Recirculating System Technology for Shrimp Maturation

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Recirculating systems have been used successfully in fish aquaculture for the past 20 years, and are now finding increasing application in shrimp maturation, where they increase production of nauplii and improve biosecurity. This article discusses advantages and disadvantages of using recirculating systems for shrimp maturation, as well as design considerations for this application.

Typical shrimp maturation tank

Advantages of Using Closed Systems

Biosecurity

A primary advantage of recirculating systems is increased biosecurity, due to reduced usage of potentially contaminated coastal water. In the wake of white spot syndrome virus, many farms now demand hatchery-reared rather than wild postlarvae to reduce the risk of disease outbreaks in ponds. Hatcheries, in turn, are screening broodstock used in maturation systems to avoid introduction of infected stocks. Recirculating systems reduce the risk of infecting these stocks with surface water contaminated with disease organisms or carriers. Such protection is particularly important for valuable broodstock used for genetic selection programs.

More Stable Water Quality

Properly designed closed systems provide stable water quality, which mimics the environment found at natural oceanic spawning grounds. Fluctuations in temperature, salinity, pH, ammonia, nitrite, and other parameters inhibit shrimp maturation. Yet, these fluctuations are nearly unavoidable in flow-through systems. Also, flow-through systems are vulnerable to insidious contamination from pathogens, red tides, industrial pollution, pesticide runoff, etc.

Increased Production

In a traditional flow-through system, about 4% of females spawn per night, while in recirculating systems, 6-8% spawn per night. In addition, females mature more completely in recirculating systems, and produce more viable eggs per spawn. For example, L. vannamei matured in flow-through systems typically average about 90,000 nauplii per spawn, while those matured in recirculating systems average about 120,000 nauplii per spawn.

Reduced Cost of Nauplii Production

The higher productivity of recirculating systems has a dramatic effect on the cost of production, because fewer broodstock are required to produce a given number of nauplii. This translates to less capital expense for maturation tanks and less operating cost for expensive maturation diets (bloodworms, squid, Artemia biomass).

Reduced Mortality of Broodstock

Decreased stress on females due to improved water conditions decreases broodstock mortality from 0.5% per night in a flow-through system to 0.1% per night in a recirculating system. Decreased mortality and stress allow the production cycle to be extended from 2-3 months in a typical flow-through system to 4-6 months in a recirculating system.

Production Based On Low Water Exchange Systems

These increases in production are based on systems that exchange 0.5 - 10% of total volume of water per day. The low water exchange rate allows hatcheries to take full advantage of the benefits of moving to a closed system such as retaining pheromones and maintaining stable water quality. Systems which recirculate < 75% of their water have not shown significant production increases due to recirculation.

Water Quality Classification for Shrimp Maturation

Recirculating systems can be categorized into three classes according to the trophic level requirement of the target organism (Malone and de los Reyes, 1997). The category with the highest water quality defined by the lowest nutrient load is referred to as "oligotrophic". "Mesotrophic" describes higher nutrient loads common in high-density production systems, where water quality and economics must be carefully balanced to achieve profitability. "Eutrophic" describes water with very high nutrient loads, which cause instability including algal blooms, dissolved oxygen crashes, and ammonia peaks. Only tolerant fish species prosper in a eutrophic environment.

Shrimp maturation systems require the very highest water quality conditions in order to assure stress-free development. Malone and de los Reyes (1997) characterized such water quality as oligotrophic "marine reef" conditions with dissolved oxygen > 6.0 ppm, CO_2 levels < 1.0 ppm, total ammonia level < 0.3 mg-N/L, nitrite < 0.3 mg-N/L, etc. In order to achieve such water quality for shrimp maturation, one must choose the most appropriate filtration equipment.

Filtration Components For "Marine Reef" Conditions

Filtration systems usually include several different components that perform four critical processes:
1. aeration to replenish oxygen,
2. degasification to remove excess carbon dioxide.
3. mechanical filtration to remove suspended solids,
4. biofiltration for the nitrification of ammonia

Aeration

Aeration may be provided by the inherent design of the recirculating system, for example water discharge through a packed column. However, if the system design does not include aeration, additional equipment such as a blower will be necessary to perform this task

Degassification

Excess carbon dioxide can be toxic to aquatic species, therefore biofiltered water must go through a degasification chamber such as a packed column to prevent accumulation.

Mechanical Filters

One of the main causes of failure in recirculating systems for shrimp maturation is clogging of filtration media and consequent discharge of anaerobic toxins that inhibit maturation and mating. This problem can be avoided by choosing an effective mechanical filter, placed before the biological filter, to effectively remove particulate matter from the tank. Considerations in choosing mechanical filters are: size of particles allowed to pass through the filter, amount of maintenance required, and amount of water discharged during backwashing. For marine reef conditions, a mechanical filter must be capable of removing particles from 10-15µ in size.

The most common mechanical filters are:
- Rotating Micro-Screen filter
- Rapid Sand filter
- Bead Filter
- Protein Skimmer

Micro-screen filters are effective in removing small particles, but they require large volumes of water for backwashing. They are also prone to mechanical failure due to constant moving parts.

Rapid sand filters are effective at removing small particles, but they tend to clog after about six months. Also, they require 300-500 gallons per day for backwashing.

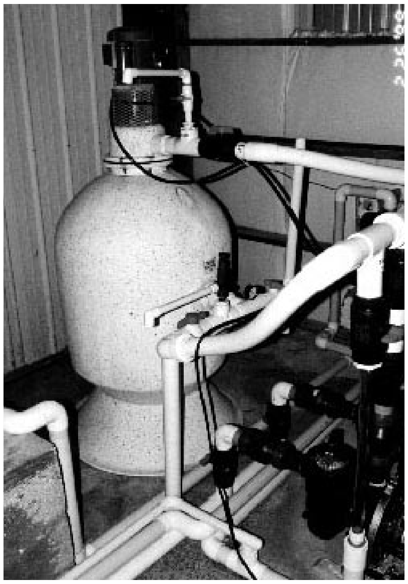
Bead filters are effective in removing particles down to 15µ, and only require 50 gallons per day for backwashing. The design of bead filters also concentrates sludge, which reduces the water requirement for backwashing.

Protein skimmers are very effective for removal of particles ranging from 0-15µ.

Biological Filtration

Ammonia and nitrite are good indicators of overall water quality, and will be used in this discussion to describe biofilter requirements for maintenance of "marine reef" conditions. Biological filters eliminate toxic ammonia and nitrite through the process of nitrification. Nitrification is accomplished by providing surface area for nitrifying bacteria to grow. The effectiveness of nitrification in removing ammonia in a biological filter is therefore a function of the amount of surface area provided for nitrifying bacteria. When choosing a biofilter for shrimp maturation, it is important to provide a cost-effective biofilter with a high enough surface area to keep ammonia levels within oligotrophic parameters. It also may be necessary to oversize the biological filter in order to handle "shock loads" of ammonia, when changes in feed rate or biomass occur in the tank.

The most common biological filters used in recirculating systems are:
- Bead filters
- Trickle filters
- Rotating Biological Contactors (RBC)
- Fluidized Bed Biofilters.



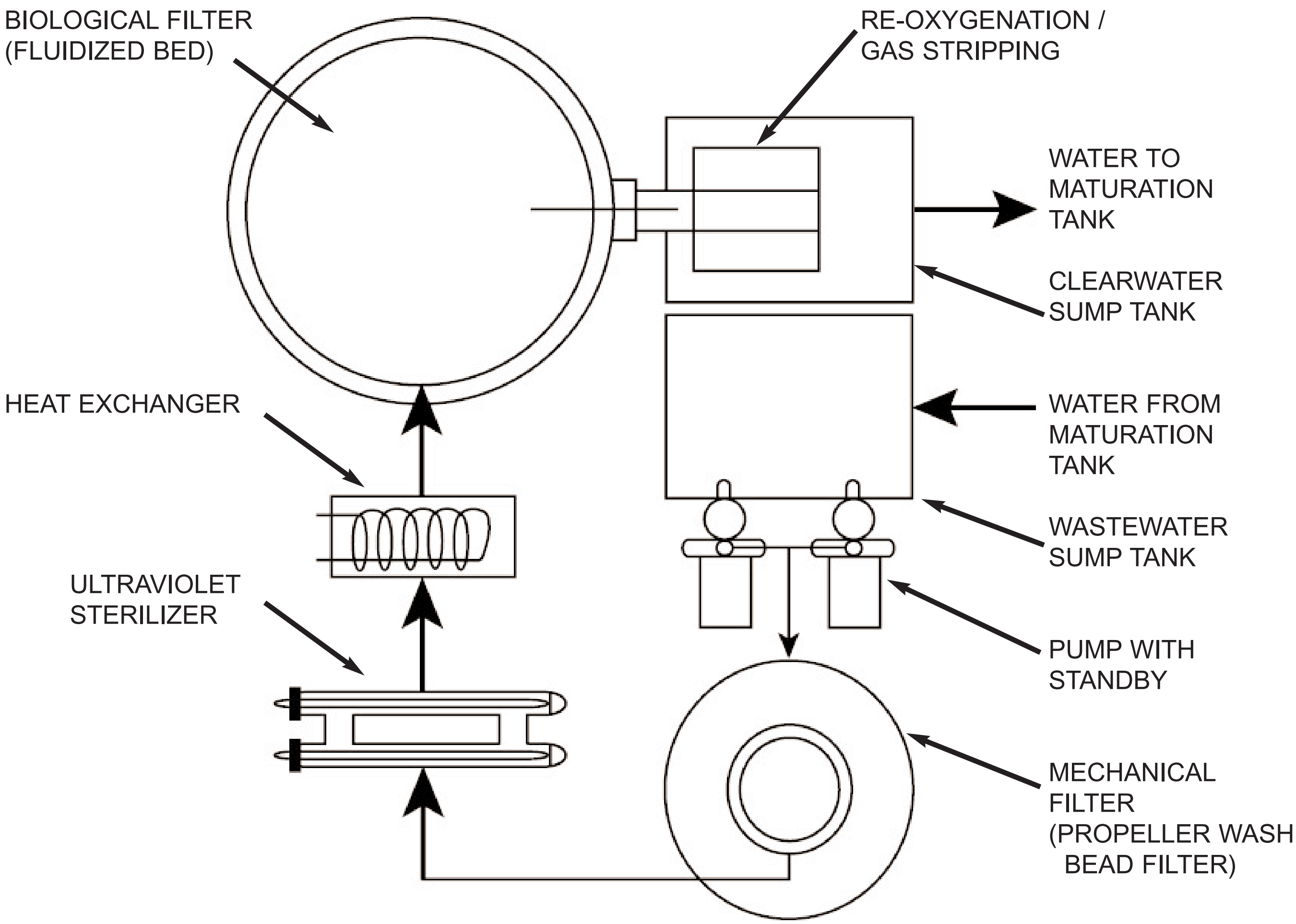
Power wash bead filter on recirculating water system for maturation tanks.

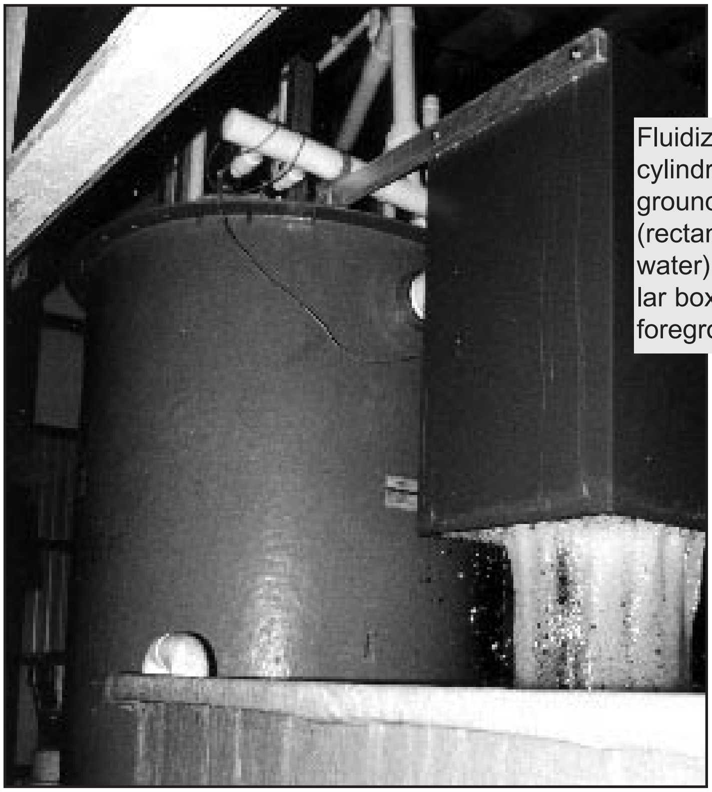
All these filters can be used to support shrimp maturation, but they differ dramatically in their cost effectiveness due to their specific surface areas per cubic foot of media.

<u>Bead filters</u> have been used effectively in mesotrophic systems as a combination filter, providing both mechanical and biological filtration. However, the conversion rate of ammonia to nitrate in bead filters becomes less efficient when extremely low ammonia levels (below 0.3 mg-N/L) are desired. They are characterized by an intermediate surface area of 400 ft^2/ft^3. To provide sufficient nitrification for oligotrophic water would require a significant increase in filter size.

<u>Trickle filters</u>, which run effluent water over plastic media such as "Bio-Balls," take advantage of very good gas exchange to help in nitrification. These filter systems are most effectively used in mesotrophic and eutrophic applications where high ammonia concentrations and good oxygen transfer favor the development of thick biofilms. However, their ability to remove ammonia to levels appropriate for oligotrophic water, is limited by the low surface area of 160

Flow Diagram for Typical Shrimp Maturation System





Fluidized bed biofilter (large cylindrical tank in background), degassing column (rectangular box discharging water), and sump (rectangular box receiving water in foreground).

ft^2/ft^3.

Rotating biodisc filters utilize the same concepts as trickle filters and work very well as in-situ, mesotrophic filters. However their low surface area of 50-150 ft^2/ft^3, greatly limits their cost effectiveness for shrimp maturation.

Fluidized bed biofilters use fine silica sand to provide enormous surface area for nitrification and are best suited for providing oligotrophic water quality. Fluidized bed filters provide 7,800 ft^2/ft^3. Fluidized beds also function as thin-film reactors, which allow the system to be "shock-loaded" without any change in overall water quality. These characteristics make the fluidized bed an appropriate choice for applications requiring oligotrophic water quality.

Additional water clarification and sterilization may be required for an oligotrophic system. For example, an ultra violet sterilizer can be integrated into the system to kill most harmful bacteria and viruses, and an ozone reactor also may be used to reduce the growth of algae in the tank.

Disadvantages of Recirculating Systems

The main disadvantage of recirculation is the initial capital cost for installation of pumps, filters, sumps, heat exchanger, and reliable electrical supply. This cost is partly offset by the reduced cost of pumping, the reduced number of maturation tanks required, and the reduced cost of heating/cooling of water. However, the primary savings is the reduced cost of expensive maturation diets due to the fewer number of broodstock needed to produce a given number of nauplii.

Other important considerations in operating recirculating systems are staffing and management. Water quality and biofilter performance need to be monitored carefully during startup and routinely afterwards. Daily maintenance would include checking sump tank levels, mechanical filter pressures, and making sure that filters are backwashed correctly. These duties must be performed regularly, to avoid equipment malfunction.

Conclusions

The shrimp maturation facilities are making the transition away from traditional flow-through systems to recirculating systems, which allow more accurate and stable control of critical water quality parameters and greatly reduced water usage. Recirculating systems enable greater productivity, greater biosecurity, reduced operating costs, and reduced environmental impact.

Reference

Malone, R. F. and A. A. de los Reyes, Jr. 1997. Categories of Recirculating Aquaculture Systems. In: M. B. Timmons and T. Losordo (editors) Advances in Aquacultural Engineering. Aquacultural Engineering Society (AES) Proceedings III, ISTA IV, Orlando, FL, November 9-12, NRAES New York, pp. 197-208