Salinity Measurements for Marine Aquariums

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Introduction

The fundamental difference between freshwater and marine aquariums is of course, their respective salt content. The salt level is usually reported as either salinity (parts per thousand of salt in water) or specific gravity (the density of the solution relative to freshwater). Measuring the specific gravity of an aquarium is one of the first tasks learned by new marine aquarists. Obtaining an approximate specific gravity of an aquarium is as simple as dipping up a sample into a specific gravity meter and reading the number across from the pointer. There are instances however, (such as hyposalinity fish treatments and reef aquariums) where more accurate measurements may be required. This article offers some tips for more accurately measuring and managing the salinity of your aquarium's water. Beginning aquarists may find it helpful to jump ahead to the glossary in order to familiarize themselves with some technical terms used in discussing this topic

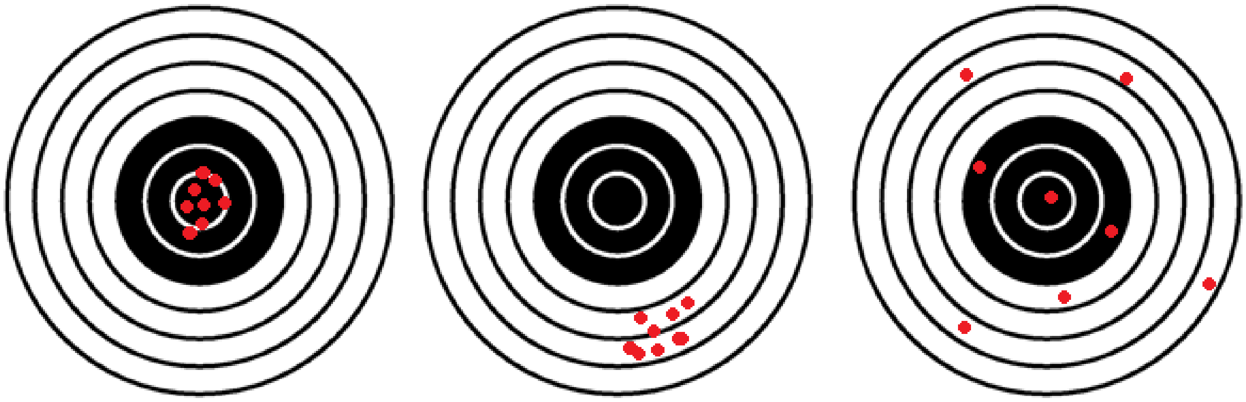
Glass hydrometers

A glass hydrometer is a long glass tube with a narrow neck with a scale on it. When floated in a liquid, it rises higher the denser the solution is. In most cases, it is best to fill a tall cylinder with the water to be tested and immerse the hydrometer in the cylinder rather than floating it free in the aquarium. The hydrometer reading is taken by determining where the water level intersects the scale on the stem. Remember to take the reading at the actual waterline, not the meniscus (the thin layer of water that tends to creep up the side of the narrow stem). To do this, take the reading from slightly below the water level looking upwards towards the stem of the hydrometer. Two issues can change the precision of a glass hydrometer; tiny bubbles adhering to the tube will lift the hydrometer higher, giving a false high reading, and the tube sticking to some adjacent surface, tending to hold the hydrometer lower in the water and resulting in a falsely low reading.

For early aquarists, the floating glass hydrometer was usually the only device available to measure the specific gravity of their marine aquariums. Over the past 25 years, these small glass hydrometers have almost been entirely replaced by the more convenient dip and read plastic hydrometers. Laboratory grade hydrometers are still perhaps the best reference (on the basis of cost versus ease of use) for confirming the accuracy of another type of specific gravity meter. While small glass hydrometers have a precision of between .001 and .0005 specific gravity units, a high quality glass hydrometer can have a precision of .0001 specific gravity units, higher than any other device routinely available for a home aquarist.

Precision Versus Accuracy

Most methods used to measure salinity or specific gravity are very precise. This means that repeated tests using the same device will give similar results (assuming there are no problems such as air bubbles attached to the swing arm, etc.) However, not all devices are accurate enough for critical use in aquariums. It is possible that a device will be precise, but inaccurate – giving repeated readings close to one another, but far from the actual specific gravity. Aquarists need a device that is not only precise, but accurate as well. The three targets in the accompanying diagram explain this issue graphically.



Dip and read hydrometers

Dip and read plastic hydrometers (or specific gravity meters) have become almost ubiquitous in their use by marine aquarists. Generally reliable and certainly less prone to breakage than glass hydrometers, these units can however lose their accuracy over time, or may even be inaccurate when first purchased. Standardization is problematical because of the difficulty in locating an accurate reference source to compare them against.

With plastic hydrometers, it is known that new units have a propensity to give false high specific gravity readings due to minute air bubbles that can attach to the pointer. With time, the surface tension of the plastic pointer seems to become reduced, and bubbles are less of a problem. Older units are suspected of reading lower due to mineral build-up at the pivot point or even a change in density in the plastic that composes the swing arm. Always make certain that the hydrometer is perfectly level when you take the reading as any tilt from left to right will change the reading at the end of the pointer, and any tilt from front to back may cause the pointer to bind up. Many plastic hydrometers can achieve a resolution of .0005 specific gravity units and are very precise over the short term (but need to be re-checked periodically to ensure their accuracy hasn't changed).

Dip and read hydrometers

Electronic salinity meters

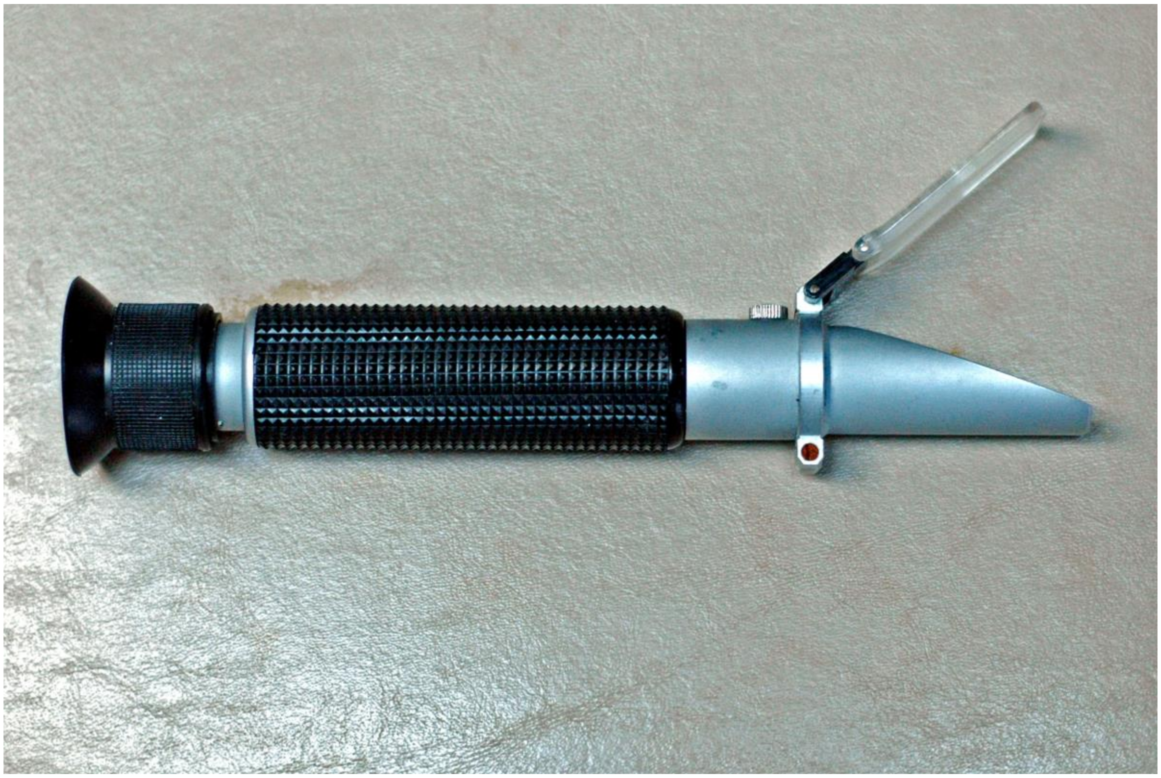
Using gold-tipped electrodes, these devices measure the sodium concentration of water through changes in its conductivity. Some of these meters can read in salinity and specific gravity units, as well as read the water's temperature. Accuracy and precision (repeatability) may not be high enough to use some of the less expensive units in critical applications. In addition, most come with a sodium or potassium chloride solution to standardize the device – and it is unclear if the conductivity of these single salt solutions are equivalent to that of seawater (which is composed of many different types of salts). One possible work around is to determine the salinity of a sample of seawater using a laboratory grade hydrometer, and then using that seawater to standardize the salinity meter. One salinity meter could only achieve a precision of plus or minus .001 specific gravity units as the reading would change dependant on how the probe was positioned in the water sample.

Electronic salinity meter

Refractometers

Refractometers are handheld devices that measure the difference in light refraction between solutions. It turns out that the amount of salt dissolved in the water changes its refractive index, allowing slight differences in salinity to be measured optically. Choose a refractometer that is designed for use with seawater and that has automatic temperature control (ATC). Avoid trying to adapt clinical or brix (sugar solution) refractometers for use with aquariums.

Many aquarists rely on a refractometer as their “gold standard” for determining salinity, assuming because these units are expensive, they must also be accurate. This is only true if the device has been properly calibrated. Using distilled water to calibrate a refractometer gives only moderately accurate results. A better method is to use a calibration solution. You can make one yourself by dissolving 3.65 grams of sodium chloride in 96.35 milliliters of distilled water. Using this solution, adjust your refractometer so that it reads 35 ppt. Refractometers are excellent for measuring the salinity of very small aquariums such as pico-reefs because only a couple of drops of water are needed to perform the test. Always wipe the viewing plate and cover off with a soft cloth soaked in tap or distilled water after each use. With practice, most people can achieve an accuracy of .0005 specific gravity units when using a refractometer, and the readings are also very precise.



Optical refractometer

Direct calculation

When mixing up large batches of seawater, it is often easier to calculate the amount of salt you will need to add to a given volume of water than to add some salt, retest, and some more, retest again, etc. There are three ways to begin such a calculation; by weighing the salt, by measuring its volume, or by relying on the manufacturer's information (e.g. adding a ten gallon bag of sea salt to ten gallons of freshwater). One cup of sea salt will prepare from 1 ½ to two gallons of synthetic seawater (depending on the brand of salt used and the desired final salinity).

When working out a direct calculation based on information supplied by the salt manufacturer, it is important to know the final specific gravity expected for the solution. One company's "50 gallon mix" with a calculated final specific gravity of 1.024 is going to contain more actual product than another's "50 gallon mix" that is based on a final specific gravity of 1.021.

General recommendations about using synthetic sea salt

Remember that it is always better to use an entire bag of sea salt mix than to try to take small amounts from a bag. Not all salt mixes are homogenous – and by dipping out a cup of salt from a larger bag, you may be selecting an area of the bag that has more of one compound than it should have. Additionally, once a bag is opened, if not resealed well, the salt begins absorbing moisture from the air, making it weigh more and possibly clump up.

When mixing up sea salts, always add the salt slowly to the full amount of freshwater needed for the batch of salt you are producing. Adding water to salt or adding a large amount of salt to a small volume of water will create conditions which may cause certain compounds in the mix precipitate out of solution.

If you elect to perform a hyposalinity treatment for the marine parasite *Cryptocaryon irritans* your hydrometer must be highly accurate and precise. Some aquarists reduce their aquarium's specific gravity to very low levels (1.009) which is just above the lethal lower limit for some marine fish. An inaccurate hydrometer that reads too high may cause fish loss in these cases. While the salinity of water the fish are being treated in can be lowered quickly (over one day's time) returning the fish to full salinity at the conclusion of the treatment must be done very slowly – over five to seven days. Finally, be aware that a ciliate protozoan *Uronema marinum* thrives at low salinities. This disease is often misdiagnosed as a bacterial infection and then incorrectly treated.

Be aware that some brands of sea salt contain trace amounts of ammonia at a level of around 0.2 mg/l. This is lower than many test kits can register and is typically only a problem if using the solution immediately after mixing with very delicate animals such as invertebrate larva (Hemdal 2006).

Hydrometer Standardization

To test how widespread the problem of inaccurate hydrometers might be, 20 hydrometers were removed from service at a public aquarium and tested against two known standards – a laboratory hydrometer and a good quality refractometer. The devices tested were of six different styles and ranged in age from 10 years old to brand new. Brand names are not shown with this data as the intent here is not to determine the quality of a given product, but rather to demonstrate the need to check and calibrate these devices. It should be noted that many of the older units had previously been calibrated, and correction factors etched into their sides. Over time, it was found that these factors had changed; indicating that periodic re-testing of their accuracy is required. Units with readings in red were discarded as being too inaccurate for critical use.

Type of Device	Observed Specific Gravity	Percent Error
Laboratory hydrometer	1.0240	0%
Refractometer (calibrated to pure H2O)	1.0245	+ 2.1%
Refractometer (calibrated to 35 ppt water)	1.0240	0%
Electronic salinity meter	1.0230	- 4.2%
Brand A glass hydrometer	1.0225	- 6.3%
Plastic hydrometer, small Brand B	1.0230	- 4.2%
“ “	1.0215	- 10.4%
“ “	1.0225	- 6.2%
Plastic hydrometer newer style Brand C	1.0250	+ 4.2%
“ “	1.0265	+ 10.4%
“ “	1.0250	+ 4.2%

"	"	1.0255	+ 6.3%
Plastic hydrometer old style full range Brand C		1.0230	- 4.2%
"	"	1.0245	+ 2.1%
"	"	1.0250	+ 4.2%
"	"	1.0250	+ 4.2%
"	"	1.0250	+ 4.2%
Plastic hydrometer new style Brand D		1.0210	- 12.5%
"	"	1.0210	- 12.5%
"	"	1.0210	- 12.5%
"	"	1.0210	- 12.5%

Conclusion

Forty years ago it was common practice to just leave a small hydrometer / thermometer bobbing around in the tank and check it once a week. Not only were these devices often inaccurate, floating them increased the chance of breakage, as well as having the precision change due to algae growth on the tube. We now know that salinity measurements cannot be treated so lightly, and with a little extra effort, you can increase the accuracy of your salinity measurements to a level that is appropriate for virtually any situation you will experience with your aquarium.

Glossary

Many technical terms are used by aquarists as they discuss the topic of salt levels in aquariums. The following basic definitions of terms are based on how aquarists use these terms (as opposed to scientists or the general public as a whole).

Density – The ratio of the mass of a material to its unit volume. Often expressed as grams per cubic centimeter (g/cm^3). When the density of a material is compared as a multiple to that of a known standard, it becomes an expression of specific gravity. The density of seawater is 1.025 g/cm^3.

Euryhaline – An organism that can survive at a wider range of salinities or that can tolerate more rapid changes in salinity. Examples include *Aiptasia* sp. sea anemones, black mollies and mangrove killifish.

Hydrometer – A device that measures the specific gravity (relative density) of aquarium water. The basic principle is that a material of known density (either a floating glass tube, or a plastic swing arm) will be buoyed up to a greater or lesser degree in water that is more or less dense.

Hypersalinity – Water that has salinity higher than normal seawater. Generally, this is a condition to be avoided in aquariums, however treatment for a protozoan infection (*Uronema* sp.) may include a hypersalinity component.

Hyposalinity – Water that has a salinity below that of normal seawater. Commonly used as a therapy for minor outbreaks of the marine ciliate, *Cryptocaryon irritans*.

Osmosis – The diffusion of water through an organism's cell membranes, or other semi-permeable barrier from the region of low salinity to one that is higher. This diffusion must be controlled by all aquatic organisms. If the difference of salinity becomes too great between the inside of the animal and the water it lives in, the organism may not be able to cope.

Parts Per Thousand (ppt) – A means of describing a ratio of solute to solvent. In the case of seawater, there are approximately 35 grams of salts dissolved in 1000 grams of water.

Salinity – A measurement of the amount of salts dissolved in water. Typically expressed at parts per thousand, (seawater is typically 35 ppt) but sometimes a different scale is used, so ocean water is also 3.5% or 35,000 parts per million.

Specific Gravity – This is the number most often used by aquarists to report the density of their aquarium's water as given by a hydrometer.

Stenohaline – An organism that can only survive in a relatively narrow preferred salinity range, or which cannot adapt to rapid changes in salinity. Examples include echinoderms (starfish and sea urchins), octopus and some deepwater reef fishes. Many South American freshwater fish are also stenohaline; even small amounts of salt in the water can prove harmful to them.

Refractometer – A device that optically measures the differences in refraction (how light bends when it passes through it) of a substance. The better devices automatically compensate for different room temperatures. After the refractometer is calibrated to a known standard, it then gives the results as salinity and specific gravity units.

References

Hemdal, J.F. 2006. **Advanced Marine Aquarium Techniques.** 352pp. TFH publications, Neptune City, New Jersey