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Considerations and Reflections on Design and Construction of a Centralized Zebrafish Facility

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Successful design and construction of the modern, centralized zebrafish facility requires an approach with distinct differences from typical vivaria.

While the zebrafish is coming into its own as a model organism for research, the common attributes of the modern, centralized zebrafish culture facility are beginning to take shape. An understanding of what is required to design and build a facility whose layout and construction maximize the use of the available space, while standing up to the harsh environment and high traffic flows, is critical for success.

Although the centralized aquatic animal facility shares some similarities with mammal vivariums, most are superficial and it pays to put the experiences of building such facilities aside when planning a zebrafish facility.

Zebrafish researchers spend a great deal of time with their fish, and, unlike in conventional mammal vivaria, perform the majority of their work within the confines of the facility. This represents a new challenge to the designers of conventional vivaria and demands a significant amount of input from the PIs, managers, and researchers with respect to ergonomics and work flow design.

Materials selection is a key area of difference from mammal vivaria as well. The highly corrosive nature of this environment, due to both high-purity water as well as water containing salts, not to mention the high humidity and warmer than typical temperatures, all add up to a facility whose base construction and fixtures must be selected for impermeability and oxidation-free qualities.

Realities and Challenges

While some new zebrafish facilities are constructed in new buildings, many are being built in existing buildings, often reclaiming space from mammal facilities that are obsolete. This represents special challenges, especially with respect to scheduling and material handling. The noise generated by demolition and the obligations of responsible waste removal may result in “off-hours” work only, which comes with its own complications and expense.

When considering the design options for the physical footprint of aquatics facilities, one must accommodate the substantial mass of the water that will be employed. This often lends a preference to basement locations, but does not preclude upper level sites, as long as the slab is adequately stiff, and the drainage capabilities are adequately provisioned to protect your

neighbors below if there is a large leak of water; which there will be—eventually. And although very few aquatics facilities are designed with a dirty side vs. a clean side, adopting a traffic pattern in your layout that minimizes the back tracking of dirty equipment into areas where clean equipment is stored is still desirable.

Most zebrafish housing vendors can supply products which include sumps below the housing racks. If the sumps are consolidated in isolated life-support systems areas, this space can be recovered for as much as 10% additional tank space. This approach may, or may not, require some equipment to be located below-grade. Alternatively, a double-pump approach may be employed, but when considering the drainage requirements for these facilities, and the work that must be done to provide adequate floor and trench drains, a below-grade approach may be preferable.

You can't have too many floor drains, as long as they actually are the lowest point in the room, and trenches are even better, but will require additional maintenance to reduce pests. Either approach will likely require you to make some substantial cutting and excavation, and if the building is a new construction project, it may require a whole new perspective on the building's drain layout and capacity. Be sure that drain covers are easily removed for inspection and cleaning and access for pest control measures.

Wet location lighting and electrical fixtures, properly rated electrical enclosures, specialized lighting, and specialty casework all add up to greater expense and longer lead times than normal, and should be anticipated and accounted for as early in the project as possible.

Layout and Design

The need for rapid grow-out of larvae into sexually mature adults is driving the popularity of the allotment of space for a dedicated nursery, separate from the housing areas for adult fish, not only spatially, but environmentally as well. Specifically, photo-periods may be different in scheduling as well as duration, providing more time in the "day" to feed fish.

While the standard development temperature for zebrafish is 28.5°C, the water temperature of some adult housing rooms may need to be maintained lower or higher to facilitate work with temperature sensitive strains of fish.

When managing a mono-culture, it's always best to keep your eggs in as many baskets as possible, and this maxim is perpetuated in the need for separate life support systems for each room. This provides a modicum of comfort in that if there is a disaster in one room, other rooms are isolated and protected to some degree.

With properly designed HVAC, the animal rooms may be maintained at comfortable room temperatures and humidities rather than at the old 28°C and 85% RH that is so common in older facilities. Similar to mammal vivariums, the use of negative pressure will help to keep the odors and airborne components of the animal housing rooms from permeating the surrounding spaces.

The needs for work space in the housing rooms may vary and are certainly different from mammal vivariums. As previously mentioned, zebrafish researchers perform a great deal of work with their animals within the facility and much of this is done in the animal holding rooms. There will likely be a need for large amounts of counter top space and sinks as well as taps for pure, municipal, and perhaps system water.

Since breeding zebrafish for embryo production is a primary activity in zebrafish facilities, there

will need to be a substantial amount of space dedicated to this purpose, and perhaps as much space should be allotted for storage of fish awaiting genotyping results or similar short-term storage.

Lighting is another area where wet-label fixtures will be preferable. Sophisticated control systems are becoming more common to ensure proper, uninterrupted photo-periods which are critical to breeding success, and to minimize the growth of algae that obscures our view into the tanks, can cause fouling of the life support system, and increases the labor demands dramatically in aquatics facilities.

It is tempting to hide much of the infrastructure above a suspended ceiling, but an exposed ceiling, with properly insulated and coated duct and conduit make for a much more durable choice and one that can be cleaned more easily too.

Life Support Systems

The areas housing the life support systems of centralized facilities are more accurately described as engineering spaces and consequently, they will require oversight by a manager who is competent to identify the underlying cause should a problem arise and implement a repair or solution. Access to the life support systems from outside of the holding rooms may be preferable and may also serve to increase the space available for fish racks.

Like much of the historically used equipment and materials, the UV disinfection employed in large, centralized facilities is also beginning to look more like that of water treatment facilities.

Biofiltration is an area where several choices are available to the designer of the life support system, but virtually all of the options share one characteristic, fluidization. Whether you opt for beads, extruded plastic media, or sand, all rely on fluidization with air or water flow to maintain the highest efficiency of nitrification. This is one aspect of facility design where it pays to be liberal with your estimates of waste that needs to be remediated.

Not all zebrafish culturists agree that the use of granulated activated charcoal (GAC) is necessary. If you choose to include it in your life support design, be sure that the filter vessels and the media canisters are rated for this purpose. A by-pass and back wash loop should be plumbed in to allow flushing of the fine sediments that build on top of the media bed.

Alarm notification is another area where much needed advances have been made. We now have sms (text) messaging and e-mails that can deliver very specific information. These systems are addressable remotely, meaning that the manager or supervisor can log in to the systems from any device with a wireless or adequate cellular signal and internet access.

This brings me to a very important point; get your IT staff involved in the project as early as possible. There will need to be some very technical discussions between the controls/automation designer and the IT staff to ensure that everybody is happy with the levels of access and security moving forward.

Ancillary Rooms

There are two types of ancillary rooms in aquatics facilities; those that support the culture facility and those that support the science and researchers. The three most important rooms that support the culture facility are the water treatment plant, foods preparation, and cage-wash rooms. The water treatment plant may simply consist of carbon filtered well or municipal tap water, or Reverse Osmosis (RO) and even De-Ionized water (DI). Your choice should be made

based on the quality of the water you will be starting with and the degree to which you choose to purify it. The amount of purified water you keep on hand in reservoirs should provide you with at least two days of life support systems operation.

The foods prep rooms should be centrally located and, whenever possible, sized to accommodate expansion of the facility. They should allow for easy wash-down cleaning, with good floor drainage and ready access to pure water and hot tap water.

Cage wash should also be sized to handle the largest amount of soiled cages that can be envisioned. Space for storing cleaned items should be located nearby. Although few aquatics facilities are employing the use of chemicals in washing aquaria and mating cages, it is gaining popularity and has been long overdue in the field. I have no doubt that a safe and effective wash protocol, using a chemical or combination of chemicals, will be common in the near future.

How to Make It All Happen

In a word: Teamwork. Assembling the team is the first, crucial step in getting this done right. Aside from the normal players, such as the architects, engineers, general contractors, and sub-contractors, ensuring that the people who will inherit the project as their daily work environment, the PIs and the facility manager, are involved from the earliest possible time will be a major boon to any aquatics facility construction project. The implementation of mandatory construction meetings, from the beginning of the project until the final punch list, will help to provide insurance that everyone is always on the same page and that goals set during these meetings are being met.

One last bit of advice on the communication within the group, all parties should be cc'd on all project related e-mails and all e-mails should have the same subject line or at least the same subject line prefix; this permits better sorting within our already overcrowded inboxes.

In the end, the modern, centralized zebrafish culture facility shares many attributes with related vivaria construction projects, but attention to detail and being ever mindful of the starkly different physical working environment of aquatics facilities will pay out in dividends. Involving the end-user will minimize the need for costly revisions and delays and assembling a solid team that plays well together will ensure that your project is successful and completed as scheduled.

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