

## Reef Aquarium Water Parameters

Aquarists often ask what water parameter levels make for a successful reef aquarium. This article gathers these recommendations in one place, showing them in tables, as well as the corresponding levels in natural seawater.

Many of the recommendations are my own opinions, and other aquarists may recommend slightly different levels. To make clear the basis for each recommendation, a brief description of each particular parameter's importance follows the tables, along with links to other online articles that go into much greater depth on each subject (click on any blue text for the linked article).

Table 1 shows important water parameters for reef aquarists to control for various reasons. Table 2 shows less important parameters, or those too complicated to carefully control, but about which many aquarists have concerns or questions.

<b>Table 1. Parameters <span style="color: red;">critical</span> to control in reef aquaria.</b>		
<b>Parameter:</b>	<b>Reef Aquaria Recommendation:</b>	<b>Typical Surface Ocean Value:<sup>1</sup></b>
Calcium	380-450 ppm	420 ppm
Alkalinity	2.5-4 meq/L 7-11 dKH 125-200 ppm CaCO <sub>3</sub> equivalents	2.5 meq/L 7 dKH 125 ppm CaCO <sub>3</sub> equivalents
Salinity	35 ppt sg = 1.026	34-36 ppt sg = 1.025-1.027
Temperature	76-83° F	Variable <sup>2</sup>
pH	7.8-8.5 OK 8.1-8.3 is better	8.0-8.3 (can be lower or higher in lagoons)
Magnesium	1250-1350 ppm	1280 ppm
Phosphate	< 0.03 ppm	0.005 ppm
Ammonia	<0.1 ppm	Variable (typically <0.1 ppm)

<b>Table 2. Other parameters in reef aquaria.</b>		
<b>Parameter:</b>	<b>Reef Aquaria Recommendation:</b>	<b>Typical Ocean Value:<sup>1</sup></b>
Silica	< 2 ppm, much lower if diatoms are a problem	<0.06 - 2.7 ppm
Iodine	Control not recommended	0.06 ppm total of all forms
Nitrate	< 0.2 ppm	Variable (typically below 0.1 ppm)

Nitrite	< 0.2 ppm typically	Variable (typically below 0.0001 ppm)
Strontium	5-15 ppm	8 ppm
ORP	Control not recommended	Variable
Boron	< 10 ppm	4.4 ppm
Iron	Below Kit Detection Limits (additions OK)	0.000006 ppm

## Recommendation Details: **Critical Parameters**

### Calcium

Many corals use calcium to form their skeletons, which are composed primarily of calcium carbonate. The corals get most of the calcium for this process from the water surrounding them. Consequently, calcium often becomes depleted in aquaria housing rapidly growing corals, calcareous red algae, Tridacnids and *Halimeda*. As the calcium level drops below 360 ppm, it becomes progressively more difficult for the corals to collect enough calcium, thus stunting their growth.

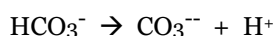
**Maintaining the calcium level is one of the most important aspects of coral reef aquarium husbandry.** Most reef aquarists try to maintain approximately **natural levels of calcium** in their aquaria (~420 ppm). It does not appear that boosting the calcium concentration above natural levels enhances calcification (i.e., skeletal growth) in most corals. Experiments on *Stylophora pistillata*, for example, show that low calcium levels limit calcification, but that levels above about 360 ppm do not increase calcification.<sup>3</sup> Exactly why this happens was detailed in a previous article on the **molecular mechanisms of calcification in corals**.

For these reasons, **I suggest that aquarists maintain a calcium level between about 380 and 450 ppm.** I also suggest using a **balanced calcium and alkalinity additive system** for routine maintenance. The most popular of these balanced methods include limewater (kalkwasser), calcium carbonate/carbon dioxide reactors, and the two-part additive systems.

If calcium is depleted and needs to be raised significantly, however, such a balanced additive is not a good choice since it will raise alkalinity too much. In that case, **adding calcium chloride** is a good method for raising calcium.

### Alkalinity

Like calcium, many corals also use "alkalinity" to form their skeletons, which are composed primarily of calcium carbonate. It is generally believed that **corals take up bicarbonate**, convert it into carbonate, and then use that carbonate to form calcium carbonate skeletons. That conversion process is shown as:



Bicarbonate → Carbonate + acid

To ensure that corals have an adequate supply of bicarbonate for calcification, aquarists could very well just measure bicarbonate directly. Designing a test kit for bicarbonate, however, is somewhat more complicated than for alkalinity. Consequently, the use of alkalinity as a surrogate measure for bicarbonate is deeply entrenched in the reef aquarium hobby.

So, **what is alkalinity**? Alkalinity in a marine aquarium is simply a measure of the amount of acid ( $\text{H}^+$ ) required to reduce the pH to about 4.5, where all bicarbonate is converted into carbonic acid as follows:



In normal seawater or marine aquarium water, the bicarbonate greatly dominates all **other ions that contribute to alkalinity**, so knowing the amount of  $\text{H}^+$  needed to reduce the pH to 4.5 is akin to knowing how much bicarbonate is present. Aquarists have therefore found it convenient to use

alkalinity as a surrogate measure for bicarbonate.

One important caveat to this surrogate measure is that some artificial seawater mixes, such as Seachem salt, contain **elevated concentrations of borate**. While borate is natural at low levels, and does contribute to **pH stability**, too much interferes with the normal relationship between bicarbonate and alkalinity, and aquaria using those mixes must take this difference into account when **determining the appropriate alkalinity level**.

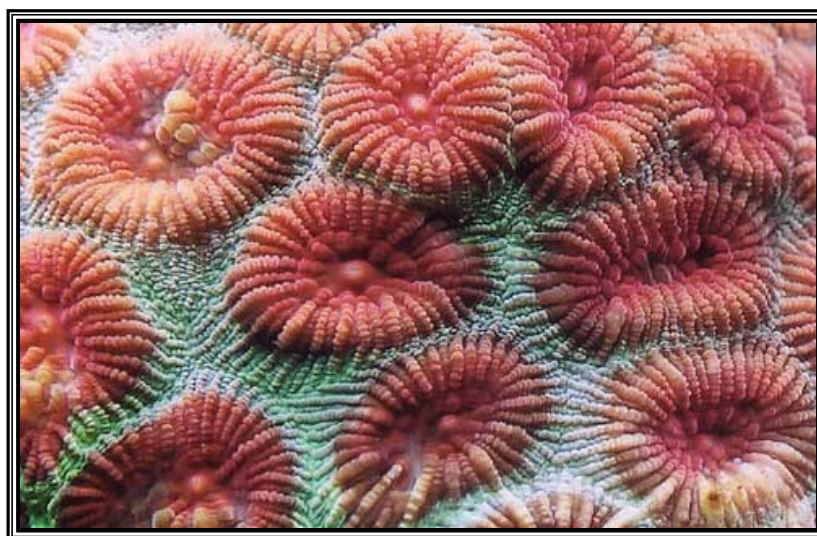
Unlike the calcium concentration, it is widely believed that certain organisms calcify more quickly at alkalinity levels higher than those in normal seawater. This result has also been demonstrated in the scientific literature, which has shown that adding bicarbonate to seawater increases the rate of calcification in *Porites porites*.<sup>4</sup> In this case, doubling the bicarbonate concentration resulted in a doubling of the calcification rate. Uptake of bicarbonate can apparently become rate limiting in many corals.<sup>5</sup> This may be partly due to the fact that both photosynthesis and calcification are competing for bicarbonate, and that the external bicarbonate concentration is not large to begin with (relative to, for example, the calcium concentration).

For these reasons, **alkalinity maintenance is a critical aspect of coral reef aquarium husbandry**. In the absence of supplementation, alkalinity will rapidly drop as corals use up much of what is present in seawater. Most reef aquarists try to maintain alkalinity at levels at or slightly above those of normal seawater, although exactly what levels different aquarists target depend a bit on the goals of their aquaria. Those wanting the most rapid skeletal growth, for example, often push alkalinity to higher levels. **I suggest that aquarists maintain alkalinity between about 2.5 and 4 meq/L (7-11 dKH, 125-200 ppm CaCO<sub>3</sub> equivalents)**, although higher levels are acceptable as long as they do not depress the calcium level.

Alkalinity levels above those in natural seawater increase the **abiotic (nonbiological) precipitation of calcium carbonate** on objects such as heaters and pump impellers. This precipitation not only wastes calcium and alkalinity that aquarists are carefully adding, but it also increases equipment maintenance requirements. When elevated alkalinity is driving this precipitation, it can also depress the calcium level. A raised alkalinity level can therefore create undesirable consequences.

I suggest that aquarists use a **balanced calcium and alkalinity additive system** of some sort for routine maintenance. The most popular of these balanced methods include limewater (kalkwasser), calcium carbonate/carbon dioxide reactors, and the two-part additive systems.

For **rapid alkalinity corrections**, aquarists can simply use baking soda or washing soda to good effect.



## Salinity

There are a variety of different ways to measure and report salinity, including conductivity probes, refractometers, and hydrometers. They typically report values for specific gravity (which is unitless) or salinity (in units of ppt or parts per thousand, roughly corresponding to the number of grams of dry salt in 1 kg of the water), although conductivity (in units of mS/cm, milliSiemens per centimeter) is sometimes used.

Somewhat surprisingly, aquarists do not always use units that naturally follow from their measurement technique (specific gravity for hydrometers, refractive index for refractometers, and conductivity for conductivity probes) but rather use the units interchangeably.

For reference, **natural ocean water** has a salinity of about 35 ppt, corresponding to a specific gravity of about 1.0264 and a conductivity of 53 mS/cm.

As far as I know, there is little real evidence that keeping a coral reef aquarium at anything other than natural levels is preferable. It appears to be common practice to keep marine fish, and in many cases reef aquaria, at somewhat lower than natural salinity levels. This practice stems, at least in part, from the belief that fish are less stressed at reduced salinity. Substantial misunderstandings also arise among aquarists as to **how specific gravity really relates to salinity**, especially considering temperature effects.

Ron Shimek has discussed salinity on natural reefs in a **previous article**. His recommendation, and mine as well, is to maintain salinity at a natural level. If the organisms in the aquarium are from brackish environments with lower salinity, or from the Red Sea with higher salinity, selecting something other than 35 ppt may make good sense. **Otherwise, I suggest targeting a salinity of 35 ppt (specific gravity = 1.0264; conductivity = 53 mS/cm).**

## Temperature

Temperature impacts reef aquarium inhabitants in a variety of ways. First and foremost, the animals' metabolic rates rise as temperature rises. They may consequently use more oxygen, carbon dioxide, nutrients, calcium and alkalinity at higher temperatures. This higher metabolic rate can also increase both their growth rate and waste production at higher temperatures.

Another important impact of temperature is on the chemical aspects of the aquarium. The solubility of dissolved gases such as oxygen and carbon dioxide, for example, changes with temperature. Oxygen, in particular, can be a concern because it is less soluble at higher temperature.

So what does this imply for aquarists?

In most instances, trying to match the natural environment in a reef aquarium is a worthy goal. Temperature may, however, be a parameter that requires accounting for the practical considerations of a small closed system. Looking to the ocean as a guide for setting temperatures in reef aquaria may present complications, because corals grow in such a wide range of temperatures. Nevertheless, Ron Shimek has shown in a **previous article** that the greatest variety of corals are found in water whose average temperature is about 83-86° F.

Reef aquaria do, however, have limitations that may make their optimal temperature somewhat lower. During normal functioning of a reef aquarium, the oxygen level and the metabolic rate of the aquarium inhabitants are not often important issues. During a crisis such as a power failure, however, the dissolved oxygen can be rapidly used up. Lower temperatures not only allow a higher oxygen level before an emergency, but will also slow the consumption of that oxygen by slowing the metabolism of the aquarium's inhabitants. The production of ammonia as organisms begin to die may also be slower at lower temperatures. For reasons such as this, one may choose to strike a practical balance between temperatures that are too high (even if corals normally thrive in the ocean at those temperatures), and those that are too low. Although average reef temperatures in maximal diversity areas (i.e. coral triangle centered Indonesia,) these areas are also often subject to significant mixing. In fact, the cooler reefs, ( i.e. open Pacific reefs) are often more stable at lower temperatures due to oceanic exchange but are less tolerant to bleaching and other temperature related perturbations.

All things considered, those natural guidelines leave a fairly wide range of acceptable temperatures. I



keep my aquarium at about 80-81° F year-round. I am actually more inclined to keep the aquarium cooler in the summer, when a power failure would most likely warm the aquarium, and higher in winter, when a power failure would most likely cool it.

**All things considered, I recommend temperatures in the range of 76-83° F unless there is a very clear reason to keep it outside that range.**

## pH

Aquarists spend a considerable amount of time and effort worrying about, and attempting to solve, apparent problems with the pH of their aquaria. Some of this effort is certainly justified, as true pH problems can lead to poor animal health. In many cases, however, the only problem is with the pH measurement or its interpretation.

Several factors make monitoring a marine aquarium's pH level important. One is that aquatic organisms thrive only in a particular pH range, which varies from organism to organism. It is therefore difficult to justify a claim that a particular pH range is "optimal" in an aquarium housing many species. Even natural seawater's pH (8.0 to 8.3) may be suboptimal for some of its creatures, but it was recognized more than eighty years ago that pH levels different from natural seawater (down to 7.3, for example) are stressful to fish.<sup>6</sup> Additional information now exists about optimal pH ranges for many organisms, but the data are woefully inadequate to allow aquarists to optimize pH for most organisms which interest them.<sup>7-11</sup>

Additionally, pH's effect on organisms can be direct, or indirect. The toxicity of metals such as copper and nickel to some aquarium organisms, **such as mysids and amphipods**,<sup>12</sup> is known to vary with pH. Consequently the acceptable pH range of one aquarium may differ from another aquarium's, even if they contain the same organisms, but have different concentrations of metals.

Changes in pH nevertheless do substantially impact some fundamental processes taking place in many marine organisms. One of these fundamental processes is calcification, or deposition of calcium carbonate skeletons, which is known to depend on pH, dropping as pH falls.<sup>13,14</sup> Using this type of information, along with the integrated experience of many hobbyists, we can develop some guidelines about what is an acceptable pH range for reef aquaria, and what values push the limits.

The acceptable pH range for reef aquaria is an opinion rather than a clearly delineated fact, and will certainly vary with the opinion's provider. This range may also be quite different from the "optimal" range. Justifying what is optimal, however, is much more problematic than is justifying that which is simply acceptable, so we will focus on the latter. As a goal, I'd suggest that the pH of natural seawater, about 8.2, is appropriate, but coral reef aquaria can clearly succeed in a wider range of pH values. In my opinion, **the pH range from 7.8 to 8.5 is an acceptable range for reef aquaria, with several caveats.** These are:

1. That the alkalinity is at least 2.5 meq/L, and preferably higher at the lower end of this pH range. I base this statement partly on the fact that many reef aquaria operate quite effectively in the pH 7.8 to 8.0 range, and that most of the best examples of these types of aquaria incorporate calcium carbonate/carbon dioxide reactors which, while tending to lower the pH, keep the carbonate alkalinity fairly high (at or above 3 meq/L.). In this case, any problems associated with **calcification at these lower pH values** may be offset by the higher alkalinity.
2. That the calcium level is at least 400 ppm. Calcification becomes more difficult as the pH and calcium levels fall. It is not desirable to push all of the extremes of pH, alkalinity, and calcium at the same time, so if the pH is low and cannot be easily changed (as may be the case in an aquarium with a CaCO<sub>3</sub>/CO<sub>2</sub> reactor), at least make sure that the calcium level is normal to high (~400-450 ppm).
3. Likewise, one of the problems at higher pH (anywhere above 8.2, but progressively more problematic with each incremental rise) is the abiotic precipitation of calcium carbonate, resulting in a drop in calcium and alkalinity, and the clogging of heaters and pump impellers. If you push the pH to 8.4 or higher (as often happens when using limewater), make sure that both the calcium and alkalinity levels are suitably maintained (that is, neither too low, inhibiting

biological calcification, nor too high, causing excessive abiotic precipitation on equipment).

4. Transient upward spikes are less deleterious than transient downward spikes in pH.

## Magnesium

Magnesium's primary importance is its interaction with the calcium and alkalinity balance in reef aquaria. Seawater and reef aquarium water are always supersaturated with calcium carbonate. That is, the solution's calcium and carbonate levels exceed the amount that the water can hold at equilibrium. How can that be? Magnesium is a big part of the answer. Whenever calcium carbonate begins to precipitate, magnesium binds to the growing surface of the calcium carbonate crystals. The magnesium effectively clogs the crystals' surface so that they no longer look like calcium carbonate, making them unable to attract more calcium and carbonate, so the precipitation stops. Without the magnesium, the abiotic (nonbiological) precipitation of calcium carbonate would likely increase enough to prohibit the maintenance of calcium and alkalinity at natural levels.

For this reason, **I suggest targeting the natural seawater concentration of magnesium: ~1285 ppm. For practical purposes, 1250-1350 ppm is fine, and levels slightly outside that range (1200-1400 ppm) are also likely acceptable.** I would not suggest raising magnesium by more than 100 ppm per day, in case the magnesium supplement contains impurities. If you need to raise it by several hundred ppm, spreading the addition over several days will allow you to more accurately reach the target concentration, and might possibly allow the aquarium to handle any impurities that the supplement contains.

An aquarium's corals and coralline algae can deplete magnesium by incorporating it into their growing calcium carbonate skeletons. Many methods of supplementing calcium and alkalinity may not deliver enough magnesium to maintain it at a normal level. **Settled limewater (kalkwasser)**, in particular, is quite deficient in magnesium. Consequently, magnesium should be measured occasionally, particularly if the aquarium's calcium and alkalinity levels seem difficult to maintain. Aquaria with excessive abiotic precipitation of calcium carbonate on objects such as heaters and pumps might suffer from low magnesium levels (along with high pH, calcium, and alkalinity).

## Phosphate

The "simplest" form of phosphorus in reef aquaria is inorganic orthophosphate ( $\text{H}_3\text{PO}_4$ ,  $\text{H}_2\text{PO}_4^-$ ,  $\text{HPO}_4^{2-}$ , and  $\text{PO}_4^{3-}$  are all forms of orthophosphate). Orthophosphate is the form of phosphorus that most test kits measure. It is also present in natural seawater, although other forms do exist there as well. Its concentration in seawater varies greatly from place to place, and also with depth and with the time of day. Surface waters are greatly depleted in phosphate relative to deeper waters, due to biological activities in the surface waters that sequester phosphate in organisms. Typical ocean surface phosphate concentrations are very low by reefkeeping standards, sometimes as low as 0.005 ppm.

Absent of specific efforts to minimize the phosphate level, it will typically accumulate and rise in reef aquaria. It is introduced mostly with foods, but can also enter with top-off water and in some methods of calcium and alkalinity supplementation.

If allowed to rise above natural levels, phosphate can cause two undesirable results. One is inhibition of calcification. That is, it can reduce the rate at which corals and coralline algae can build calcium carbonate skeletons, potentially stunting their growth.

Phosphate can also be a limiting nutrient for algae growth. If phosphate is allowed to accumulate, algae growth may become problematic. At concentrations below about 0.03 ppm, the growth rate of many species of phytoplankton depends on the phosphate concentration (assuming that something else is not limiting growth, such as nitrogen or iron). Above this level, the growth rate of many of the ocean's organisms is independent of phosphate concentration (although this relationship is more complicated in a reef aquarium containing iron and/or nitrogen sources such as nitrate above natural levels). So deterring algae growth by controlling phosphate requires keeping phosphate levels quite low.

For these reasons, **phosphate should be kept below 0.03 ppm**. Whether keeping it below 0.01 ppm will yield substantial additional benefits remains to be established, but that is a goal that some aquarists are pursuing with various ways of exporting phosphate. The best ways to maintain low levels of phosphate in normal aquaria are to incorporate some combination of phosphate export mechanisms, such as growing and harvesting macroalgae or other rapidly growing organisms, using foods without excessive phosphate, skimming, using limewater, and using phosphate binding media, especially those that are iron-based (which are always brown or black). Some aquarists have also tried to reduce phosphate by inducing blooms of microorganisms such as bacteria. This last method should, in my opinion, be left to experienced aquarists.



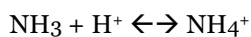
## Ammonia

Ammonia ( $\text{NH}_3$ ) is excreted by all animals and some other aquarium inhabitants. Unfortunately, it is very toxic to all animals, although it is not toxic to certain other organisms, such as some species of macroalgae that readily consume it. Fish are not, however, the only animals that ammonia harms, and even some algae, such as the phytoplankton *Nephroselmis pyriformis*, are harmed by less than 0.1 ppm ammonia.<sup>15</sup>

In an established reef aquarium, the ammonia produced is usually taken up rapidly. Macroalgae use it to make proteins, DNA, and other biochemicals that contain nitrogen. Bacteria also take it up and convert it to nitrite, nitrate, and nitrogen gas (the famous "nitrogen cycle"). All of these compounds are much less toxic than ammonia (at least to fish), so the ammonia waste is rapidly "detoxified" under normal conditions.

Under some conditions, however, ammonia may be a concern. During the initial setup of a reef aquarium, or when new live rock or sand is added, an abundance of ammonia may be produced that the available mechanisms cannot detoxify quickly enough. In these circumstances, fish are at great risk. **Ammonia levels as low as 0.2 ppm can be dangerous to fish.**<sup>16</sup> In such instances, the fish and invertebrates should be removed to cleaner water, or the aquarium treated with an ammonia-binding product such as Amquel.

Many aquarists are confused by the difference between ammonia and a form of it that is believed to be less toxic: ammonium. These two forms interconvert very rapidly (many times per second), so for many purposes they are not distinct chemicals. They are related by the acid base reaction shown below:



Ammonia + hydrogen ion (acid)  $\leftrightarrow$  ammonium ion

The only reason that ammonium is thought to be less toxic than ammonia is that, being a charged

molecule, it crosses the fishes' gills and enters their bloodstream with more difficulty than does ammonia, which readily passes across the gill membranes and rapidly enters the blood.

In aquaria with higher pH levels, which contain less  $H^+$ , more of the total ammonia will be in the  $NH_3$  form. Consequently, the toxicity of a solution with a fixed total ammonia concentration rises as pH rises. This is important in such areas as fish transport, where ammonia can build to toxic levels.

I will discuss issues concerning ammonia in greater detail in a future column.

## **Recommendation Details: [Other Parameters](#)**

### **Silica**

Silica raises two issues. If diatoms are a problem in an established reef aquarium, they may indicate a substantial source of soluble silica, especially tap water. In that case, purifying the tap water will likely solve the problem. In such a situation, testing may not reveal elevated silica levels because the diatoms may use it as quickly as it enters the aquarium.

If diatoms are not a problem, then I suggest that many aquarists should consider dosing soluble silica. Why would I recommend dosing silica? Largely because creatures in our aquaria use it, the concentrations in many aquaria are below natural levels, and consequently the sponges, mollusks, and diatoms living in these aquaria may not be getting enough silica to thrive.

I suggest dosing sodium silicate solution, as it is a readily soluble form of silica. I dose a bulk grade of sodium silicate solution (water glass), which is very inexpensive. You may find 'water glass' in stores because consumers use it for such activities as preserving eggs. Finding chemicals to buy can be difficult for many people, however, and this linked [hobby chemistry store](#) sells to individuals. Ten dollars plus shipping buys enough to last for 150 years of dosing a 100-gallon aquarium, so cost is not an issue.

Based on my dosing experience, aquarists are probably safe dosing to 1 ppm  $SiO_2$  once every 1-2 weeks. This is based on the fact that my aquarium uses that much in less than four days without any sort of "bad" reaction. Of course, there's nothing wrong with starting at a tenth of that dosage and gradually ramping it up. If you do get too many diatoms, just back off on the dosing. I presume that all of the  $SiO_2$  I have added to my aquarium has been used by various organisms (sponges, diatoms, etc), but perhaps I have more sponges than other aquarists. Consequently, diatoms may be more of a concern in some aquaria than in mine.

I would also advise occasionally measuring the soluble silica concentration in the water, in case the demand in your aquarium is substantially less than mine. If the concentration started to rise above 3 ppm  $SiO_2$ , even in the absence of diatoms, I would probably reduce the dosing rate because that is close to the maximum concentration that surface seawater ever contains. Additional details on dosing amounts and methods are described in this [previous article](#).



### **Iodine**



I do not presently dose iodine to my aquarium, and do not recommend that others necessarily do so either. Iodine dosing is much more complicated than dosing other ions due to its substantial number of different naturally existing forms, the number of different forms that aquarists actually dose, the fact that all of these forms can interconvert in reef aquaria, and the fact that the available test kits detect only a subset of the total forms present. This complexity, coupled with the fact that no commonly kept reef aquarium species are known to require significant iodine, suggests that dosing is unnecessary and problematic.

**For these reasons, I advise aquarists to NOT try to maintain a specific iodine concentration using supplementation and test kits.**

Iodine in the ocean exists in a **wide variety of forms**, both organic and inorganic, and the iodine cycles between these various compounds are very complex and are still an area of active research. The nature of inorganic iodine in the oceans has been generally known for decades. The two predominate forms are iodate ( $\text{IO}_3^-$ ) and iodide ( $\text{I}^-$ ). Together these two iodine species usually add up to about 0.06 ppm total iodine, but the reported values vary by a factor of about two. In surface seawater, iodate usually dominates, with typical values in the range of 0.04 to 0.06 ppm iodine. Likewise, iodide is usually present at lower concentrations, typically 0.01 to 0.02 ppm iodine.

**Organic forms of iodine** are any in which the iodine atom is covalently attached to a carbon atom, such as methyl iodide,  $\text{CH}_3\text{I}$ . The concentrations of these organic forms (of which there are many different molecules) are only now becoming recognized by oceanographers. In some coastal areas, organic forms can comprise up to 40% of the total iodine, so many previous reports of negligible levels of organoiodine compounds may be incorrect.

The primary organisms in reef aquaria that "use" iodine, at least as far as are known in the scientific literature, are algae (both micro and macro). **My experiments** with *Caulerpa racemosa* and *Chaetomorpha* sp. suggest that iodide additions do not increase the growth rate of these macroalgae, which are commonly used in refugia.

Finally, for those interested in dosing iodine, I suggest that **iodide** is the most appropriate form for dosing. Iodide is more readily used by some organisms than is iodate, and it is detected by both currently available iodine test kits (Seachem and Salifert).

## Nitrate

Nitrate is an ion that has long dogged aquarists. The nitrogen that forms it comes in with foods, and can, in many aquaria, raise nitrate enough to make it difficult to maintain natural levels. A decade or two ago, many aquarists performed water changes with nitrate reduction as one of their primary goals. Fortunately, we now have a large array of ways to keep nitrate in check, and modern aquaria suffer far less from elevated nitrate than did those in the past.

Nitrate is often associated with algae, and indeed the **growth of algae** is often spurred by excess nutrients, including nitrate. Other potential aquarium pests, such as dinoflagellates, are also spurred by excess nitrate and other nutrients. Nitrate itself is not particularly toxic at the levels usually found in aquaria, at least as is so far known in the scientific literature. Nevertheless, elevated nitrate levels can excessively spur the **growth of zooxanthellae**, which in turn can actually decrease the growth rate of their host coral.

For these reasons, most reef aquarists strive to keep nitrate levels down. **A good target is less than 0.2 ppm nitrate.** Reef aquaria can function acceptably at much higher nitrate levels (say, 20 ppm), but run greater risks of the problems described above.

There are many ways to reduce nitrate, including reducing the aquarium's nitrogen inputs, increasing nitrogen export by skimming, increasing nitrogen export by growing and harvesting macroalgae or turf algae (or any other organism of your choice), using a **deep sand bed**, removing existing filters designed to facilitate the nitrogen cycle, using a carbon **denitrator**, using a **sulfur denitrator**, using  $\text{AZ-NO}_3$ , using nitrate absorbing solids, and using polymers and carbon that bind organics. All of these methods are described in more detail in a **previous article**.

## Nitrite

Aquarists' concerns about nitrite are usually imported from the freshwater hobby. Nitrite is far less toxic in seawater than in freshwater. Fish are typically able to survive in seawater with more than 100 ppm nitrite!<sup>17</sup> Until future experiments show substantial nitrite toxicity to reef aquarium inhabitants, nitrite is not an important parameter for reef aquarists to monitor. Tracking nitrite in a new reef aquarium can nevertheless be instructive by showing the biochemical processes that are taking place. In most cases, **I do not recommend that aquarists bother to measure nitrite in established aquaria.**

## Strontium

My recommendation is to maintain strontium levels in reef aquaria in the range of 5-15 ppm. That level roughly spans the level in natural seawater of 8 ppm. **I do not recommend that aquarists supplement strontium unless they have measured strontium and found it to be depleted to below 5 ppm. Measuring and supplementing strontium is not a critical activity for most aquarists,** and is not a trivial exercise since the available test kits can be difficult to use (see below).

In **some recent tests**, I found that in my reef aquarium, without any recent strontium additions, strontium was already elevated above natural levels (to 15 ppm due to elevated strontium in the Instant Ocean salt mix that I was using). I would not like to see it get any higher. Consequently, adding a supplement without knowing the aquarium's current strontium level is not advisable. Scientific evidence indicates that **some organisms need strontium**, albeit not the organisms that most reef keepers maintain. Certain gastropods, cephalopods, and radiolaria, for example, **require strontium**.<sup>18-34</sup> It is, however, clearly toxic at elevated concentrations. In **one reported case**, 38 ppm was enough strontium to kill a particular species of crab (*Carcinus maenas*).<sup>34</sup> No evidence indicates that 5-15 ppm strontium is harmful to any marine organism, although it is not known what strontium levels are optimal. Finally, anecdotal evidence from a number of advanced aquarists suggests that strontium that is substantially below natural levels is detrimental to the growth of corals that many aquarists maintain, but this effect has not been proven.

How can we maintain natural strontium levels? Doing so, of course, necessitates a suitable strontium test. Some test kits are perhaps suitable for this purpose. If not, sending a sample out to a lab might be a reasonable alternative for some aquarists. If the result comes back in the 5-15 ppm range, no action likely need be taken. If the level is higher than 15 ppm, the best reduction method may simply be water changes with a suitable salt mix, without abnormally high levels of strontium. If strontium levels are below 5 ppm, adding a strontium supplement may be in order.

**Overall, water changes with a salt mix containing a suitable level of strontium may be the best way to keep strontium at appropriate levels.**

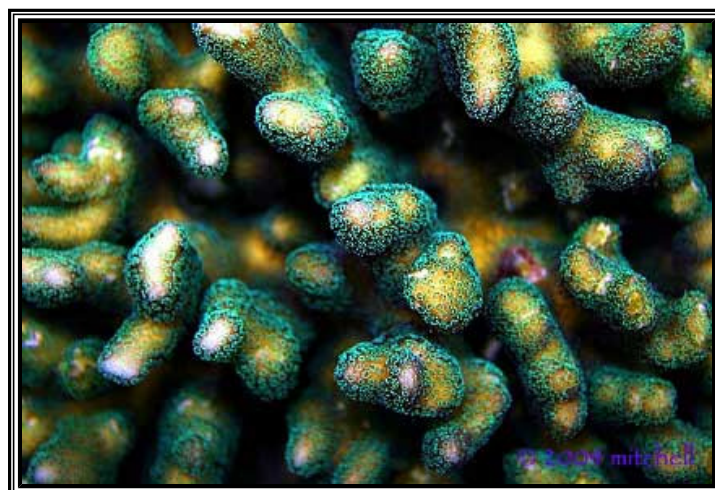


Photo courtesy of Mitchell Brown.

## ORP

I do not recommend that aquarists try to "control" ORP.

The oxidation reduction potential (ORP) of a marine aquarium is a measure of its water's relative oxidizing power. ORP has often been recommended to aquarists as an important water parameter, and some companies sell products (equipment and chemicals) designed to control ORP. Many who recommended ORP control have convinced aquarists that it is a measure of the aquarium water's relative "purity," despite this never having been clearly demonstrated.

ORP, at its heart, is very, very complicated. It is perhaps the single most complicated chemical feature of marine aquaria that aquarists will typically encounter. ORP involves many chemical details that are simply unknown, either for seawater or for aquaria. It involves processes that are not at equilibrium, and so are difficult to understand and predict. Even more daunting is the fact that the chemicals that control ORP in one aquarium might not even be the same chemicals that control ORP in another aquarium, or in natural seawater.

ORP is an interesting, if complicated, measure of the properties of water in a marine aquarium. It has uses for monitoring certain events in aquaria that impact ORP but may be otherwise hard to detect. These events could include immediate deaths of organisms, as well as long term increases in the levels of organic materials. Aquarists who monitor ORP, and who do other things that seem appropriate for maintaining an aquarium (such as increasing aeration, skimming, use of carbon, etc.) may find monitoring ORP to be a useful way to see progress.

ORP measurements are very susceptible to errors. Aquarists are strongly cautioned to not overemphasize absolute ORP readings, especially if they have not recently calibrated their ORP probe. Rather, ORP measurements are most useful when looking at changes in measured ORP *over time*.

Some aquarists use oxidizers to raise ORP. These additions may benefit some aquaria, and maybe in ways that aren't demonstrated by changes in ORP alone. I've never added such materials to my aquarium. In the absence of convincing data otherwise, such additions seem to me to be potentially riskier than is justified by their demonstrated and hypothesized benefits.



Photo courtesy of Zak Klein.

## Boron

Boron's importance in marine aquaria is a subject not often discussed by hobbyists, despite the fact that many people dose it daily with their alkalinity supplements. Most commentary on boron, in fact, derives from manufacturers who sell it in one fashion or another as a "buffering" agent. These discussions, unfortunately, nearly always lack any quantitative discussion of boron or its effects, both positive and negative. **In general, boron is not an important element to control in aquaria.**

Boron actually contributes only a minor fraction of normal seawater's pH buffering capacity. It appears to be a necessary or desirable **nutrient for certain organisms**,<sup>35-37</sup> but is also **toxic to others at levels not far above natural levels**,<sup>38-40</sup> and below amounts present in at least one

artificial salt mix.

For these reasons, my **recommendation is to maintain approximately natural levels of boron, about 4.4 ppm. Any value below 10 ppm is likely acceptable for most aquaria.** Values above 10 ppm should be avoided. The **Salifert boron kit** is suitable for determining ballpark boron levels in marine aquaria, while **other kits may not be.**

## Iron

Iron is **limiting to growth** of phytoplankton in parts of the ocean, and may be limiting to macroalgae growth in many reef aquaria. Because of its short supply and critical importance, it is also subject to aggressive **sequestration by bacteria** and other marine organisms. Consequently, aquarists might consider dosing iron if they grow macroalgae.

Iron is not easy to measure at levels normally encountered in marine aquaria. It is also not easy to determine which of its many forms are bioavailable in seawater, and which are not. Consequently, aquarists should not target a specific concentration, but rather should decide if they want to dose any at all, and then use an appropriate dosage going forward. The reason to dose iron is that macroalgae may benefit from it. If you are not growing macroalgae, then you may not need to monitor or dose iron at all.

Deciding how much iron to add is fairly easy because, in my experience, it doesn't seem to matter too much. Presumably, once you add enough to eliminate it as a limiting nutrient, extra iron does not cause apparent harm (at least that I've detected in my aquarium or have heard of from others). I dose about 0.1 to 0.3 mL of a solution containing 5 g of iron (as 25 g of ferrous sulfate heptahydrate) in 250 mL of water containing 50.7 g of sodium citrate dihydrate. I presently dose once per week to my system with a total water volume of about 200 gallons. This iron(II) citrate turns brown and cloudy over time, but I still use it.

I've noticed no negative effects from dosing this iron, or of Kent's iron and manganese supplement that I have also used, that were attributable to the iron, nor have I heard of any negative effects from others doing similar dosing. Still, I don't keep all organisms available to the hobby, and if a negative reaction does appear, I advise backing off the dose or stopping completely.

Since many hobbyists do not have access to the chemicals required to make iron(II) citrate, I advise most aquarists to obtain a commercial iron supplement. A number of appropriate and inexpensive supplements are available. Some commercial supplements, such as Kent's product, combine manganese with iron, presumably because the scientific literature has demonstrated that phytoplankton also scavenge manganese from the water column. I've not experimented with manganese, but it is likely acceptable to use if a pure iron supplement cannot be found.

I'd also advise using only iron supplements that contain iron chelated to an organic molecule. The iron sold for freshwater applications is sometimes not chelated because free iron is more soluble in the lower pH of freshwater aquaria. I'd avoid those products for marine applications. It will likely still work, as many of the studies in the scientific literature use free iron in seawater, but probably not as well because it may precipitate before it has fully fortified the system with iron.

In many cases of iron products intended for the marine hobby, the product may not state what the iron is chelated with, in order to protect proprietary formulations. I don't actually know if it matters much. Very strong chelation by certain molecules will actually inhibit bioavailability by prohibiting release of the iron unless the chelating molecule is completely taken apart, but I expect that manufacturers have avoided those molecules. EDTA, citrate, and some others actually degrade photochemically, continually releasing small amounts of free iron. It is believed to be the free iron that many of the organisms actually take up. "Captive Seawater Fishes" by Stephen Spotte includes a more detailed discussion of this degradation and uptake.<sup>16</sup>

It should be noted that iron may be a limiting factor for many organisms other than macroalgae. These might include microalgae, bacteria (even pathogenic bacteria), and diatoms. These possibilities were discussed in a previous article. If such problems should arise, backing off or stopping the iron additions may be warranted.



## Summary

Chemical issues in reef aquaria are often daunting to aquarists. There are many chemical parameters that aquarists monitor, some of which are critical for success, and some of which are much less important. Of those critical for success, only calcium and alkalinity require regular supplementation in all reef aquaria, although the others in Table 1 may require monitoring. Successfully keeping the parameters in Table 1 at appropriate levels should go a long way toward allowing aquarists to more fully enjoy their aquaria while at the same time ensuring that the inhabitants are well cared for.

Happy Reefing!

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If you have any questions about this article, please visit my author [forum](#) on Reef Central.

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