HOW NOT TO KILL YOUR FISH

THE ROLE OF STRESS IN FISH DISEASE

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As a preface to my remarks, I should say that I am directing them to the people who, however small they are starting, are doing so not as a hobby, but with the idea in mind of beginning a business.

It is difficult to sell the idea that a major cause of disease in fish is the aquaculturist. We want to have something or someone to blame, other than ourselves. It is so easy to say "Well, the fish got a nasty disease bug that's giving me a big problem and costing me a lot of losses." What do I do about it?" "Well, let's treat 'em," (with chemicals, antibiotics, the kitchen sink, or whatever comes to mind).

Let's back up from this typical money losing scenario for a moment and examine the reason that the fish got sick in the first place.

I have been in this business for a long time, diagnosing fish diseases. During that time, every case of fish disease that I have ever handled confirmed what I was taught by a wise old man, Dr. Stan Sniezko. MOST FISH DISEASES ARE STRESS MEDIATED. FISH DISEASE AND THE ORGANISMS ASSOCIATED WITH IT ARE ACTUALLY SYMPTOMS NOT CAUSES. Although there are exceptions to every rule, bacteria and parasites are rarely so invasive that a healthy fish can't resist them (viruses are another story, but there are only a couple of them that affect warm water fishes and they are rather rare).

What the aquaculturist often fails to recognize is that if he would do his best to minimize stress in his fish, most of the disease which happens would be avoided, and no treatment would be necessary. This failure is so common, it even has a name, PMD. Translated, this means poor management disease. More fish die of it than anything else!

An example of how stress mediates disease is provided by the following, which is an actual case history. It is not intended as an indictment of fish haulers as a group.

Unlucky Fish Company pulls up to farmer Jones pond with a load of channel catfish on board and says, "Have I got a deal for you!" He then proceeds to sell farmer Jones (cheap!) a bunch of catfish for his pond. Somehow, it slips his mind to inform farmer Jones that the fish have been on the truck for 72 hrs. during which time the truck broke down twice and the aerators failed each time.

The next day, farmer Jones notices a few dead catfish. Seven to ten days later, the stocked fish begin dying like flies and farmer Jones shows up at the pathology lab with a cooler full of dying catfish. These channels look like they have been dead three weeks, but are still wiggling weakly. Examination shows that they have 4 different external parasites, any of which would be sufficient to kill them. They also have 2 kinds of bacteria, both highly lethal to catfish, one tearing the hide off the fish and the other causing a blood poisoning.
Farmer Jones says, "What's killing them?" My reply is that something has stressed the heck out of these fish. Every disease organism that happened to be around is lining up like hogs at a trough to see which one can kill the fish first. Farmer Jones says, "Oh my gosh, what's going to happen to all the other channel catfish that are in my pond?" My reply, and I've never seen it fail is, "Nothing."

The fish on the truck were heavily stressed by crowding, high temperature, and high ammonia levels, combined with low dissolved oxygen. After a few days, they were crawling with bacteria and parasites of all kinds. The fish in the pond, well fed, content, uncrowded, and with plenty of oxygen, resist the introduced bacteria and parasites as though they were not there.

It's different in aquaculture you say? Not really. Naturally there are greater stresses than in an ordinary farm pond, but a philosophy of stress management can save the aquaculturist much money and many headaches on his way to a crop of fish.

What we are talking about here is planning ahead. There are some stresses on fish about which we can do very little. However, there are many that we can head off and deal with before they become a problem. The reason for planning ahead is that once these things become a problem, it is too late to deal with them, and one is doomed to suffer the consequences.

The most common of these is low dissolved oxygen (D.O.). Once your fish suffer an episode of low D.O., it is almost certain that disease will follow. Most often this is within 7 to 10 days. The cost to you will be money, time, chemicals, growth, and your food conversion to treat it. The disease will be whatever is available in your pond. The type and severity of disease will differ, depending on the time of year and how stressed the fish were.

It makes much more sense to test the oxygen in your pond often, especially just after dawn in order to catch low trends. You must learn to predict what weather conditions precede a D.O. crash in your ponds. They will not be the same for each pond. Often, a long dry spell followed by a 2" rain signals an all night session with the paddle wheel aerator, perhaps several nights in a row. You must have the equipment already on hand and know how to use it. And, I am sorry, but you must learn that you can't deal with it tomorrow. Tomorrow they will be dead. Your bed may sing you a siren song, but don't listen to it, because it can spell the difference between profit and loss.

Fish in an intensive culture situation must be handled occasionally, which is a stressful experience for them. You can help to minimize this stress by handling them in water which contains 0.5% salt (with no additives). This is about 4 pounds of salt (sodium chloride) per 100 gallons of water. You should also make it a practice to haul fish in this mild salt water.

Fish go into shock by losing chlorides through the gills. Chlorides are one of their most important blood components. When stressed, the fish lose control of their ability to conserve chlorides. Salt in the water at 0.5% almost exactly matches the amount naturally found in the fishes blood. A fish in such water gains chlorides back as fast as they are lost. This acts just the same as an IV following surgery does for people. The fish are prevented from going into shock. When the stressful situation is past, the fish
regains control of its blood chlorides and will perform as though the stress had never happened.

There are many other stresses on fish. Some of them are very subtle and difficult to identify without special equipment. They can place a large burden on the fish which it must overcome before it can use energy to grow. All these stresses may add up to express themselves as disease.

One common one is the frugal farmer who has bought too much feed at one time. To save money, he feeds this feed to his fish regardless of how old it is, or whether it got wet, until he runs out. He may wonder why his fish get sick often, don’t convert feed to fish flesh well and don’t resist other stresses as well as they did before. Feed older than 3 months is suspect for lack of vitamin C and probably has rancid fats and oils. Feed that gets wet accidentally will get moldy within hours in warm weather, and it won’t necessarily turn green. Mold toxins are subtly to acutely toxic to fish.

Raising fish is hard enough without subjecting your animals to this kind of nutritional stress. It doesn’t actually kill them usually. It just makes them harder to raise, and who needs that? All you have to do is adjust your feed order so your feed is always fresh, and discard any feed that gets wet if it cannot be used that day.

The smart fish farmer is always looking for ways to relieve stress on his animals. Not only do they perform better for him, but they will then provide a better product to his customers who will remember and be back next year for more. Aquaculture is simply animal husbandry of aquatic animals. The principles are the same with any species in confinement. Only the specific requirements of each animal differ.

An experienced person in animal husbandry is less likely to attempt to make his animals conform to his wishes. He is more likely to conform his actions to his animal’s needs. A good animal husbandry man learns to speak the mute language of his animals, and he listens to them. A husbandry man must have a feel for his charges and be sensitive to what they are trying to tell him. They will always tell him when something is wrong. They may even tell him what is wrong if he is bright enough to listen. A person who remains deaf to his animals often has “bad luck” in culturing them.

Aquaculture is not a get rich quick proposition. It is a job! It can be a tough job! It is an art! Some people have the touch and some don’t. It is almost a matter of attitude. Many problems in aquaculture are only manageable if one heads them off before they develop (listen to your animals!) Once these problems develop fully, there is nothing that can be done about them, except to use the aquaculturist’s traditional cure for everything, aspirin and Jack Daniels.

The next common misconception is that water is the same everywhere, or, "Water’s water isn’t it?" Well no, it isn’t. There is one fact rarely appreciated by the beginner at aquaculture, but one that holds true in every case. Each and every body of water is unique. There are so many parameters, so many variables in the way that a body of water will react to the fertilizer that one applies or to chemicals used to treat fish disease, that books written about the subject of aquaculture are, and will remain, only approximations. From these approximations (unfortunately through trial and error) the aquaculturist must extract those things which work on his pond, and those things which do not.
Often, only way that one learns what not to do is through the wholesale deaths of the species being cultured. Quote, "But the book said the treatment for this disease is ... parts per million, and that's what I used!" Unquote. Not in your pond its not, or not in your pond at that time of year its not, or not in your pond when the oxygen is that low its not, or not in your low alkalinity water its not, and so on, almost endlessly.

Problems

The first big barrier in aquaculture is oxygen. You must load your ponds, (tanks, cages, etc.) with many pounds of animals per acre (cubic foot, gallon per minute). This loading is well beyond any natural ability of the pond to deal with the waste products produced, or supply their oxygen demands, without occasional wild environmental swings. These swings happen most often when the weather conditions are less than ideal (that is, often). One of the consequences of high loading is the production of large amounts of ammonia. Ammonia is produced as a by-product of the fish's protein metabolism. This fertilizer results in artificially high populations of one celled plants (phytoplankton) called algae. This is fine you say. Don't plants produce oxygen and isn't that what we want more of?

Well yes, to a point. As with all things, one can get too much of a good thing. Your author has seen fish die in droves because the oxygen was too high and before the fish recognized this, they were too buoyant, couldn't go down and died of oxygen gas bubble disease. The other side of the coin is that the same plants that produce oxygen when the sun is shining, use it when the sun is not shining, or even when the sun is not shining enough, such as a cloudy day.

Since the sun provides the energy that drives the system, lack of sunlight leaves the algae starved for energy. They can tolerate this lack overnight. If this night is followed by a day which is also deficient in light intensity... Only one or two repeats of this scenario is sufficient to cause the collapse and death of the algae population.

This has a twofold effect. In the first place, all the dead algae cells now present the bacteria of the pond with an enormous increase in the amount of food available. They respond to this food with a logarithmic (2 4 8 16 32 64) population increase, all of which use oxygen in the process of growing and dividing. These bacteria then rapidly use up all the oxygen present. At the same time, with most of the algae dead, there are few plants available to generate more oxygen when the sunlight intensity returns to normal. This is serious, since oxygen diffuses poorly in undisturbed water. The rate is so slow that people have difficulty believing it (something like an inch a century!). By the time all this has occurred of course, most of your animals are dead due to lack of oxygen and those that aren't dead will die later due to stress induced diseases. It is easy to do the above, and it will happen. It is one of the most common occurrences in aquaculture. Because of this, the aquaculturist must have on hand, and be prepared to use, mechanical aeration to restore or attempt to maintain livable oxygen levels in the pond, until the algae populations recover. The trick is recognizing when such a situation is likely to occur and heading it off before it develops. No one will be able to exactly predict for you when this is likely to occur on your ponds. You must learn this through experience. Be watchful. Don't be too tired and go to bed, trusting to luck. You must do for your animals when they need you and rest later. It is the difference between profit and loss.

Sometimes, events that set off the above scenario do not seem logical. Fish farmers have learned for instance, that a cool rainfall on a summer's afternoon often spells...
oxygen problems that night. This on the face of it does not compute, since cooler water holds more oxygen than warmer water does. Perhaps a discussion of the pond cycle through the year is in order here.

The Water

There is much to know about water, especially your water. Water is your animal’s whole world. They live in it, breathe it, excrete their waste products in it. It is their environment. Physically, water has a number of properties of which you as an aquaculturist need to be aware. With the exception of Lake Michigan, the surface waters of Illinois are classified as “warm water”. These are waters that have a midsummer surface temperature of 70°F or higher.

Temperature is one of the key factors which govern the lives of fish and regulate the kinds of species which can live in our streams and ponds. The amount of dissolved gases that water will hold varies with the temperature. The warm water of summer holds much less oxygen than cold winter water.

Temperature is the principle regulator of physiologic change in fish, including feeding, growth and spawning. Most warm water fishes grow fastest at temperatures above 70°F and dissolved oxygen content of 5 to 8 parts per million (ppm).

Temperature is also one of the principle factors influencing the pond cycle through the year. Layers of water at different temperatures are layers of water of different weights. The heaviest (densest) that water gets is at about 39°F. Water warmer than this, or colder than this is lighter. If it were not for this fact, life on earth would not exist. If water just kept on getting denser as it got colder until it froze, ice would sink and all bodies of water, including the oceans would be permanently frozen solid! Fortunately for us, the lightest water of all is ice and it floats.

Let us look at the annual cycle of the pond. In the spring just after the ice thaws, the coldest water is on top at 32°F and the warmest water is on the bottom, at about 39°F. As the warm breezes of spring begin to blow, the cold surface layers of water begin to warm. As they get warmer, they get heavier and sink into the depths of the pond, replacing the lighter, colder layers beneath. At some point, all the water reaches 39°F.

Up to this point, there have been layers of water at different temperatures and densities in the pond, making them difficult to mix. Now that the water is all the same temperature and density, it mixes easily and the winds of spring mix the pond thoroughly, bringing the water which has been on the bottom all winter to the top.

Ponds can be thought of as breathing twice a year, once in the spring and once in the fall, breathing out the waste products of respiration of the aquatic life. These are carbon dioxide (CO₂) hydrogen sulfide (H₂S) and other gases. At the same time, the pond is breathing in new oxygen from the air to replace what was used up. So the pond starts the year with its water freshened and a new supply of oxygen from top to bottom.

As the winds warm the surface layer of the pond above 39°F, it becomes less dense and begins to float on the colder waters below. During the summer period, a layering effect called thermal stratification sets up, separating the pond into three zones of differing temperature and density called the epilimnion, the thermocline, and the hypolimnion. These terms simply stated mean the upper lake, the transition zone, and
the lower lake. The thermocline is a layer in which the temperature drops rapidly, at a rate of 0.5°F or greater per foot of increasing depth. Most people who have dived into a pond or lake have experienced the thermocline. Often, they come back up thinking that they have dived into a spring!

The thermocline ends where the temperature ceases to drop rapidly. Once these layers set up in the summer, they are almost as difficult to mix as oil and water and tend to remain stable throughout the warm weather. The upper two layers then effectively seal the lower lake off from contact with the atmosphere. In a deep lake (50-60 feet or more), the temperature of this lower layer may remain in the low 40's during the hottest of summer weather.

During this time, all the aquatic life is gradually using up the dissolved oxygen present in the lower lake, until in about mid-July, in most lakes in Illinois, the oxygen is used up entirely. This is why you can't have trout in your lake over the summer, even though the temperatures on the bottom are plenty cold enough for them. In most Illinois ponds and lakes there isn't any oxygen for them to breath below a depth of 12 feet in the summer.

As fall comes, the warm surface layers of the lake begin to cool off. Being cooler than the layers below them, they are also denser. This cooler, denser water sinks, displacing the lighter, warmer water below. This process breaks up the thermal stratification which has been so stable all summer, and the pond takes its second breath of the year, the fall turnover. The deoxygenated water of the lower layer is brought to the surface, where its oxygen supply is renewed, and all the waste product gases which accumulated in the lower layer during the summer are exhausted to the atmosphere. The process is complete when all the water in the pond is once again at 39°F.

So the pond begins the winter period as it began the summer with its water freshened and oxygen from top to bottom. As the air temperatures continue to cool, water colder than 39°F floats on the warmer water below it. This provides a (relatively) warm refuge for the fish, frogs and turtles of the pond to survive the winter. Believe it or not, many of the our fish would die of what we would call exposure if they were at temperatures below about 35°F for very long during the winter. Ice, being the lightest water of all, forms on the top and the pond is sealed off from contact with the atmosphere.

As winter progresses, snow accumulates on the ice and, depending on the year, lasts for varying lengths of time. At some point, the accumulation of snow is sufficient to shut off sunlight. Aquatic plants need sunlight to renew the oxygen supply, which is continually used by the living organisms of the pond. The plants can do this even under the ice if the sunlight can get to them.

Once the snow blocks off the sunlight, a count down clock begins, ticking off the number of days before the fish run out of oxygen. One factor that determines the number of days on the clock is the water volume. At the time the countdown clock starts, there will be more oxygen available in a deeper impoundment than in a shallower one, simply because the volume of water is greater. In Illinois, a pond 8 to 10 feet deep over 1/4 of its area is deep enough to withstand most winters. When fish are found dead in the spring when the ice thaws, it is referred to as winterkill. The cause of winterkill is not simply low oxygen under the ice. If it were, many more lakes would undergo winterkill than actually do. Other factors enter in, such as the amount of accumulated
organic matter, leaves, dead aquatic woods and so forth, which are slowly decaying under the ice.

Also involved is a simultaneous rise in carbon dioxide from ordinary respiration of fish, plants, and bacteria, as well as H₂S, generated by anaerobic (no oxygen present) respiration of bacteria.

The fish, being cold in the winter, do not require a lot of oxygen to maintain life. However, if the oxygen drops low, if the carbon dioxide (which acts as an anesthetic to fish) rises to an anesthetic level, and hydrogen sulfide rises to a mildly poisonous level, the fish are hit from three different directions at once, and winterkill may occur unless the aquaculturist is prepared, vigilant and takes steps to prevent it. In a very long, cold winter, the problem will be particularly severe.

As spring approaches, in some years, several freeze-thaw cycles take place. These are characterized by partial thawing of the ice over the surface of the pond, which then re-freezes as the weather cools, only to thaw again and so on, until the final thaw occurs. The author has seen severe gas bubble disease in 4’ channel catfish induced by thawing ice. This thawing ice had very little snow on it and there was no run off from snow. When the pond refroze, many of the affected fingerling channel cat died from fungus, infecting the places damaged by gas bubbles in the skin.

When the final thaw happens, the pond has it’s second breath of the annual cycle. As the surface warms, again a point is reached when all of the water in the pond is 39°C. Since all the water is the same temperature, it mixes very easily. The winds of spring then accomplish a second turn over, ridding the pond once again of any noxious gases accumulated over the winter and re-oxygenating it at the same time. The thermocline starts to set up again as water warmer than 39°C begins to float on the colder water below it.

Now, having discussed some of the physical characteristics of the pond water, let’s go back for a moment to the pond that experienced the cool rainfall on a hot summer day. You should now have a better idea of what happens. The bottom mud is very rich in nutrients due to feces, uneaten food, and organic matter.

Ponds designed for aquaculture are often shallow and flat bottomed. When the cold rain falls, it tends to break up any stratification which may be present. The cold rain, being much heavier than the rest of the water, sinks to the bottom, churning those nutrients up into the water column.

The bacteria of the pond respond quickly to these nutrients and begin to divide and grow with great rapidity. In doing so, they require large quantities of oxygen, often more than the pond can supply. If the farmer is not prepared for this, the result is often a massive fish kill due to the oxygen content of the water going down to or near zero.

If one goes into aquaculture not expecting problems to occur, one is naive in the extreme (and broke!). As I have said before, it is not sufficient to deal with problems as they occur. By that time, it is usually too late. One must learn to anticipate problems and head them off. One of the prime reasons for doing so is to prevent stress to the animals being cultured. Stress is the number one factor in the development of disease in animals in aquaculture.
As with everything, there are many variations to the sudden cold rain scenario, including one in which the oxygen does not reach zero, but approaches it. For most warm water fish, an oxygen content of 5 parts per million (ppm) or 5 pounds of oxygen per million pounds of water is adequate for good health. Any less than 5 ppm begins to be stressful to the fish. The degree of stress caused by any given level of oxygen, say 2 ppm, depends on the species of fish in question.

Let us say that in our cold rain scenario, the oxygen at dawn has fallen to 1.2 ppm. During the day, it never rises above 3 ppm, and by the next morning, it has fallen again to 1 ppm. The fish respond to low D.O. (dissolved oxygen) in a variety of ways. The first thing the farmer sees is all his fish on top of the water piping when he rises in the morning. This term comes directly from pipe smokers and the sounds and mouth movements that they make sucking on a pipe. The fish do this because regardless of how low the $O_2$ (oxygen) gets in the pond, the water at the surface is always saturated with oxygen. The fish come up and try to utilize this surface film. The smaller the fish is, the smaller the mouth is. The smaller the mouth is, the more successful the fish is at utilizing this surface film, and the more likely it is to survive the episode.

Internally, the fish are also taking drastic, last ditch measures to try to stay alive. Among these are the clamping off of blood flow to the digestive tract and diverting it to the heart, brain, and gills in order to keep them functioning to the last. If this scenario continues long enough, the lining of the gut dies and sluffs off, leaving the fish open to invasion by bacteria. Disease usually begins killing the fish in 7 to 10 days.

In aquaculture, disaster is inevitable and is going to occur unless it is anticipated and prevented. Therefore, what are the most likely ones which will happen and what remedy is needed to head them off? The answer will vary somewhat by species, but for the most part, there are certain things that any facility ought to have before anything happens.

Save yourself a lot of "if onlys" and "gee, I wishes" and install electricity at each pond. Water is very valuable if you can afford it and have it available in time of need. Lacking that, you must have aeration devices. One of the best is the paddle wheel aerator, PTO driven by a tractor. It is a given however, that if you have 8 ponds and 3 paddle wheels and tractors, 6 of the ponds will be in trouble all in the same night. It helps therefore to have the electricity and at least a 1 horse electrical aeration device for each pond, to give the fish a refuge until you can get to that pond with the paddle wheel.

You may have noticed that so far, I have not said anything specifically about cage culture. That is because everything stated so far applies to all forms of aquaculture.

One of the things which differs about cage culture is feed. Be sure that the feed which you are using is formulated as a complete diet. One of the specific stresses on cage reared animals is that they are not able to supplement any dietary deficiencies by foraging on the natural foods produced in the pond.

We discussed the fact that there are stresses over which you have no control. One of these is what is done to the fish before you receive them, just before and during shipment. This is one of the few cases in which I agree with prophylactic treatments as a policy. When you receive your fish and place them in the cages, it is a wise policy to put your fish on Terramycin medicated feed at 3 grams of active drug per 100 lbs. of fish (yes, fish) per day for 7 to 10 days to protect them from the fish equivalent of shipping fever.
You may safely assume that the fish have been stressed and you are heading off problems which have a more than good chance of developing. It will serve another function at the same time, in that it will mark the bones of your fish with an oxytetracycline mark that will identify them as a farm reared product. This mark will be clearly visible to any properly equipped laboratory, but would not be visible to the naked eye.

Cage placement in the pond for maximum depth under the cage and maximum exposure to the fetch of the wind will minimize stress due to the accumulation of waste products and oxygen consumption within the cage. Cages should be plastic or plastic coated wire mesh with a minimum size of 0.5" bar (0.75" diagonal measure). Any smaller mesh tends to fill up with filamentous algae, block the flow of water, and cause stress due to environmental deterioration.

Serious producers will eventually come to the realization that any other fish in the pond outside the cages should either be producing profits (fathead minnows?), or should not be taking up the space for waste products. Loading in the cages is not really a function of cage size, but of pond size. In order to produce enough to be profitable, except for a pilot project, loading should be 2500 lbs/acre and up. Unfortunately, this is also about the level of loading where you will begin to run into environmental stresses of phytoplankton collapse due to cloudy weather, low D.O., ammonia, nitrite, and so on, which will begin to threaten production due to disease and/or direct suffocation.

Research by the Mississippi catfish growers has demonstrated that they are money ahead if they do not wait for oxygen problems to develop. Early in the cycle, they run their electric paddle wheel-type aerators every night, whether they anticipate problems or not. They find that it pays off in extra profits due to better feed conversion, increased and faster weight gain due to the prevention of marginal environmental conditions (stress management), and less disease.

Eventually, after a year or two, when you feel that you've got this thing whipped, the fish will start dying. Sometimes, even though you have tried your best to minimize stress in the fish, you fail. From time to time, the most difficult thing of all is to identify just what it is that is stressing them. At this time, you should head for the nearest diagnostic lab with 6 or so sick and dying (not dead ones) fish place on ice. Don't freeze them, it causes so much damage, it makes it difficult to tell what is going on.

Let me say that in 13 years of diagnosing fish diseases I have learned that no one can look at a fish and diagnose what is wrong with it. Each time I get cocky and try it, I then march into the laboratory and invariably prove myself wrong. There is no substitute for microscopic examination, bacterial cultures, and the other procedures available to a diagnostic lab. So save yourself time and money and get it diagnosed! A wrong guess as to what the problem is leads to the choice of incorrect therapy, which doesn't work, costs money in chemicals/antibiotics, mortalities, lost weight gain,....

If the problem happens to be a parasitic protozoan, or an external bacterial infection, this presents special problems to the cage culturist. It does not make sense to stress the fish further by chasing them around in the cage with a dip net until they are exhausted and can be caught and placed in a treatment tank. This sort of action is worse than simply letting the disease run its course.
The treatment chemicals/antibiotics used against external disease problems are used at rates that are only slightly less toxic to the fish than they are to the disease organisms. These chemicals are not only prohibitively expensive to use in the amounts required to reach treatment level for the entire pond, but also, following the treatment, there is no way to remove the chemical, which would then go on to kill all the fish as well. Therefore, a bath treatment is used, of short duration, such as an hour.

The problem is how does one do that with a cage full of fish? Two methods come to mind, one for the small producer and the other for the larger investor. The first problem of such a treatment is to maintain the oxygen level of the treatment water at least 5 ppm for the duration of the treatment. The second is containing the treatment to the boundaries of the cage. The third is getting rid of the treatment chemicals after the treatment is over.

For the small producer, it is best to rig the cage with the ability to create a containment bag out of black plastic, fastened with Velcro fasteners to isolate the cage from the pond during the treatment. Remember, you must keep the oxygen level in the cage from falling during treatment.

IF YOU USE COMPRESSED OXYGEN IN A CYLINDER AND AN OXYGEN STONE, NEVER, REPEAT, NEVER GREASE OR OIL THE FITTINGS OR USE A COMPRESSED AIR STONE ON AN OXYGEN SYSTEM. A COMPRESSED AIR STONE IS CONTAMINATED WITH OIL FROM THE COMPRESSOR PISTON. ANY CONTAMINATION OF GREASE OR OIL IN AN OXYGEN SYSTEM WILL REPEAT WILL SPONTANEOUSLY EXPLODE, EVEN UNDER WATER! THE RESULTING SHRAPNEL HAS BEEN KNOWN TO TRAVEL FROM THREE FEET UNDER WATER, THROUGH THE AIR SOME 80 FEET!

Following the treatment, remove the containment bag and allow the treatment to dissipate into the pond. Don't swim! Remember the treatment! In many cases, until it dissipates, it is strong enough to burn your eyes if you are in the water.

For the larger producer, the simplest expedient is to have a work boat large enough to have a treatment tank on board. Design the cages to be capable of being lifted from their floating rack and swung inboard, to be placed, cage and all into the treatment tank. The same system will simplify harvest as well. Even for the small producer, a boat, or a dock extending out into the deep water will be necessary to keep the cage clean, feed the fish and so on.

Remember that no one will ever be able to write the book that will cover everything that will happen with your pond, and your fish, in your hands. The water, fertility, configuration and location of your pond, the style and timing of stocking, feeding, genetics of the stocked fish, and a whole host of other factors combine to make any fish culture operation unique. You will have to pick and choose what fits for you in your situation. Unfortunately, you will have to learn what those things are in the college of hard knocks. It is a difficult school, but the only one available in which to learn your business. Good luck.