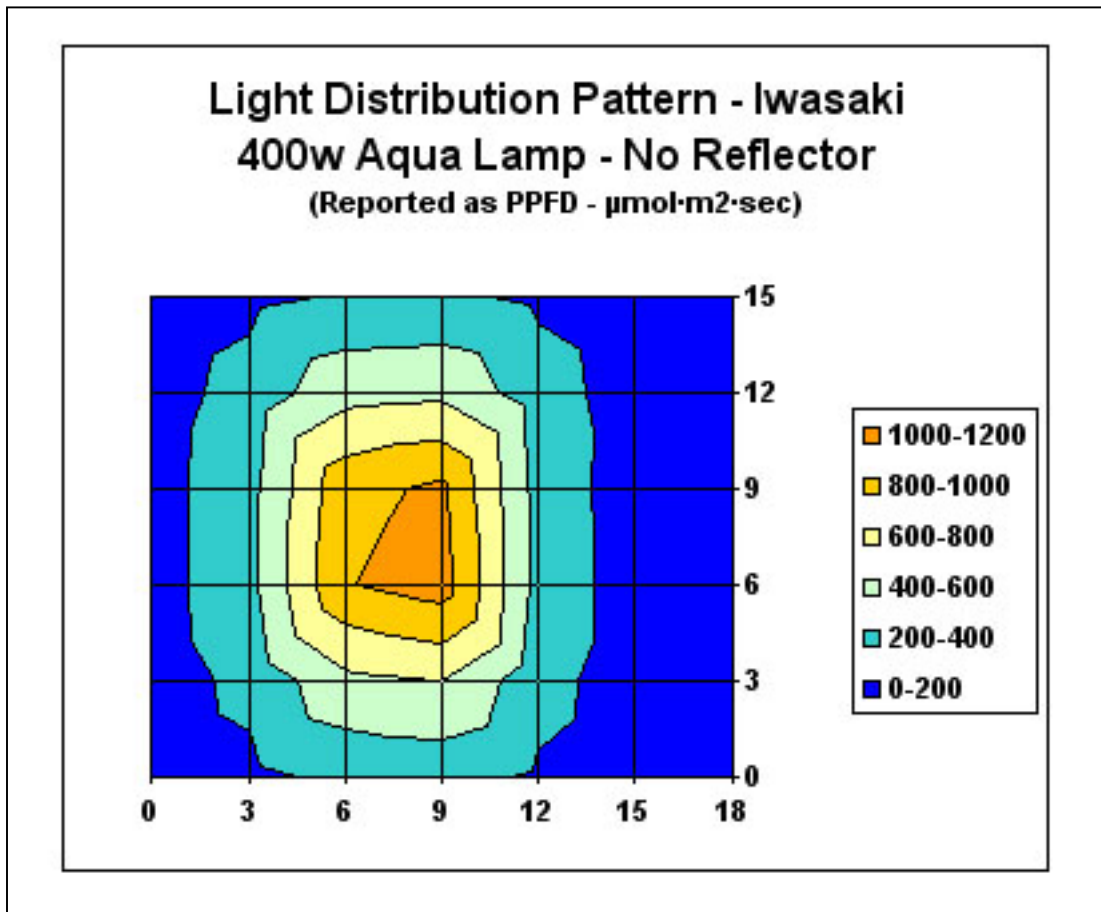
### **Metal Halide lighting**

A reasonable guide for MH lighting uses tank depth and width to determine the size of the MH bulb. The most common metal halide bulbs are the 175, 250 and 400 Watt models. Use one bulb every 24" horizontally and then use the table below for your initial bulb selection. Now the type of corals you are lighting is more important than this general table. This table best fits the soft corals and SPS corals, go up a bulb for the LPS

<b>Tank Depth</b>	<b>MH Watts</b>
Up to 18"	175
Up to 24"	250
24" and up	400

**Usable lifetime – 6-12 months**

## 400 W Metal Halide coverage



200-400  $\mu\text{mol}/\text{m}^2/\text{sec}$  area 12" x 15"  
400 - 600  $\mu\text{mol}/\text{m}^2/\text{sec}$  area 9" x 12"  
600 - 800  $\mu\text{mol}/\text{m}^2/\text{sec}$  area 7" x 9"  
800 - 1000  $\mu\text{mol}/\text{m}^2/\text{sec}$  area 5" x 5"  
1000 - 1200  $\mu\text{mol}/\text{m}^2/\text{sec}$  area 3" x 3"

### Cost of lighting

You also need to take into account what your lighting will cost you per year.

Electricity → each 100 watts used for 10 hrs = 1 kwh

Using 200 watts in a 60 gal tank for 10 hours a day, uses 2 kwh per day

Using 400 watts of CF light in a 100 gal tank for 10 hours a day, uses 4 kwh per day .

Using the average cost of 10 cents/kwh means

400 watts@ 4kwh per day costs \$0.40 per day \* 365 days = **\$146 per year**.

200 watts@ 2kwh per day costs \$0.20 per day \* 365 days = **\$73 per year**

## Reef.Org Lighting Survey

Reef.Org conducted an aquarium survey. They received 492 results to their survey. The results don't necessarily mean that everyone knows what they are doing or made the best or most informed decisions or they may know what they are doing and did make good decisions. The results do show what about 500 people are doing in regard to their lighting, so you may find it useful as information in making your decisions.

From [http://www.reefs.org/cgi-bin/survey/survey.cgi?survey\\_name=lighting](http://www.reefs.org/cgi-bin/survey/survey.cgi?survey_name=lighting)

### Dominant Lighting

MH 57%    VHO 15%    PC 17%    NO 6%

### Dominant Color Temperature

6500K 39%    10,000K 30%    12,000K 6%    Actinic 5%

### Photo Period

10 hrs/day 27%    12 hrs/day 24%    8 hrs/day 12%

### Supplemental light

VHO 27%    NO 23%    PC 21%    none 18%

### Supplemental Color Temperature

Actinic 53%    none 18%    7100K 9%

### Total Intensity per Volume

5 W/gal 13%    6 W/gal 12%    7 W/gal 11%    8 W/gal 9%    4 W/gal 9%    9 W/gal 4%

### MH Distance above water

6" 11%    8" 9%    4" 7%    5" 7%    7" 6%

### Fluorescent Distance above water

4" 14%    3" 12%    6" 12%    2" 11%    8" 8%

### Recommended lighting references

Marine Lighting <http://www.wetwebmedia.com/marine/setup/lighting/index.htm>

and many of its links

Lighting Technical Data [http://www.coralreefecosystems.com/lgt\\_technical\\_data.htm](http://www.coralreefecosystems.com/lgt_technical_data.htm)

Introduction to Reef Lighting; <http://www.kentmarine.com/kurl.html>

Photosynthesis and Photoadaptation; Sanjay Joshi

<http://www.animalnetwork.com/fish2/aqfm/1998/june/features/2/default.asp>

Spectral Analysis of Metal Halide Lamps Used in the Reef Aquarium Hobby Part 1: New 400-watt Lamps; Sanjay Joshi and Dave Morgan

<http://www.animalnetwork.com/fish2/aqfm/1998/nov/features/1/default.asp>

Spectral Analysis of Metal Halide Lamps Used in the Reef Aquarium Hobby Part 2: Used 400-watt Lamps; Sanjay Joshi and Dave Morgan

<http://www.animalnetwork.com/fish2/aqfm/1999/jan/features/2/default.asp>

Photosynthesis/Irradiance (P/I) Curves and Why They Are Important to Reefkeepers;  
Dana Riddle and Andy Amussen;  
[http://www.reefs.org/library/talklog/d\\_riddle\\_090599.html](http://www.reefs.org/library/talklog/d_riddle_090599.html)  
Lighting FAQ [http://www.coralreefecosystems.com/ltg\\_qa.thm](http://www.coralreefecosystems.com/ltg_qa.thm)  
Saltwater Aquarium Lighting Chapters 1 – 4,  
<http://saltaquarium.about.com/library.weekly/aa022800.htm>  
Premium Aquatics: Lighting <http://www.premiumaquatics.com> (select on left hand nav)  
Aquarium Lighting Selection Guide Drs. Foster and Smith Articles (see next entry)

A Quantum Leap in PAR Meters

<http://www.animalnetwork.com/fish2/aqfm/1999/june/product/default.asp>

An Inexpensive Light Meter and Its Application to Reefkeeping

<http://www.animalnetwork.com/fish2/aqfm/1998/june/product/default.asp>

### **Other references**

Introduction to Physical Oceanography, Chapter 6 – Temperature, Salinity, and Density

[http://oceanworld.tamu.edu/resources/ocng\\_textbook/chapter06/chapter06\\_10.html](http://oceanworld.tamu.edu/resources/ocng_textbook/chapter06/chapter06_10.html)

GE Lighting Quality <http://www.gelighting.com/na/institut/quality.html>

Illuminats <http://webexhibits.org/causesofcolor/1H.html>

The Color of Water <http://starryskies.com/articles/2003/03/water.html>

Light and the Color of Water <http://www.punaridge.org/doc/factoids/light/default.html>

Fluorescent Bulb Selection Guide

[http://www.drsfostersmith.com/pic/article\\_print.cfm?dept\\_id=0&aid=354](http://www.drsfostersmith.com/pic/article_print.cfm?dept_id=0&aid=354)

Power Compact Lamp Specifications and graphs

[http://www.marinedepot.com/a\\_lt\\_pc\\_lamp\\_info.asp?CarId=](http://www.marinedepot.com/a_lt_pc_lamp_info.asp?CarId=)

Power Compact Fluorescents <http://www.thekrib.com/lights/power-compacts.html>

Philips Lighting Data Sheets

[http://www.lighting.philips.com/nam/feature/mcolor/data\\_sheets](http://www.lighting.philips.com/nam/feature/mcolor/data_sheets)

Metal Halide Lighting for Aquariums

[http://www.aquarium-supply.biz/ordering/ov\\_metal\\_halide\\_lighting.html](http://www.aquarium-supply.biz/ordering/ov_metal_halide_lighting.html)

Metal Halide Bulb comparison lighting photographs

[http://www.marinedepot.com/a\\_lt\\_mh\\_bulb\\_info.asp?cartid=](http://www.marinedepot.com/a_lt_mh_bulb_info.asp?cartid=)

Metal Halide Lighting Specifications <http://www.specialty-lights.com/a100805.html>

Electrons and Solutions Color, Chemistry 125

Aquarium Lighting Questions <http://www.specialty-lights.com/aquariumfaq.html>

How do different colours of light affect photosynthesis and the growth of plants,  
particularly algae? <http://www.shu.ac.uk/schools/sci/sol/cgi/answers/sf197.htm>

Summary of Lighting Costs <http://www.cyberreefguru.com/lighting/light.all.html>

Lighting <http://www.cyberreefguru.com/lighting/new-lighting2.html>

Sam's F-Lamp FAQ Fluorescent Lamps, Ballasts, and Fixtures (31 pages)

<http://members.misty.com/don/f-lamp.html>

“Light”, Burnie, David; Dorling Kindersley