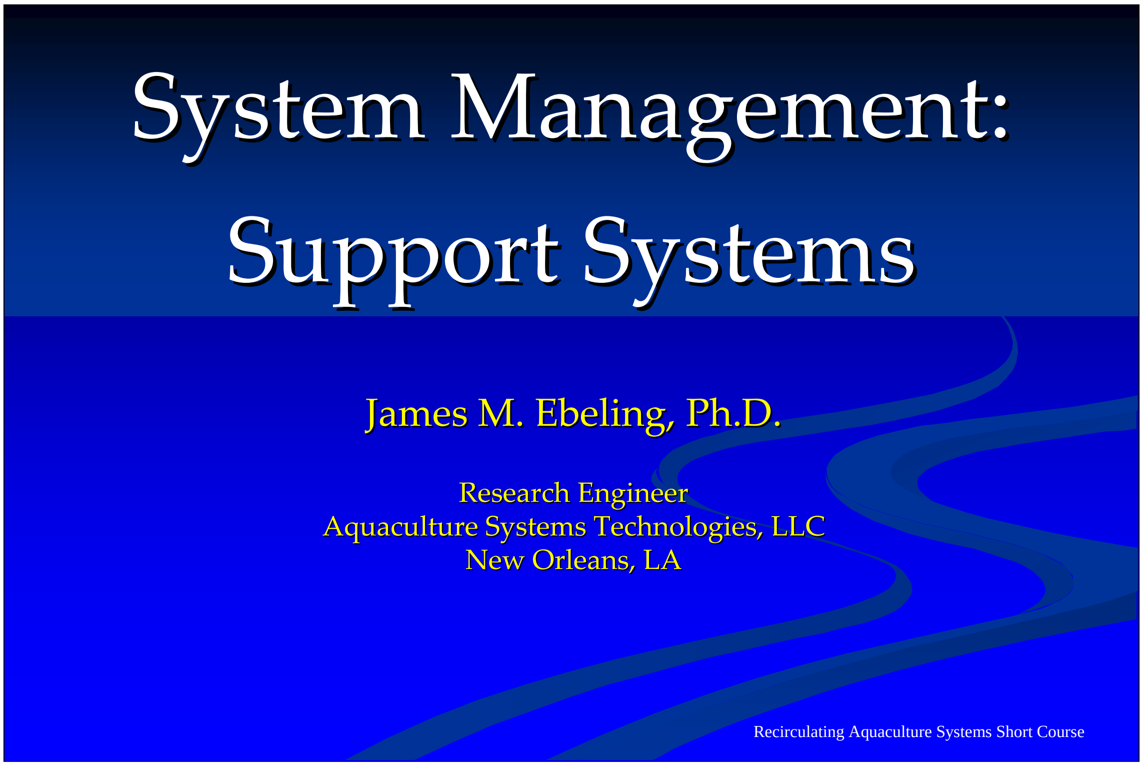
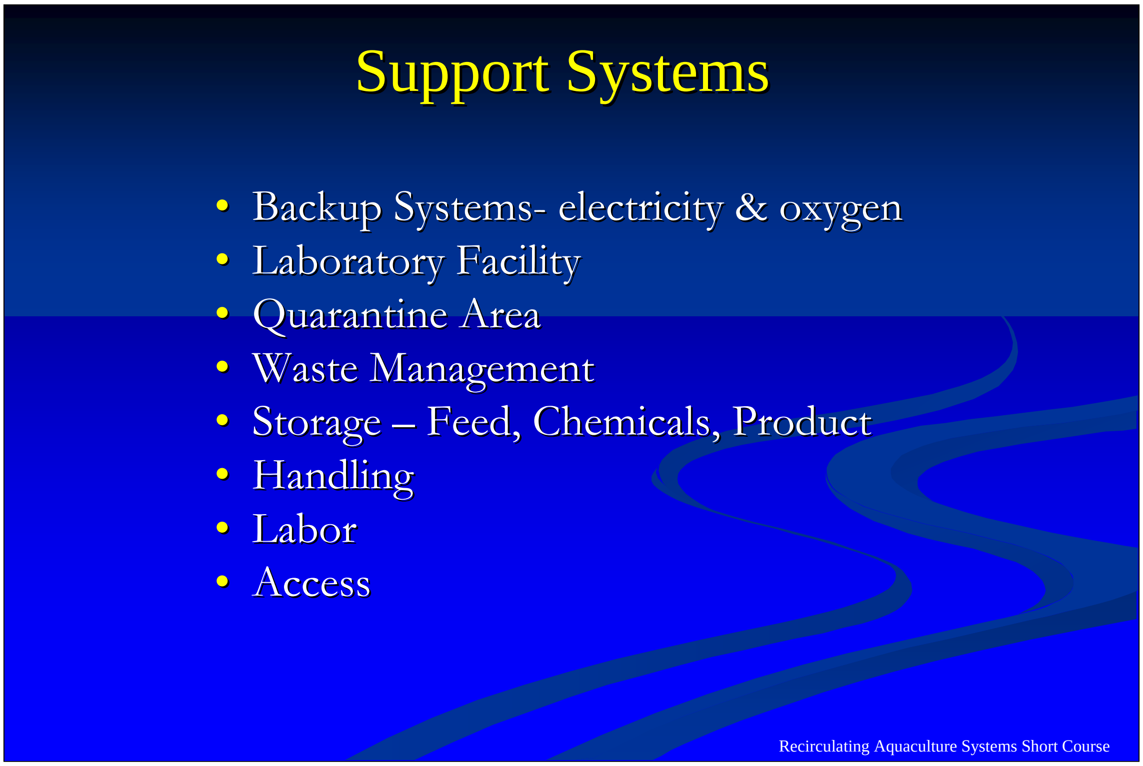


During almost all discussions of intensive recirculation aquaculture systems, the focus is on the culture tanks, filtration systems, aeration/oxygenation systems, and the species being cultured. Yet the system's support components, which are just as important and in some cases critical to commercial success, are rarely mentioned. Support components include all of the other parts of a recirculating system that are necessary for its profitable operation. How well these support systems are designed, integrated into the operation, and managed often determines whether a recirculating system survives commercially or not. Many of these supporting systems are common to all fish production facilities; some requirements are unique to recirculating systems. One common characteristic is that they are often ignored in estimating culture system construction costs. As a result, support systems are often installed late in the construction phase or as an afterthought subsequent to a disaster. When this happens, funding is limited and typically the least expensive support system is installed, regardless of its reliability or whether it is appropriate to the system. Such false economy usually compounds problems in an already marginal operation. The result of such activities is then just a matter of when, and not if, the system will fail.



The list of support components necessary for an intensive recirculating aquaculture system (RAS) is a reflection of the level of sophistication, the interplay of upfront capital investment versus daily operational costs, size of operation, number of employees, geographic location, and numerous other parameters. A short list includes such items as:

•Backup Systems

•Laboratory Facility

•Quarantine Area

•Waste Management

•Storage – Feed, Chemicals, Product

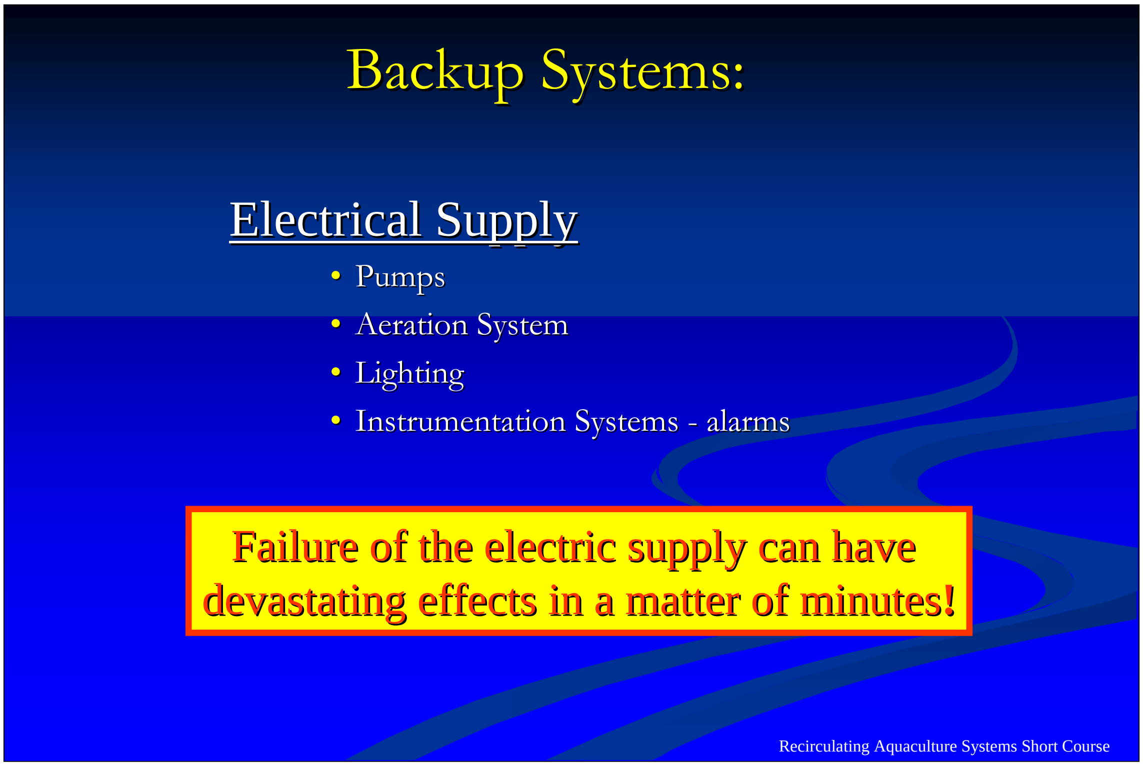
•Handling

•Labor

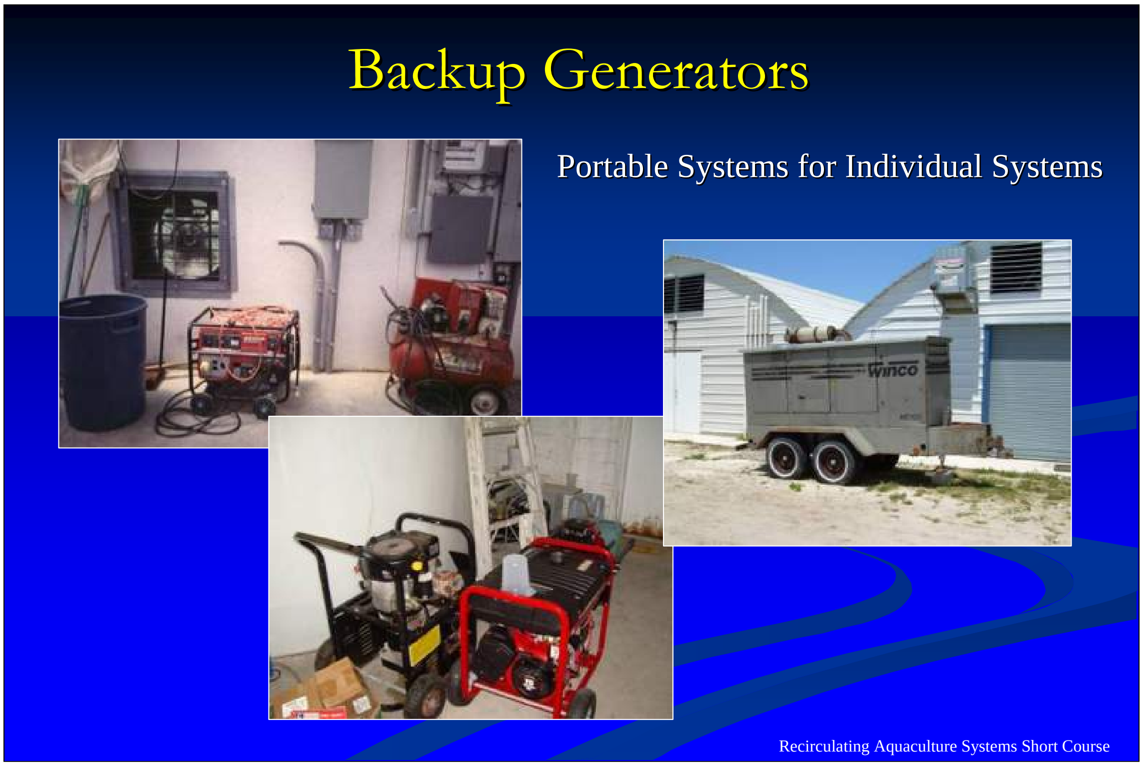
•Access

The objective of this presentation is to identify some of the needed support systems with no attempt to be all inclusive or to prioritize. Each recirculating system will have it own special needs and the priority of needs for one system is often different from another system. Thus, the system design engineer and the manager must include the required support systems pertinent for any specific production unit.

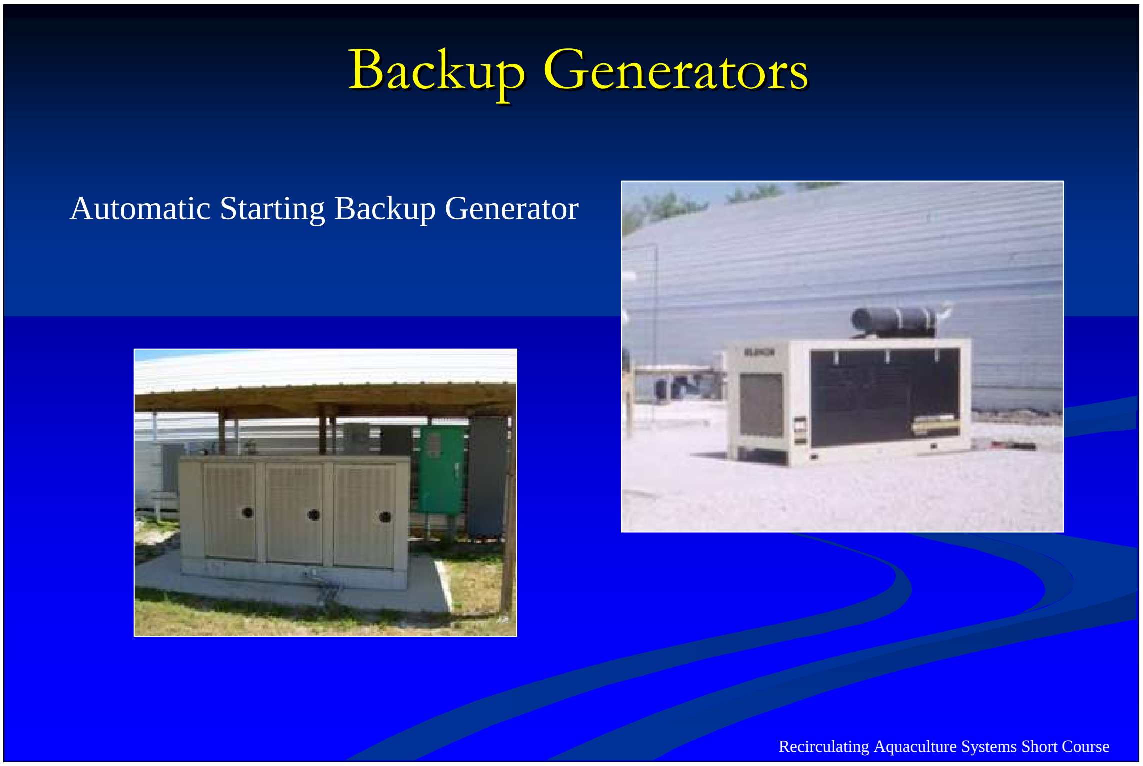
In science, a concept only becomes a "law" after being tested and observed countless times. Murphy's Law is an excellent example of this concept. It states simply: *If anything can go wrong, IT WILL.* This is the entire design rational behind backup systems and even backup systems for backup systems. During design, construction, and operation, it is critical to try to imagine the "worst case scenario!" Because if it can happen (and often when you think it can not possibly happen), IT WILL! **Anticipate! Plan! Train! Respond!**



One of the primary systems requiring backup is the electrical power supply, which is required to operate pumps, aeration systems, instrumentation systems, and to perform a variety of other functions in a recirculating system. Failure of the electric supply can have devastating effects in a matter of minutes, especially in heavily loaded systems. Backup electricity can be provided by a generator that is fueled with gasoline, diesel, or natural or propane gas. Backup generators are a critical must for any commercial (for-profit) system. Several commercial manufacturers can supply turnkey systems over a wide range of power requirements.



The cost of the generator is directly related to the generator size, i.e., the power in kilowatts that is generated. The generator size required for backup power is determined by the loads that are critical to the maintenance of good water quality or otherwise support the survival of the fish in the culture systems during power blackouts. Typically, this includes powering such items as the circulating pumps, aerators or blowers, the data acquisition system, and building emergency lightning. Usually, these loads are handled by a separate emergency circuit breaker panel. The capability of the backup generator in terms of voltage (120–240 V AC), current, and phase (single or three phase) will be determined by these essential support requirements.



One of the important design parameters in specifying a backup generator is whether it will or will not have automatic starting capabilities. Automatic starting systems monitor incoming power lines and when the external power supply goes down, the generator automatically starts, so power is always available to critical components. Automatic systems or cut-over switches are expensive, but are necessary when personnel are unavailable during certain periods of the day or are unable to get to the facility rapidly enough to carry out manual emergency measures.

An automatic transfer switch will cost roughly 35% of the total cost of the backup generator system, but is generally well worth the investment if continuous manual coverage is not possible. If you use an auto-transfer mechanism, make sure that protocols are in place to protect the fish if the auto-transfer fails. Sometimes, the alarm sensors will "sense" that power has been restored when in fact it has not. Three-phase systems are particularly problematic and tend to fail more often in the transfer operation than single phase systems. Remember, an auto-transfer is not nearly as reliable as 24-7 coverage by humans and a manual transfer switch.

Even people are not 100% reliable as a backup system. They must be properly trained to respond to emergency and to monitor continuously. It is a good practice for a night shift person to have duties that require them to remain active throughout their shift. Intentionally schedule activities that keep them busy, e.g., water chemistry measurements, and some hand feeding.

Regardless of the generator system chosen, an automatic or manual transfer switch will be required that disconnects the power company supply lines and connects the generator lines. These switches are required to prevent feedback of power into the power company grid from the system generator. Feedback into the power company grid is a safety hazard to power line workers repairing lines. In addition, if feedback occurs, shorts or loads on the power grid can overload the generator and burn it out. Whether manual or automatic, transfer switches are expensive and can cost as much as the basic generator. It is important to work with the local power supplier to determine exactly what their requirements are and in some cases, whether equipment can be leased from them.

Generator maintenance is an absolute must! If power outages are infrequent, the backup generator may sit for long periods of time between uses. Fossil fuel engines, whether diesel or gasoline, not started for prolonged periods tend to be difficult to start. Failure of the backup generator’s engine to start due to dead batteries, low fuel levels, or other reasons will lead to catastrophic fish loss and perhaps the end of the business itself! Most commercial models are designed to be operated for a specified period every few days. Smaller generators should be periodically started and maintained in top running condition at all times.

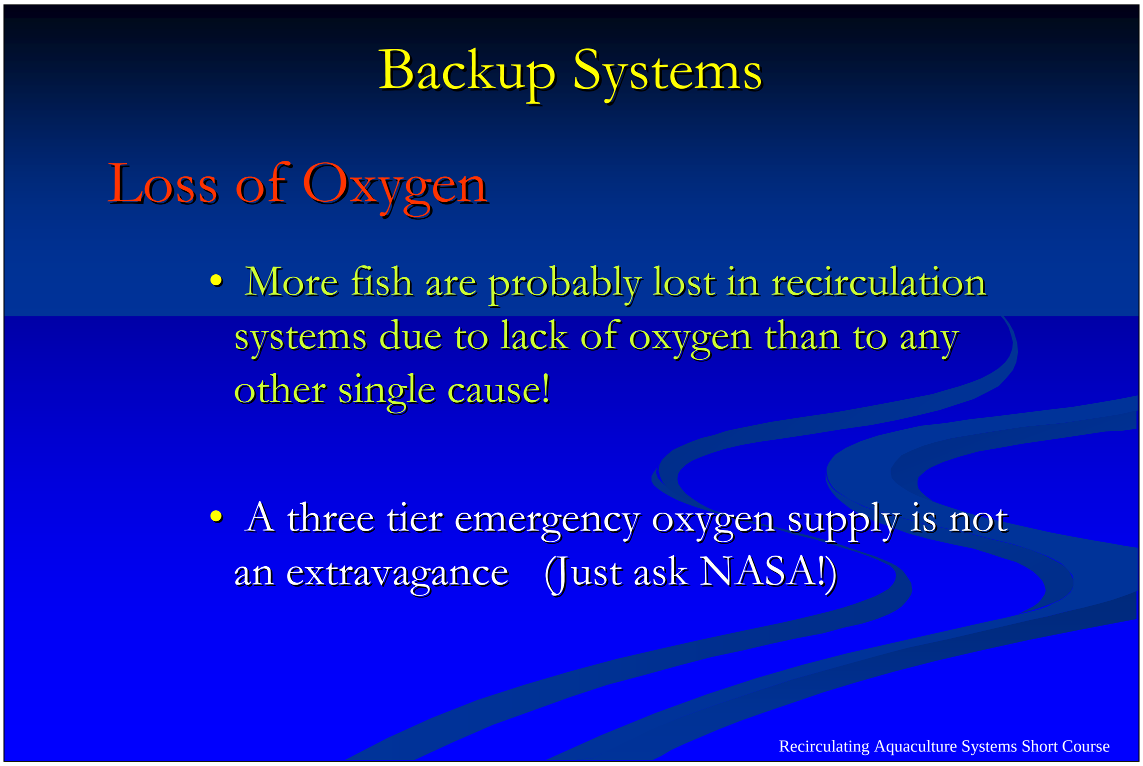
Testing Back-up Generator

Your back-up generator must work when the time comes. You will not have time to refine your protocols once you have lost power. The acid test is to go over to your main power panel and disconnect the incoming line power. Then check the following:

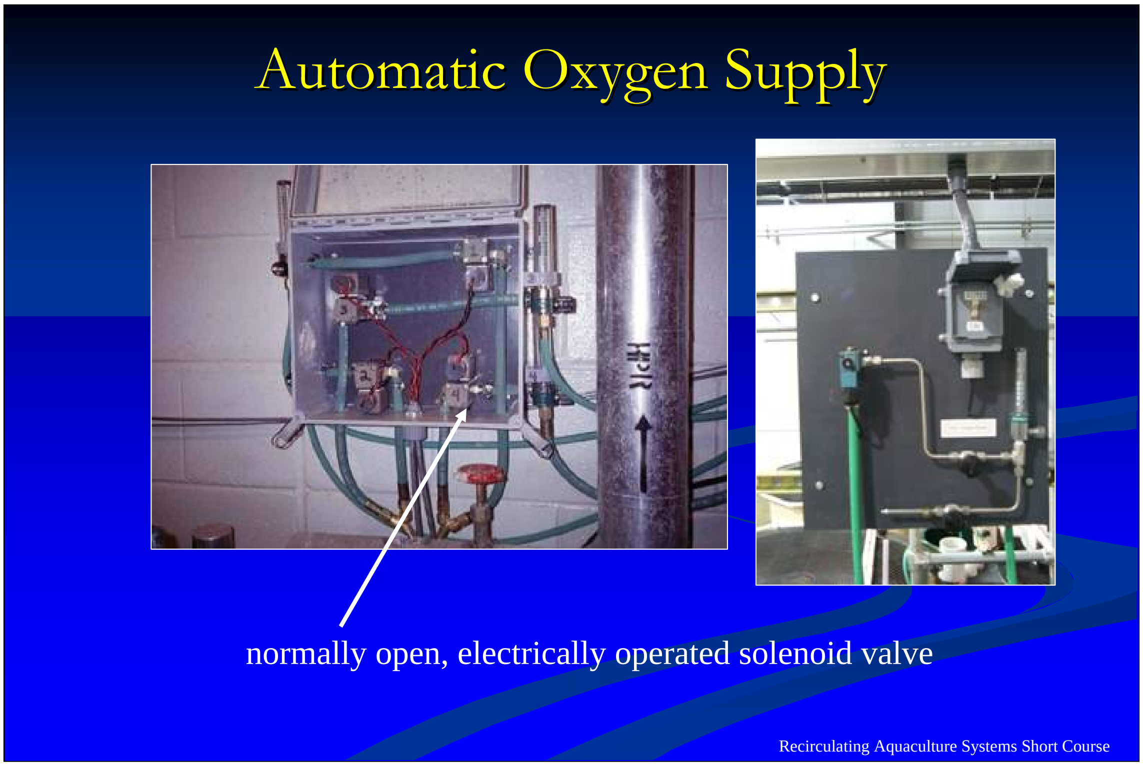
•Is all the critical equipment running (or was there insufficient power to start all the critical units). If not, consider installing delay timers on specific equipment so that the entire load is not activated at startup (startup amp requirements may be two to five times running load amps).

•Let the system run under full load for 6 hours at least twice a year to be sure that the generator set is adequate. This will allow any problems to be identified and corrected before a crisis occurs.

Final advice on this subject: make sure your backup generator set is installed and has been tested prior to your fish being placed into the facility.



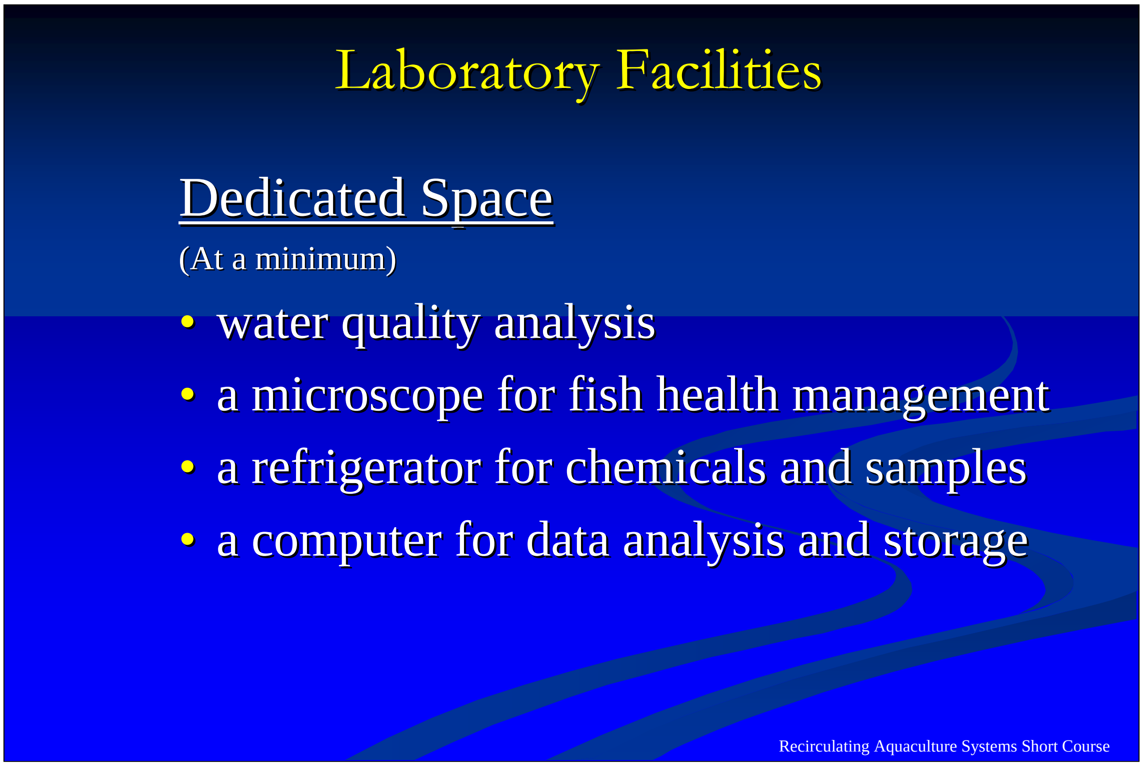
More fish are probably lost in recirculation systems due to lack of oxygen than to any other single cause. Backup oxygen systems are a basic requirement for a culture system to be economically feasible. Because oxygen availability is so critical to heavily loaded culture systems, often a three tier emergency oxygen supply is not an extravagance



There are many types of oxygen supply systems used in recirculating aquaculture systems and the type of emergency backup system needed varies with the primary oxygen supply system used. One of the simplest and cost-effective emergency oxygen systems uses an oxygen tank, either liquid or gas, connected to micro diffusers in the culture tank through a normally open, electrically operated solenoid valve. When electricity is applied to the solenoid valve, the valve is closed and oxygen is provided by the regular oxygen supply system. When the power goes out for some reason or manually operated, the solenoid opens allowing oxygen from the tank to flow into the culture tank. It is important for any backup system, especially oxygen systems, that they are automatic and engage at the first sign of a potential problem.

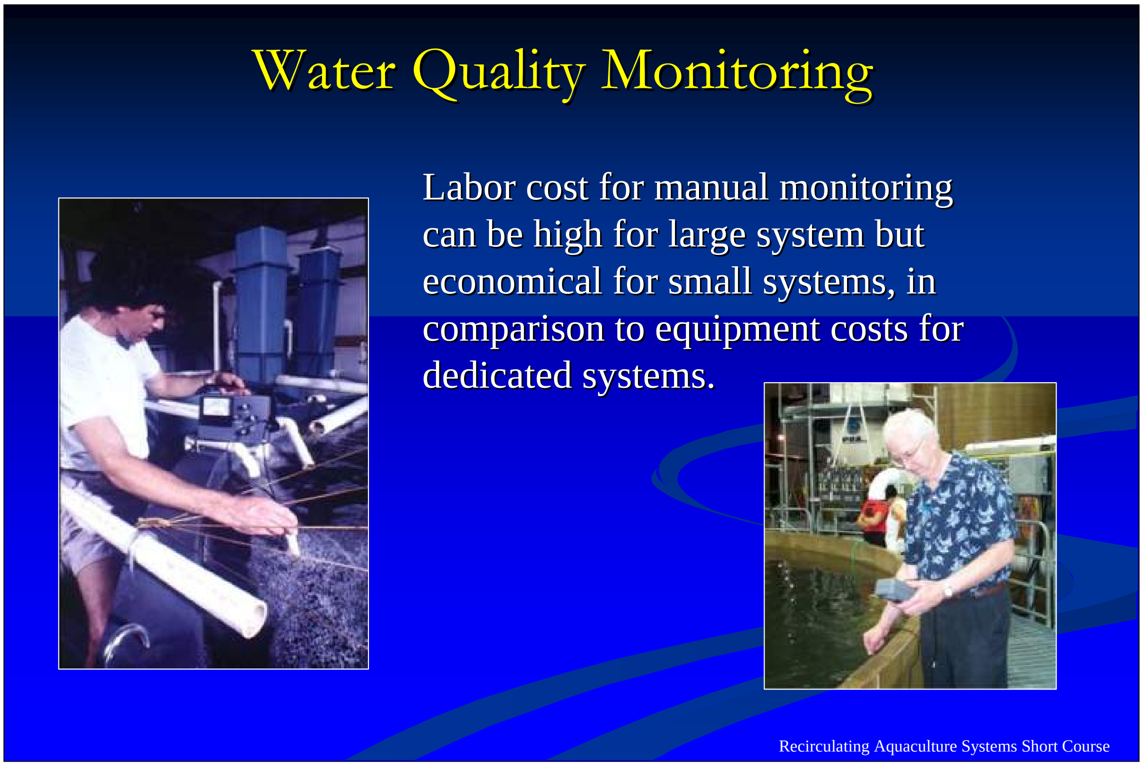
Have your oxygen back up systems in place. These units, whatever they are, need to be in or near the tank so that on a moments notice, you can activate them. Once you lose power (flow) you have only minutes to respond to protect all the tanks in the facility.

So, do a dry run before the crisis occurs. Can you put all tanks on their backup oxygen systems in 5 minutes? If not, re-evaluate and re-plan until you can.



The size and sophistication of the laboratory space needed for an aquaculture facility will vary with the size and complexity of the recirculation system. However, every recirculating aquaculture production system will require at least a minimum amount of space set aside for laboratory analysis. At a minimum the laboratory will include equipment for water quality analysis, a microscope for fish health management, a refrigerator for chemicals and samples, and a computer for data analysis and storage..

Water quality monitoring and control is a routine task in any aquaculture facility. The amount of laboratory space and equipment needed for this work will vary with the methods used, facility size, and the frequency of sampling. Smaller fish farms can often get by with commercial water quality test kits that are available from several manufacturers. They use pre-packaged chemicals, indicator strips, or color comparison techniques. They are convenient, relatively inexpensive per analysis, and provide sufficient accuracy for small production facilities with low stocking densities. More importantly, they require very little laboratory space.



As the number of samples and the corresponding risks to production increase, the sophistication of the analysis also needs to increase. Several important water quality parameters can be monitored using electrode sensors that provide an electrical output signal proportional to the water quality parameter being measured, such as temperature, pH, dissolved oxygen, conductivity, and oxygen reduction potentional (ORP). Portable meters do require that someone physically go to each sampling point and manually measure and record the required water quality parameter at whatever is the desired frequency. Labor costs for manual monitoring can be high for large system, but economical for small systems, in comparison to the equipment costs for dedicated systems.

In heavily stocked systems, dedicated systems can be used to both monitor and control critical water quality parameters, such as temperature, pH, and dissolved oxygen. Commercial systems are available that will monitor selected parameters, and also provide an alarm when a parameter deviates from the preset minimum and maximum. Combined with the necessary computer hardware and software, real time water quality data becomes available to the system's manager. This provides accurate information for management and historical data for system performance evaluation and analysis.

As the sampling protocols become more sophisticated, a higher quality laboratory will be needed. Currently, for example, there are several commercially available laboratory spectrophotometers designed for water quality analysis. These dedicated pieces of equipment are able to analyze for a wide range of critical water quality parameters using pre-packed chemicals and simple laboratory procedures. At this point, the laboratory should be equipped with a sink, refrigerator, and computer, and have adequate room for equipment storage and personal work areas.

Many of the disease outbreaks occurring in recirculating systems come from diseases introduced on or in fish purchased from outside the system. Disease introduction can be minimized by quarantining incoming fish for one to a few weeks prior to introducing them into the recirculating system. During this period any disease problems can be treated without contaminating the recirculating production system.

Quarantine areas require space and must be located such that the incoming fish are never in close contact with the growing systems. Personnel traffic must never be allowed to move from the quarantine area directly into the area containing the growing systems. Permanent physical barriers must make such movement impossible. Where possible, the quarantine area should be in a separate building from the main production systems. The size of the quarantine area is a function of the management techniques used in the facility. The quarantine area must be large enough to house all of the fish entering during one quarantine period, whether it is one week or several weeks. The water supply must be adequate for the volume of fish in the quarantine area and separate waste discharge should be provided.

Aquaculture waste discharge regulations are currently in a state of flux. However, it is clear that aquaculture producers will be required to meet discharge regulations and these regulations probably will become more stringent in the future. Thus, waste management facilities and management methodologies will be an important component of any aquaculture facility put on-line in the future. Because recirculating systems do not use as much water as many other types of aquaculture systems, their waste management problems may not be as severe, but there is waste that must be disposed of or put to use in an environmentally beneficial or at least benign way.

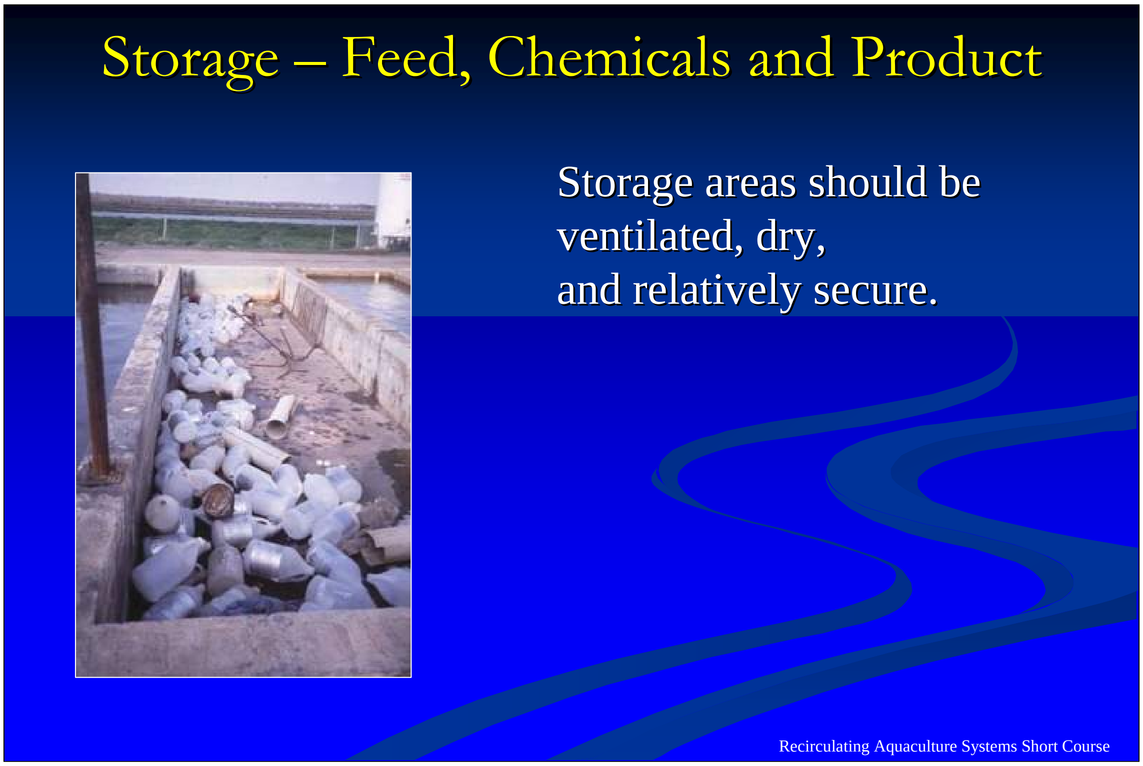
Waste disposal needs for an aquaculture facility depend on the system size, species cultured, feed used and other variables. The major problem is removing the wastes from the culture water. There are mechanical, biological, and chemical methods to accomplish this removal, and a variety of specific implementing systems. The best technique to use depends on the waste characteristics, concentrations, and form in which the waste is found. Once the waste is removed from the culture water, it must be disposed of or used for some useful purpose. Solids from fish culture systems contain considerable nitrogen and phosphorous, which are useful nutrient elements in fertilizers. Thus, one disposal technique is to use the solids for organic fertilizers, by spreading it on agricultural land. Composting for later use as a soil amendment, mulch, or fertilizer can be used for both solid and liquid fish wastes. Holding facilities may be necessary to contain the wastes between periodic disposal cycles. Such facilities must contain the wastes in an acceptable manner and must prevent development of odors and other noxious nuisances.

Waste Management

Some waste disposal systems are more cost effective than others!

Some waste disposal systems are more cost effective than others!

Nearly all aquaculture facilities will suffer some mortality, although under normal operation the volume of dead fish will be low. Nevertheless, if mass mortalities occur due to oxygen stress, disease, or some other reason, the volume of dead fish that must be disposed of can become high. These fish must be disposed of in an environmentally acceptable manner, and they cannot create noxious odors or pose sanitation or health risks to either humans or other fish in the culture system. Acceptable disposal techniques will depend on the volume of dead fish, the land use near the facility, the depth of the groundwater table and other factors. In the event of a mass mortality, lack of planning for disposal of dead fish can be embarrassing at best and may result in a legal morass. If fish are processed on-site, processing waste must also be disposed of or used. Some of the options for large quantities of fish waste are composting, anaerobic digestion, burying, or moving to a landfill. The key is to be prepared ahead of time.



There are several obvious materials that must be temporarily stored at any aquaculture production facility including: 1) chemicals for disease treatment and for running water quality tests, 2) finished product, and 3) feed.

There are several potential uses of chemicals in recirculating systems, although only a limited number are available for disease treatment of fish. However, those chemicals that can be used must be stored in an appropriate manner. Some require refrigeration, while others require only dry storage conditions. All of these chemicals should be secured against accidental use and/or theft.

Chemicals used for water treatment are probably more common than disease treatment chemicals in recirculating systems. Typically, flocculants, disinfectants, and cleaning compounds are used in or around recirculating systems and space must be allocated for their storage. Normally such storage areas must be ventilated, dry, and relatively secure. Chemicals are necessary for calibration, titration, and other applications when measuring water quality. Most of these chemicals can be stored in a dry, secure area. Occasionally, a chemical is needed that is corrosive or volatile; these type of chemicals must be stored in an appropriate safety cabinet or refrigerated safety cabinet.

OSHA material safety data sheets (MSDS) describing the chemical and its effects must be available for all workers. EPA labeling and disposal requirements must be met. CVM (FDA) withdrawal times must be adhered to.

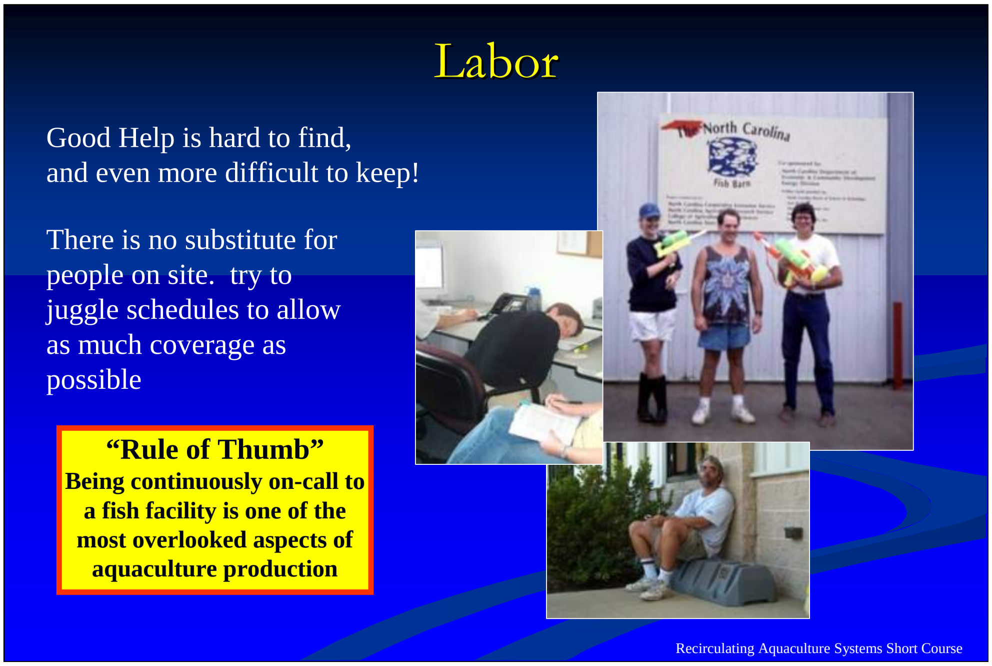
Equipment storage is just as important, because when you need that fitting, you usually **NEED THAT FITTING!** It doesn't cost that much in time, labor or resources to make a work area clean, well organized and efficient.

Whatever the production facility, it will produce some final product, usually either live fish ready for sale, or dead fish in the round or processed to some extent (at least gutted, in most cases). Temporary storage must be available for the product. If live fish are to be sold, a holding tank and/or a depuration may be necessary. Often fish are graded from the production tanks just prior to sale. In this case, the fish to be sold are often collected and held in a separate holding tank that is readily accessible to the truck to be used for transportation

Grading is generally accepted as a way to improve growth rates by eliminating negative interactions between fish of different sizes. Grading also allows for a more accurate feeding regimen, feeding the proper feed particle sizes, and makes harvesting easier to plan and to carry out (see Chapter 16 for further details on feed management). The less variability in fish sizes across the cohort, the less grading that will have to be done. Generally, the less deviation in sizes, the more marketable they will be to a growout facility and to the processor.

Some Norwegian salmon farmers use grading to cull the smallest, least efficient feeders and might remove as much as 50% of the population. Maintaining inefficient feeders can create a 30–50% increase in production costs; therefore, these fish should be removed as early as possible. Culling decisions will need to be made by the manager, based on experience with the facility's production. If it is not clear how well various size ranges of fish are converting feed, a small percentage of the smallest fish from a single tank can be removed. Feed conversion or other parameters can then be monitored to determine whether the initial cull improved production efficiencies.

There are many fish graders commercially available. Whatever the system used, facilities, and/or equipment are needed for grading. The type of grading equipment needed depends on the system design, species, management methods, and other factors.



One of the most demanding aspects of aquaculture is the need for labor that is dedicated to the task and has the necessary knowledge and training. When there are fish in the recirculating system, someone has to be present at the facility or on call 24 hours per day, 7 days per week or 24-7. If the operation is small and is operated by one person, that individual must be willing to be on call continuously for long periods of time. The person must be dedicated to the job. Large operations can afford to hire more than one person, so the on-call burden can be spread across different people. Everyone can get some time off, if all employees take their turn being on-call during some weekends and/or holidays. Particularly in small operations, being continuously on-call requires dedication that few people are willing to make, and is one of the most overlooked aspects of aquaculture production.

Aquaculture production requires a mixture of knowledge learned in a classical school or college setting, as well as knowledge learned on the job. Currently, there are only a limited number of people who have the needed combination of knowledge and experience to successfully operate a recirculating aquaculture facility. Any sizable recirculating aquaculture operation must make a concerted effort to hire people possessing most of the needed knowledge and to be prepared to train these people on the parts they are missing and to train new people from the beginning of their employment. The manager, owners, and/or investors must be aware that training new people will involve a certain amount of risk and probably will involve loss of at least some crop.

The location of the aquaculture facility will strongly influence the type of people that can be hired. Are the local conditions such that people with the educational backgrounds and experience needed are going to be satisfied to live there? Are the needed people available locally or must they be moved to the site? Obviously, the availability of a suitable labor supply is not the only determining factor in site location, but it is the one most often overlooked.

Access to the aquaculture site is necessary for employees, feed supply trucks, oxygen supply trucks, fish haulers, and other functions. This implies that there is a road or some method of getting people and vehicle traffic in and out of the site. There must be available access in all weather conditions and there must be space enough to maneuvers trucks and other vehicles. These areas may be gravel covered or hard surfaced. The physical size of these areas will depend on the type of truck expected and the frequency of truck traffic. The turning radius of a tractor trailer is about 65 feet (20 m), which means that the smallest radius on any driveway should also be no less than 65 feet (20 m). Plan for efficient ingress and egress from the farm site for all large trucks. Loading docks may also be necessary. These facilities can be expensive, particularly if not properly planned into the overall facilities design.

Provide necessary safety devices and train, train, train on how to use them.

It is critical that all the staff be well trained in daily operations and how to respond in emergency situations.

Take time out when your not in a rush to save your livelihood and anticipate what could go wrong, plan how to respond, train yourself and your first responders and then do it.