An Analysis of Reef Tank Test Kits (Phase 1)

ABSTRACT

For years now, there has been ongoing discussion and chatter among hobbyists about which Test Kit was better, which was more accurate and exactly how reliable our Test Kits are in providing quality and accurate parameter results. In many cases the topic came down to personal preference, either due to the type test, how the results were read, what unit of measure was used in the test and/or the brand of test. This undertaking was done not to choose a winner or best of breed in Test Kits; it was to examine how accurate Test Kits were in general compared to some professional laboratory tests of the same sample of water and to provide the hobbyist some comfort level in the choices they make when selecting which Test Kits to use. The Test Kit market ranges from very affordable to outrageously expensive for the average hobbyist and it's important to know which kits we can rely upon in our individual budget range.

INTRODUCTION

While we rely upon the claims of manufacturers on the accuracy of their Test Kits, we often fall back on the experience of fellow hobbyists to determine which kits are more accurate and which are worth the added expense to purchase. Unfortunately, this methodology often leads to problems because people are easily influenced by the bells and whistles of a kit, its shape, its design and its price tag. After all, if a Kit costs $120 for a Nitrate Test, it has to be better than one that cost $10 right?

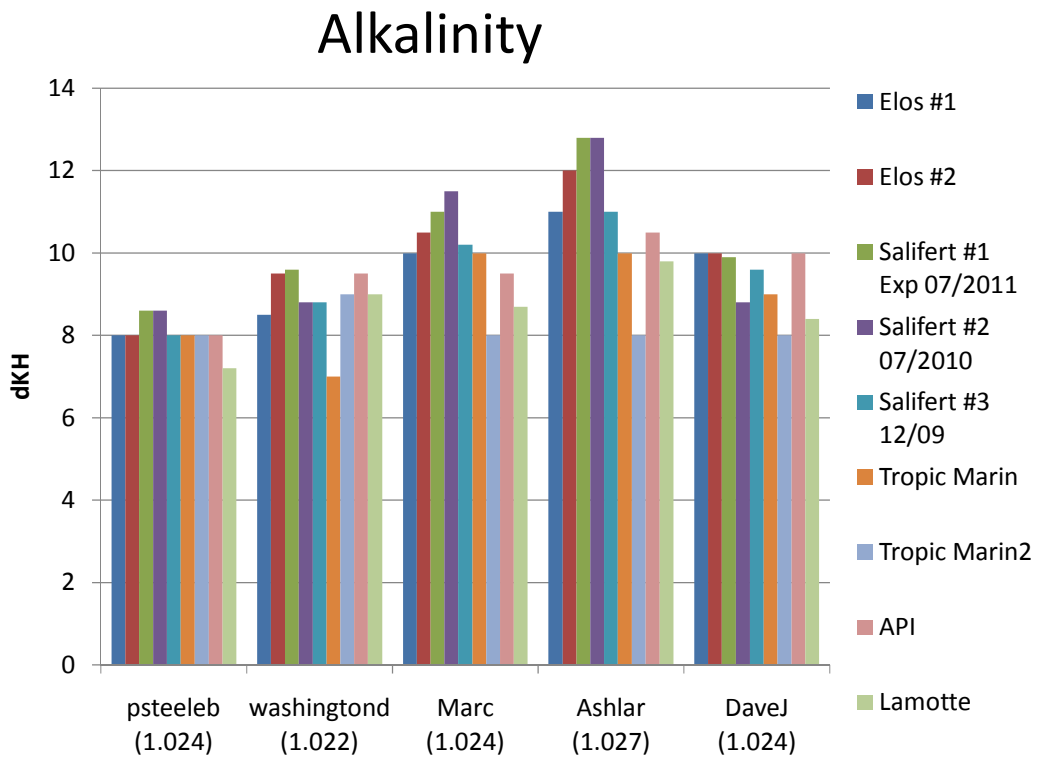
What we decided to do was pool our resources and put all our kits together into a pool and then methodically test samples of water from our own tanks. We would then send off some of these samples to an outside 'lab' for an independent evaluation of our water. The goal was to test a wide array of water, with as many kits as possible and have a solid foundation (by way of the outside lab) to which we can compare results.

METHODOLOGY FOR TESTS

While the individual Test Kits have different procedures, the methodology of the test itself was consistent. We took 5 samples (5 tanks) and systematically ran these samples through all test kits we had on hand (See Table 1). We rinsed each test tube after use as well as rinsed the syringes used to measure sample quantity in RO between uses. In the case of a test utilizing a color change (from blue to yellow for example), the reading was taken and reported on the drop that changed the color to the indicator color and held it for 30 seconds or longer. Tests requiring color shading to indicate a result were read using the best light available and it was up to the user to call for help to ID a particular result. Some kits were more prone to this than others and all results were agreed upon in these cases, there were no disputed readings. All tests were conducted specifically following the instructions for each manufacturer. Finally samples from two tanks were sent to AquariumWaterTesting.com to use as a baseline.

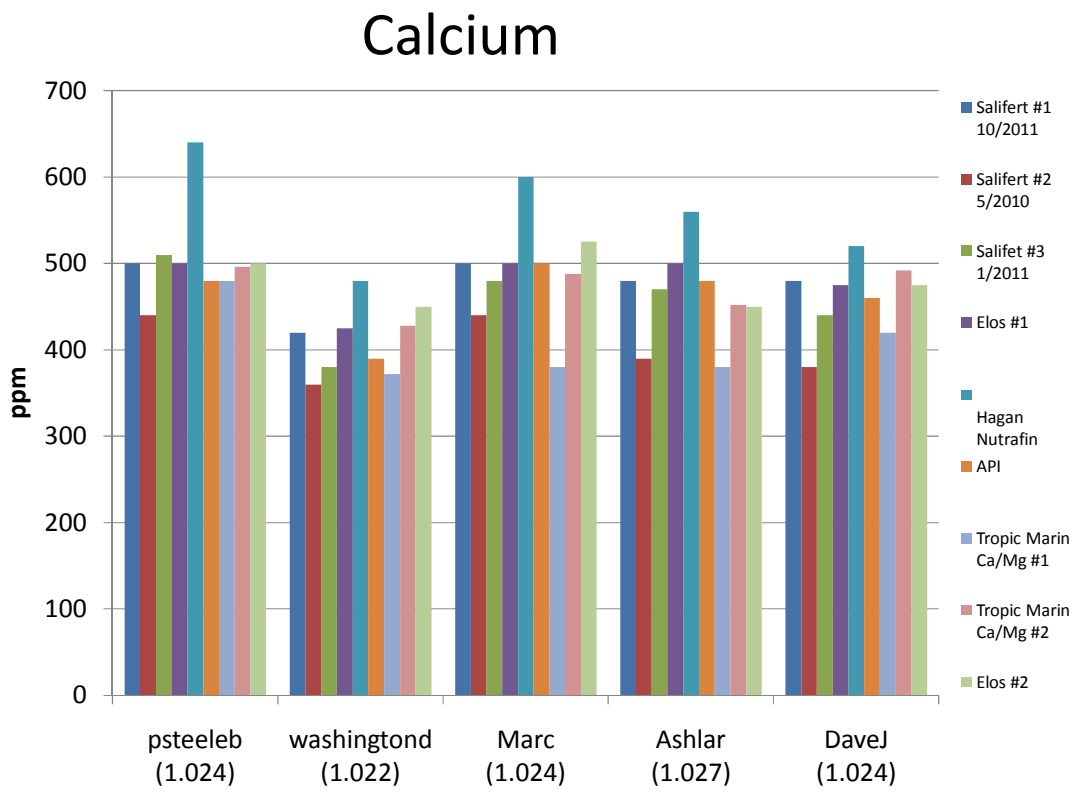
RAW RESULTS

Here are the results of our testing. Please refer to the CONCLUSIONS AND OBSERVATIONS section for our own analysis of the results.



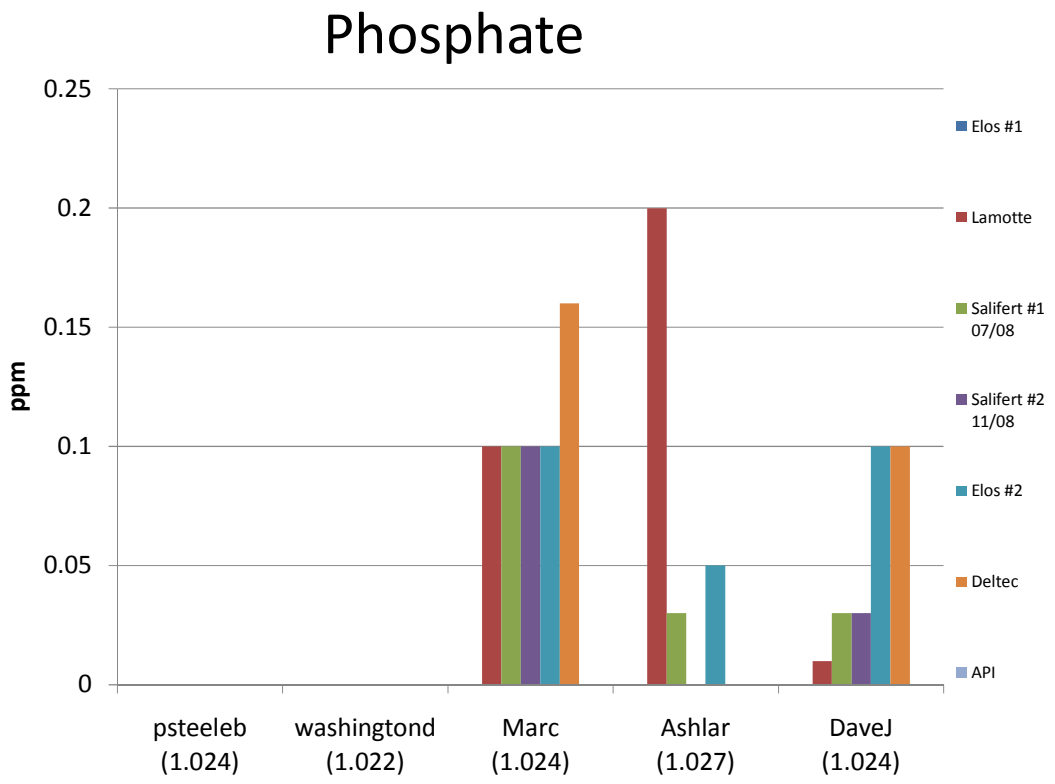
Alkalinity

	Elos #1	Elos #2	Salifert #1	Salifert #2	Salifert #3	Tropic Marin #1	Tropic Marin #2	API	Lamotte	Mean	Mean w/o Hi-Lo	St Dev	Margin of Error
DaveJ	10	10	9.9	8.8	9.6	9	8	10	8.4	9.3	9.28	0.73	0.24
Scott	11	12	12.8	12.8	11	10	8	10.5	9.8	10.9	11.01	1.45	0.48
Marc	10	10.5	11	11.5	10.2	10	8	9.5	8.7	9.9	9.99	1.02	0.34
Pete	8	8	8.6	8.6	8	8	8	8	7.2	8.0	8.09	0.39	0.13
WashingtonD	8.5	9.5	9.6	8.8	8.8	7	9	9.5	9	8.9	9.01	0.75	0.25



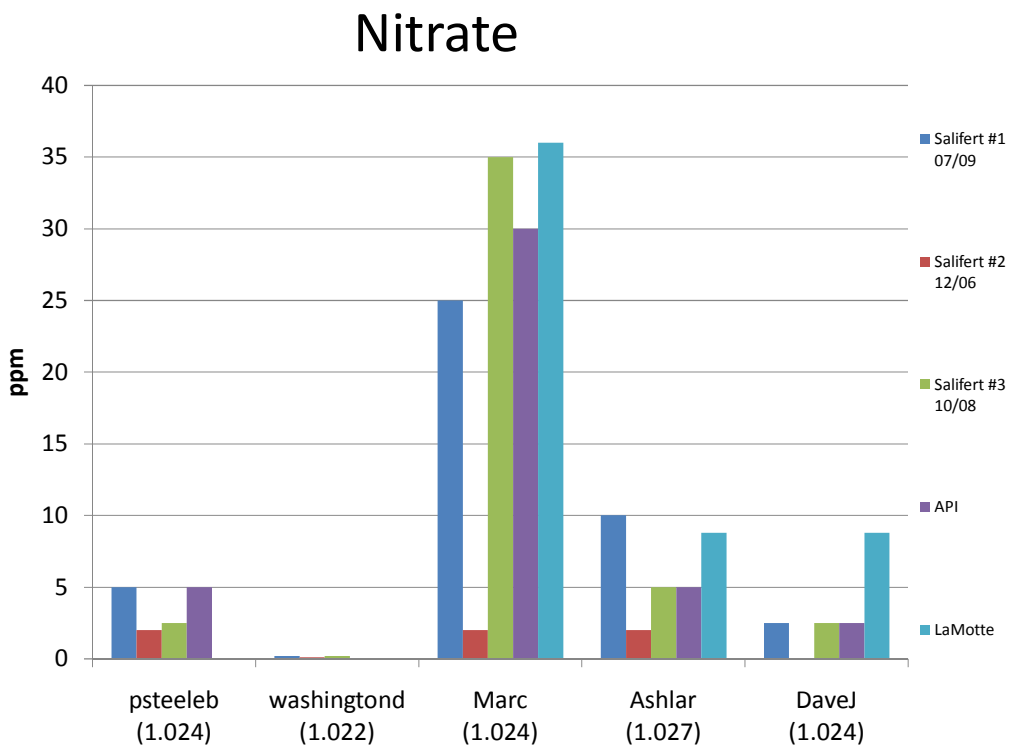
Calcium

	Salifert #1	Salifert #2	Salifet #3	Elos #1	Hagan Nutrafin	API	Tropic Marin Ca/Mg #1	Tropic Marin Ca/Mg #2	Elos #2	Mean	Mean w/o Hi-Lo	St Dev	Margin of Error
DaveJ	480	380	440	475	520	460	420	492	475	460	460.22	39.26	13.09
Scott	480	390	470	500	560	480	380	452	450	462	460.29	51.54	17.18
Marc	500	440	480	500	600	500	380	488	525	490	490.43	56.10	18.70
Pete	500	440	510	500	640	480	480	496	500	505	495.14	51.51	17.17
WashingtonD	420	360	380	425	490	390	372	428	450	413	409.29	39.19	13.06



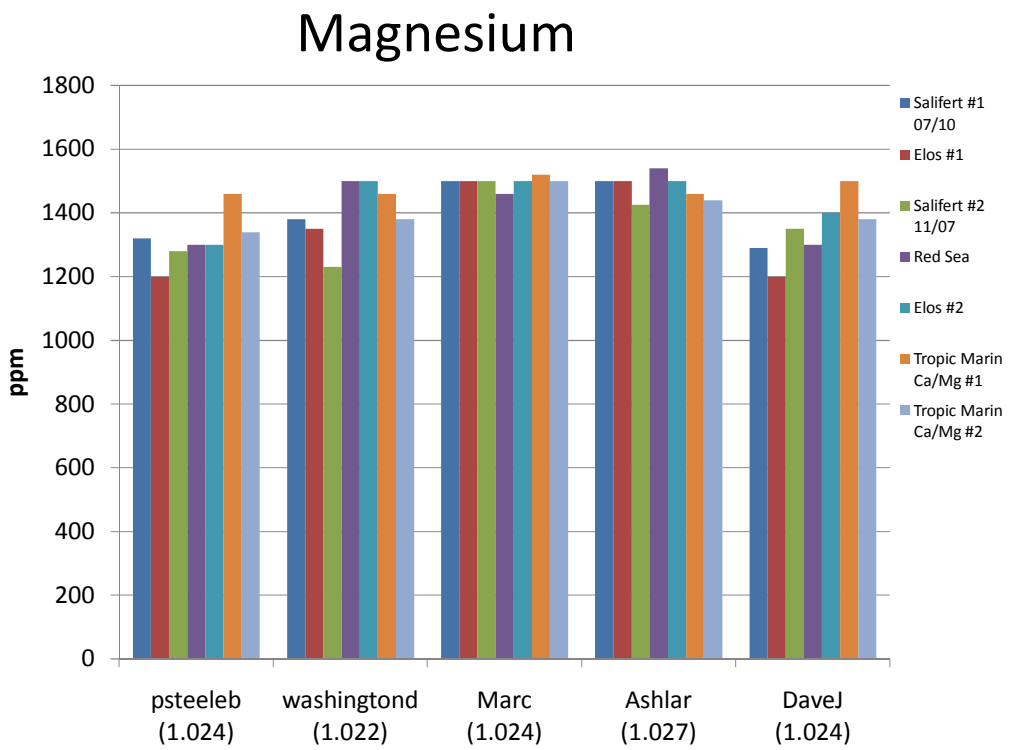
Phosphate

	Elos #1	Lamotte	Salifert #1	Salifert #2	Elos #2	Deltec	API	Mean	Mean w/o Hi-Lo	St Dev	Margin of Error
DaveJ	0	0.01	0.03	0.03	0.1	0.1	0	0.04	0.03	0.04	0.02
Scott	0	0.2	0.03	0	0.05	0	0	0.04	0.02	0.07	0.03
Marc	0	0.1	0.1	0.1	0.1	0.16	0	0.08	0.09	0.05	0.02
Pete	0	0	0	0	0	0	0	0	-	-	-
WashingtonD	0	0	0	0	0	0	0	0	-	-	-



Nitrate

	Salifert #1	Salifert #2	Salifert #3	API	LaMotte	Mean	Mean w/o Hi-Lo	St Dev	Margin of Error
DaveJ	2.5	0	2.5	2.5	8.8	3.3	2.50	2.93	1.31
Scott	10	2	5	5	8.8	6.2	6.27	2.89	1.29
Marc	25	2	35	30	36	26	30.00	12.44	5.56
Pete	5	2	2.5	5	0	2.9	3.17	1.91	0.85
WashingtonD	0.2	0.1	0.2	0	0	0.10	0.10	0.09	0.04

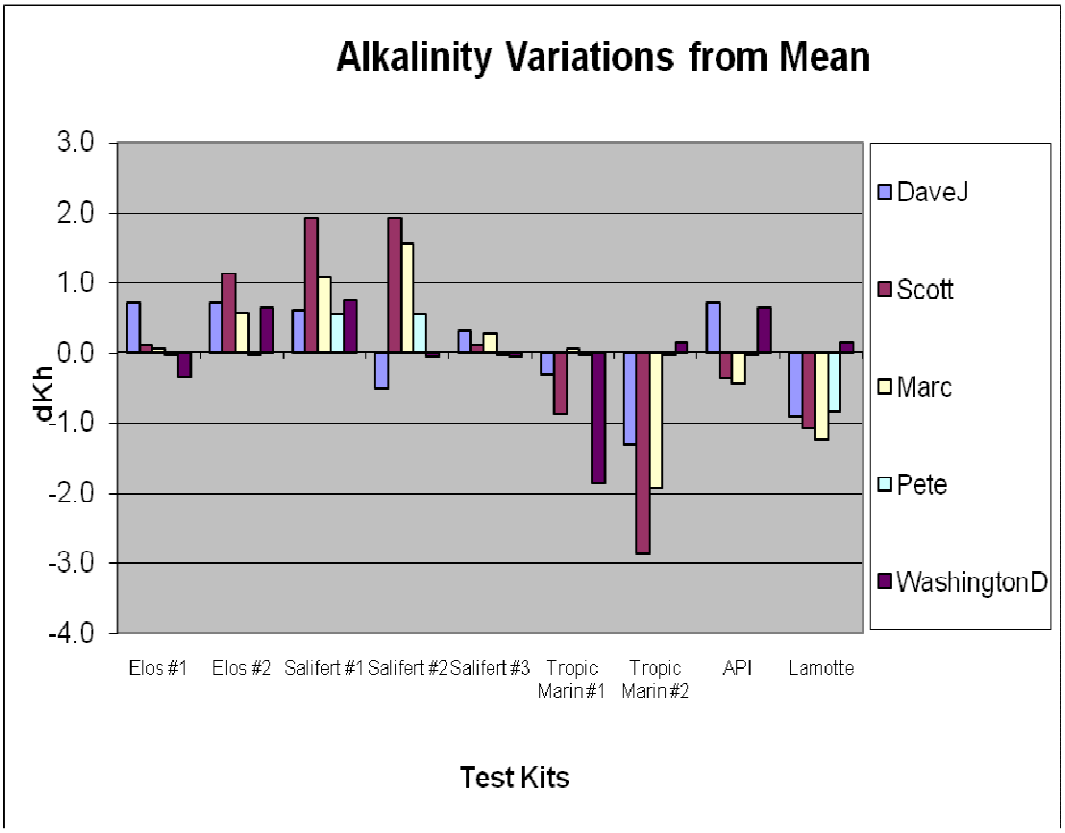


Magnesium

	Salifert #1	Elos #1	Salifert #2	Red Sea	Elos #2	Tropic Marin Ca/Mg #1	Tropic Marin Ca/Mg #2	Mean	Mean w/o Hi-Lo	St Dev	Margin of Error
DaveJ	1290	1200	1350	1300	1400	1500	1380	1346	1,344	88.13	33.31
Scott	1500	1500	1425	1540	1500	1460	1440	1481	1,480	37.46	14.16
Marc	1500	1500	1500	1460	1500	1520	1500	1497	1,504	16.66	6.30
Pete	1320	1200	1280	1300	1300	1460	1340	1314	1,308	72.28	27.32
WashingtonD	1380	1350	1230	1500	1500	1460	1380	1400	1,414	89.28	33.75

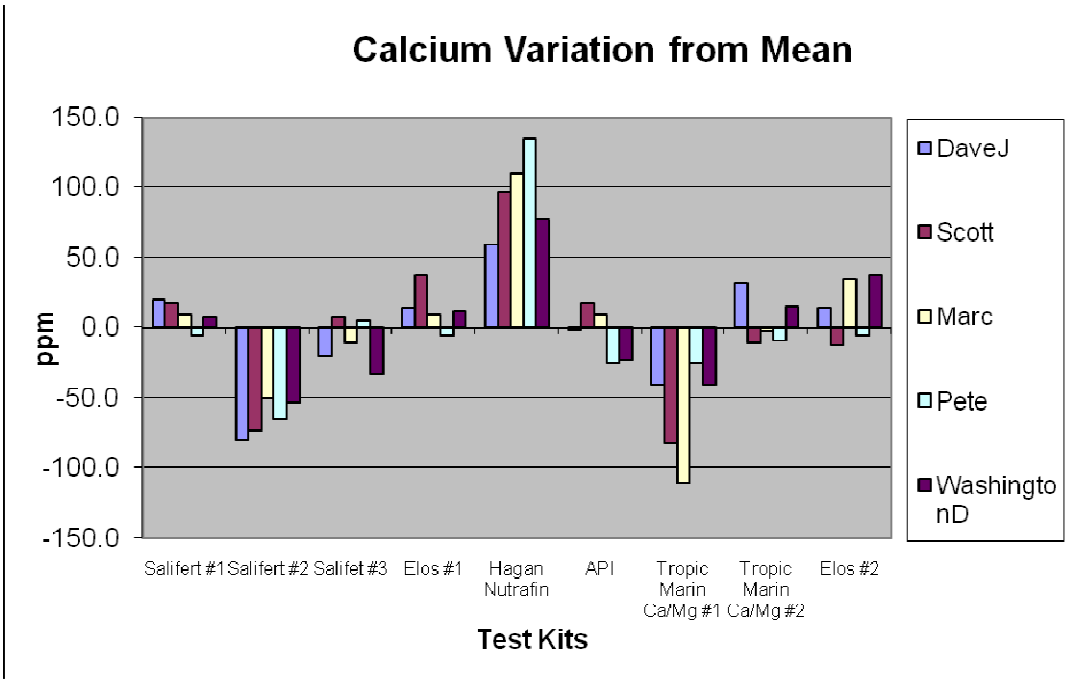
MEAN ANALYSIS – KIT ACCURACY

The following is the analysis of Kit Accuracy. By determining the mean of all Test Kits, we are able to see how accurately a specific test performs. Assuming the mean is an accurate representation of the true value, a Kit that performs and reflects a value closest to the mean will be considered more accurate, thus the ideal score for a Kit would be 0, the farther a value from 0 (either plus/negative) a Kit gets the more inaccurate it is considered.



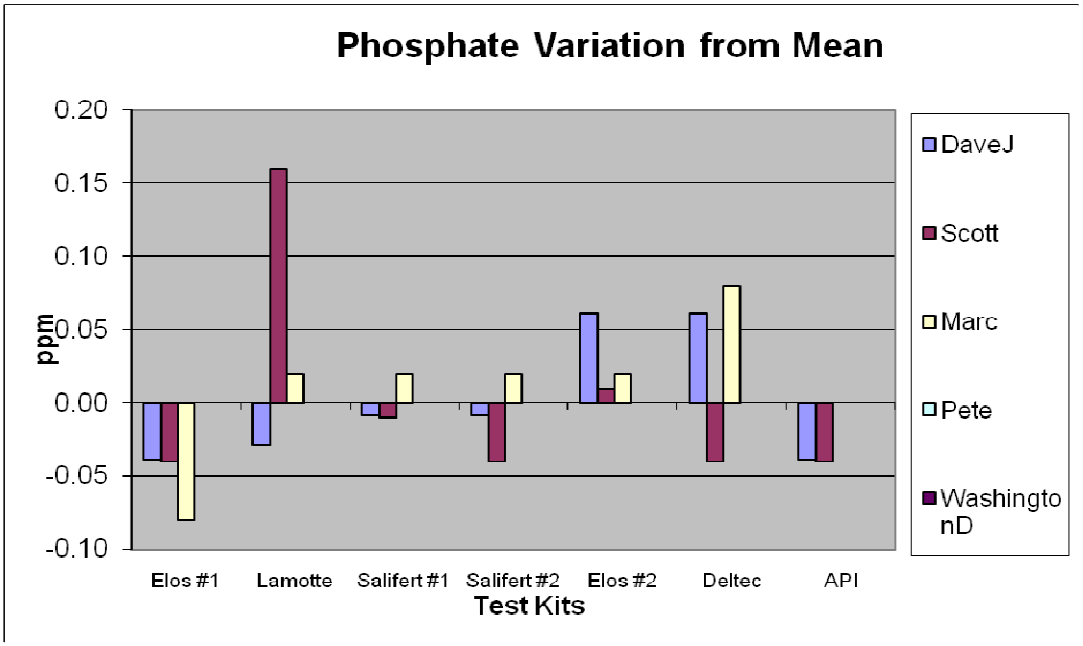
Alkalinity

Elos #1	Elos #2	Salifert #1	Salifert #2	Salifert #3	Tropic Marin #1	Tropic Marin #2	API	Lamotte
0.1	0.6	1.0	0.7	0.1	0.1	-1.2	0.1	-0.8



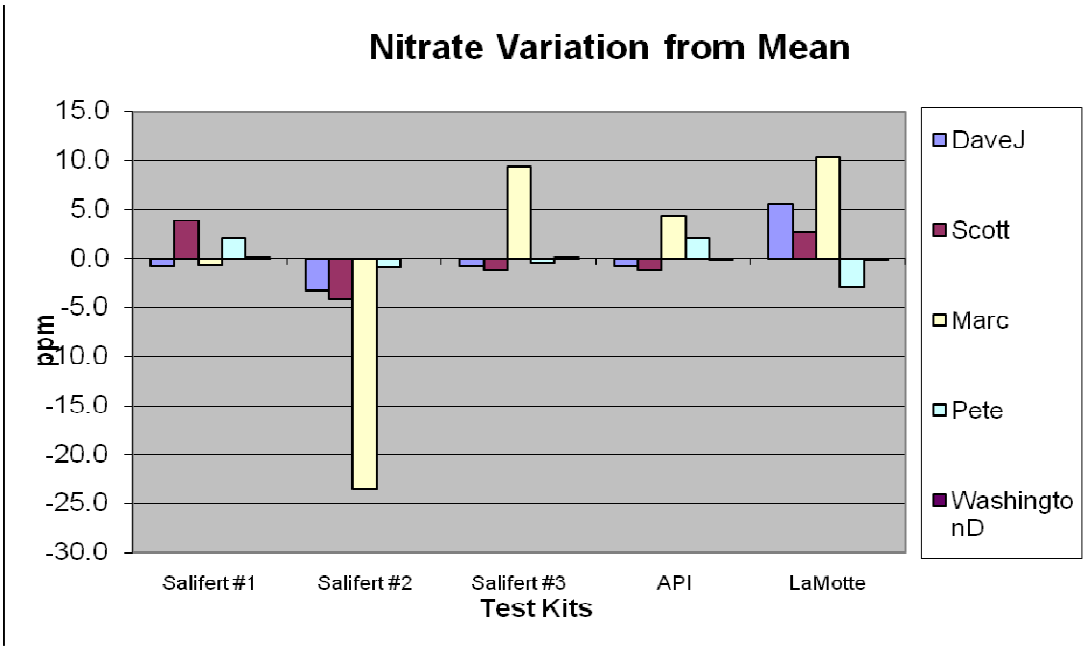
Calcium

Salifert #1	Salifert #2	Salifet #3	Elos #1	Hagan Nutrafin	API	Tropic Marin Ca/Mg #1	Tropic Marin Ca/Mg #2	Elos #2
9.8	-64.2	-10.2	13.8	95.8	-4.2	-59.8	5	13.8



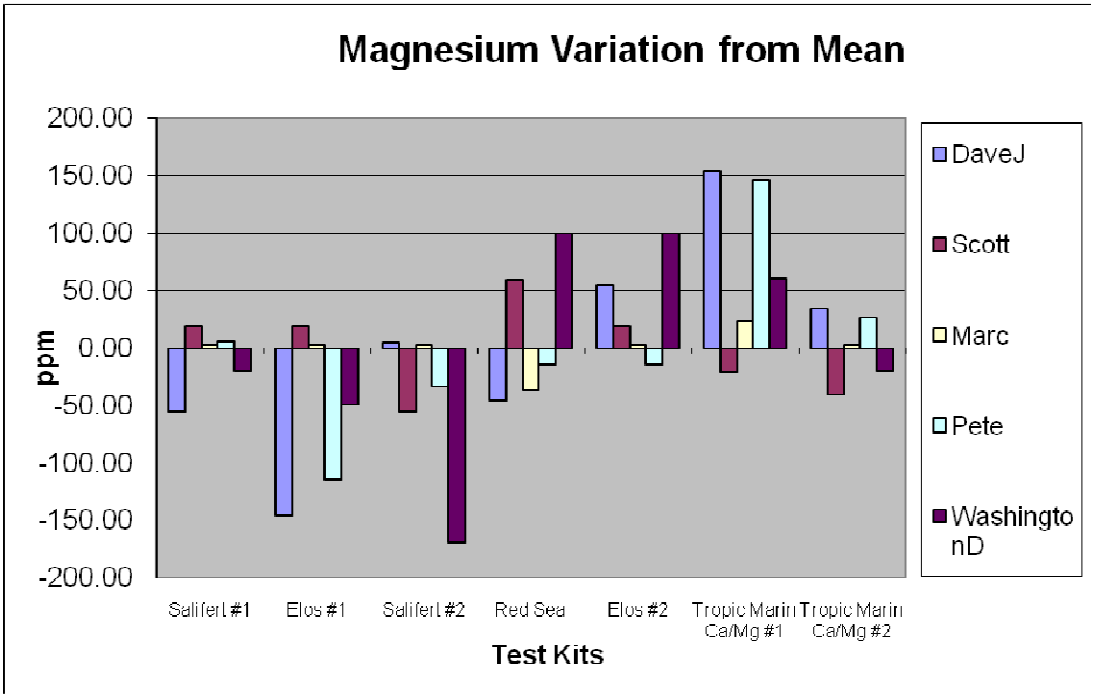
Phosphate

Elos #1	Lamotte	Salifert #1	Salifert #2	Elos #2	Deltec	API
-0.30	0.03	0.00	-0.01	0.02	0.02	-0.03



Nitrate

Salifert #1	Salifert #2	Salifert #3	API	LaMotte
0.94	-6.38	1.44	0.90	3.12



Magnesium

Salifert #1	Elos #1	Salifert #2	Red Sea	Elos #2	Tropic Marin Ca/Mg #1	Tropic Marin Ca/Mg #2
-9.57	-57.7	-50.7	12.43	32.43	72.43	0.43

CONCLUSIONS AND OBSERVATIONS

The Group that conducted these tests got together and over a period of a couple of weeks, we discussed at length the various results we got, why we thought we got them and what we can conclude from this exercise. The primary finding we came to agreement on was that of all the Test Kits used, the majority of them were accurate enough for hobby use, regardless of price.

We found that the difficulty and accuracy of a Test Kit tends to be a two-prong animal, the first being the natural accuracy/sensitivity of the agents used in the test kit itself. The latter being the method of reading the results once the test has been concluded. The use of color charts was based on individual vision and lighting conditions and in some cases was very difficult to quantify shade differences (PO4 Kits for example). These two issues combined together build in a natural accuracy gap that is difficult to eliminate. Proper lighting is essential as is a white background to view against.

There were a few Test Kits that caused us some concern from a usability aspect, the Tropic Marin Ca/Mg Combo kit for example was difficult to read due to color tint in the water. One Kit in particular that caused us concern due to the drop size that the dropper produced was the Tropic Marin Alkalinity test. We had two of them and they rarely matched and the difference between them was large ranging from 0-2dKH which is a very large margin of error. Our conclusion on the TM Alkalinity Test was that the dropper was unreliable and prone to over/under dropping reagent. We also noticed that the Hagan Nutrafin Calcium test was not reliable; it was always off to the high side. We also felt that the Elos Kits tended to be easier to use and required shorter times for PO4 and Nitrate than some of the others, this combined with a reasonable accuracy (even between different kits) make them an attractive option. What really surprised us was how well API Kits did, these are some of the most economical Kits around and they did reasonably well against the more expensive ones.

ANALYSIS OF MEAN VS 'LAB GRADE' (AWT.COM)

Once we completed all the tests we sent out samples to awt.com for comparison purposes. What we found was both helpful and troubling. The raw numbers are below compared against the mean results of the Test Kits above. As you can see, they were accurate within hobby tolerances, except with Calcium and Magnesium, these were dramatically and (we concluded) dangerously low.

Results of the AWT.com tests for the two samples we sent:

	Pete	Mean	DaveJ	Mean
Alk	7.31	8	9	9.3
Ca	306	505	284	460
PO4	0	0	0.08	0.04
NO3	2	2.9	0.7	3.3
Mg	1012	1314	1010	1346

As you can see the numbers fairly close to the means of the tests, but with two exceptions, Calcium and Magnesium which were off by quite a margin. These numbers were so significantly off from our results, we decided to get to the bottom of the differences in greater detail. We contacted all the manufacturers and asked if Salinity or time (1-7 hours) would make a difference in the results. Of the 3 manufacturers who actually responded to our request for Technical Help (LaMotte, Tropic Marin and Red Sea), they all indicated it would not impact accuracy at all. We verified this with an independent Professional Lab as well. We then sent requests to AWT.com for feedback on why their results varied so much. Here is there response verbatim…

AWT.com – Dated 2/08/2008

> Hello David,
>
> First, I'd like to thank you for bringing your concerns/questions directly to us. I believe that I have some answers to your questions. First, as far as your calcium level is concerned. We use an ion-specific electrode to measure calcium in the water. This probe is sensitive only to calcium IONS! That is, it only "sees" Ca++ in the water. However, at any given time in your water, as much as 20% of your calcium can be found in temporary associations with other compounds such as carbonates, bicarbonates, chlorides, fluorides, ect. The electrode does not see these bound forms. Now, the vast majority of the bound calcium is bound with carbonate. Only very small quantities are with the others, but certain other conditions, like pH, alkalinity, dKh, magnesium, ect can affect the normal 20% binding ratio. Effectively, this situation will cause a certain amount of your total calcium to be invisible to our electrode. Please note that your corals don't really care what form the calcium is in. They will preferentially choose calcium ions in the water over calcium carbonate because it is already ready to be deposited as skeletal material, but they don't really care one way or the other.
>
> As for magnesium, again, the interaction of other ions in the water can affect magnesium test results. In this case, a hobbyist-grade test kit is positively interfered with by the presence of calcium ions. The testing process that we use for magnesium uses a process that precipitates the calcium out of the water sample prior to the magnesium testing to eliminate this interference, so the value we are giving you is the total magnesium,(bound and ionic)that is in your water. Let me give you a practical example. On many of the "Reef Central" type forums, aquarists are advocating a magnesium level of around 1400. Why would they do this, since the oceanic concentration is only around 1200? If you know that calcium presents a positive interference with the magnesium test, then having a magnesium level of 1400 will bring you closer to the actual value of 1200. Likewise, if you try to keep your magnesium at 1200, then ,again, because of the positive interference of calcium, your actual magnesium is now several hundred parts lower than 1200. Really, what you are seeing is two different ways of measuring the same parameter. The important thing is not really the actual values, but is the stability of those values over time. If we consistently give you a calcium value of 280 calcium ion, and your titration test consistently gives you a total value of 400, then everything is great. You can tell how much of your calcium is ionic and how much is interacting with other molecules, and even get indirect information on your alkalinity and magnesium levels. You see, the stability of the two values over time give you much more information than any one test. This is really what AWT.com is for. We are a method of getting even more information about what is going on in your water than you can get by yourself. I hope this has helped you. Please don't hesitate to contact us with you questions in the future."

In order to handle the response to the above, we engaged another Professional Testing Lab, one that has done work with Public Aquariums and some of the manufacturers of the Test Kits themselves to give us their feedback on the response above. Here is their response.

> David,
>
> Regarding ISE's, they can be used to obtain accurate measurements but they also have a lot of caveats. It is true that they only measure free ions. This is why manufacturers recommend using ionic strength adjustors, optimum pH ranges, slope determinations in the range of quantitation, and preferably standard methods of addition for accurate results. We have found the calcium ISE's in particular to be more prone to interferences and influences from the aforementioned phenomena. This is precisely why, we use an atomic absorption spectrophotometric method to measure total calcium. Even this technique must be managed carefully as it too suffers from interferences.
>
> I do not understand what the author below is trying to explain regarding magnesium. Co-precipitation methods are actually quite dated and because of other interferences and much improved spectroscopic methods, most modern laboratories use more sophisticated techniques. We use

> atomic absorption spectrophotometry for magnesium as well. This element is very sensitive in the flame and suffers from few interferences typically found in natural and synthetic seawater.
>
> The alkalinity, calcium, and magnesium are all important in seawater and can be easily measured incorrectly when using more subjective techniques that require attention to their plethora of interferences.

Our conclusions based on the Calcium Test response: Testing using the probes they use, unless the hobbyist knows the amount of non-free ions is pointless for true reference if theirs is the only test being conducted. Corals and other tank inhabitants utilize more than just free Ion's. The goals we set for our Reef Tanks (i.e. 440 ppm Calcium), need to be consistent with any tests we run. While their test is probably accurate, without a number of the non-free ions, it's not very helpful to us for use in our tanks because it leaves an unknown gap in Calcium. According to the quote attributed to Randy Holmes-Farley, "10-20% non-free ions exist in our water"[1]. That means that using their probes, there is an automatic 10-20% error rate compared to what we test for and that unless you run two tests to see what the difference is, you have no idea what your total Calcium is in the tank. This is not an acceptable alternative to us, so the calcium test using those probes can't be relied upon if it is your sole source of information. You can't plan or maintain a tank with a 10-20% unknown for a key component of your water chemistry., so it still comes down to doing a test at home to gain the two numbers as they stated in their response.

Our conclusions based on the Magnesium Test response: While their reasoning appears accurate, it fails to address the key point that their number is wrong to the low side AND that fact that tests that pull the magnesium out of solution for testing, or the calcium out as the case may be, these are unreliable and outdated tests. This may be the method they choose to use for any number of reasons, but it lends itself to inaccuracies due to a number of factors. While an accurate test can be obtained by their method and procedure, quite clearly there is a problem with the two samples we went and the tests conducted on them. We won't go into their assumption that hobbyists target 1300-1400ppm to off-set real test results, because that does not reflect accurately why we set such a target. We set that target to improve the bio-mechanics so that higher Calcium and Alkalinity helps corals achieve in growth and bio-function…. Higher Mg, Higher Alk, Higher Calcium equates to better utilization of Calcium by corals.

We do agree that stability is more important than maintaining a specific number for these tests, however we also believe that using a service that provides only partial results is not the way to go about maintaining this stability. You need to augment that service with your own testing.

FINAL NOTES

While this was not intended to be a scientific and definitive exercise, we feel that we have answered some of the basic questions that we set out to answer. The primary one being exactly how accurate are the various kits we employ to test our water. A side question was the accuracy of a service such as AWT.com. While their tests appear to be problematic in certain areas we will not take it to the point of discounting them as a source of testing your water or suggest you avoid their service completely. What we do suggest is that you do not rely upon them as a baseline or as your sole source of chemistry parameters for your tanks until they fix their problem with Calcium and Magnesium, if it's even considered a problem. There is no question a service such as theirs, priced as it is, could be a very valuable addition to our hobby, but until those issues are addressed and reconciled it will be

difficult to recommend them as the definitive source for testing, you still should run your own Calcium and Magnesium tests (at a minimum) to insure you are getting an accurate picture of how your tank is doing.

We also would like to highlight the advantages of using kits that require the fewest steps and easiest reading mechanisms. This is strictly a user dependent situation, but the various kits we utilized did point out that not all test kits are equal in ease of use, just fairly accurate when put up against one another.

What does the future hold? As indicated by the title of this document, this was Phase 1. Phase 2 will take place in the near future and will strive to eliminate any user specific issues such as knowing which samples are being tested and user interpretation of results. We will accomplish this by using a blind test, where the tester has no idea which sample is being tested and using a buddy system to read results. We will also use a higher quality professional lab to test these results that more accurately report the values we are comparing their results to. We will also attempt to quantify ease of testing and reading of results into our exercise, hoping to come to some agreement on Kit recommendations.

Table 1 – Test Kits Utilized

Manufacturer	Test Kit(*)
ELOS	ALK(2), CA(2), PO4 (2), NO3 (2), MG (2)
API	ALK, CA, PO4, NO3
LAMOTTE	ALK, CA, PO4, NO3
REDSEA	MG
SALIFERT	ALK (3), CA (3), PO4 (2), NO3 (3), MG (2)
TROPIC MARIN	ALK (2), CA/MG (2)
HAGAN	CA
DELTEC	PO4

(*) Number in parentheses indicates the number of identical kits used (multiples).

References:

[1]Randy Holmes-Farley - Reefkeeping Online Magazine - April 2005 "Electronic Calcium Monitoring" (http://www.reefkeeping.com/issues/2005-04/rhf/index.php)