Statistics in Aquaculture:

How it can help you make good decisions on the farm

Many deplore statistics. When the topic is brought up, usual responses are: "We are a production facility, not a research lab," or: "You can make statistics say anything." These retorts reveal a lack of understanding of what the basis of statistics really is and how useful it can be in helping fish farmers make sounder decisions.

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So, at the risk of immediately losing the reader, this month's column will attempt to explain basic statistics in plain language (using as little statistical jargon as possible) – and WITHOUT mathematics. It will attempt to illustrate what statistics can actually do in crunching data and illustrate how statistical analysis can help you not be misled as to what a product or husbandry practice can or can't do.

When fish culturists come across a new product, or suggested new practice, most will ponder for a while, intuitively reject the idea outright, or say: "Just give me that to try and I will be able to tell if it works." Unfortunately, it is easy to get fooled that something works when it doesn't, or doesn't work when it does. A decision misstep could be a missed opportunity in production savings, or a waste of time and expense if something is adopted that doesn't work. Statistics is simply a tool to help you decide through all the noise of uncertainty.

To start – statistics is only a formalized way of presenting data that considers the fuzz or noise in the numbers (jargon alert: "variation") AND of portraying whether an observation is probably real or not. That is all. No magic. It DOES require you to measure something (generate numbers vs. a "look-see"), and yes, this formalization can be abused by the nefarious (or ignorant).

This noise/fuzz/variation is the essence of how statistics helps present the data and helps you make a decision on a difference between things.

Figure 1. How can I tell if something is really working on my farm?

To fully appreciate and understand this, it is critical to review what this noise or variation is and how it is fundamental to nature and therefore can make differences difficult to see. To start, taking an example of fish sizes, Figure 2 illustrates what we almost never see. In the tank on the left, labelled "WITHOUT," all fish are exactly the same size. When something is applied to another group of fish in another tank ("WITH" on the right), all fish respond exactly the

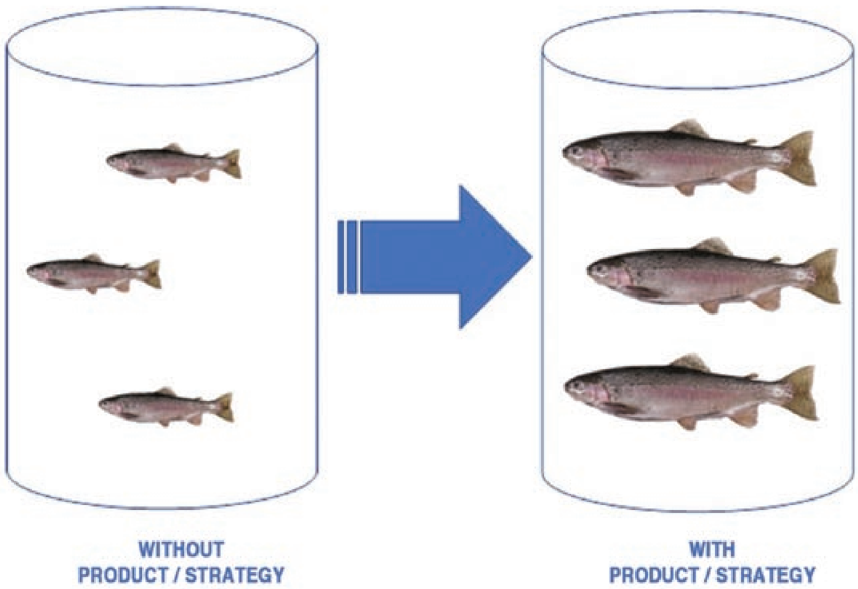

Figure 2. No variation.

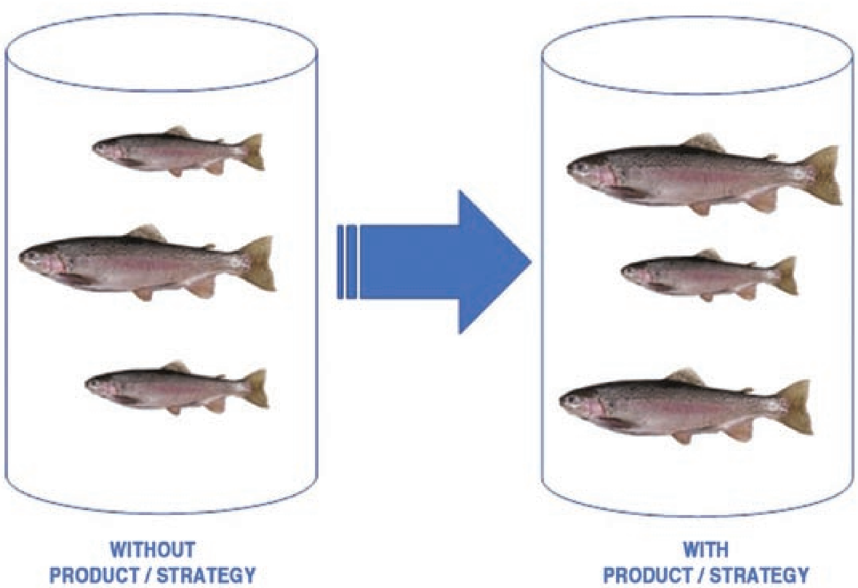

Figure 3. Variation before and after with low numbers.

same way. So, the decision is easy and clear: whatever was applied to the fish worked - no statistics necessary. Chances are, the product/procedure worked although an extreme skeptic might say, I want to try it a couple more times to see – and that wouldn't be a bad thing! The decision might very well be: "If the price is right – I am sold!"

However, in the "real world" we are trying to cultivate biological organisms, and as we know, there is that thing called "noise" or variation in fish sizes: before and after (even with the tightest grading)! Figure 3 shows that fish at the start ("WITHOUT") are not uniform in size AND, for various reasons, the effects of anything we try ("WITH") usually does not produce uniform results. This is the "noise," "fuzz," or variation inherent in nature. It is the sum of all the things (some we can minimize and some we cannot) that cause the fish to grow at different rates. These include, but aren't limited to, differences in: genetics, feed consumption, behavioral interaction, water flow, lighting, care bias, vaccination status, etc. So, again, because of the sum of these controllable and uncontrollable factors, the fish will start out with different sizes, and the effect of what we are trying to evaluate will produce variable and unequal results. Because of this noise, with the example in Figure 3, we are left scratching our heads wondering if the product/procedure really did something, or if any difference is just imagined and by chance.

Although this example uses size of fish, parameters of interest could also be things like: inventory, feed conversions, growth rates, mortality, etc., depending on what a culturist is interested in and the specific claims of a product or procedure. Furthermore, the example provided involves individual fish, whereas more typically we evaluate the performance of whole containers (tanks, raceways, ponds, etc.) against each other (more on this later). But, the point is the same: like fish size, these other parameters will also have inherent noise and variation in what can be measured, both between the "with" and "without" groups and within each of them. This is what can make comparing difficult.

So, what can be done to "see" any differences above all this noise and variation of nature? This is where statistics comes to the rescue. It guides us in how to interpret results in the wake of the noise, or whether the results are decipherable above the noise. A statistical analysis considers three aspects of the results and does a calculation to tell you whether the difference is probable or not:

1) The **degree of noise/variation** (Here: How much does fish size vary before AND after?)

2) How large is **the difference between the two groups** that was produced before and after (Here: How large is the growth difference?)

3) The **overall number of things** that you are comparing with each other (How many fish are we comparing "with" to "without")

Statistics does this AFTER the fact, and says: "Yes, the effect is probably real," or: "No, there is too much noise (variation), and/or you haven't compared enough fish/tanks/raceways, and/or the difference before and after isn't great enough to tell, given the above." Jargon alert: the analysis does this with numerical tools like a statistic called the P-Value (or "Probability-value") that will give a magnitude of how likely it is that the results are truly different.

Now, a real power of statistics (there is a pun in there for any stats geeks), is that it can actually guide you into designing a comparison BEFORE you do it. It can give you a rule of thumb – generally how many fish or tanks/raceways/net pens/ponds to use, given 1) the noise present and 2) the claimed or desired effect of the product, in order to increase the odds that you will see a real difference if it exists. It will tell you a stated "Power" of your proposed comparison and help you adjust so that confusion is minimized after the fact.

Statistics will recommend how many units you should be comparing (fish, tanks, ponds, etc.). It does this because within the calculations, the more variation there is, the more units are needed to clarify what is going on. Figure 4 illustrates this concept. So, this example has the same variation (noise) in fish size as in Fig. 3, but the number of fish we are looking at has been increased. Visually, you would most likely conclude that there is probably a difference. Again, statistics will calculate for you and give you a number, so you don't have to guess visually as to whether what you are seeing is probably real or not. You have heard that statistical jargon: "Reject the null hypothesis"? All this means, in this case, is that you have enough numbers to punch through the variation/noise to say that there probably IS an effect of the product/practice, and you can reject the notion that there is no difference.

The other concept that figures into the power of the comparison is the size of the effect. IF the product or practice produces a huge result (or you are only interested in a certain amount to make it worthwhile and want to know whether the comparison will probably "see" that difference), then the amount of noise doesn't matter as much (Figure 5). This is always desirable, but not always possible. Remember, the cul-

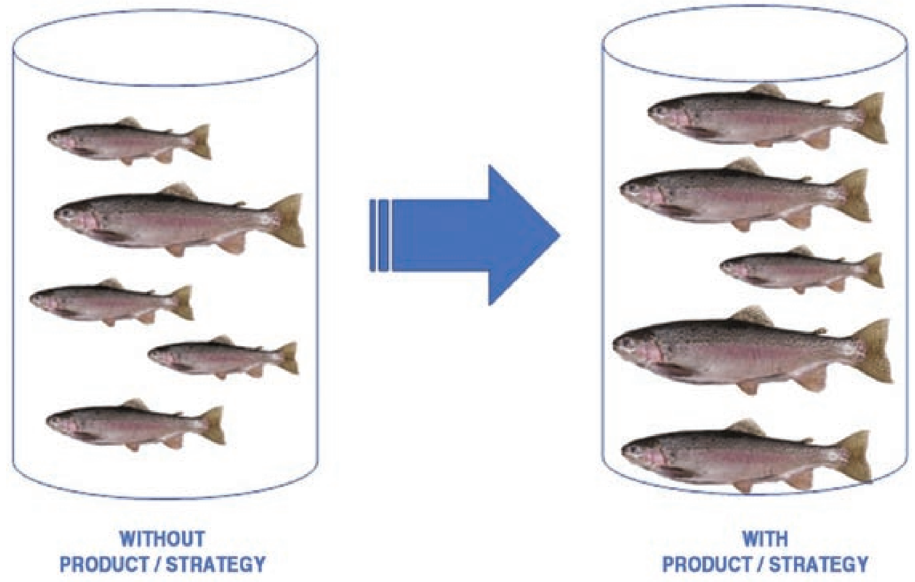

Figure 4. Variation before and after with more numbers to better assess.

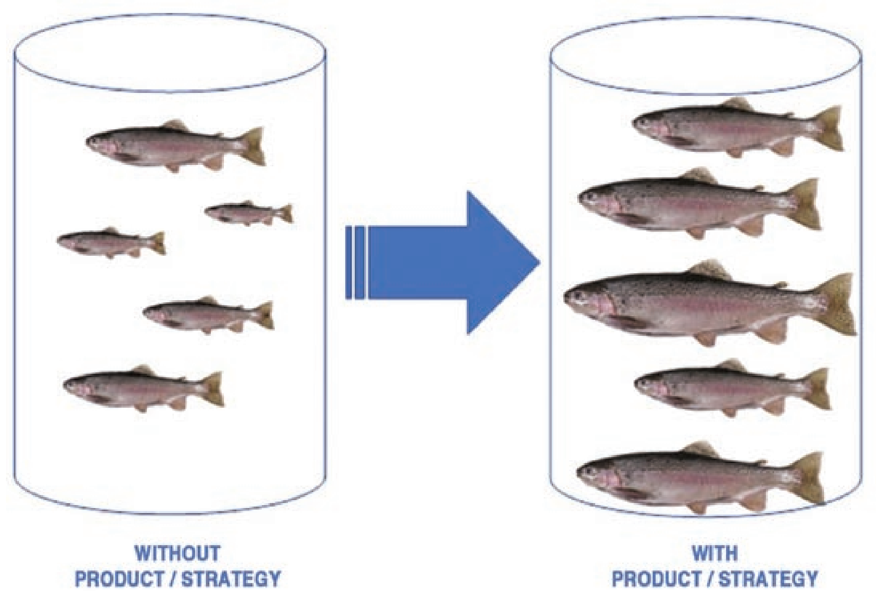

Figure 5. Variation before and after but with a large effect.

turist can reap massive benefits with only moderate effects, yet these can easily be missed if the comparison is not done correctly.

So, in summary, statistics helps you decide whether there is any real difference in our noisy world, when you want to determine the worth a new product pitched at you or when there is a new production strategy or practice that you are considering implementing (e.g.: densities). Simply put, it looks at the relationship between: 1) average difference before and after; 2) numbers used for that average (called: replicates); and 3) the noise or variation with those numbers, to tell you whether any observed difference is most likely real or not.

Some caveats to all this (and a bit of jargon - sorry). For statistics to do its calculations, and help you decide, the things that generate the data (fish, tanks, etc. - let's call them "units") should be independent. What this means is that they shouldn't influence each other (like fish eating together in a tank). So, we usually compare performances of whole "independent" containers (raceways, ponds, tanks, or net pens), for things that we measure for all the fish in a container: growth, FCR, mortality, etc. Also, statistics works at assuming no one is purposely or inadvertently favoring the results toward a certain desired outcome. This means that the assignment of tanks to "with" or "without" should be done randomly – not out of convenience – and people carrying out the trial should not know which are which (called: blinding). Even if you think there won't be a bias, there are all sorts of subtle and insidious ways that this can happen, making outcomes less valid.

Also, if variation is the key to detecting any differences, everything should be done to start out with units as consistent as possible and treat them as similarly as possible through any comparison period. This will reduce the noise, so the minimum difference possible can "punch" through and be detected.

One more thing: statistics isn't convenient. It will look at the variation and the desired or claimed effect and decide on how many units to compare in a trial. Unfortunately, it is not uncommon in aquaculture, that the variation/noise between containers, given the desire to see a certain magnitude of difference, can result in the need for an annoying number of required replicates. In the end, it may not be possible to do the trial at your facility and get any adequate insight. Statistics will say: "Don't waste your time!" This, however, is a useful decision and you will have to seek other sources of information/studies to help you make the call (but you can ensure the statistics done on these follow the rules you now know!).

Also, statistics JUST tells you information about how probable the difference between the "before" and "after" numbers is for THAT experiment. It doesn't make any conclusions about: cause, repeatability (will you get the same results next time), or biological sense (can a biologist make a case why it works?).

So, if you have followed to this point, it is hoped that you have a new appreciation for how statistics might help you make sounder decisions. Next time someone tells you they have this new product that will grow your fish 10% faster, ask if they will provide it to you to evaluate, then:

1) Find a consultant who knows something about statistics (maybe one of your farm-hands does).

2) Tell them what you are trying to do and what level of growth you want to detect (it may pay for itself if it provides a 5% increase - calculate that out!).

3) Ask them to work out how many tanks you need to compare in order to be fairly sure that a difference is real if one actually exists (tell him/her you would like to be 80% sure!).

4) Alternatively, if you only have so many tanks to compare, ask them to calculate how strong ("Power of the Test") your suggested comparison is to find a difference if there is one, given what you have.

5) Go for it, with the new knowledge that if a difference is produced with this product, you will probably see it above the noise/variation, because your comparison has been set up to see it the best way possible within your facility.

And if someone asks you whether you "believe in statistics," just nod and say: "Well, I understand the basic principles of what it tries to do for me, and how it can help me sort the 'B' from the 'S'." am

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