Cold Water Koi Keeping
Cold Water Effects on Koi and the Pond
"The Winter Course"

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The purpose of this section is to introduce the KHA to the effects of water temperature on the ecology of the pond and physiology of the fish during the coldest months of the year. It is important to understand the dynamics of the pond as the seasons change and in particular, during cold water conditions. For the purposes of this section, we will focus on the approaching Winter season.

This course will teach the KHA how cold water and changing water temperatures affect the health of koi and also the ecology of the pond as they go into winter and emerge in the spring.

As winter approaches in those climes that endure cold weather, we need to consider what is happening in our ponds as the water turns cold and the fish become less active and the ecology of the pond changes. When we consider the ecology of the pond, we look not only at the water quality but also the effects of cold water on the organisms within the ecology. Most notably, we need to focus on the metabolic changes that the fish will experience as the water temperature drops and what effect the change in water temperature has on the naturally occurring nitrifying bacteria and parasites in the pond.

Water Temperature Effects

One of the few things that we cannot effectively control in our pond's ecology is the water temperature. The good news is that Mother Nature has provided our fish with a natural ability to adapt to the colder temperatures. This makes it our job to provide the best environment possible and to duplicate what Nature intended to happen in natural waters. The bad news is that Nature has equally provided the other organisms in our ponds the same survival mechanisms. Throughout this course we are going to discuss not only the effects of water temperature on our fish, but also on the nitrifying bacteria in our filters, the algae and plants in our ponds, the parasites that live on and around our fish, and finally on the disease-causing pathogenic bacteria that also inhabit our ponds. Managing a pond into and out of the cold weather season thus becomes a balancing act of Nature and the man-made effects to the ecology our ponds.

The Physics of Cold Water. The first thing to consider when looking at water temperature effects is to ask how cold our pond water really gets. As KHAs, we should know which temperature zone we live in and from this we can determine the expected frost line depth in our soil. Local agriculture extension services and most garden shops know this information, as do all building inspectors. The importance of the frost line is that this is the depth that the soil temperature will potentially reach 32 degrees F. Below this depth, chances are that the soil temperature will remain at 35 degrees F or above.

Keep in mind that the soil around your pond will act as a natural insulator and keep the water at the bottom of the pond at a temperature above 35 degrees F. If you had the ability to measure soil temperature at depths of twice the frost line, you should find that the soil temperature does not drop below 40 degrees or so, thus providing a nice natural insulator for our pond water.

Knowing the frost line depth should then be a major factor when determining the depth of your new pond or whether or not your fish can survive in an existing pond. As a general rule, the pond depth should be ***at a minimum*** twice the depth of the frost line. For instance, in Zone 7, the expected frost line depth is 12 inches, so the minimum safe pond depth should be 24 inches below ground level. But these rules only apply to ponds built into the ground and not for ponds built above the ground. For above-ground ponds, the effects of cold air are remarkably more drastic and cause thicker ice coverings and lower temperatures throughout the pond as the natural insulating effects of the soil are not present. In evaluating the condition of a pond suitable for winter, pay close attention to the height above ground of the water line as this will always cause problems with freezing.

To understand how cold our ponds really can get, we need to use some principles of both physics and meteorology. From physics, we first need to understand that *mass* has everything to do with how our ponds react to sub-freezing air temperatures. By mass, we are talking about volume in terms of length, width and almost most importantly depth. The greater the mass of the pond, the more assured we can be that natural cooling of our ponds will occur and water temperatures will remain within predictable levels. Ice cubes in our freezer freeze because they lack the mass to avoid freezing solid. Also from physics, we know that as water cools it becomes denser and this dense “heavier” water sinks to the bottom. Fresh water reaches its maximum density at 39 degrees F and this means that fresh water as we know it, does not get colder than 39 deg F. Given a proper mass of our pond, we can expect the entire pond to get no colder than 39 deg F. Although for ponds deeper than four or five feet below the frost line, we may expect some thermal layering (see below).

So, as the cold (below 35 deg F or so) air and soil temperatures cause the pond water temperatures to lower, the denser cooler surface water sinks to the bottom and eventually the entire pond will achieve the same 39 deg F temperature. Since koi can withstand water temperatures down to 35 deg F, this 39 deg F is a good temperature for our koi to appreciate its winter surroundings (see ***torpor***, below).

But with closed system ponds, such as most koi and goldfish ponds, we routinely see water temperatures below this magical 39 deg F. This happens primarily because the ground around the pond and above the frost line is contributing to the cooling of the water. We can make an analogy to the ice cubes in a freezer as the air surrounding the water in the tray causes the water in the tray to freeze solid. The same thing is happening to closed system koi ponds and the smaller the pond, the worse the situation is likely to be.

But this begs the question: if water can only reach 39 degrees F, how does it freeze? And here is where some principles of meteorology come into play. First, let us understand what "ice" really is: ice is the crystallization of water particles in the air. We can prove this because we know that ice cubes and icebergs float. Freezing water is a physics phenomenon as water expands and becomes less dense as it freezes. Virtually everything else does the opposite. The composition of ice is 10% less dense than water and so it floats. Freezing water also expands which causes pipes to break.

Why does this happen?? As mentioned, ice is formed by the crystallization of water particles but this freezing occurs ABOVE the water line. During this process, air is trapped in the freezing crystals and this causes increased mass but less density as air has very little density. The meteorologists also tell us that evaporation is always occurring above a body of water and with "calm" conditions, the air layer directly above or ponds becomes saturated with water making the humidity 100% directly over the water. Since we know that ice is formed by crystallizing water particles, it is this layer of humid air directly over the pond surface that freezes, not the water surface itself. The depth of the ice is determined by the air temperature at the ice surface interacting with the surface water temperature. The colder the air, the lower the temperature of the ice will be just above the water's surface. Between the surface of the water and bottom of the ice is an air gap where a continuous 100% humidity level is maintained by the evaporation of the pond. It is the interaction of the warmer pond water and colder ice that causes an increase (or decrease) in ice depth.

One other point about how water freezes "over" the pond is that ice forms from the outside and moves the center. And this happens as the coldest part of the pond will be the edge and so this is were the ice block starts.

The Effects of Salt on Water Temperature. As we are aware, salt is used in many ponds for a variety of reasons and many pond owners still use high levels of salt in the fall to help reduce parasite loads going into winter. In fact, not too many years ago it was an "accepted" practice to keep high levels of salt in the pond all winter long to guard against parasites. We know now that this is a bad practice as high levels of salt in the pond over winter can lead to serious, if not deadly, problems for the fish. The chloride component of salt (sodium chloride for table salt) affects the density level of water and by doing so can effectively lower the physical temperature of water. As stated earlier, the physics of water tells us that water at natural "fresh water" levels cannot get below 39 Deg F under normal conditions. We know that the natural chloride (or salt) levels of fresh water are between .02 and .1% depending on location and source water. At these levels, the temperature of water is not affected by the presence of chloride. However, as we raise the level of chloride above the natural levels, the density of water reaches its maximum level at lower water temperatures. This effectively will allow the water temperatures in the pond to drop below the 35-39 deg F range and adversely affect the fish.

So, it is a good practice to recommend to those using salt to reduce their salt levels to "natural" levels (below .1%) before winter sets in.

Thermal Layering. There is often much discussion about thermal layers in water especially when water movement (through pumping) is considered. Thermal layers are distinct changes in water temperature and density that can be registered at certain depths. In the summer, the water is warmer at the surface and cooler as we get deeper due to the effects of both the sun (warmer) and the insulating qualities of the soil (cooler). Also, the cooler water is denser and will sink to the bottom. In the winter, this effect remains the same even with the colder water (caused by surface cooling) at the surface and the warmer water at depth. During winter, the pond will constantly adjust itself as the water warms from the sun and cools again at night. This effect is transient and does not usually affect the overall condition of the pond. But this explains why we might see our fish swimming at the surface in the cold sunshine of winter.

Many ponders believe that water movement should not be permitted in ponds during cold water times and especially a pump should not be placed at the bottom of the pond as it will remove the "warmer" water and cause the entire pond water temperature to drop below acceptable levels. In fact, appreciable thermal layering does not occur in ponds less than six feet deep and so in most ponds thermal layering is not an issue and pumps and water movement can safely be done all year long. However, to be on the safe side, it is advisable to place any pump no more than mid-depth in the pond, as the real value to any water movement is the more effective removal of gas build-up in the water. Plus, if something goes wrong, the entire pond will not be drained. As always, automatic pump shut-off switches are recommendd.

In deeper ponds, 5-6 feet or deeper, the potential for thermal layering, called thermoclines, exists. A thermocline is a weak physical barrier caused by changes in water temperature at depth. Under the thermocline is the warmer water and since this is also at the bottom of the pond, this is where we can expect the fish to be while in torpor. Since the thermocline is an effective, albeit weak barrier, gasses such as CO2 and Hydrogen Sulfide can get trapped below the barrier and create worse water quality conditions than above the barrier. The net effect is that the fish are exposed to these trapped gases and adversely affected. The simple way to eliminate the potential for thermocline problems is to place a small pump on the bottom of the pond to move the water gently thereby disrupting the thermocline barrier.

Cold Water Effects on the Biological Nitrification Processes

One the issues often discussed in cold water keeping circles is what really happens to the biological bacteria as the water gets colder. To get the “right” answer, we can look to an industry that has contributed much to the technology of koi keeping… the water waste treatment industry. This industry brought us both the trickle tower and bead filter technologies and has taught us much about the nitrification processes under all conditions. Waste water treatment plants use floating bed media for the biological treatment of nitrogen products in waste water. These floating media beds remove ammonia, nitrites, and nitrates from the water during the treatment process and are the forerunner of our bead and floating media filters. But what is really important is that these water treatment plants run all year long! What this tells us is that the biological nitrification processes continue even during the coldest water conditions. This is an important fact to remember as those ponders who keep their filters running all winter will retain a significant level of biological nitrification processing throughout the winter and will see no accumulation of ammonia or nitrites while the fish are "under the ice."

Cold Water Ecology and Magic Numbers

But for many ponders, keeping their filters running all winter long is not possible or practical and the filter systems need to be shutdown to prevent freezing and damage to the filter system or the potential for draining the pond. We also know that many ponders will remove their filter media and place it into the pond itself for safekeeping over the winter. While not as effective as keeping the filter running all winter, this is a viable technique for keeping a portion of the biological bacteria alive.

NOTE: The discussion below focuses mainly on those ponds where the filter system is or will be shutdown for the winter.

As the water temperature at mid-depth of the pond begins to drop and hold at lower readings, we need to pay special attention to what is happening to the ecology of our ponds. The first magic number we need to look for is 62 degrees F. At 62 degrees, the activity of the nitrosomonas bacteria begins to reduce primarily as the fish begin to slow down and produce less ammonia through respiration (less ammonia, less nitrogen processing). While there is some debate on which bacteria actually effects which biological filtration processes, for the purposes of this course, we will use nitrosomonas and nitrobacter as the principle nitrifying bacteria. The net effect is that the biological bacteria colony in the filter will reduce in proportion to the amount of nitrogen food available to colony.

Also at 62 degrees, we see a significant dip in the koi's immune system's ability to fight off bacterial invasions. This is where the fish start becoming increasingly vulnerable to ulcer and other bacterial infections. If the fish are strong and the pond is healthy (well cleaned), the owner should not have problems.

The next important temperature mark is 55 degrees F. At 55 degrees, the nitrifying bacteria in those ponds where the filters have been shut down will start to die off although they will not be completely gone until about 42 degrees F. While the fish are still producing ammonia primarily through respiration, we need to consider methods of reducing ammonia output and here are some recommendations:

First, we need to change the diets of our fish to a food with lower protein content. Normal summer-type koi feed has protein levels in the range of 35-40% (or higher) depending on the type of food used. For colder water feeding, we need to switch to a food with a lower protein content, somewhere in the range of 30-32%. The reason? It is protein content in food that is a major contributor to ammonia production by the fish. By lowering the protein levels in the food, we thereby lower the ammonia output. It is important to note that 65% of the ammonia produced is not from feeding but a result of normal respiration. Thus it is important to make sure we control the 35% that we can.

Below, and courtesy of the Hikari USA Company, are the protein levels and contents of three well known koi foods. The first is a high-growth food, normally fed only during summer months. Note the protein level.

Hikari Hi-Growth
Koi With Championship Size & Form Can Be Yours!

Guaranteed Analysis: Crude Protein 42% Min. (Green)

Crude Protein 25% Min. (Yellow)

Crude Fat 8% Min. (Green)

Crude Fat 7% Min. (Yellow)

Crude Fiber 1.5% Max. (Both)

Moisture 10% Max. (Both)

Ash 12% Max. (Green)

Ash 7% Max. (Yellow

This food is a basic stable diet for koi and fed normally only during warmer months as well. The fish will not grow as fast nor will the filter system complain as much.

Hikari Staple
Preferred Daily Diet For Koi & Other Pond Fish

Guaranteed Analysis: Crude Protein 35% Min.

Crude Fat 3% Min.

Crude Fiber 5% Max.

Moisture 10% Max.

Ash 12% Max.

This type of food is a good cold-water food because of the reduced protein levels and ease of digestability. Note the low protein levels.

Hikari Wheat-Germ
Easily-Digested Daily Diet For Koi & Other Pond Fish Providing Outstanding Conditioning Of The Skin

Guaranteed Analysis: Crude Protein 30% Min.

Crude Fat 4% Min.

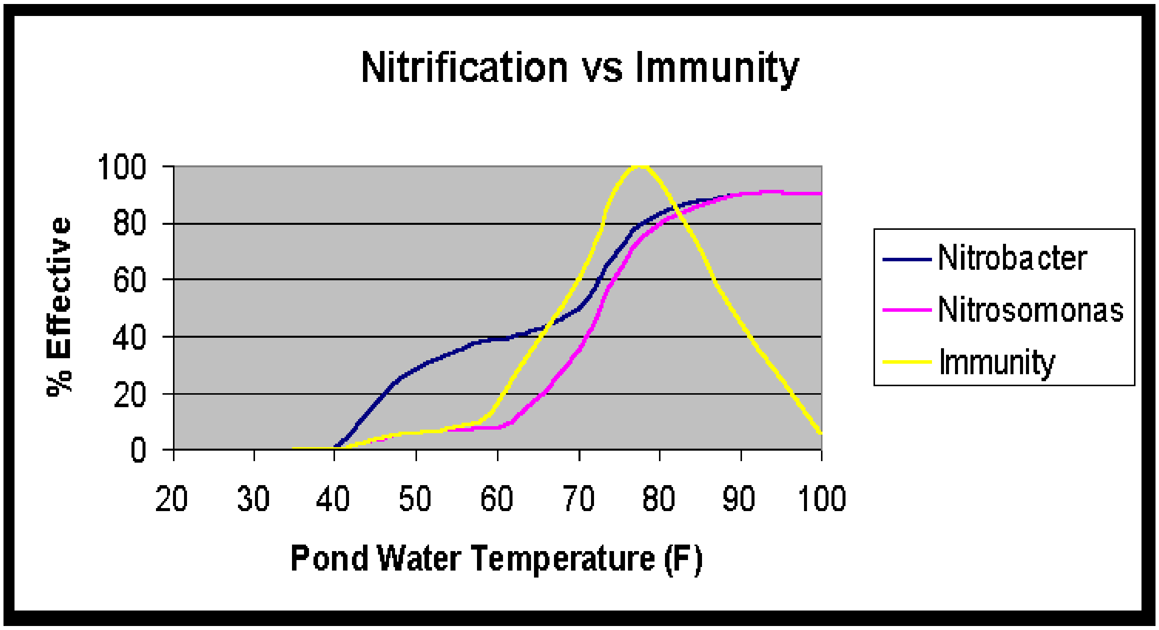
Crude Fiber 4% Max.

Moisture 10% Max.

Ash 12% Max.

Next, as the water temperatures drop into the 55-degree range, the koi's metabolism begins to slow and its need for nutrition reduces as well. This slowing of the koi's nutritional needs also allows the owners to reduce the amount of food provided to the fish. You will begin to notice that the koi are less active and they begin to form groups at the bottom. The exception is during times when the sun warms the pond and then they like to be near the warmer surface. Occasionally the fish will graze on the algae growing on the sides and bottom of the pond and seem quite content to do nothing more.

The charts below illustrate a correlation of water temperature, immune system condition and nitrifying bacteria condition. This is a compilation of accepted data from a number of published sources. In the first chart, the effects of pond water temperature are shown against the activity levels of the nitrifying bacteria (nitrosomonas and nitrobacter) where the filter is not operational. Also note the range where the koi's immune system is most effective. The increased activity of the nitrifying bacteria increases the quality of the water as harmful ammonia and nitrites are removed from the water. This increase in water quality then supports the koi's ability to build and maintain its immune system. It looks like Mother Nature knew what she was doing when she developed this part of the ecosystem



For many years, Cheerios was recommended if the owner had to feed the fish something (guilt complex) and the reason for using Cheerios is that it was very low (like zero) in protein. But as we have learned, Cheerios is high in carbohydrates and as such, are not good for fish in cold water conditions where they cannot burn off the carbohydrates effectively. A lower protein fish food is a much better choice for cold water feeding IF it must be done at all.

Another thing to consider regarding feeding is that owners should NOT "pack it on" during the fall as the fish's natural storage and processing systems provide for sufficient nutrition all winter long. Keep in mind the fish are not in torpor and so their processing nutrition requirements are minimal during cold water times.

At 50 degrees F, stop feeding the fish altogether. At this point the fish's much lower metabolism will not allow proper processing of food in the gut. Koi, unlike most animals, do not have stomachs and so all food is processed in the gut. With a slower metabolism, the food moves through the gut slower and the body's need for nutrients is reduced as well, so the net effect is that the food is not processed properly. If overfeeding during cold weather occurs, there is a real chance that the food will spoil in the gut and cause significant damage to the fish intestinal tract and quite possibly kill the fish.

And finally, at 40 degrees F, all nitrobacter activity in the pond ceases if the filters are not running. If the owner plans on shutting down their filters for the winter, this is a good time to do it. When the pond owner actually shuts down the pumps and filters is a call only the owner can make, but the overriding concern is freezing of the plumbing and the loss of a pump, filter, or worse yet - the draining of the pond from a ruptured water line.

Cold Water Ammonia and Nitrites

Now that we understand what happens when pond water temperatures drop to 50 degrees Fahrenheit and below, we are all too aware that the biological nitrification processes have ceased to be effective against ammonia and nitrite build-ups in ponds without filters running. So, let's look a little deeper at the effects of ammonia and nitrite on our fish during the cold-water months.

First ammonia: in numerous articles and publications, we have read that ammonia is much more toxic in high pH (alkaline) water and since this is true, we must always balance our ammonia readings with the pH readings of the water to get a better picture of the extent of the effect on our fish. However, it is also very important to point out that water temperature has a profound effect on the toxicity of ammonia as well. In order to understand the effect of water temperature and pH on the toxicity of ammonia, let's take a look at how we need to interpret ammonia testing.

Most commercial kits for ammonia testing provide readings for what is called Total Ammonia Nitrogen or TAN. If you read the labels and instructions on your test kit, chances are you will see where the manufacturer uses the term "NH3/NH4" as the "ammonia" the test kit is capable of reading. The term "NH3/NH4" is Total Ammonia Nitrogen. So, let's take apart this "Total Ammonia Nitrogen" and see what we are actually dealing with.

Ammonia in water occurs in two different forms: **Ionized Ammonia** which is represented as NH4 and **Unionized Ammonia (UIA)** which we see as NH3. The combination of NH4 and NH3 are what is termed **Total Ammonia Nitrogen (TAN)**. The average ponder's test kit cannot differentiate between NH4 and NH3 readings and so the TAN number is provided. But it is the Unionized Ammonia (NH3) that is the only ammonia form that is toxic to fish. And it is **both** water temperature and pH levels that will determine which form of ammonia is predominant in the water at any given time.

The toxicity of UIA begins at levels as low as 0.05 mg/l and so determining the UIA level from inside a TAN reading can be a valuable exercise for pond keepers. UIA levels of 2.0 mg/l are the levels where fish begin to die off quickly. As stated, both water temperature and pH levels impact the toxicity of UIA and so when TAN tests are performed, it is important to read to both the water temperature and pH levels as well in order to complete the picture. Below are a couple of examples that illustrate the effects of water temperature and pH on TAN readings:

In Table 1 below, the first example shows a TAN reading of 0.5mg/l from the ammonia test kit. The water temperature is 50 degrees Fahrenheit and the pH 8.0. The first reaction to getting a positive ammonia reading is that the ammonia level is unacceptable and water changes, chemical treatments, or other measures are necessary to bring the ammonia under control. But a closer look at the actual situation shows that the UIA, the toxic form of ammonia, is 0.0219 mg/l and in fact under the 0.05 mg/l "undesirable" level and thus does not pose much of a threat.

TAN	Water	Water	Factor *	UIA (NH3)
Level (mg/l)	**Temp (F)**	**pH**		**Levels (mg/l)**
0.5	50	7	0.0018	0.0009
0.5	72	7	0.0046	0.0023
0.5	86	7	0.008	0.004
0.5	50	8	0.0182	0.0091
0.5	72	8	0.0438	0.0219
0.5	86	8	0.0743	0.03715
0.5	50	8.6	0.0688	0.0344
0.5	72	8.6	0.1541	0.07705
0.5	86	8.6	0.2422	0.1211

Table 1

***** The "**FACTOR"** column of the chart provides conversion factors available from a number of sources, including the University of Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences.

In reviewing the contents of ***Table 1***, it is easy to see the correlation between water temperature and pH and the toxicity of UIA. For instance, compare the UIA level for a pH of 7 and a water temperature of 86 (.004 mg/l) and the UIA level for a pH of 8.6 and a water temperature of 86 (0.1211 mg/l). The effect of increased pH at a constant water temperature and constant TAN reading yield dramatic differences in UIA levels, with the increased pH resulting in greater toxicity of the UIA. This is the basis of the argument that higher pH readings make ammonia levels more toxic.

Next, compare the UIA level for a water temperature of 50 deg F. at a pH reading of 8 (0.0091 mg/l) and the UIA level for a water temperature of 86 deg F also at a pH of 8 (.03715). Here it is easy to see the impact of water temperature on UIA levels with constant pH and TAN readings with the cooler water offering more protection against UIA toxicity.

Now nitrites: unlike ammonia, which has an immediate toxic effect on fish, nitrite problems are caused by an accumulation of nitrites over a period of time. Nitrites basically replace the O2 levels in the blood thus causing "brown blood syndrome" and eventual death to the fish through extreme O2 deprivation. So, it takes some time for koi to accumulate enough nitrites to cause serious problems. How much time? That depends on a number of critical factors including nitrite levels in the water, the chloride levels of pond water, and the metabolism of the fish. In colder water (50 deg F and under) we know that the fish's metabolism slows significantly and one of the results is that he respiration will be less. Also, since the conversion of ammonia to nitrites stopped before the conversion of nitrites to nitrates, chances are the nitrite levels are exceptionally low and approaching zero. This results in a decreased opportunity to take up nitrites from the water. However, lethal levels of nitrites can still be accumulated over time if the nitrite problem is not addressed.

For most ponders facing nitrite levels during cold water periods, salt is the best treatment as salt levels of only .1% will inhibit the uptake of nitrites and prevent brown-blood syndrome. And salt levels of .1% can be maintained for indefinite periods of time without a risk to the fish or concern for developing salt resistant parasites.

Water Quality

One of the major points we need to make to pond owners is to check water quality over the winter months routinely as this can tell them how the pond is doing and what needs to be done to head off or fix problems. This should happen whether the filter is running or not. Here are some key points to water quality in winter:

1. Expect levels of ammonia in the water. Even though the fish are not eating, ammonia is being produced by respiration and with no biological activity to speak of (unless the filters are running), ammonia will accumulate. However, the cold water makes it less toxic and almost harmless during the winter.
2. Expect low levels of nitrites. Low levels of nitrites will not adversely affect the fish due to low uptake potential. However, if there is concern, raising the salt level to .08 to .1% will protect the fish and not affect the water temperature.
3. Test for KH levels routinely. Photosynthesis and other biologic activity in the pond are depleting the KH levels continually and as such, they will need to be replenished during the winter months.
4. Test the pH often, getting both early morning and late afternoon readings for comparison. The goal is hold the pH stable at whatever level is natural for the pond (assuming the KH levels are correct).
5. ORP readings can quickly tell us the overall condition of the pond and from those readings we can react accordingly, including water changes.
6. Do not be afraid to change water in the dead of winter. Remember that significant evaporation has occurred (especially if there is an ice layer) and the water levels need to be replenished and refreshed. Add the water more slowly than usual to allow for temperature changes and use dechlorinators as needed.
7. Significant thawing and heavy snow will have the same effect on a pond as heavy rain. Typically, snow (like rain) is acidic and can affect the pH of the pond unless the KH levels are properly maintained.

8. Use a good in-water digital water thermometer to keep track of the water temperatures at the bottom of the pond.
9. Aerate and circulate the water to help release the gases in the pond and refresh the water.

Cold Koi

As stated above, Nature has provided koi with the ability to withstand cold water temperatures down to 35 degrees F. Koi are primarily bred in Niigata, Japan, where winters are long and harsh, and snowfalls of over 20 feet are not unusual. Of course, we are not talking about rapid temperature changes but merely the "natural" cooling of the water as the seasons change. As the water temperatures decrease and stabilize at incrementally lower temperatures, the fish experience metabolic changes where their body functions slow and nutritional requirements decrease as well. As with most health issues for Koi, their immune systems can handle many water parameters changes – if they do not change rapidly.

At about 45 degrees F, koi start to become increasingly lazy. In fact what is happening is that they are lapsing into a condition called ***torpor***. Webster’s Dictionary defines ***torpor*** as a condition of mental or physical inactivity or insensibility; lethargy or apathy. Many animals hibernate during winter, which is an almost complete shutdown of the body’s systems. Torpor is different in that it is **not** hibernation but a reduction of metabolism and related supporting body functions to the point where the fish is lethargic. Unlike hibernation, torpor allows the fish to understand its surroundings and still be able to react to threats. So, while there is mental activity, there is little physical activity. While the fish may be grazing around the bottom during this time, it is not a serious search for food.

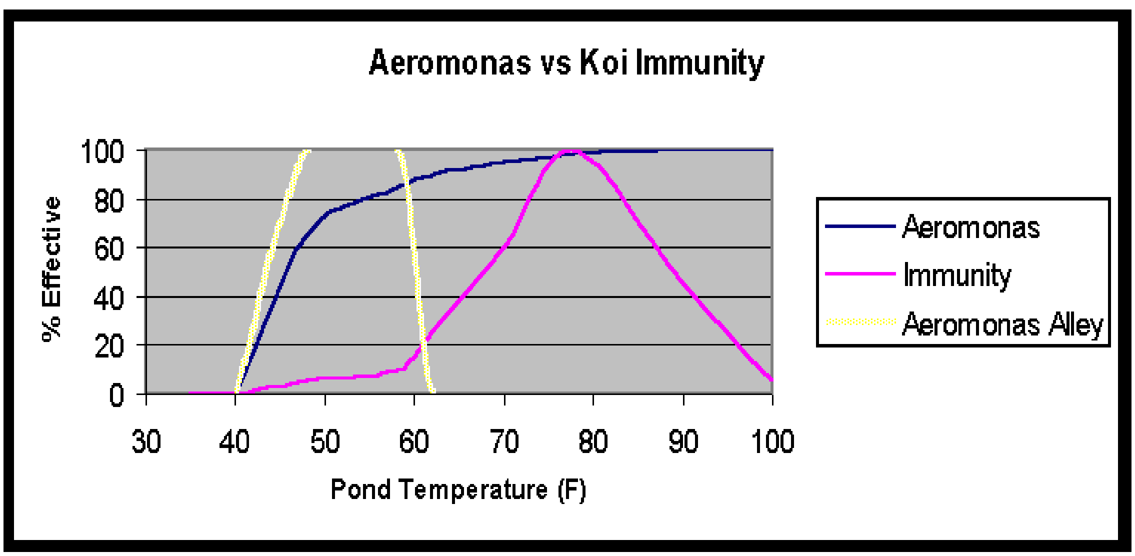
It is also important to make sure that the Koi are not startled or stressed, as they almost completely lose their ability to manage stress situations. While have Koi a "fight or flight" capability (that which allows most animals to manage increased adrenalin build up), they will always flee a stress-producing situation and they do so with a great burst of speed. In order for the fish to burst away from a bad situation, they have a unique capability of producing great quantities of adrenalin and epinephrine hormones into the muscle. This is why fish can go from zero to warp-speed in a quick sudden burst. But what fish do not have is the ability to easily remove that hormonal build up. The net result is that fish maintain a higher level of adrenalin and epinephrine too long, and this results in an increased need for metabolic support and reduction of immune capability. So, it is easy to see that with a reduced metabolic capability, a sudden and dramatic increase in adrenalin build-up without proper release forces the fish into great stress. This high level of stress can actually kill fish in very short order.

Parasites, Bacteria, and Cold Water.

The next sets of organisms we need to discuss in the pond’s ecology are micro- and macro-organisms, more notably known as the parasites and the bacteria. Here we will differentiate between the nitrifying bacteria discussed above and the pathogenic bacteria that cause disease in our fish. Both of these bacteria types are aerobic bacteria, which simply means that they need oxygen to survive. Most parasites are basically warm-water creatures and as the water temperatures dip into the very low 50's and high 40's, the common micro- and macro-parasites begin to die off in great numbers. The lone exception to parasitic cold-water intolerance is costia. Costia, which is formally named *ichthyobodo necator* and not to be confused with common "ich", is one of the smallest ectoparasites (lives on the outside) and is especially active in water down to about 38 degrees F. This is what makes it so dangerous to the fish during cold-water times. As the fish's immune system and metabolic processes are reduced due to decreasing temperatures, costia parasites are still active and have the potential to cause significant damage through normal parasite attacks (cold water ulcers) and increased stress on the fish.

But the real problem we face as koi keepers is how to reduce the effects of aeromonas and pseudomonas bacteria on our fish during cold-water times. Aeromonas (and I will lump pseudomonas bacteria into this discussion as well) are the pathogenic bacteria that are the primary cause of ulcer disease, fin rot, and mouth rot. There is significant truth to the statement that aeromonas bacteria are ever-present in our ponds and they really only get to effect our fish when the fish become stressed or lack the ability to fight them off. Think of it this way: - cold germs are ever-present in our surroundings and we become significantly more susceptible to catching a cold when our resistance is low, such as when we are cold or tired.

Consider the chart below. The activity levels of aeromonas and the koi's immune system are compared. Note that aeromonas becomes active at about 42 degrees (F) and remain active well above 90 degrees (F). Now notice the koi immunity system activity. The fish only begin to have the ability to fight off infection at about 45 degrees (F) or so and by that time, the aeromonas are off and running at greater than 60 percent lead.



But the real problem area we need to consider is that portion of time/temperature that we call Aeromonas Alley, where the net effect of the aeromonas activity is so great and the koi's immune system so weak that the potential for real trouble exists. Aeromonas Alley is the pond water temperature range between 40 degrees (F) and 62 degrees (F) and this represents the time where our fish are in most danger from aeromonas infections.

To counteract the potential for disaster, especially while temperatures are in Aeromonas Alley, ponders can take a number of steps to reduce aeromonas loads, including the following:

1. Reduce the amount of organics in the pond with a thorough cleaning of the pond bottom and filters. Remember that bacteria thrive in high organic environments.
2. If possible, treat the pond with therapeutic potassium permanganate treatments. PP removes the organic load through oxidation and also kills off significant, if not all, bacteria in the pond. A therapeutic dose of PP is 2PPM for 4-8 hours)
3. Add salt to your pond at a dose rate of no less than .2 % (that is two pounds per 100 gallons) and keep it there for at least two weeks. Then reduce the salt level to about .08 to .1% through water changes and salt at that level for the remainder of the winter. This will reduce the parasite load as well provide much needed chloride levels into the water. Consider water temperature before using salt.
4. Reduce feeding of the fish. The primary food source of aeromonas bacteria is fish feces. Actually, the slime coat on the feces. Reduced feeding causes less feces and so less food source for the aeromonas.

There are a number of other tricks for protecting koi such as feeding them immune system enhancing food, but the one that seems to work the best is the use of Lymnozyme or Koizyme. It is rare that I will specifically recommend any one product, but this is one product that every koi owner should use. Lymnozyme is a natural enzyme developed to help eliminate aeromonas bacteria by out-competing them for their primary food source. In effect, the presence of Lymnozyme starves out the aeromonas and reduces their numbers.

Below is an excerpt from a post I made on the AKCA web board. The question was related to the use of Lymnozyme on fish already infected with an aeromonas bacteria infection:

> First, every pond has aeromonas bacteria.. it is a fact of life. They typically only become a problem when the fish are stressed or weakened by something else. Consider them opportunistic, if you will, as they are looking for open wounds caused by injury or parasites, flukes, etc. Lymnozyme reduces the number of aeromonas bacteria by exclusion, in that it competes with the food source of the aeromonas, which is an element of the fish's feces. Lymnozyme stays in effect for about four days in your pond, so you can see that its addition reduces the aeromonas count quickly. The most opportune time to use it is when you suspect that your fish are stressed by bad water, parasites, flukes, etc. and susceptible to infection. It is recommended to use it extensively in the early spring and late fall when the fish's immune system is easily compromised.

If you are using Lymnozyme now, then your problem is not necessarily the standing aeromonas in the pond. Because you have an active case of fin rot and this is mostly caused by aeromonas, the problem is that the aeromonas on the fish have a food sources (tissue) as opposed to competing for food in the water. This is why Lymnozyme does not work on already infected fish. So, you need to treat the fin rot as an infection and quite possibly systemic. Topical antibiotics, such as PP paste or iodine, will help but if the infection is getting into the tissue of the body, then you need to move to injectable medications to stop it.

Lymnozyme is effective down to about 45 degrees F.

Hypothermia

Like all living creatures, koi and goldfish can suffer from hypothermia. Hypothermia occurs when the core body temperature becomes so cold that normal body functions begin to fail. In human beings, this temperature is about 93 deg F. For koi, this temperature depends on basically two things: how cold the water gets and how fast the water gets cold. Koi are poikilothermic, which means that their body temperatures are essentially the same as the water temperatures. And because of this, koi have no ability to regulate their body temperatures. As the water temperatures drop, so does the koi's body temperature and this affects the fish's immune system and physiology. So it is pretty easy to see why water temperature in a koi environment is so critical.

Hypothermia can become a factor when the pond water drops below 39 degrees and really is a problem when it approaches 35 deg F or lower. While all fish are susceptible to hypothermia, most fish do just fine under normal cooling conditions, but there are some fish who just cannot handle the cold. First evidence of hypothermia in fish is a loss in color followed by rapid breathing/gill movement. Additionally erratic swimming may occur that looks like that the fish is disoriented. The affects of hypothermia can lead to hypoxia, which basically means that the fish is starving for oxygen. While it is true that cold water has the potential to hold more oxygen by its nature, because the fish's metabolism is so slow it cannot adequately take up oxygen and suffers from low oxygen affects. Hypoxia can then lead to anemia and this puts the fish in a serious position. Reversing the conditions of hypothermia requires that the fish be removed to a tank that can be warmed <u>slowly</u>.

Snow, Ice and Photosynthesis

Once our fish have settled in for the winter and the pond ices over, owners tend to (deliberately) forget about their friends under the ice. Actually most of us don't want to think about them because we think they are suffering. And while we know they really are not suffering, what we do not know is what is happening under the ice.

So, let's consider what happens under the ice: if there is a heavy layer of snow on the ice, certainly this will restrict the photosynthesis processes and an abundance of CO_2 and consumption of O_2 will occur. Additionally, the algae, which need sunlight, will die off and this will up the ammonia levels and reduce the O2 levels as well. So, collectively a number of bad things are occurring, including the reduction of the carbonate (KH) levels.

If there is significant algae in the pond, a common pond feature, there is a photosynthesis process that contributes to the O2 levels in the water. As you know, during daylight hours, plants through photo-synthesis produce O2 (by consuming CO2) in the water and during the nighttime, the process reverses and CO2 is produced (by consuming O2). In ponds with grossly unbalanced ecosystems (plants vs. animals)... the consumption of O2 becomes a real problem and will kill the fish. For those of us who have seen it, we can confirm that it happens very early in the morning and starts with the larger fish.

Oddly enough, the same process exists on very cloudy days and becomes a real problem when we have a number of cloudy days in a row. The lack of sunlight inhibits the photo-synthesis process and everything in the pond thinks it is nighttime and so all of the O2 is being eaten up and CO2 levels become dangerous. The simple solution of course is increased aeration.

Now, the problem with CO2 is that is it highly acidic and will dump the pH to hazardous levels quickly. So you get a combination of low O2 (suffocating) and a high acid (low pH) environment. This causes acidosis in fish that no amount of Tums or Zantac will help.

You can confirm all of this by a couple of quick tests. First, check the pH early in the morning and if it is on the low end of the scale or unacceptably acid, then there is the makings of a CO2 problem. Next, check the KH. The same thing if it is too low. Low KH also causes an additional problem in preventing pH swings. Always watch the fish. If they are near the surface, either near the air hole or near the ice, then chances are that they are piping and looking for O2 and not getting warm or watching the TV. This is an indication that low O2 exists in the bottom of the pond. And finally, monitor ammonia levels always, just in case...

The simple remedy for all of this is aerating the pond in the winter. Some ponds will do just fine with an air hole while others, especially those with good algae growths, may need an air stone or pump breaking the surface.

One more test if you are wondering about the ecosystem of the pond.... if there is some open water, fire up a pump and splash it for 48 hours and see if foam (DOC) appears on the surface. If it does, then the pond has a high organic load and evidence that potentially you may have a low O2/high CO2 problem. In some ponds, you may also get foam forming around the air hole heater. This is not a casual coincidence, but evidence that you have the potential for problems. Using an ORP meter routinely throughout the winter can give an excellent indication of the water's condition.

As you can see, the ponds ecology continues even though the fish have gone into a state of torpor and it appears all is calm in the pond.

Some hints for helping the pond and fish out during the winter months:

1. Test the water routinely, especially for ammonia, pH, and KH levels. This will tell you almost everything you need to know about what is happening under the ice.
2. Remove snow from the pond's surface as soon as possible. This will permit sunlight to filter through and positively affect the photosynthesis processes.
3. Keep a hole in the ice open at all times. This will permit the escape of gases (mostly CO_2) from the pond water and allow the pond to breathe. This is an essential step.
4. If practical, keep an air stone or a small pump running just so there is some water movement. This will assist in the agitation of the water and the release of gases such as CO_2. If a pump is used, make sure that a hydrostatic shut-off switch is used also or place the pump high enough in the water so that it will not drain the pond if something goes wrong.
5. Keep supplies of Amquel/Prime, baking soda, and salt on hand just in case you need them to help Nature along just a bit.

Cold Water First Aid

No matter how hard we try to keep things perfect, too often something goes wrong and the fish will need some first aid. In the late fall and very early spring we are likely to see aeromonas infections (ulcers, mouth and fin rot) as this pathogenic bacteria have the upper hand in the cold pond. Also, we are likely to see fish under great stress from the cold water and a parasite load or internal bacteria infection. Indicators of this are when the fish assumes a laying-over position and will appear dead on the bottom until disturbed. At this point, the fish may right itself and swim normally for a while only to resume the laying-over position. While this laying over posture can occur under hypothermic conditions as well, chances are greater that the problem is a bacterial infection with such evidence as pale gills (anemia) and/or redness in the belly (septicemia). In any event, treatment starts with a very slow warming of the fish.

So, when we see these types of problems, we need to perform a little first aid to help the fish along. But there are some tricks to treating fish in cold water/weather environments.

1. Try to keep the fish in the same temperature water to which he is acclimated. Many well-meaning fish owners will put the fish in warmer water thinking this will help, when in fact this will most likely kill the fish. Koi can only handle a temperature change of 10 degrees at a time. Plus, fish "know" their water and by keeping them in water they know will reduce some of the stress. A good trick is to perform pond-side treatments with a quick release back to the pond.
2. If the decision is to bring the fish indoors, plan on keeping him inside until spring. Too many ecological changes will do more harm than good. When the fish is brought inside, use pond water in the largest container that can be handled and let the water warm "naturally" until it hits room temperature. The longer it takes to warm, the better. A little ice can help to slow down the process – monitor the

water temperature and allow no more than a 1 degree temperature change per hour, and no more than 5 degrees in 12 hours.

3. If the fish needs to be netted, do so as gently as possible. Netting adds to the stress of the fish coupled with cold water and parasites/infections, only compounds the problem. Pond-side salt dips for parasites (.6% for 30 minutes or less) should be done using pond water in a large container and with some effort at reducing the effects of the cold air.
4. If the fish requires injectable medications, consult your veterinarian on which anti-bacterial agent has the best uptake in cold water (I am willing to bet it is Baytril – although the effectiveness of any drug is somewhat area-dependent, and high levels of resistance have been cropping up for Baytril). Perform the injections pond side and release the fish. But keep an eye on it closely as possible. Curing bacterial infections is a tricky business in warm water, let alone in cold water where the fish has no immune system to speak of. If you are experiencing ulcers or tissue rot, the only course of action may be to bring the fish indoors for the Holidays.

Cold Water Bloating

One of the more common problems we see in cold water settings is a bloating of the fish, including bulging eyes and raised scales. Normally these symptoms are associated with ***dropsy***, the clinical presentation of fluid accumulation in the body cavity. With dropsy, it is usually a bacterial or viral infection or a parasitic attack on one of the internal organs that causes the fish's body to react with increased body fluid production. However, there is another cause of bloating that will offer the same symptoms but is a much less sinister problem. As was mentioned earlier, the metabolism of the fish slows considerably as the water temperature decreases and one of the results of this process is an adverse effect on the osmotic regulation system. Once the osmotic regulation system gets out of balance, the fish loses an effective way to regulate its body fluids and the result is a retention of excessive body fluids. Thus we get classic bloating. I have found this common in ponds where there is a fluctuation of water temperatures in the colder ranges (35 to 50 deg F) or that temperature range where the fish is moving in and out of torpor.

The treatment for this type of bloating is fairly simple, however the procedures for maintaining the fish post-treatment can get tricky. A bloated fish needs to be removed to a separate tank with water the **same** temperature as the pond's water. It is best to use pond water for this treatment not only for its temperature but also to reduce stress on the fish. I use a 100 gallon Rubbermaid trough as the q-tank. The q-tank is placed in the garage (unheated) and fitted with a small pump, a 300 W heater, and a grow-light on a timer (with on-off the same as the sunset-sunrise). I then wrap the tank with R19 house insulation and put a cover on the tank (but not sealed). Let the water warm slowly with the heater and at the same time, bring the salt levels up to .3%. The water temperature you finally achieve will of course depend on many factors but anything above 52 degrees and holding steady is good. The combination of warmer water and increased salt levels should jump-start the osmotic regulation system.

I have seen bloating reduce within 48 hours and the fish start responding to the warmer environment by looking for food. If the fish does not respond within 48 hours and a noticeable reduction in bloating is not realized, up the salt level to .4%. You can repeat this every 48 hours up to .6% without significantly stressing the fish.

The drawback to this regimen is what to do now with a warm fish in the middle of winter. This is a tough call and must be considered before removing a fish for treatment under winter's conditions. Obviously the fish would be reasonably content to stay in the warm tank but this may not be convenient. So, what you need to do is reverse the procedures for getting the fish to this point by reducing the water temperatures slowly until they equate to the pond's temperature. More than likely you had to change the water in the q-tank and so it is a good idea to now use pond water to replace any tank water lost to water changes. Also reduce the temperature settings on the heater. If you are lucky you can catch a warm spell where the pond's temperatures may have risen a few degrees. If not, once the tank temperatures and the pond's temperatures are within 5 degrees of each other, it is time to return the fish to the pond.

One critical thing to consider when adjusting q-tank water temperatures is that the water temperatures in the tank may vary greatly during the night as the outside temperatures drop. This is why we should use as large a tank as possible to do this procedure as increased water volumes are less susceptible to temperature changes.

And finally, the same q-tank procedures can be used for any fish in distress that may need to be temporarily removed from the pond for treatment.

Filter Cleaning

One of the really important parts of maintaining a healthy winter environment and ultimately a successful spring start-up, is proper cleaning of the pond's filter systems. If the pond has a bead-type filter or filter systems that collects solids from the pond, special precautions are needed to make sure that they are cleaned properly. In the beginning of this chapter we referred to the pathogenic and nitrification bacteria as aerobic bacteria, or bacteria that need oxygen to survive. There is a second type of bacteria, called anaerobic bacteria, which also requires mentioning. Anaerobic bacteria does not require oxygen to thrive and as such lives in some of the more distasteful environments, such as in heavy mulm on pond bottoms or the accumulated crud in filters. Left alone, this mulm and crud will become havens for anaerobic bacteria and it presence is potentially very harmful to our fish. One of the most common effects of anaerobic bacteria build up is hydrogen sulfide, an extremely deadly compound that has killed more than its share of fish.

In all too many cases, filter systems are not properly cleaned and shut down during winter and when they are re-started in the spring, great clouds of anaerobic bacteria are released into the pond much to the detriment of the fish. Also, bottom crud (mulm), including sludge and decaying plants and leaves, will produce large quantities of anaerobic bacteria and hydrogen sulfide gas that when disturbed later will poison the pond and its inhabitants.

The best bet is to take a little extra time in the late fall to thoroughly clean and shut-down the filter systems and clean the bottom of the pond. One of the tricks that the fish may enjoy is to swirl around the bottom stones and rocks and mix up the crud on the bottom just before your last filter cleaning. Not only will this get the crud into the water so it can be filtered out but will also release many tasty morsels for the fish to enjoy as a final snack. Filters can be taken off line and bleached to kill off any unwanted bacteria. If you bleach filters in the fall, the chlorine should not be harmful when you start up the pond again in the spring.

Many pond owners, especially with bead filters, are finding ways to keep them running all winter long as means of achieving a fast start in the spring. This can be an excellent practice so long as the filter is protected from freezing. The most exposed area of a bead filter is the bottom sludge drain as these tend to freeze and break open first. A simple trick to protect the filter is to place a 60W light bulb (on a GFCI circuit) at the base of the filter near the sludge drain and then wrap the entire filter base with fireproof household insulation.

And finally, at the first falling of the leaves, cover your pond with a net. This simple act will save you and your fish much time and trouble. Make sure that you remove all leaves and debris that get into the pond as often as possible. Clean any power skimmers that are in use at least every 24 hours.