



A case study in exceptional reefkeeping using LED lights.



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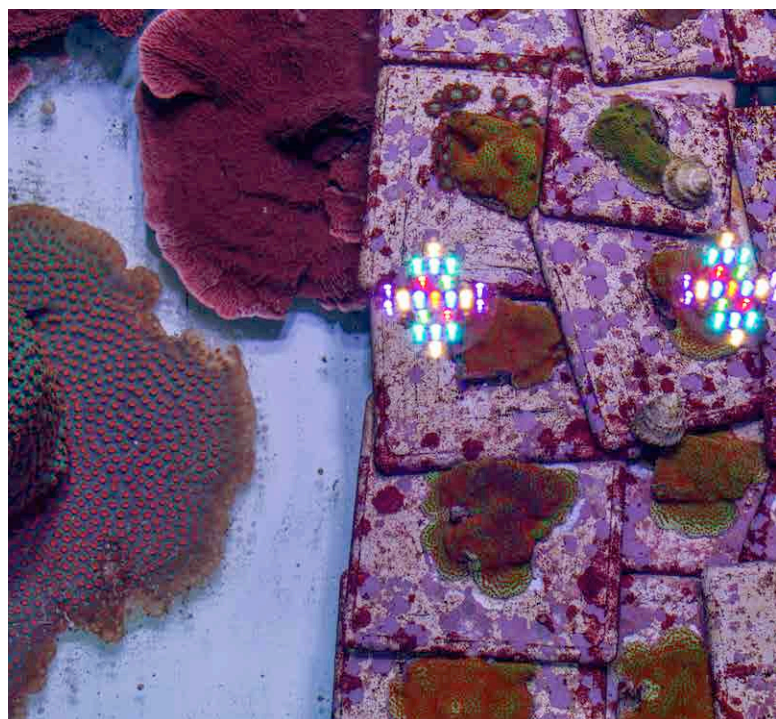
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Radion® LED Lighting in a Professional Aquaculture Facility

LED lighting for aquariums has been a popular topic over the last few years. Many successful hobbyists have made the transition to LEDs, while others have continued to use older technologies such as metal halide and T5 bulbs.

LED technology is rapidly becoming the standard in the vast majority of lighting applications including reef aquariums. With this focus, EcoTech Marine® founded a program we are calling our “Coral Lab” to further the study of successful strategies in coral keeping. We wanted to share the findings and success of our industry partner, Reef Wholesale (RW), a coral importer and aquaculture specialist in Toronto, Canada. RW has slowly and deliberately transitioned from metal halide and T5 lighting to Radion® XR30wG3 Pro™ LED fixtures. RW uses LED lighting in their coral acclimation and grow out beds and in turn rely on the productivity of these beds for their livelihood. Their changeover to LED has been successful and has been driven by needs and goals common to all aquarists.

Lighting Goals

- Maximize coral coloration
- Maximize coral growth
- Reduce operational costs

While higher efficiency and cost reduction are beneficial to all aquarists, coral coloration and growth are the primary goals of the committed reef keeper. This is the first in a series of Case Studies to be produced by EcoTech® Coral Lab and is an example of successful methodology and results keeping and growing coral. In this study, we will observe the RW system to see how they achieve these results. What follows is the Reef Wholesale Radion® lighting setup, chemistry, filtration, and overall techniques. Although Reef Wholesale is a business, this information can be translated and applied by the hobbyist and other professional aquaculturers alike.



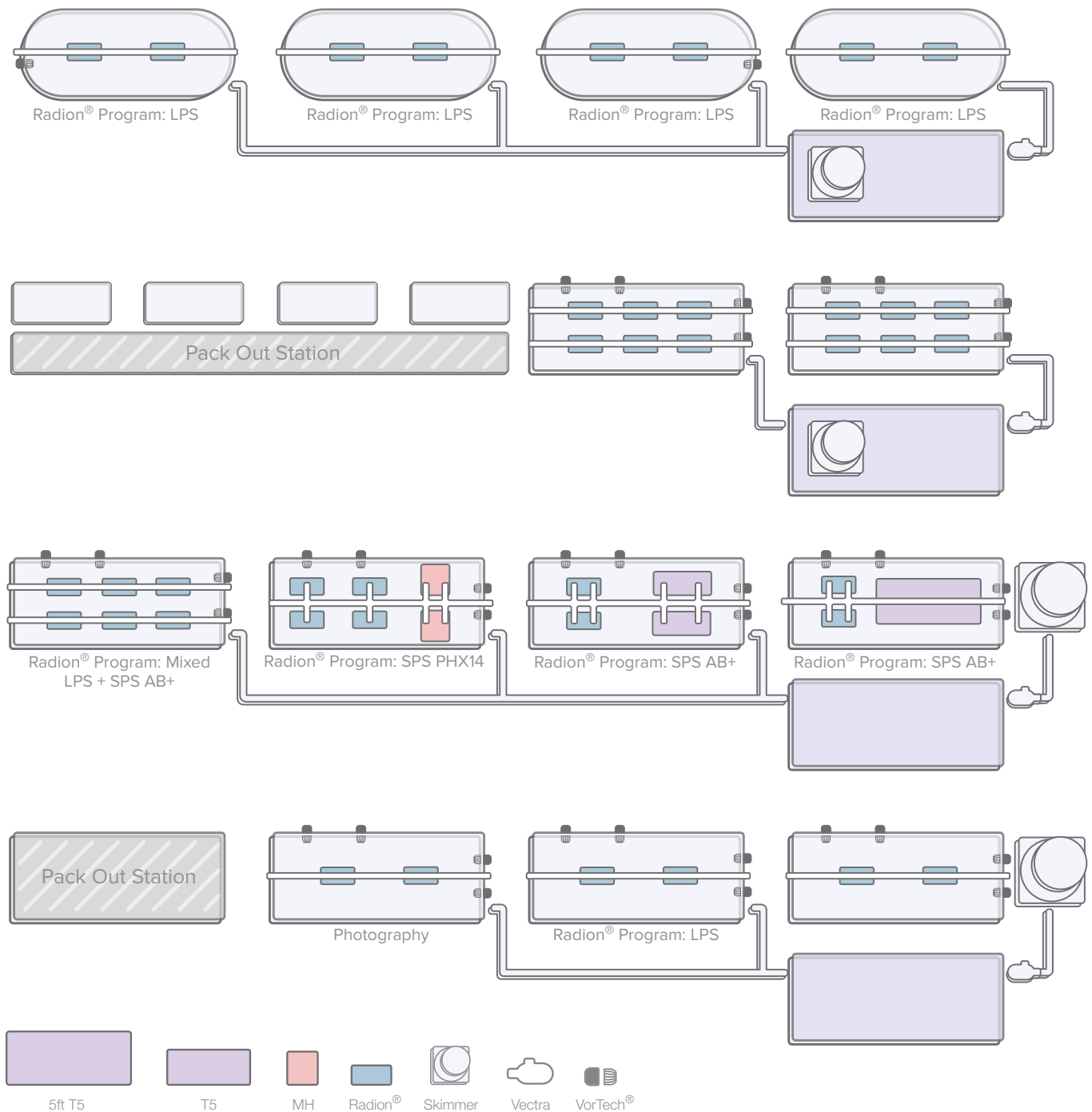
Reef Wholesale has been refining their lighting parameters using Radion® G3 Pros over the last year.



The primary goal of a commercial aquaculture facility is coloration and or growth.

System Setup

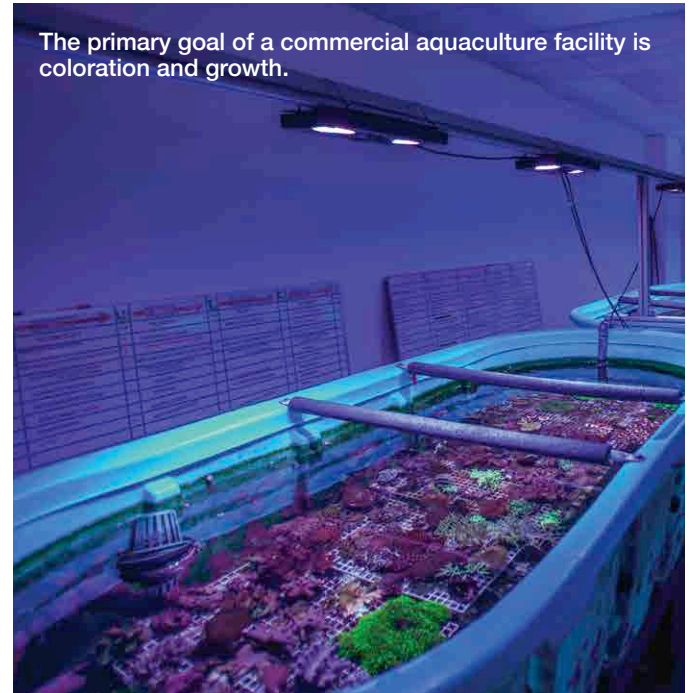
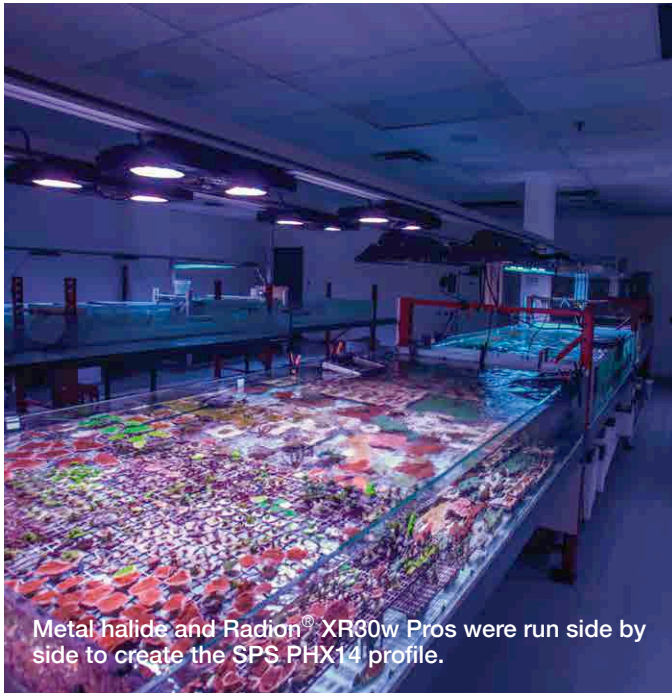
The livestock system at Reef Wholesale is typical of a commercial import and holding facility. RW runs four independent systems and each is composed of five similar sized beds (tanks), one of which is used as a sump and is located beneath a coral bed. The coral beds are constructed of glass and have egg crate racks that elevate coral frags and colonies 3-4 inches above the bottom of the bed allowing for proper flow. All beds in each system are plumbed together via the shared sump.



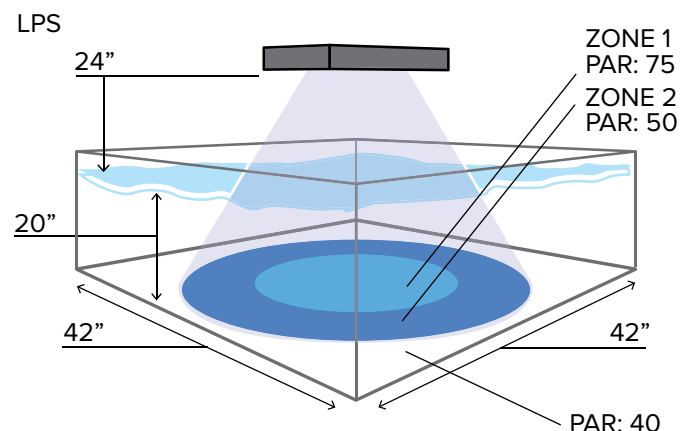
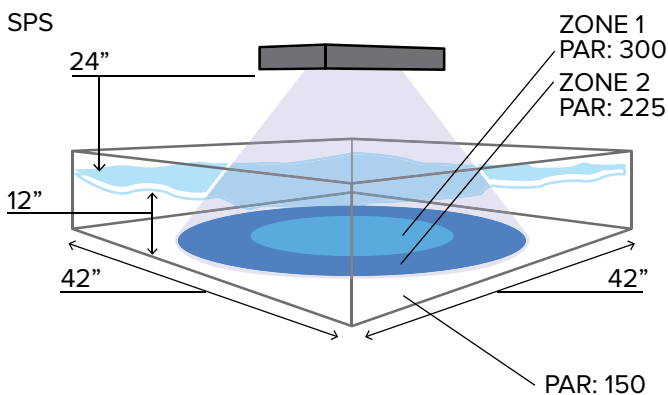
Flow in each bed comes from 4 EcoTech® VorTech® MP40™ Propeller Pumps, for the sump return Reef Wholesale uses a total of 4 Reflow pumps (soon to be swapped with Vectra L1™ pumps after seeing their performance on their newest fish raceways). There is no substrate (sand or rocks) in the coral beds, however each sump contains more than enough live rock to support the bacterial load required for each 1,047 gallon setup.

System Setup (cont.)

Coral holding and grow-out beds are relatively shallow, the SPS beds are 12 inches deep and the LPS beds are slightly deeper at around 24 inches. Lighting is mounted 24 inches above the water to optimize spread and accessibility. Reef Wholesale runs all of their LED lighting at 100% schedule brightness - this is due to the height of the fixtures above the water.



With any lighting, but particularly LEDs, it is important not to over light the coral – so depending on height of fixtures and depth of tank etc. – it may be necessary to reduce brightness for best results. The layout shown above indicates how metal halide and T5 lighting were run side by side with Radion® LED's while RW tuned their LED programs. The diagrams below illustrate the relative depth, par and spread of the Radion® in relation to the different needs of the corals.



Coral placement with respect to zone1 and zone2 is addressed in each program (p.5, p.6, p.7)

Lighting Programs

Over the past decade Reef Wholesale has optimized the art of quickly improving the health and coloration of imported coral in preparation for sale. Prior to using LEDs, RW identified the specific mix of metal halide and T5 bulbs that best achieved these results. Metal halide and T5 bulbs degrade through operation which results in a shift in spectrum and intensity over time (until the bulbs are changed). The LED spectrum and schedules RW targeted were therefore based on the outputs of fresh but “burnt in” T5 or metal halide bulbs.

The details of each schedule are discussed in the next section. Note that the Radion® program and spectrum color mix were tuned based on several factors including par, spectrum, photo period, and the **response of coral** to the schedule. This is important to note because using a LED light to match the key elements of a T5 or metal halide light spectrum may result in light output that may not be visually identical. The reason for this is that the individual LED diodes have narrow spectral output in their respective wavelength but combined, the output of a puck of red, green and blue LEDs will appear white. Similarly, the white output of a T5 or metal halide bulb may have spectral peaks at certain wavelengths, but the output delivered across the whole spectrum will also appear white.



The Radion® XR30w Pro™ Generation 3 expands on the technology found in the award winning Radion® XR30w™. The Pro features 42 energy-efficient LEDs and full spectrum output from violet to hyper-red.

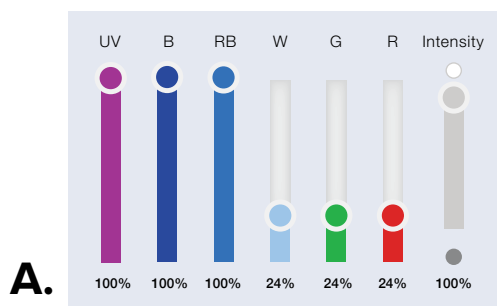
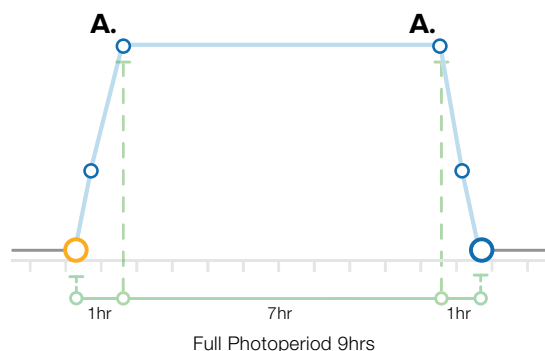


At 9 hours a photoperiod under LEDs is significantly shorter than the 10-12 hours previously used for metal halide and T5.

“We started at what looked like the general spectral mix of our favorite metal halide and T5 bulbs then over the course of a year slowly tweaked the schedule and spectrum based on the ongoing coloration of the corals. Having each bed half lit with Radion's® and half with our favorite metal halide or T5 mix gave us the control or benchmark. For example if a red dragon frag was looking better on the T5 side of the trough, then we might try increasing the blue channel on the Radion LED side by 5% and evaluate again after 10 days. Obviously not super scientific but then our interest is in the result more than the photo-biochemical mechanism at work.”

- Patrick Foster, CEO Reef Wholesale

Prior to using Radion® G3 Pros RW (Reef Wholesale) determined that the best coloration and growth in their SPS corals were achieved using T5 bulbs. Specifically *ATI Blue Plus and *ATI AquaBlue Special in a combination of 80%/20% and specifically in *ATI Powermodules. In the same time period given the same parameters and frags from the same mother colony, this T5 bulb mix generally outperformed (for most, but not all corals) their original lighting staple, metal halide.

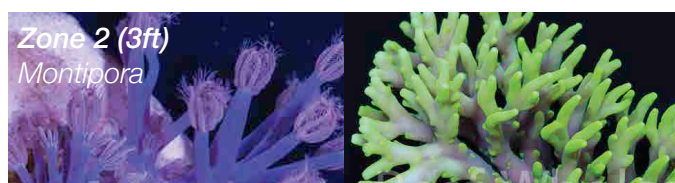
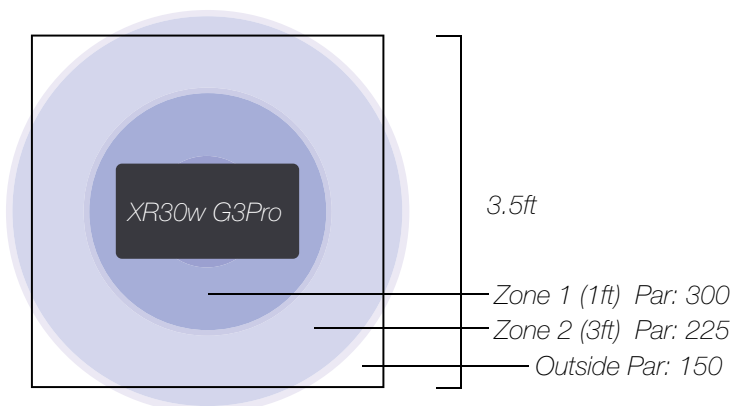


The SPS AB+ program has a photo period of 7 hours for the core spectrum with a one hour ramp up and ramp down. In a non-commercial setup where viewing is a priority – these ramp periods would be the optimal time to experiment with a desirable viewing spectrum.

Matching and then improving the performance of the Radion® G3 Pros over the T5 ATI bulbs took RW the better part of a year. Initially a visual match provided a starting point, but given that the eye is a poor tool for evaluating lighting, additional refinement took a combination of PAR measurement and spectral analysis. Although the visual appearance of the light output was different between the T5 bulbs and the Radions®, coral response was similar if not identical. From there further adjustment of the spectrum and fortnightly reviews resulted in a spectrum that outperformed the T5 benchmark.



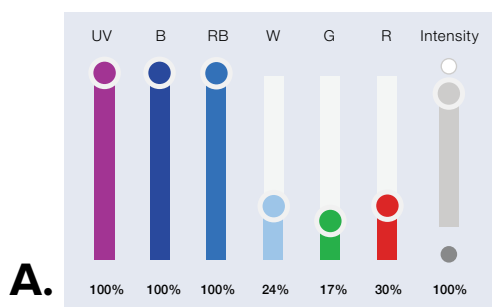
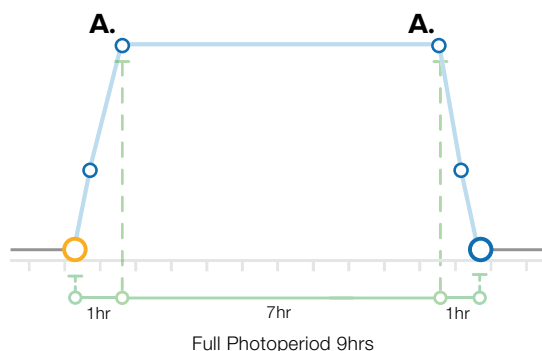
RW recommends this program for rapid growth balanced with deep and vibrant colors for SPS. On the reef the vast majority of species of SPS are found in the tropics in clear shallow water typically at depths often in less than 20 meters (60ft) of depth or less. As a result SPS generally prefers the highest light levels of coral species.



SPS PHX14

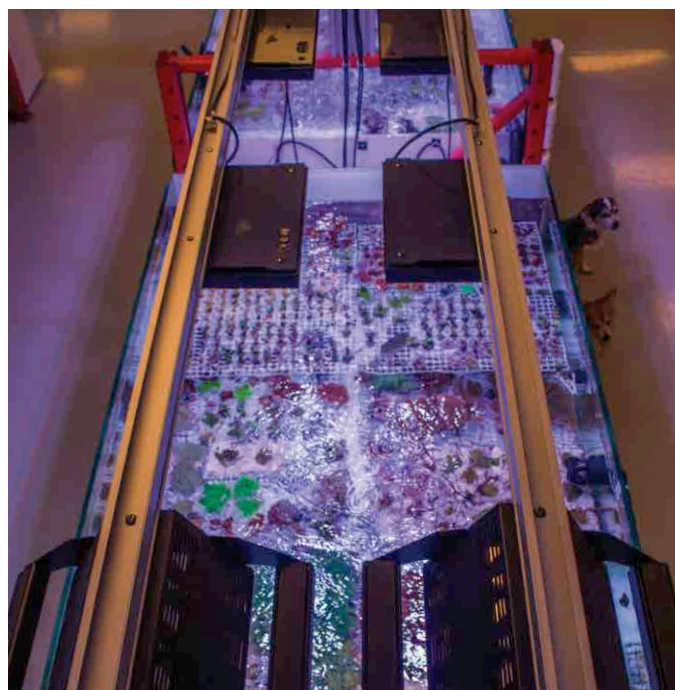
download this schedule at: <http://ecote.ch/phx>
(schedule intensity set at 50% some adjustment may be needed)

The SPS PHX14 program is based on the Phoenix[®] 14K double ended 250w metal halide bulb. RW found that despite most corals coloring up better under T5s, some corals always seemed to color up better under metal halide. This profile was developed during the same time period as the SPS AB+ program. This spectrum developed is slightly different to the SPS AB+ program and incorporates a different mix of the non-blue channels particularly. The red channel is higher in the SPS PHX14 (metal halide) spectrum than in the SPS AB+ spectrum.

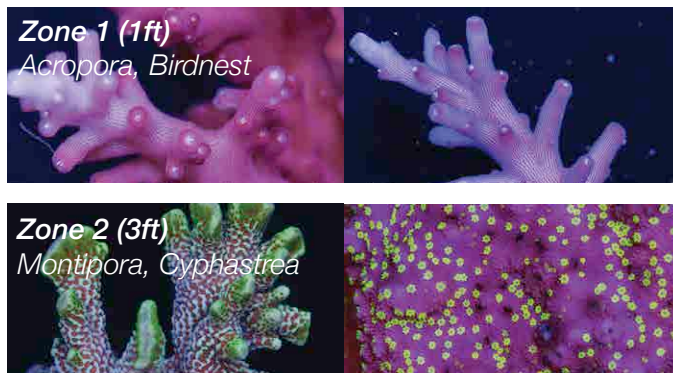
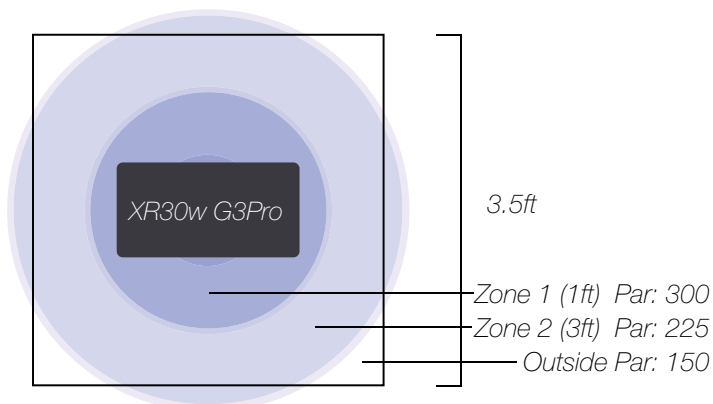


Generally speaking the SPS AB+ profile edges out results for growth in coloration in the majority of corals, particularly in deep water corals, however RW has found the spectrum in the SPS PHX14 profile appears marginally better for growing.

- Red and Purple Dragons
- Torte (Acropora Tortusa)
- Montipora (some species)



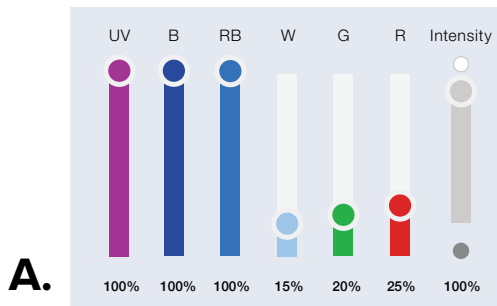
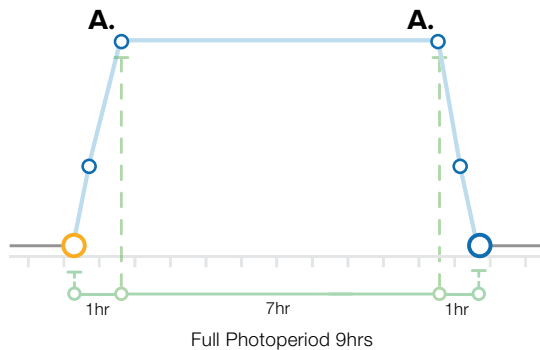
RW would recommend the SPS PHX14 program if a tank or coral has been lit with metal halides, a transition to Radions[®] running the SPS PHX14 program might be less stressful for the coral. Additionally if the tank is heavily populated with Red and Purple Dragons, birdnest, stylophora or Montipora colonies the SPS PHX14 spectrum may be preferable. In general, the SPS PHX14 gives more rapid growth and better coloration for those select sp. mentioned above.



LPS/Soft

download this schedule at: <http://ecote.ch/lpsmix>
(schedule intensity set at 50% some adjustment may be needed)

The LPS program is very similar to the SPS AB+ program but has been altered to improve the color expression. Generally LPS is much less sensitive to the specifics of light spectrum and prefers much lower light than SPS. Note that although the LPS/Soft program shown below indicates an intensity setting of 100%, the LPS system is very different in that it is 24 inches deep and lit with only two XR30 G3 Pros per coral bed. With one third of the lighting, twice the depth and water rich in tannins the intensity of the light reaching the corals is significantly lower. (see spread chart below)



For new Radion® users planning to implement the LPS schedule, RW recommends carefully ramping up output. A suggested program intensity level of 30-40% is a good starting point for a light mounted 9-10 inches over a 20-30 inch tank.

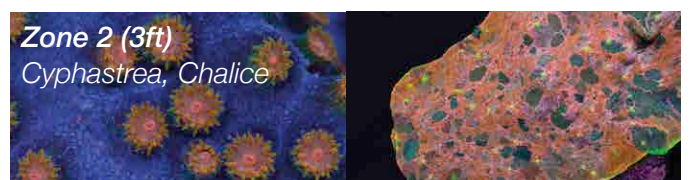
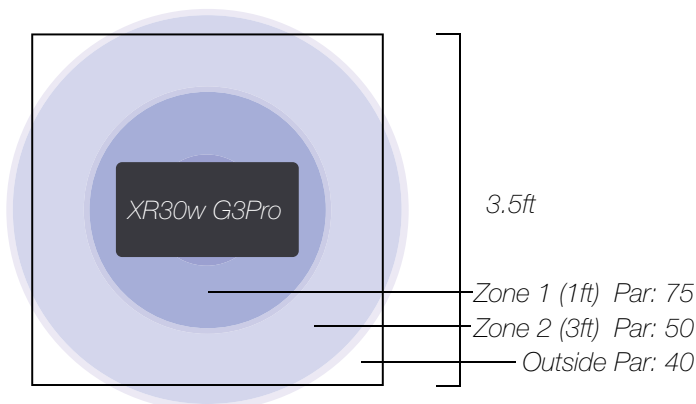
In a SPS dominated system it may prove advantageous for a hobbyist to run the SPS AB+ program and place LPS corals at mid-level or bottom of the tank or in areas where they are not receiving direct light. It is also important to note that LPS corals generally prefer higher nutrient content in the aquarium making mixed reef tanks generally more difficult to maintain than exclusively SPS or LPS systems.



The larger and deeper LPS beds are lit with only 2 XR30wG3 Pros each as opposed to 6 per comparably sized SPS bed.



LPS corals are generally less sensitive to spectrum mix allowing for lighting profiles with a greater range of customization.

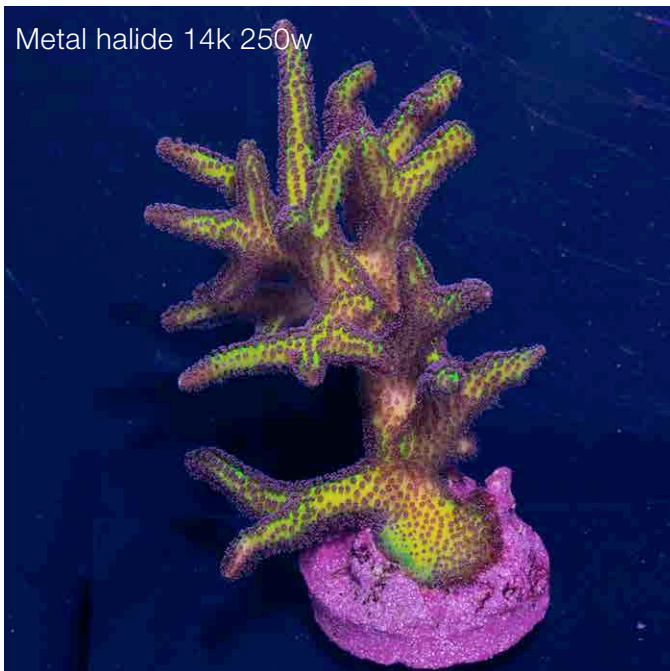


Lighting Results

RWs comparative testing of lighting solutions and the resulting Radion® G3 programs that were developed were done so in a qualitative rather than quantitative manner. Each of the following pairs of frags pictured were taken from the same mother colony and grown in the same system with near identical flow conditions. Comparison images for each colony and species studied are explored below.



Seriatopora sp. Birds of Paradise - Birds Nest



Note: all images taken with the same camera settings. Colors are as close to visual appearance as was possible.

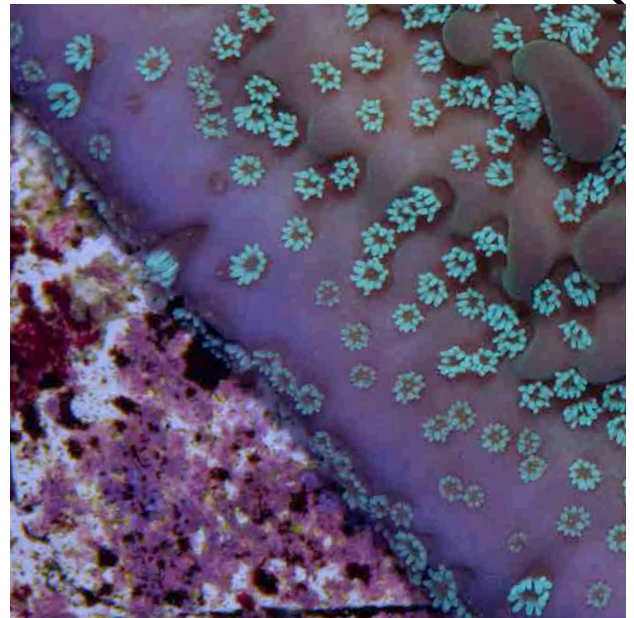
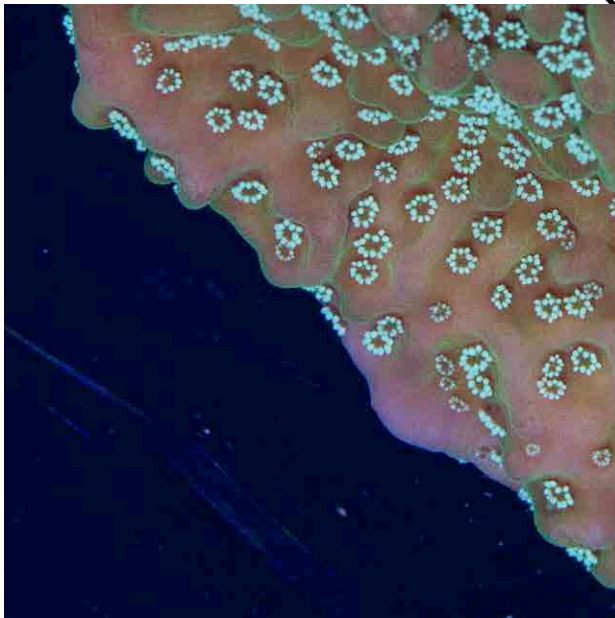
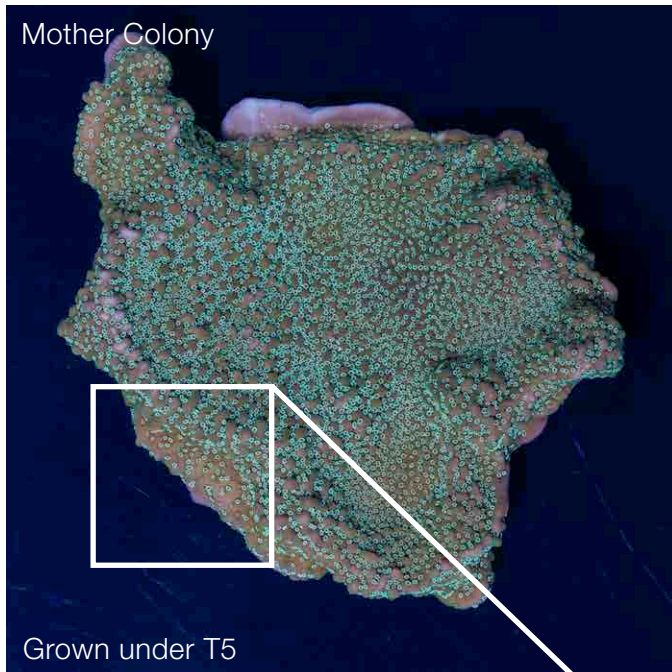
Note: The burns on the tips on the right occurred while attempting to photograph as the birdnest fell into another coral out of the picture frame.

The two coral frags imaged above started at approximately equal sized 1" frags from the same mother colony. Both frags were grown out in the same coral system under different lighting conditions holding flow and chemistry constant. Both of the images show sixteen weeks of acclimation and growth time. The frag on the left was grown under a 250w Phoenix* 14k metal halide bulb and the frag on the right was grown under the Radion® G3 Pro LED. The difference in growth between the metal halide and LED spectrum is clearly observable, but also very importantly to RW the coloration that developed under the Radion appears more intense. Additionally the white tips seen under the Radion® LED indicate the rapid growth rate of the colony.

* Phoenix is a registered trademark of Phoenix Electric Company. All rights reserved to the respective trademarks owners.

Lighting Results (cont.)

Montipora Undata

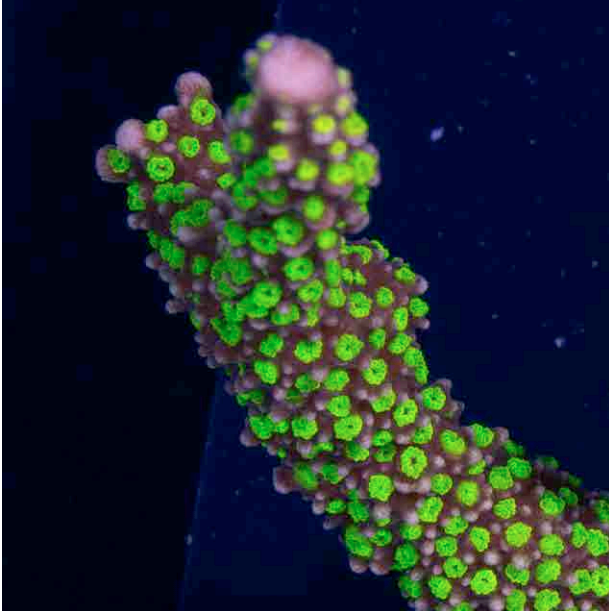
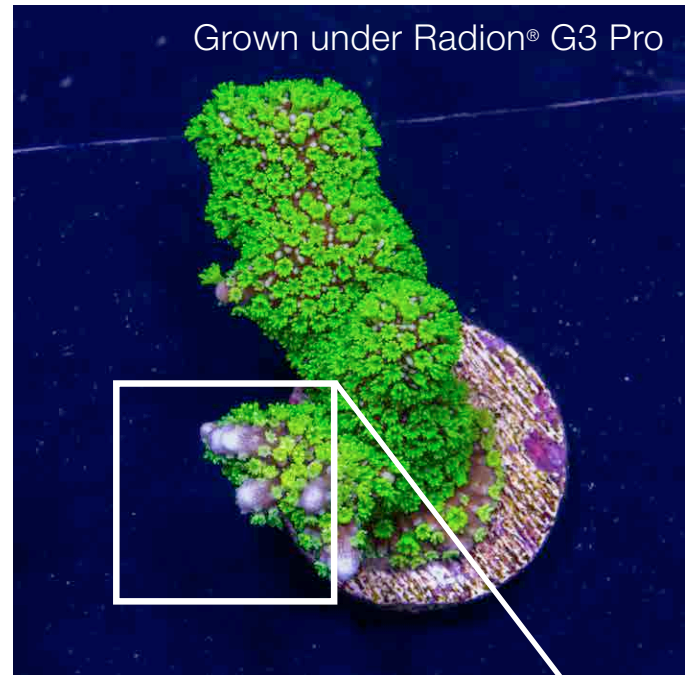
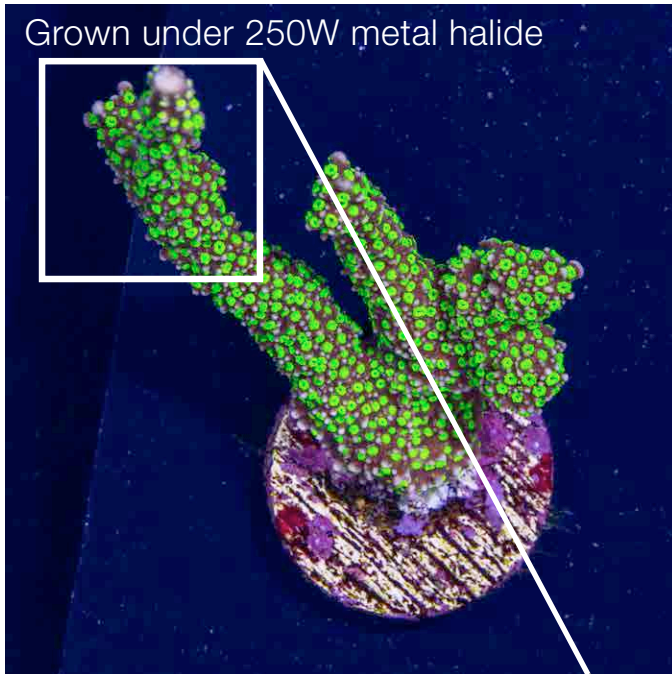


Note: all images taken with the same camera settings. Colors are as close to visual appearance as was possible.

The above example illustrates the growth of a Montipora Undata frag from its mother colony. The mother colony on the left was cultured under T5 lighting. Several frags were cut and mounted to ceramic plates then moved under Radion® G3 Pro LEDs running the SPS AB+ schedule. The frags puddled onto the plate relatively quickly and encrusted over 95% of the plate. Under the Radion® LED's, the Montipora Undata frags developed a much richer and broader purple outer rim. While this rim is still visible on the mother colony, in comparison it is extremely thin and muted when compared to the frags grown under the Radion® LED's. Additionally under the Radion® LED's, the polyps of the Montipora Undata appear to be more florescent and provide additional contrast against the base color - a highly desirable characteristic of this monti. It should also be noted though the green in the base of the Undata does appear to be richer in color under the T5's than under the Radion® LED's. With this in mind, RW views coloration under the Radion® LED's to be substantially more desirable and they were very happy with the growth rates achieved on this species. As only the frags were mounted to ceramic plugs and placed under the Radion® LED's, a fair comparison of the growth rates is not possible, but is planned for a future test.

Lighting Results (cont.)

Montipora sp.



Note: all images taken with the same camera settings. Colors are as close to visual appearance as was possible.

This green montipora was grown under both metal halide and Radion® G3 Pro LEDs with dramatic difference in coloration and growth rates. Looking at the macro images you will notice the distinct contrast between the white tipped branches that developed under the Radion® versus the blunted nubs that appear under the metal halide. There were two distinct anatomical areas of the coral that exhibited color differentiation; (1) the tissue beneath the polyps grown beneath the Radions® were distinct purple as opposed to the brown of the tissue exhibited by the frag under the metal halide bulb, (2) the polyps of the frag under the Radion® were a distinctly noticeable florescent green as compared to the duller forest green viewed in the frag under the metal halide.

Water Parameters and Chemical Additives

Water parameters are as important in achieving coloration and growth in coral as lighting schedule. With lighting out of the equation, Reef Wholesale advocates that 80% of the coloration and growth they achieve come from simply maintaining core parameters (Alk, Ca and Mg). The remaining 20% is achieved with Amino Acid, Carbon Source and Bacterial Dosing.

"As important as lighting is water chemistry, if you don't have good parameters you will never maintain good coloration over time. Without good lighting you can achieve decent coloration but not amazing." -Patrick Foster

Target SPS System Parameters

Temperature	78°F
Salinity	1.025 sg
dKh	8 ppm
Cal	400-420 ppm
Mg	1350 ppm
Nit.	0 ppm
Phos	0 ppm

Target LPS System Parameters

Temperature	78°F
Salinity	1.025 sg
dKh	9 ppm
Cal	400-420 ppm
Mg	1350 ppm
Nit.	0 ppm
Phos	0 ppm

SPS SYSTEM		TARGETS			
	Salinity	Alk:	Ca:	Mg:	K:
Monday	27/26	8.0	500	B 12.75	
Tuesday	26	7.7		P 13.80	
Wednesday	27/26	8.3	+500	M 1350	
Thursday		!!		S 1350	
Friday					
Saturday					
Sunday					

Flow: Flow is extremely important to coral growth and coloration, without adequate flow coral cannot perform vital biological functions. RW utilizes VorTech Mp40s® at a rate of 3500 GPH per 50 gallons of coral bed. Return from the sump system is four Vectra Pumps (one for each coral bed).

Filtration: Four Large Filer Socks for 880 Gallons ; TLF Carbon Reactor 550* (Nyos Carbon changed every two weeks) for 880 Gallons, TLF PhosBan Reactor 550* (Nyos Phosphate Remover media changed every two weeks) for 880 Gallons. One MRC ORCA Pro Skimmer* for 880 Gallons.

Sump: Is an unlighted cryptic zone completely filled with 1200lbs airfreighted live rock. Includes large bacterial biodiversity and a large sponge mass. (RW advocates sponges as excellent for maintaining water quality.)

Testing: Salinity, Alkalinity (daily) MG and Ca (twice a week)

Core Dosing

Element	Target
Kh	8.5-9 ppm
Ca	400-420 ppm
Mg	1350 ppm

Supplemental Dosing

Supplement	
Active Elements	170ml/880gallons /week
Active Iodine	170ml/880gallons /week
Active Strontium	170ml/880gallons /week

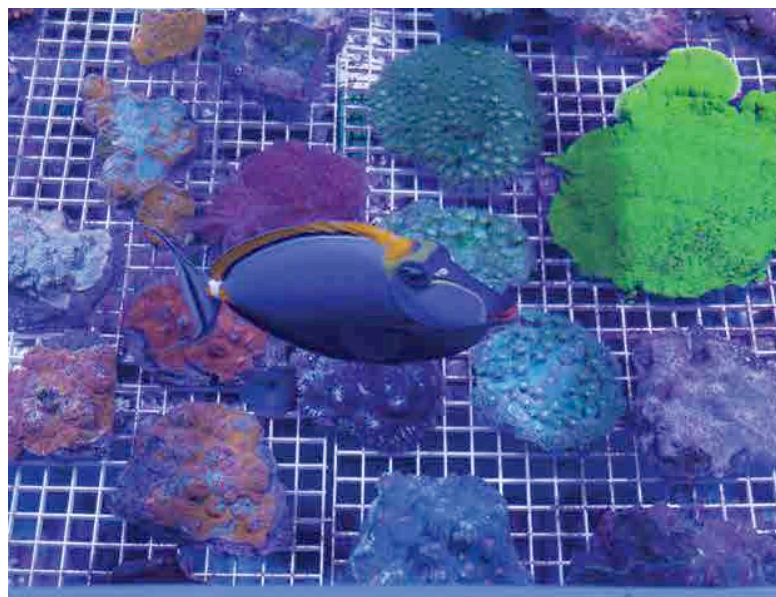
*Core dosing is adjusted to maintain preferred system parameters

* PhosBan Reactor 550 and associated trademarks are owned by Two Little Fishes; ORCA Pro Skimmer and associated trademarks are owned by My Reef Creations. All rights reserved to respective trademarks holders.

Bioload

Reef Wholesale firmly believes in maintaining a healthy bioload (fish and inverts) in their coral systems. The fish and inverts play a critical role in maintaining the right water chemistry as well as removing algae and parasites.

Tangs and inverts such as shrimp and snails consume any algae that grows or arrives with new coral. Wrasses, pipe fish and peppermint shrimp control parasites that might otherwise damage coral and prevent good coloration and growth. Large schools of juvenile captive bred clownfish make up the balance of the fish population and ensure a consistent level of fish waste to help maintain a healthy bacterial population. The number of fish and specific fish in the system may change over time but here is a typical snapshot of what RW keeps in a Coral system. (Across the four coral beds)



When choosing livestock for a reef aquarium or coral system RW emphasizes the benefits of choosing creatures which compliment to the ecosystem as a whole.

Livestock Per System:



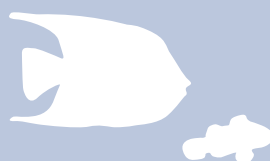
Wrasses:

Leopard Wrasse (4)
(*Macropharyngodon meleagris*)
Red Coris Wrasse (4)
(*Coris gaimard*)
Bluestreak Cleaner Wrasse (4)
(*Labroides dimidiatus*)
Six Line Wrasse (4)
(*Pseudocheilinus hexataenia*)



Tangs:

Sailfin Tang (4)
(*Zebbrasoma velifer*)
Scopas Tang (3)
(*Zebbrasoma scopas*)
Two Spot Bristletooth Tang (4)
(*Ctenochaetus binotatus*)
Bristletooth Tomini Tang (2)
(*Ctenochaetus tominiensis*)
Naso Tang (4)



Other:

Ocellaris Clownfish,
Captive-Bred (100)
(*Amphiprion ocellaris*)
Dragonface Pipefish (8)
(*Corythoichthys* sp.)
Masked Swallowtail Angelfish
(4)
(*Genicanthus semifasciatus*)



Inverts:

Peppermint Shrimp (200-400)
Margarita Snail (400-600)
Turbo snail (400-600)
red banded trochus snail(400-600)
Spiny Star *Astraea* (800)
Emerald Crab (800))
Harlequin Sea Star (8)
Indian Sea Star (*Fromia indica*) (20)
Pincushion Urchin (12)
Longspine Urchin, Blue Spot (12)



Reef Wholesale's employees enjoy feeding some of their oldest and friendliest resident tangs.

Feeding involves a combination of foods including frozen, dry and LPS pellets. Feeding is done twice daily and is not overly controlled but to prevent overfeeding only as much food as will be consumed within 10 to 15 seconds is added to each coral bed.

In the LPS system spot feeding, particularly of monostomatous corals such as fungia, scolymia and trachyphyphyllia is recommended.

About Reef Wholesale

Reef Wholesale has been importing and distributing coral for over a decade. Patrick Foster and Trina Parsons began as hobbyists in early 2000, their obsession with marine creatures led them first into retail and then into import and distribution.



Reef Wholesale currently supplies over 100 retailers in Canada with livestock and dry goods. RW's primary aquaculture partner is Bali Aquariums, Indonesia (Jake Adams of ReefBuilders has featured this facility several times). Reef Wholesale receives multiple shipments per week from South East Asia, the Caribbean and Mexico.

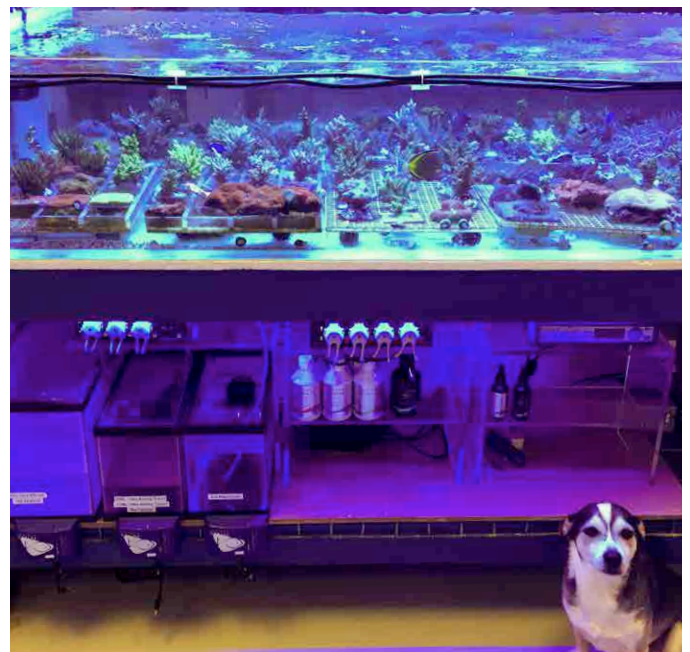
"We're hobbyists at heart and we think that really reflects in the health and quality of our coral."

-Patrick Foster

Patrick and Trina are firm believers in ethical reef keeping and sustainable promotion of the hobby. As an importer that means choosing vendors with ethical collection techniques and shipping practices. As a distributor, that means providing the most accurate information on livestock care to their dealers to ensure the health of all livestock and promoting products they use and believe in themselves. At RW's facility employing proper acclimation, feeding techniques and training are paramount in ensuring that only the healthiest and most suitable livestock reach the hobbyist.



Patrick and Trina typically visit Indonesia and their other livestock vendors several times a year diving the reefs where their mother colonies are collected, committed to ensuring that their suppliers practices are not damaging local ecosystems.



Reef Wholesale uses all of the dry goods, food and additives that they supply in their own aquaculture and livestock facility.