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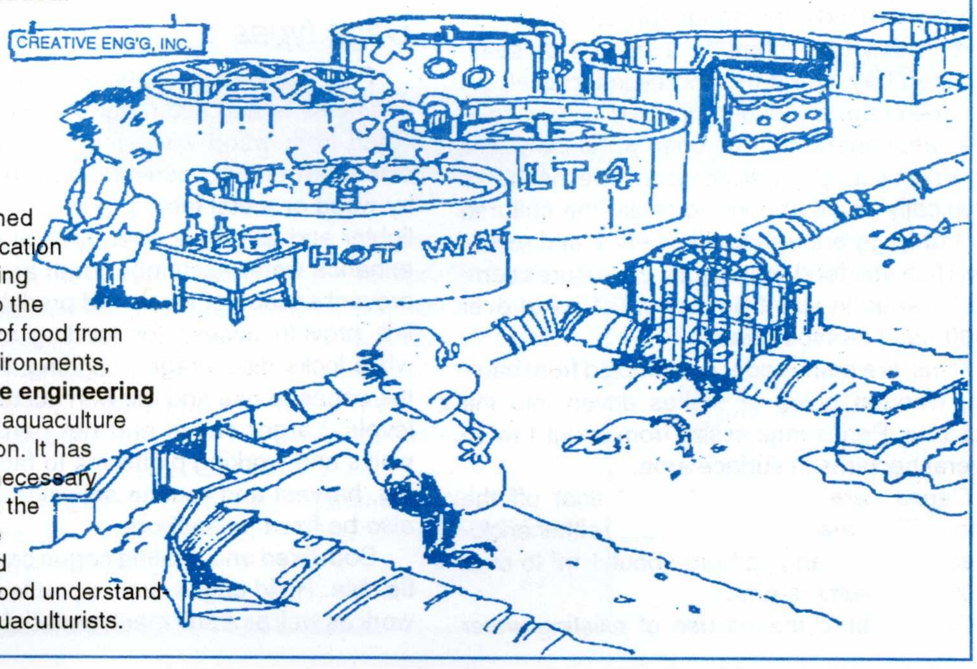
AQUACULTURE ENGINEERING

Successful aquaculture ventures are the result of the combined expertise of biologists, chemists, economists and other specialists among whom is the aquaculture engineer. Aquaculture has heavily drawn from engineering science the design and construction of farms.

New approaches in culture systems, other countries' experience, converting a hatchery from shrimp to fish, a fishfarming success story and some engineering fundamentals are discussed in this issue. Other facets of the industry requiring an engineer's input are also included.



Simply defined as the application of engineering principles to the production of food from aquatic environments, **aquaculture engineering** is a distinct aquaculture specialization. It has become a necessary discipline in the aquaculture industry and demands good understanding from aquaculturists.

The fundamentals

Culture systems categorized

There are three basic categories of culture systems: open, semiclosed and closed systems. *Open system* culture generally refers to fish farming in natural bodies of water such as oceans, bays, estuaries, coastal lagoons, lakes or rivers. *Semiclosed* systems are those in which the culture water makes one pass through the system and is discharged. These are referred to as *flow-through* or *once-through* systems. The raceway falls into this category. *Closed* systems are those where the water is reconditioned and recirculated to culture units. These are also called the closed *recirculating* systems.

The open system is most often used for commercial and recreational fisheries. It is low-cost and requires limited management. A step beyond the open system is the *modified open system*. This involves the confinement of fish in enclosures, floating cages, net pens, baskets, trays, etc.

CAGE CULTURE

The terms *enclosure, pen* and *cage* are sometimes used interchangeably. Enclosure as used in this text refers to a natural or semi-sheltered bay where the shoreline forms all but one side of the enclosure. In most cases, enclosures are separated from open water by a solid barrier or by a net or plastic mesh. The mesh size is typically small enough to retain the cultured fish but large enough to allow entry and exit of small fish and food organisms. Enclosures commonly range in size from about 0.1 ha to over 1,000 ha in surface area.

Pens are man-made, constructed from bamboo, wooden poles or stakes driven into the substrate. Pens range in size from about 1 m^2 to several hectares in surface area.

Cages are man-made and float off the bottom. They are much smaller than either enclosures or pens, ranging from about 1 m^2 to over 1,000 m^2 in surface area.

Cage culture makes use of existing water bodies which can give nonland-owning sectors of the community access to fish farming. Lease agreements from local governing authorities eliminate the need to invest large amounts of capital in land. Cage farm management is less complex than land-based systems. Cage farms can be expanded by simply adding cages as experience grows. Cages are "mobile"; they can be moved to other sites to take advantage of better-quality water and more abundant food organisms, and to "escape" storms.

A negative side to cage culture is that farmers have no control over water quality conditions, and pollution is often responsible for serious damage. Also, cage installations are at the mercy of the weather and may suffer damage from high winds, tides and waves if they cannot be moved when storms approach.

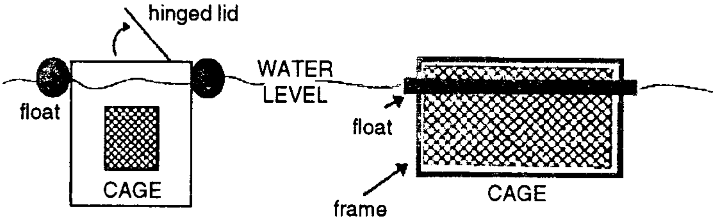
Cages can have negative impacts on the aquatic environment. Large quantities of uneaten feed and feces are released which may adversely affect water quality. Cages take up space in public waters, which can make navigation hazardous or may deny access to certain areas by commercial and sportsfishermen.

Cage types

Four basic cage types are: fixed, floating, submersible and submerged. Cages are fabricated from wood with small openings on the sides and bottom or constructed with nets framed by wood or metal tubing (Fig. 1). The latter is lighter and has more open area at the sides to enhance water exchange. Both are covered to prevent escape of stock and predation. Hinged lids provide access for feeding and harvest, while locks discourage poaching. Floats allow the cages to rise and fall with fluctuating water levels. Larger cages and net pens have catwalks and working platforms to facilitate feeding, harvest and routine activities. Cages can also be fixed by anchors.

Both fixed and floating cages can be rigid or flexible. Rigid cages use a nonflexible framework as well as a stiff mesh material at the sides

Fig. 1. Common small aquaculture cages: a wooden cage with mesh sides and bottom (left) and a net cage framed in wood or metal (right).



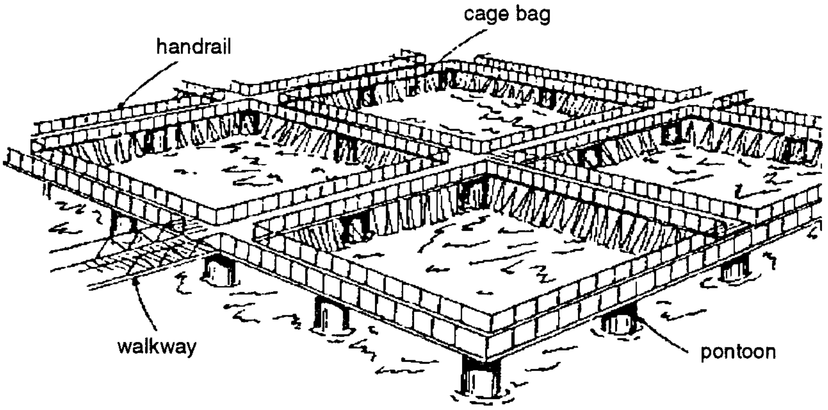


Fig. 2. Floating net pens can be grouped together.

and bottom. Rigid cages are used most often in swiftly flowing rivers and streams. Flexible cages are usually floating, with collars that support catwalks and working platforms. The collar assembly also supports the cage bag that contains the fish. Large net pens are up to 15 m^2, and are often grouped so that walkways serve more than one pen (Fig. 2). Handrails may be built into walkways. Flotation devices include large vertical spars or pontoons.

Some cages can be rotated to control biofouling. They are usually cylindrical and are floated with the cylindrical axis lying horizontal and the cage rotated about the axis. Daily rotation allows all sections of the cage to be exposed to the sun, drying and killing the fouling organisms.

Submersible cages are used primarily in places prone to storms. The cages can be fixed and floating. A simple, submersible fixed cage is used for tilapia culture in the Philippines . The cages are fitted with net tops, and when a storm threatens, the rigging is untied, and the cages are lowered 1 m or so beneath the surface.

Cage design depends upon a number of factors -- fish cultured, environmental conditions in the farm, type of culture whether extensive or intensive, and cost and availability of materials.

Cage bag

The cage bag holds the fish. It can be round, square, rectangular, 6-sided or 8-sided. Round cage bags are stronger and make the most efficient use of materials at the least cost per unit volume. Also, schooling species like salmon and milkfish appear to be less stressed when cultured in round bags since they tend to swim in circles when enclosed. A disadvantage to round cages is that the surface area to volume ratio (SA:V) is small compared to other shapes, resulting in poor water exchange.

The ideal bag material should be strong and light. It should also be rot-, corrosion-, weather- and fouling-resistant, easily repaired, drag force-resistant, nonabrasive, and economical. Materials used to construct cage bags range from cotton and synthetic fibers to semirigid materials such as plastic and metal. Flexible cages are fabricated from fibers, either natural or synthetic.

Natural fibers are used very infrequently because they rot easily.

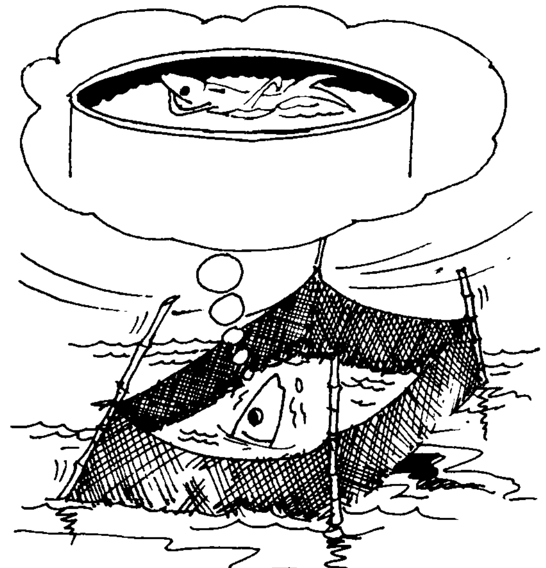
Frames

The basic frame that supports the cage bag generally follows the shape of the bag. It can be made of bamboo, wood, metal or synthetic substances. Small, cottage-industry-type cage frames are normally fabricated from wood or plastic; larger cages are fabricated from galvanized steel or 90:10 copper-nickel alloy. Plastic or nylon fasteners are used to attach bags to the framework since metal fasteners tend to create galvanic cells and to corrode rapidly.

Bags and frames are designed with a freeboard extending above the water surface to prevent fish from jumping out. The height of freeboard is dependent on fish cultured as some are better leapers than others.

Collars and supports

Fixed cages typically do not have collars. They are supported by bamboo poles, wooden posts or columns that are driven into the substrate. The support structure must be able to withstand the static vertical forces imposed on them by the weight of the cage, working staff, equipment, etc. while at the same time resisting dynamic forces exerted by wind, waves and currents.



"THIS RICKETY CAGE MAKES ME NERVOUS. I DREAM OF A MANSION THAT CAN WITHSTAND WIND, WAVES AND CURRENTS."

A collar is normally used to support and buoy the cage bag and to help retain its shape, or used to support catwalks, which serve as work platforms. In many cage designs the flotation material is an integral part of the collar. Flotation can be provided by bamboo poles, hard or soft woods, foam-filled drums or tubing, or air-filled drums, tubing or pontoons.

Linkages and groupings

Most small cages are moored individually, however, it is common practice in large cage farms to group several cages together.

Cage grouping depends upon (1) size of the farm, (2) site conditions, (3) cage design, (4) mooring design, and (5) environmental considerations. Cages in large farms are often grouped to house fish in various life stages or grouped according to species, if more than one species is being cultured at the same time.

Mooring systems

Mooring systems consist primarily of lines and anchors, but some may also have floats.

Horizontal and vertical forces acting on cages and supporting structures should be considered in designing mooring systems. Mooring lines should not break easily. Lines are constructed from braided galvanized steel strands, open-link steel chain or braided natural or synthetic fibers.

The simplest and cheapest anchors are deadweight or block anchors consisting of bags of sand or stones, concrete blocks or large pieces of scrap metal. Deadweight anchors are typically inefficient, however, since they move across the substrate whenever the horizontal force (like current) exceeds the frictional force between the anchor and the substrate.

The embedding-type anchor is constructed to grip the substrate, e.g., a small boat anchor. However, embedding anchors are more expensive than deadweight anchors and must be dragged a certain distance over the substrate before they take hold.

An alternative mooring technique in lieu of using chains and anchors is to drive long poles into the substrate and attach the cages directly to them. If cages are located near the shore, land anchors can be used. Wooden stakes are driven into the ground, and the cages are tied to them with ropes or cables.

POND CULTURE

Commercial fishpond production is profitable only when a combination of resources is available at a reasonable cost:

(1) Large tracts of land with the proper soil, slope and topography
(2) Large volume of good-quality water
(3) A growing season where temperature does not fluctuate widely
(4) Ready market for the product

Fishponds provide a static or dynamic environment. In static ponds (rain-fed ponds for instance), water does not flow although the ponds may be supplemented with pumped water. In dynamic ponds, water continuously flows or a certain percentage is exchanged daily.

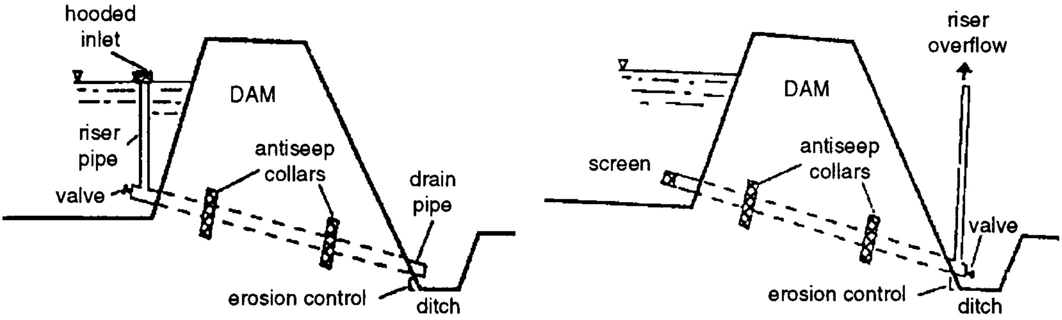


Fig. 3. Cross section of dam showing two types of drain commonly used: hooded inlet pipe (left) and outside drain valve (right). Also note use of antiseep collars.

There are two basic types of ponds: *watershed* and *levee*. The choice depends on topography, land slope, capital investment and level of production.

Watershed ponds

Watershed ponds are created by constructing a dam or dike across a small stream. These are also called hill or embankment ponds, and are filled entirely by precipitation and runoff from the surrounding watershed. Watershed ponds are preferably constructed in gently sloping, shallow valleys rather than in deep valleys with steep slopes. Ponds built in shallow valleys can be cut and filled so that the finished basin has a uniform and shallow depth to facilitate harvest without draining. Additional soil is hauled from other sites to build the dam.

Ponds must be located in areas where there are no runoffs from feedlots, orchards, root crops, or other sites where pesticides or manure are applied. The watershed should have sufficient grass cover to prevent erosion of soil into the pond. The site should be fenced to prevent livestock from trampling and damaging the pond slopes and the dam. A well is desirable even in areas of high rainfall. Well water can also be used to supplement runoff or refilling ponds drained for harvest.

Soils containing at least 20% clay by volume are suitable for fish ponds. Clays and silty clays are best. For dams, foundation soil must be able to support dam weight. Swampy, muddy or plastic soils should be removed and the dam constructed on the underlying consolidated soil material. Highly organic soils should not be used as foundation material since they decompose and cause the dam to settle and eventually leak (and possibly fail altogether). Foundation material should have low permeability to prevent excessive seepage.

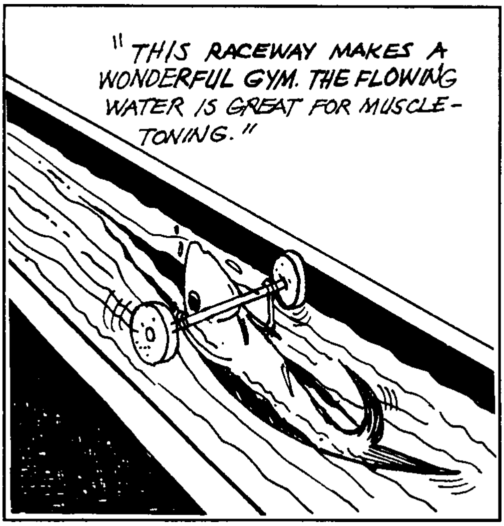
Detailed dam design is best left to a professional engineer, especially in the event that human life or valuable property may be lost due to dam failure.

Ponds should be constructed with two outlets: a mechanical and an emergency spillway. A mechanical spillway carries the normal water flow and can be designed to partially or completely drain the pond to facilitate harvest. There are two types (Fig. 3). The first, called a drop-inlet trickle tube, consists of a common interior riser pipe with a drainpipe. The crest of the riser maintains the desired water depth in the pond. A hood is sometimes used to cover the riser inlet to prevent trash from entering.

The emergency spillway takes care of storm flows that exceed the capacity of the mechanical spillway. It is usually constructed at either end of the dam. Soil borings should be taken to locate an adequate site for an emergency spillway. Loose, sandy soils and other highly erodible soils should be avoided. Small farm ponds may not have an emergency spillway.

Levee ponds

Levee ponds are principally used for commercial fish, shrimp and crawfish production. They are constructed by digging holes in the ground and building levees around them (also called *excavated* ponds) or by impounding water above natural dikes or levees.



Levee ponds cannot be filled by surface runoff. Water must be pumped from a well or a surface source. A well is usually drilled after ponds are constructed so that it can be strategically located to make water delivery easy.

Ponds vary in sizes: 0.05-2.0 ha for nursery ponds, 0.25-10 ha for broodstock or grow-out ponds, 1-5 ha for intensive culture, and 0.01-0.05 ha for spawning ponds.

Rectangular ponds can be constructed adjacent to one another, making water supply and management practices easier. Square ponds are more economical to construct than rectangular ponds, but on steep slopes, rectangular ponds are easier to drain. Regardless of the shape, ponds should be no more than 213 m (700 ft) wide to make harvest by seining easy.

Soil that is removed when excavating ponds is usually used to construct the levees. These should be built to last and must be large and compact enough to support large trucks or heavy equipment. Wider levees are more convenient and more resistant to wave damage but are more expensive to build. Good pond management dictates that motorized vehicles should have access to ponds on at least two sides.

RACEWAY CULTURE

Raceways, also called flow-through systems, are culture units in which water flows continuously, making a single pass through the unit before being discharged. They are designed for highly intensive culture. Good water velocity is essential to the health of the culture stock and to flush wastes from the system. Water quality is maintained by manipulating water flow rate and by putting in place water treatment processes. Water quality and quantity are easier to manage in raceways than in ponds.

The number of fish that a flow-through system can support is dependent on water quality, management skills, local conditions and species biology, including the ability to tolerate crowding.

Flowing water forces the fish to "exercise." Studies have shown that exercised fish have better survival rates when stocked into the wild. The shallow water in raceways allows visual observation of the fish so that diet and disease problems can be promptly corrected. Feeding and disease treatment are more easily managed in raceways than in ponds. On the negative side, raceways have higher risk of diseases due to stress caused by confinement and crowding.

Raceways can be designed simply (Fig. 4). Incoming water usually requires pretreatment -- aeration, heating or cooling, degassing or filtration -- before it can be used. Depending on the effluent water quality, discharged water may also require post-treatment before it can be released into the environment. Although earthen raceways are sometimes used, majority are constructed from concrete or cement blocks. Earthen raceways are sometimes lined with waterproof materials to reduce water leakage. Many small, experimental raceways are fabricated from wood, metal, fiberglass, plastic and other materials.

Multiple raceways are arranged in parallel or in series (Fig. 5). Series raceways can be used in regions where there is sufficient land slope -- about 1-2% -- so that the outlet for one raceway serves as the inlet for the next in the series (Fig. 6). However, waste buildup can be a serious problem since the wastes from the upstream unit enter the next unit downstream. Wastes tend to increase as the water traverses through the system. The waste problem is somewhat alleviated if downstream culture units do not receive wastes from upstream units.

One major advantage of raceways is ease of harvest. Harvest is usually accomplished by pulling a seine from one end of the raceway to the other, crowding the fish into a small area where they can be netted. Some facilities have automated harvest screens or grader bars which allow smaller fish to escape from the crowding area to grow larger in the raceway.

TANK CULTURE

Tanks are used for fry production or as temporary holding facilities for fingerlings or broodstock. Tanks may also hold aquarium fish for culture or for public display. Except for small operations, tanks are not normally used to produce food fish.

Tanks must be durable, portable, easy to clean and sterilize, non-corrosive and affordable. Its interior should be smooth and non-toxic. Non-toxic seals such as epoxy, fiberglass resin paint or waterproof liners can be used.

Fabrication

Tanks are constructed from wood, concrete, plastic, fiberglass, metal and glass.

Inexpensive tanks can be easily fabricated from marine plywood. Plywood that are 19 mm thick (or thicker) are used so that tanks won't flex excessively when filled.

Concrete is practical for large tanks or pools. Properly reinforced with steel bars, concrete will last indefinitely. Concrete is best used to construct permanent facilities because of its weight and expense.

Plastic tanks are made of polymers including polypropylene, polyethylene, polybutylene, polyvinyl chloride (PVC), acrylics and vinyl. Each has its own set of good and bad features. A major

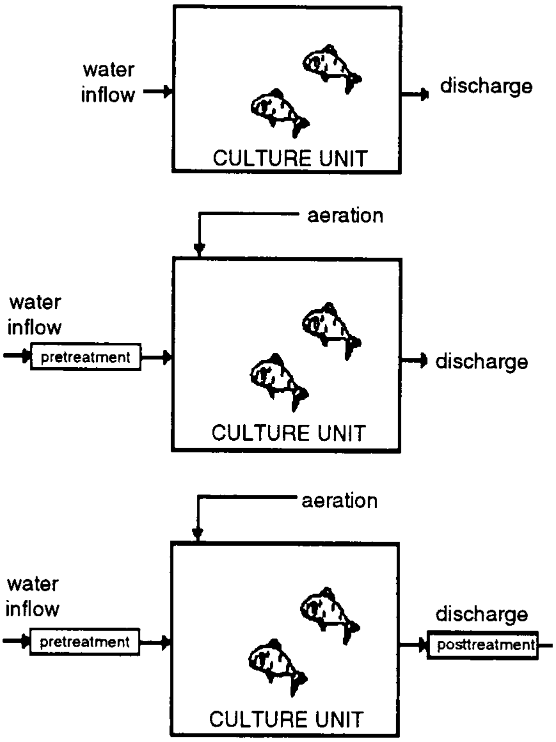


Fig. 4. Single-pass raceway systems (top to bottom): no treatment, with treatment and aeration, and with pre- and posttreatment.

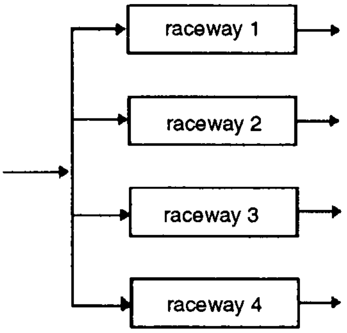


Fig. 5. Parallel raceway units.

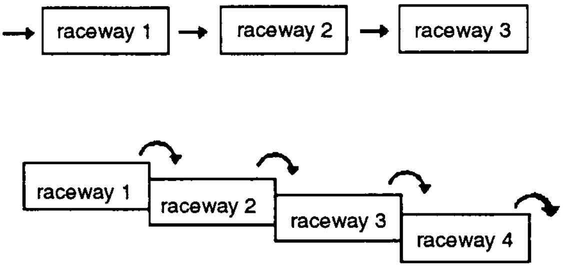


Fig. 6. Raceway units in series: on flat ground (top) and on sloping ground (bottom).

advantage of plastic tanks is that they are lightweight and portable. Repairs are also easier.

Fiberglass is preferred for tank culture since it is lightweight, strong, durable, modestly priced, inert in both fresh- and saltwater, and can withstand the effects of UV rays if used outdoors. Fiberglass tanks are normally gel-coated to smoothen the inner surface so that it can be easily cleaned and disinfected. The tanks can be easily drilled to install drains and fixtures.

Aluminum and steel are two metals commonly used to fabricate small tanks (several hundred liters and smaller) popular in hatcheries for rearing fry and fingerling. If used with caution, some aluminum alloys can be used for brackish- or saltwater culture. Some are rubber-coated but most are lined. Without coating or lining, zinc can leach from galvanized coating and cause heavy metal poisoning.

Glass culture units are found almost exclusively in the aquarium trade or for public display aquaria.

Waterproof liners can be used with tanks fabricated from virtually any material. These can substitute expensive coatings or sealers, eliminating toxicity by heavy metals, paints, treated wood or other substances. Liners can be custom-made to fit any tank size or shape. If carefully handled, these can last for 5-10 years.

Shapes and sizes

Round tanks are commonly used for nursery or grow–out. Square and rectangular tanks make better use of available floor space since they can be placed side by side, but round tanks typically have better hydraulic characteristics.

Round tanks have either a flat or a sloping (conical) bottom. Although sloping round tanks are more expensive, they are more efficient at removing wastes. Flat-bottomed tanks will self-clean if there is adequate water velocity. Water circulation in round tanks does not allow dead areas where water hardly moves; wastes are also efficiently removed (Fig. 7). Round tanks have central standpipes that are fitted with outer pipes or sleeves. Openings near the tank bottom facilitate waste removal. Screens or grader bars that can be rotated around the central standpipe facilitate the removal of fish by crowding them into a small area where they are netted. Selective harvest is possible by using big nets to catch bigger-sized fish.

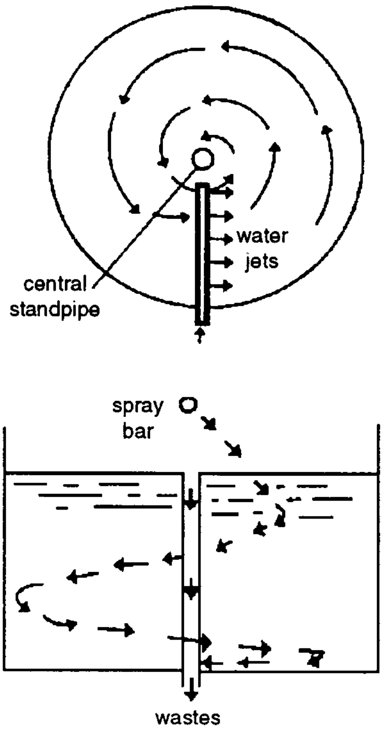


Fig. 7. Round tank: water circulation patterns (arrows, top) and water direction during draining (bottom).

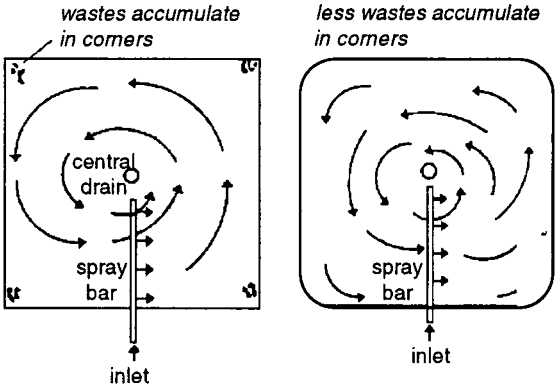


Fig. 8. Rectangular tanks: flow patterns (left); if modified – with more rounded corners -- less wastes accumulate in corners (right).

Rectangular tanks and troughs are most often used for rearing fry and fingerlings in hatcheries. The bottom can slope towards one end or towards the center. In tanks that drain at one end, the water enters from a different end, much like a raceway. Flow patterns often form dead areas like tank corners. Fish may become

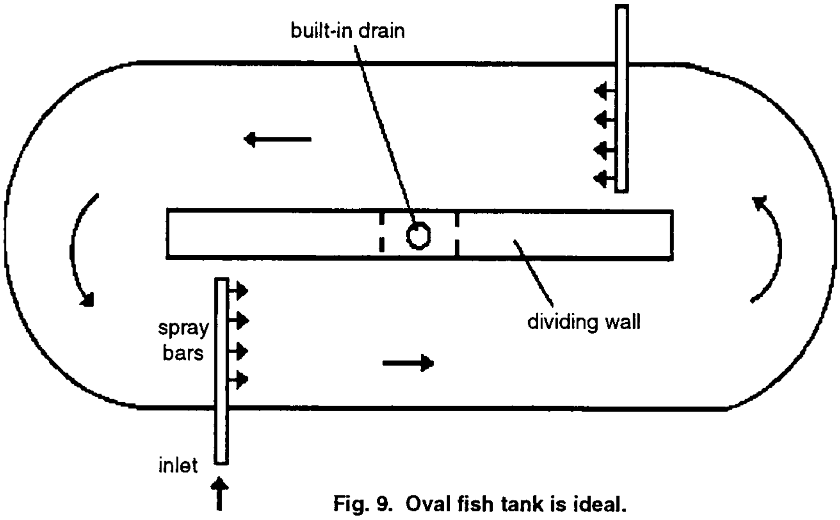


Fig. 9. Oval fish tank is ideal.

stressed, if not die, if metabolic wastes accumulate to dangerous levels. Fish collected from the wild and then placed into rectangular or square tanks tend to crowd into a corner where they may locally deplete the oxygen, or they may bash into the sides of the tank, causing serious injury.

Square culture units have disadvantages similar to rectangular tanks in that wastes tend to accumulate in the corners (Fig. 8). The hydraulic characteristics of square tanks can approximate circular tanks by constructing them with rounded corners (Fig. 8). And like round tanks, a central or external stand pipe with screen may be used as drainage.

A compromise between the round and rectangular tank is the oval tank constructed with a partition that divides the tank (Fig. 9). Water flow is generated by spraying the inlet water through a nozzle or series of water jets in the direction of circulation. In lieu of water jets or nozzles, a small paddle wheel can be installed. The outlet standpipe is normally placed at the center of the partition.

If floor space is limited, square or rectangular tanks can be stacked. The number of tanks in the stack depends on tank depth and ceiling heights. Bracing support must be strong enough to hold the tanks if filled to capacity. Space should be adequate for stocking, feeding, harvest and other activities. Elevated tanks can be drained completely by removing the central standpipe, but those on the ground must be pumped.

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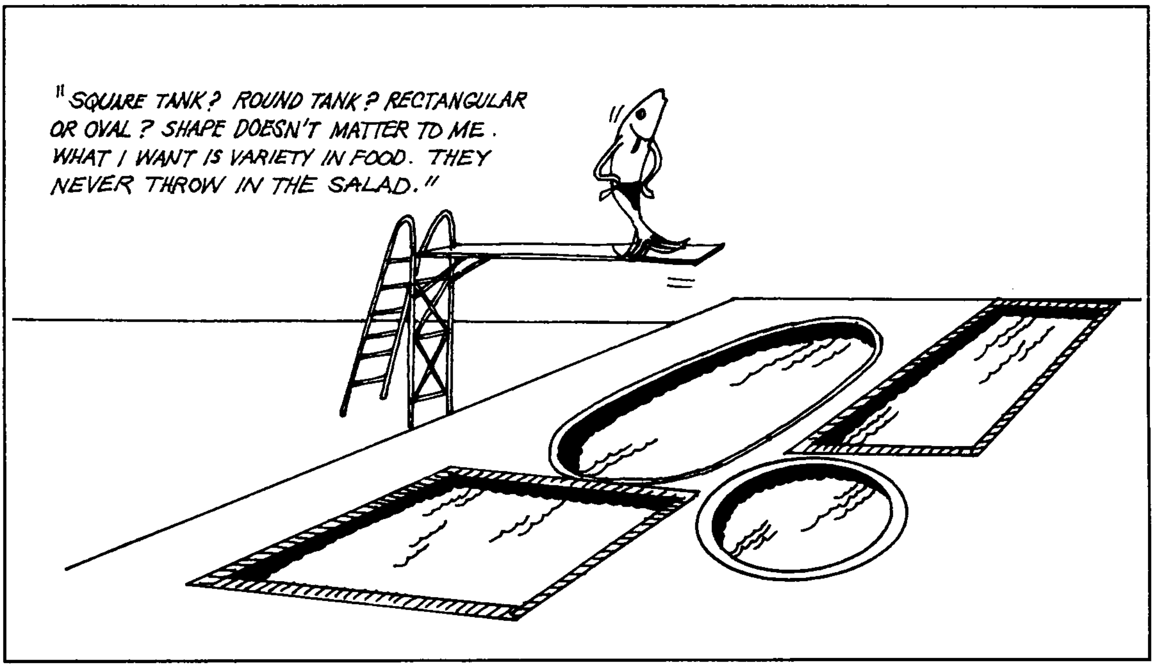


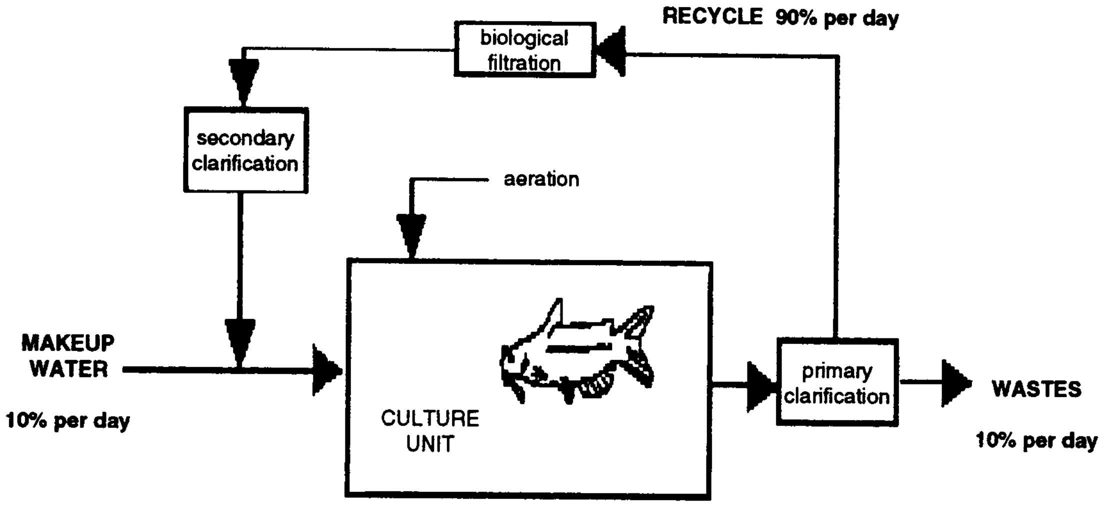


Fig. 10. A recirculating culture system utilizing 90% recycled water per day.

In recirculating systems, fish are confined at high densities. Normal culture density is 61-122 kg/m^3, but densities in small-scale experimental systems have exceeded 545 kg/m^3.

Economic analyses of recirculating systems indicate two key operating parameters:

(1) system operation with minimal energy input
(2) proper water purification

Aquaculture engineers are challenged to develop designs that optimize these criteria.

Contaminants that have negative effects on water quality are ammonia, urea, CO_2, feces and other metabolic wastes. Organic wastes are further degraded to produce additional ammonia, nitrite and nitrate. In the close confines of recirculating systems, the effects of these substances are acidic water, depleted dissolved oxygen and increased turbidity, making water more inhospitable to the fish. In addition, many minerals and essential trace elements are lost.

The amount of wastes produced depends on the fish species cultured and life stage, system biomass, and the type and amount of feed given to the fish. The rate and degree of water quality degradation can be managed with proper water treatment. The principal treatment processes include screening, settling (sedimentation), granular media filtration, biological filtration, aeration and disinfection.

A generic recirculating system is illustrated in Fig. 10. *Primary clarification* includes screening, sedimentation, granular media filtration or a combination of any of the three. It is important to remove solids prior to biological filtration. Biofiltration lowers ammonia and nitrite levels. It is the heart of any recirculating system.

Secondary clarification usually follows biological filtration to remove the biological floc that frequently sloughs from the filter media. It is important that this material not be allowed to remain suspended. Secondary clarification includes sedimentation but may also include screening. Finally, aeration is added for basic life support system. The system is driven by a water pump (not shown in Fig. 10).

Water in recirculating systems completes the entire circuit many times daily. Depending on culture intensity, filtration may be required from two to four times per hour. At a minimum, the water should receive complete treatment one to two times per hour. A daily partial water exchange is necessary to control nitrate, remove pollutants and replenish minerals and trace elements. As much as 90% of the water can be recycled daily. The other 10% is "new" water. In effect, the total volume is replaced once every 10 days. Lightly loaded systems may fair well with a 3-5% daily water exchange. Systems employing 100% recycle are rare.

Physical, chemical and biological processes used to recondition water for recycling

PHYSICAL
- Screening
- Settling
- Sand filtration
- Diatomaceous earth filtration
- Centrifuging
- Temperature control
- UV sterilization
- Cartridge filtration
- Bag filtration

CHEMICAL
- Aeration
- Pure oxygen injection
- Alkalinity and hardness control
- Carbon adsorption
- pH control
- Reverse osmosis
- Degassing
- Foam fractionation
- Ion exchange
- Ozonation

BIOLOGICAL
- Nitrification
- Denitrification

Screening

The simplest and the oldest wastewater treatment process, screening is often used as pretreatment prior to the primary treatment. Screens placed across the waste stream can trap solids. Coarse ones are used to treat the raw effluent from the culture unit. It can also trap the biofloc that sloughs from biofilters.

Activated carbon

Activated carbon is made by charring coal, pecan, coconut or walnut shells, wood or animal bones. These materials are heated to about 900°C in the absence of air. The charred material is then activated by exposing it to an oxidizing gas at high temperature. The gas creates a highly porous structure in the char and a large internal area. Activated carbon can remove volatile organics, color, odor and suspended solids.

Ion exchange

Certain ions are displaced from an insoluble exchange material (resin) by ions of a different chemical dissolved in the wastewater. Ion exchange resins are manufactured in the form of tiny porous beads about 1 mm in diameter.

Foam fractionation

This process removes dissolved organic carbon (DOC) and particulate organic carbon (POC) by adsorbing them onto the surfaces of air bubbles rising in a closed contact column. The bubbles create a foam at the top of the liquid column, and are discarded.

Biofiltration

This technique utilizes living organisms to remove a substance from a liquid solution. Algae or higher green plants are used. *Biofilters* can remove ammonia and nitrite. It is generally accepted that, after oxygen, ammonia often becomes the limiting factor in recirculating systems.

Types of biofilters include submerged, trickling, rotating disks or drums, fluidized beds and low-density media filters.

Submerged filters consist of a vessel filled with a media upon which nitrifying bacteria grow. Culture water is passed through the filter by a spray bar, and gravity pushes water downward through the unit. Completely submerged at all times, the media is supported by a perforated bottom through which the treated water drains and flows out of the unit. Rock is the most common type of media used in submerged filters. Limestone rock is popular since it provides buffering against rapid pH changes.

Trickling filters basically function the same as submerged filters except that the media is not submerged. Culture water trickles downward through the media and keeps the bacteria moist but not completely submerged.

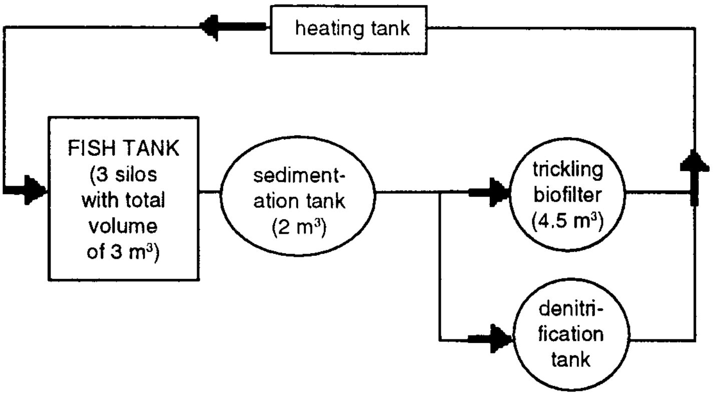
Rotating media filters incorporate aspects of both fixed and suspended media operation. Fixed media are rotated in vessels through which the culture water (suspended media) flows.

In fluidized bed reactors, the media is contained in a vertical vessel with a cylindrical or square cross section. The media is kept in suspension or fluidized by the upward flow of water. The degree of fluidization depends on the upward flux of water through the vessel. Coarse sand is the most common media used.

Source: Lawson, Thomas B. 1995. **Fundamentals of Aquaculture Engineering**, Chapman & Hall, New York, NY 10119.

IN BERLIN, GERMANY: FISH-VEGETABLE PRODUCTION IN RECIRCULATING SYSTEMS

The Institute of Inland Fisheries and the Institute of Vegetable Production tested fish-vegetable production in recirculating systems. In the model that supports only fish (figure below), wastewater is allowed to settle at the sedimentation tank for 10 minutes after passing through the fish tank. Sludge is removed through a slide-valve at the tank bottom. Then, wastewater is distributed in the trickling biofilter through a rotating sprinkler (hydraulic load, 1.2-2.4 $m^3/m^3/h$). Curl-papers with biologically active surfaces (100 m^2/m^3) are used. Before water is recycled back to the fish culture unit, it is denitrified (retention time is two hours) and reheated. About 5% of total water volume is replaced daily.



For fish-vegetable production, the model is the same except that a nutritive-film-technique unit (NFT-unit) replaces the denitrification tank. The heating tank is also unnecessary because the whole system is built inside the greenhouse. Water temperatures remain at 22-23°C.

The NFT-unit has a nutrient solution tank. "Enriched" water is pumped to channels where vegetables are planted (cultivation area is about 450 m^2). Unused nutrient solution flows back to the nutrient solution tank where nutrient deficits and water are automatically compensated. Differences between nutrient excretion of fish and nutrient demand of plants are determined by permanent analysis and compensation. The whole system, however, does not allow water flow from the NFT-unit back to the fish unit. Instead, two separate but interconnected recirculating systems are used.

The fish tanks are stocked with carp weighing 340 g. Stocking density is about 127.33 kg/m^3. In the NFT-unit, tomatoes and cucumbers are cultivated. Nitrogen from the fish unit account for 16% (monthly average varies from 1.6 to 40.7%) of the total nitrogen demand of the plants. Potassium accounted for 12% (2.6-36.2%) and phosphorus 13.8% (5.9-35.4%).

In about eight-and-a-half months, carp harvest can total 382 kg, or an increase of about 296 kg. Fish survival is about 97%. Feed conversion is about 1.48 at harvest, or about 1.91 increase per day. For vegetable production, tomatoes are harvested at 21 kg/m^2 and cucumber at 37 kg/m^2. The same amount of tomato is harvested in the system where vegetable is grown without fish, but less cucumber is produced (31.70 kg/m^2).

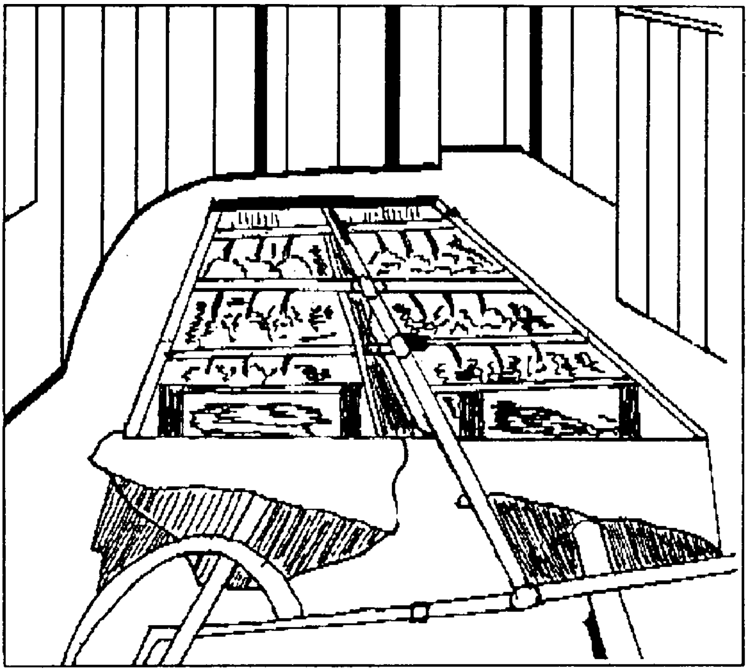
The make-up water added to the fish unit averages 1,535 liters a day. The same amount of nutrient-loaded waste water enters the NFT-unit. Additional water is not necessary.

It is indeed possible to combine production of fish and vegetables using a closed system technology. One part of the system is not a negative influence over the other. The advantages include: saving on manure; two-fold utilization of water and heat energy; no costs related to denitrification; and no discharge of nutrient-loaded waste water.

Source: B. Rennert. 1992. *Simple recirculation systems and the possibility of combined fish and vegetable production.* In: B. Moav, V. Hilge and H. Rosenthal (eds.). **Progress in Aquaculture Research.** European Aquaculture Society, Special Publication No. 17, Belgium.

IN JOHOR, MALAYSIA: RACEWAY SYSTEM GP 300 AS SEA BASS NURSERY

It has become necessary to raise sea bass fry in hatcheries because of decreasing catch from natural sources. The fry demand from the rapidly expanding cage culture industry has also increased.



Ramli Hj. Khamis and Hambal Hj. Hanafi show that sea bass (*Lates calcarifer*) fry can be effectively and economically nursed in a raceway system 'GP 300' fabricated at the Brackishwater Aquaculture Research Centre in Johor, Malaysia. Fry are raised from 10-25 mm to more than 75 mm within 8 weeks. Fry are fed a well balanced diet containing the necessary vitamin supplements. The highest survival is about 78% at a stocking rate of 5,000 fry/m^3.

The water supply system can be an open system or a recirculating one. For the open system, the water supply is pumped directly and continuously into the raceway trough from a suitable source. In the recirculating system, a reservoir tank is needed to store water. An automatic electric heater maintains water temperatures of 28.0-31.0°C. Water flow and oxygen level are maintained by jetting water from the reservoir into the raceways using 25 mm PVC pipes. The PVC pipes (with 3 mm diameter holes) are placed horizontally across the raceways.

Khamis and Hanafi note the advantages of the GP 300 raceway nursery system:

Portability. The GP 300 can be conveniently installed and operated wherever a good water source is available. The space required is small and the GP 300 can be extended lengthwise, if necessary. Both the system and the technique have been shown to have good potential and could be practiced easily with low capital input.

Ease of feeding. With the shallow water levels in the GP300, feeding activities of the fish can be observed and monitored closely. Although the fish are initially shy and behave erratically, they soon get accustomed to their surroundings and normal feeding commences. The GP300 also serve as a place for training and weaning the fish to accept artificial feed which later on would be the feed in the ponds and cages.

Ease of grading. Grading fish according to size can be easily carried out in the GP 300, thus reducing cannibalism. Having similar sized fish in a population improves feeding, and subsequently, promotes better growth.

Source: Ramli Hj. Khamis and Hambal Hj. Hanafi. 1992. The use of raceway system 'GP 300' as a nursery facility for sea bass (*Lates calcarifer*) fry. *In*: Cheah, S.H. and Thalathiah, S. (eds.) **Proceedings of the seminar on New Technologies in Aquaculture.** Malaysian Fisheries Society, Selangor, Malaysia.

In Norway: Light as a Force in Voluntary Fish Transport

The effect of different light intensities (0, 15 and 200 lux) over a fish tank and a voluntary fish transport canal was studied. The experiments were carried out in an experimental plant where the fish tanks are connected to a transport canal with gates located at the bottom of the fish tanks. By using different light intensities over the fish tank and over the transport canal, the voluntary fish transport from the fish tank into the canal started quicker than in normally lighted tanks, where equal light intensity was used over the tank and canal.

Using no light in the tank and keeping normal light in the canal resulted in a great number of fish moving into the canal during the first 30 min (on average 74%). During the rest of the experiment some of the fish moved back to the tank. Using brighter light than normal in the canal (200 lux) did result in more fish moving into the canal than when using brighter tank light than canal light, but the results were not as good as with normal light in the canal and dimmer light in the tank.

Earlier experiments showed that the activity of the fish is dependent on light conditions. It has also been shown in separate cases that light sources have the effect of attracting the fish.

The present experiments indicate that fish are reluctant to voluntarily swim through a gate that is darker than where it is coming from. The experiments further indicate that more fish move through the gate if the brightness in the tank is reduced and the brightness on the other side of the gate is kept normal.

Source: O.I. Lekang and S.O. Fjaera. 1995. *Effect of light condition on voluntary fish transport.* **Aquaculture Engineering** 14 (1).

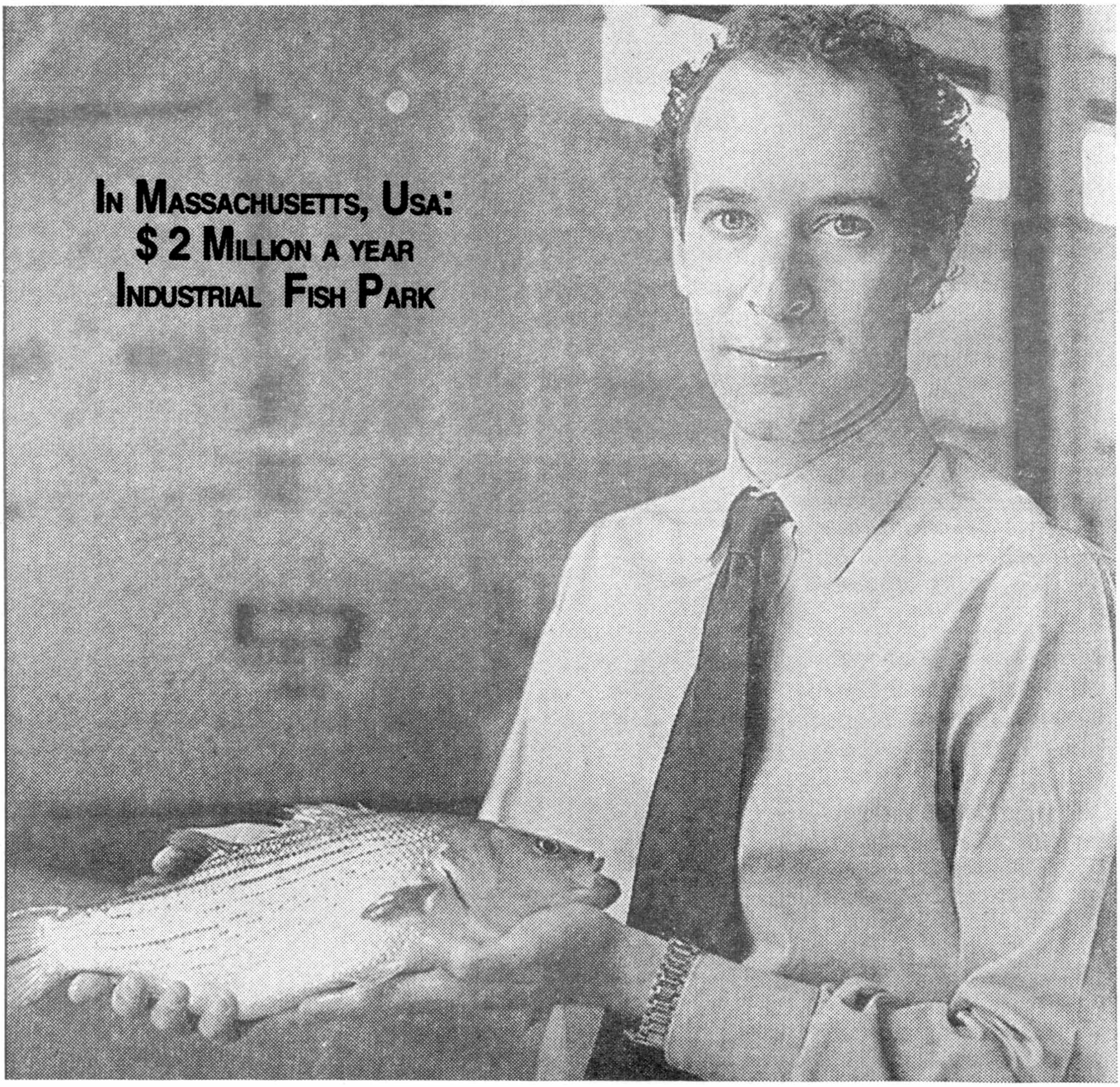
In Alabama, USA: an In-pond Raceway Incorporating Removal of Fish Wastes

To develop an aquaculture system that circulates and aerates pond water while removing fish wastes before they can enter the pond, Auburn University Fisheries Experiment Station in Alabama designed an in-pond raceway (IPR) and tested it with channel catfish *Ictalurus punctatus.* Four rectangular raceways (4.9 m x 1.2 m x 1.2 m high) were built from treated lumber and suspended between walkways of a floating pier. A set of airlift pumps located at the head-end of the raceway circulated pond water into the raceway. The raceway had an approximately 4% bottom slope along the 4.9 m length to assist the movement of fish wastes (feces and uneaten feed). In 1992, the raceways were stocked with 2,078 fingerlings per raceway. Mortalities during the 124-day culture period averaged 341 fish (16.4%) per raceway. The growth rate averaged 1.29 g per day with an average food conversion ratio (FCR) of 1.95. The average total weight of the harvested fish was 297.3 kg per raceway (52.2 kg/m^3). A total of 20.1 m^3 of effluent containing fish wastes was removed and sampled. The samples were analyzed for concentrations of total solids, biological oxygen demand and nutrients (nitrogen and phosphorus). The system was intended to remove settling wastes with primary and secondary waste collectors. Soluble wastes were allowed to enter the pond.

This new IPR aquaculture system sustained a high stocking rate with water circulation, supplemental aeration, and showed potential for removing fish wastes before they enter the pond. The study will continue to identify and solve problems and improve components of the system.

Source: K.H. Yoo, M.P. Masser and B.A. Hawcroft. 1995. *An in-pond raceway system incorporating removal of fish wastes.* In: **Aquacultural Engineering** 14 (2).

IN MASSACHUSETTS, USA: $ 2 MILLION A YEAR INDUSTRIAL FISH PARK



Reproduced hereunder *in toto* for maximum impact is Hubert Herring's article in the New York Times, "New Type of Fish Farming Takes Off" which was reprinted by the *San Francisco Chronicle*, November 9, 1994.

To Josh Goldman, it's all very simple. On a display board, he draws one line, slanting upward - that's the world demand for fish, growing steadily.

Below that, a second line, slanting down - the wild supply, steadily being depleted. The widening gap represents the fish the world will need from other sources. And for reasons he is eager to enumerate, he insists that traditional fish farming will not be able to fill that gap.

But Goldman says he has the solution, and with supreme confidence and the blinders of the true believer, he is out to prove it.

At the age of 31, Joshua N. Goldman has turned a passion born in his college days into a 3-year-old venture called Aquafuture Inc. It is here that he sees the future of fish farming - or aquaculture, as it's called in this $28.4 billion-a-year global industry.

Aquafuture is closing in on selling a million pounds a year of hybrid striped bass, all raised in a single vast building here in western Massachusetts. As a private company, Aquafuture does not divulge its financial data, though

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Goldman did say annual earnings were more than $2 million.

Aquafuture now occupies a boxy 45,000-square-foot building (that's an acre-plus) in a cluster of similar hulks in an industrial park, the bland facade giving no clue to what's inside - an elaborate web of tanks and piping and electronics. And, oh yes, a lot of fish.

Those fish - a hybrid of saltwater striped bass and freshwater white bass - are spawned elsewhere, then brought here at two months of age. In the first tank, thousands of these "fingerlings" can be kept for up to nine months, their growth slowed by chilling the water, if the company wants them to mature later; here, striped bass are always in season.

No slouches, by the time they do their last laps before becoming dinner, they log 20 miles a day. And they're far from lonely - cradle to fillet, the building houses 900,000 fish.

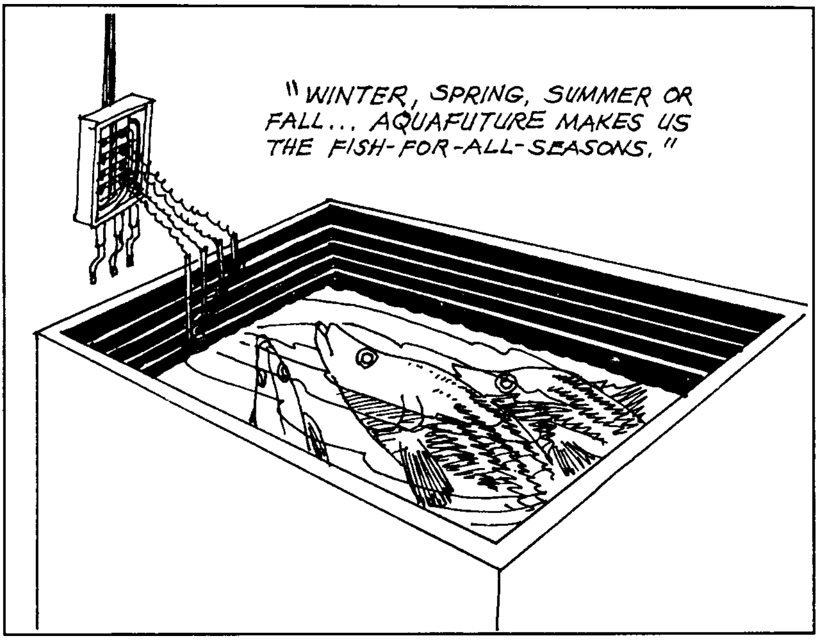
The last stop is a "purge tank", where the fish are given no feed. Goldman says he can grow the fish to market size in nine months, half the normal time.

All is controlled and sanitary. A visitor entering a cavernous, tank-filled room follows Goldman's lead and dips his shoes in a pan of disinfectant. Up ahead, two men in orange aprons work under lights on a high platform, as if on a surgical stage set.

On a table lies a pile of 6-inch fish, anesthetized to keep them still, and, needles flashing in a quick rhythm, the men vaccinate fish after fish - between them, they say, 8,000 an hour.

From there, the fish plunge through a plastic pipe into a cold wake-up bath, electronically counted en route. All these safeguards, Goldman says, enable Aquafuture to reduce mortality to less than 15 percent, half the industry average.

So why not traditional fish farming, in either ponds or offshore cages? There are many environmental concerns, like the creation of faster-growing hybrids. When these escape, "we are genetically polluting the wild fishstock," said Rebecca Goldburg, senior scientist at the Environmental Defense Fund.



Such farms also consume large amounts of water - at least 1,000 gallons for each pound of fish, Goldman said. "Even the best water resource in the world would eventually prove wanting."

And the water discharged, unless it's treated properly, is laden with fish feces and uneaten feed.

Goldman says his system solves these problems. Because the fish are raised indoors, it would take a striped Houdini to find its way to the nearby Connecticut River. And no birds, bearing disease, can get in.

IN ILOILO, PHILIPPINES: SEAFDEC'S MULTI-SPECIES FISH HATCHERY

Along the coasts of Iloilo, Capiz, and Aklan provinces in Panay island, west central Philippines, over 175 small- to medium-scale shrimp hatcheries produces 0.30 to 2 million shrimp fry. Most of these hatcheries were established to generate additional income for rural families and proliferated between 1988-89. The recent glut in the world market for shrimp, however, dealt a heavy blow to the once-lucrative shrimp hatchery venture. Converting a shrimp hatchery into a fish hatchery is a profitable option. Hatchery technologies for milkfish and sea bass for instance are already commercially viable.

Larval stages

Shrimp and fish have major biological differences. Based on the experience of SEAFDEC Aquaculture Department in Iloilo, Philippines, hatchery management also differs.

Fertilized eggs of the giant tiger shrimp *Penaeus monodon* range from 0.27 to 0.31 mm in diameter, while most of the popular marine fish have eggs greater than 0.55 mm (milkfish is 1.12 mm). At a temperature of 26-29°C, the incubation period of shrimp is 12-15 hours; milkfish, 24-26 h; and sea bass or grouper, 12-15 h.

Shrimp has three larval stages: nauplius, zoea and mysis. These stages involve molting and may last from 9 to 12 days depending on temperature. At hatching, nauplius I is about 0.5 mm long. Marine fish larvae have four larval stages: yolk sac, pre-flexion, flexion and post-flexion. Their duration is species-specific and temperature-dependent. Most of fishes are 1.5 mm or greater in total length upon hatching.

Shrimp larvae feed throughout the day. Fish larvae until metamorphosis are pelagic and continuously swimming. Being visual feeders, fish larvae feed only in the presence of light.

Feed requirement

Being herbivorous, filter-feeding shrimp zoea can survive solely on phytoplankton but a mixed diet gives better growth and larval survival. Algal substitutes like yeast and freeze-dried microalgae have been used starting the mid-80's with promising results. Later larval stages of shrimp are given phytoplankton and zooplankton plus prepared diets. Fish larvae do not filter-feed but are primarily carnivores, thus microalgae do not constitute a major food source at initial feeding. These phytoplankton act as water conditioner or as food for the zooplankton. Larvae are fed zooplankton, primarily *Brachionus* at initial feeding while later stages are given *Artemia* and prepared diets.

In shrimp, diatoms or prepared diets are introduced as early as protozoea and zooplankton are offered starting mysis stage. In fish, algae are introduced usually in the rearing water starting day 1 as water conditioner rather than as larval feed. Rotifers are given when the mouth opens and *Artemia* nauplii are introduced two weeks after. Prepared diets are usually given together with the zooplankton and most of the time after the introduction of *Artemia.*

Rearing facilities

Larval rearing facilities are more or less the same for both shrimp and fish hatcheries. (They are interconvertible, depending on market supply and demand of fry. -Ed.) Culture tanks for the live food as well as for larval production should preferably be cylindro-conical or conico-circular with smooth surfaces to minimize sedimentation; otherwise, rectangular or square tanks with semi-circular corners sloping towards the outlet can be used. The major difference lies in the ratio of larval food production tanks to larval rearing tanks. While the volume ratio of diatom culture tank to larval rearing tank is 1:5 for shrimp, the ratio of *Chlorella* to larval rearing tank is 1:2 and the ratio of rotifer tank to larval rearing tank is 1:1

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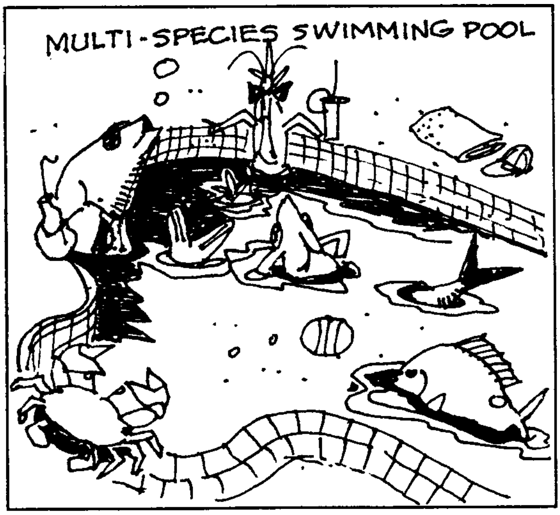
for fish. For a better fish hatchery management, a few extra live food culture tanks would be desirable.

Nursery tanks are usually considered part of a shrimp hatchery system with a volume ratio of 1 larval tank to 3 nursery tanks (assuming an average survival rate of 30% from nauplius to PL5). On the other hand, omnivorous or herbivorous fish are usually reared in earthen ponds while carnivores in net cages or earthen ponds. The size of the pond or cage for nursery varies with stocking density and the size of the grow-out ponds.

Water management

Water exchange in rearing shrimp ranges from 30 to 50% every other day or daily starting on the 4th day after stocking. In fish hatcheries, 30% of the water is changed a day after the introduction of rotifers and everyday thereafter; 50-75% is changed daily when *Artemia* or prepared diets are given. Chlorination of rearing water and corresponding neutralization or use of antibiotics in shrimp hatchery are not routine activities in fish hatchery operation. Antibiotics are used only during disease outbreaks.

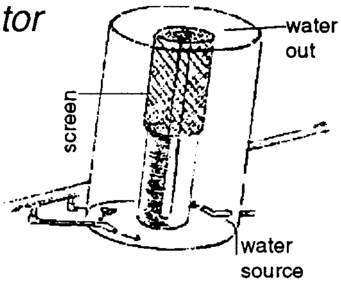
Source: Marietta N. Duray. 1993-94. *Multi-species fish hatchery.* **Aquaculture Engineering** 8-9.



ALTERNATIVE DESIGN FOR EGG INCUBATORS

Three alternative designs for egg incubators are given below. Other designs may be dictated by the availability of materials, money, space, etc. Whatever design is used, eggs must be kept gently moving at all times and must be provided oxygenated water. Caution must be taken with piped water which may be oxygenated, but can also be supersaturated with dissolved nitrogen, rendering it unsuitable for incubation without prior de-gassing.

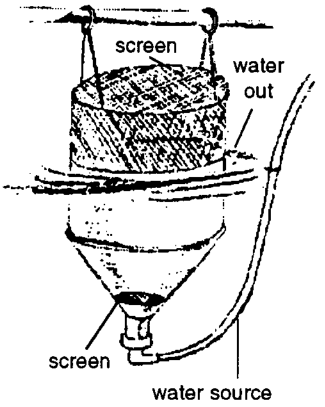
Drum Incubator



A clean steel drum may be modified as an egg incubator. A standpipe is welded to the bottom of the tank to provide a surface water outflow. An outer standpipe, the top half of which is fine nylon netting, is fitted over the internal standpipe to ensure that the eggs do not exit with the effluent water. Water inflow is provided by two or three small pipes fitted so that a unidirectional and slightly upwelling current is ensured. The desired inflow rate is that which keeps the eggs circulating in a slow but uniform fashion. If galvanized metal is used for any part, it must be coated with a non-toxic paint to preclude the leaching of zinc, which is highly toxic to fish. Copper piping is to be avoided for similar reasons.

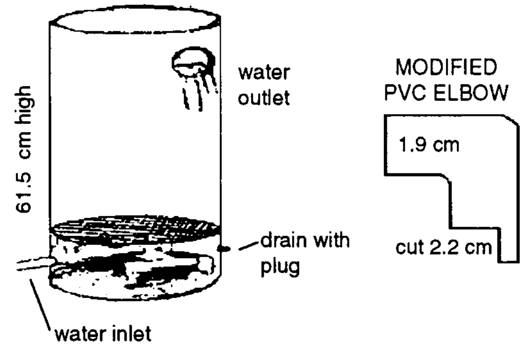
Funnel incubator

A funnel incubator may be constructed over a cement cistern or other types of holding tank which can receive the young fish after hatching. The bottom of the incubator is a large plastic funnel with the top constructed of fine nylon netting. Oxygenated water enters from the bottom and passes over the eggs before exiting through the netted area. This type of incubator can handle eggs to about half of its capacity, provided a sufficient inflow is maintained to keep all eggs rolling gently (usually about 1-2 liters per minute).



PVC upwelling incubator

This is designed for trout and salmon hatcheries, but should work equally well for carps. With the exception of the fine-meshed bottom screen, it is constructed with PVC pipe, making it cheap and easy to construct. Oxygenated water enters at the bottom and is directed downward through four modified 1.9 cm elbows. The water reflects upward to create a more uniform current than might otherwise be obtained. This incubator can be filled with water to no more than one-third of its total capacity. Again, it is essential to provide an inflow rate which ensures that all eggs are kept rolling in a gentle but uniform fashion.



Source: David R. Blakely and Christopher T. Hrusa. 1989. **Fishing News Books.** Blackwell Scientific Publications Ltd. Oxford, London.

A BROTHERHOOD OF ENGINEERS: THE SAEP, PHILIPPINES

The Society of Aquaculture Engineers of the Philippines or SAEP is a non-stock, non-profit technical service organization of engineers, architects and fisheries technologists with involvement in aquaculture engineering practice. It was an off-shoot of a National Consultative Meeting on Aquaculture Engineering on October 2-5, 1985 sponsored by SEAFDEC/AQD and the ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, a UN regional project based in Manila.

The Society's major objectives are to:

- promote the application of sound engineering principles in the design, construction, operations and maintenance of aquaculture projects;
- stimulate studies and research in the proper design and management of aquaculture establishments;
- promote fellowship and bring together under one organization all interested engineers and fishery technologists with involvement or interest in aquaculture engineering; and
- safeguard the aquaculture industry from undue losses or failures due to improper design and construction.

From an initial number of 30 charter members, SAEP has grown to 200 in a period of eight years, a 500% growth or 70% yearly. The Society holds yearly scientific and business meetings where a main theme is selected for the year, and members and guests are invited to present papers for discussion. These papers are subsequently published in the Society's scientific journal, the *Aquaculture Engineering.*

SAEP has established linkages with national and international institutions. Nationally, SAEP is linked with Systems Aquaculture Management, Inc. (SAMI), Aquafarming Development Foundation, Inc. (ADFI), the Philippine Council for

Aquatic and Marine Research and Development (PCAMRD) and Technology Application and Promotion Institute (TAPI) both of the Department of Science and Technology (DOST), Aquaculture Development Consultants, Inc. (AQUADEV), and the University of the Philippines in the Visayas (UPV); and internationally with the Southeast Asian Fisheries Development Center (SEAFDEC), Asian Development Bank (ADB) and the Food and Agriculture Organization (FAO) of the UN.

Why be a member of SAEP?

All engineers, architects and aquaculturists or fisheries technologists are invited to be members of this Society. SAEP:

- provides the only forum for engineers and technologists interested or actually involved in aquaculture engineering, by meeting regularly at least once a year.
- holds scientific sessions where papers relevant to aquaculture engineering are read and discussed.
- gives free popular publications and, at a nominal cost, technical publications on aquaculture engineering published by the Society. So far, eight volumes of the technical journal and 10 issues of the *SAEP Newsletter* have been published.
- arranges field trips to aquaculture centers or the holding of training workshops or courses relevant to aquaculture engineering.
- arranges mutual exchange of information, with the possibility of obtaining job orders or consultancies for members.
- gives assistance and consultation among the members whose expertise and experience vary.

How can one be a member?

- Submit an application form addressed to the SAEP President. Memberships are evaluated by a committee. SAEP will notify you once membership is accepted.
- Pay a one-time membership fee of ₱200 and a regular annual fee of ₱100. You will then be inducted in the regular meeting and awarded a certificate of membership. The member in good standing will subsequently receive all notices regarding the Society's activities and publications.

Corporations, institutions, agencies, associations either private or public, if interested, can become Institutional Members. For institutional members, a membership fee of ₱2,000 and an annual fee of ₱500 are assessed.

Where is the Society located?

The Society's Central Headquarters and Offices are at:

Mezzanine Flr., BFAR Estuar Bldg.
880 Quezon Ave., Quezon City 1103
Metro Manila, Philippines
Tel.: 978-561 to 65 loc. 214
Fax: (632) 911-4326

Reference: Herminio R. Rabanal. *The Society of Aquaculture Engineers of the Philippines: An Overview.* **Aquaculture Engineering** 8-9. 1993-1994.

Aquaculture clinic

The luminous bacterial disease has plagued a number of hatcheries again. Caused by *Vibrio harveyi* and *V. splendidus*, it affects the eggs, larvae and postlarvae of the tiger shrimp *Penaeus monodon.* Queries sent in by hatchery owners are answered here:

Seawater agar culture of the luminous bacterium *Vibrio harveyi.* Photo in total darkness.

Bacterial plaques on the mouth parts of tiger shrimp, mysis I stage.

What are the gross signs of the luminous bacterial disease?

Larvae become weak and opaque-white. Heavily infected ones exhibit a continuous greenish luminescence when observed in total darkness. When viewed under the microscope, the internal tissues of these larvae are densely packed with highly motile bacteria.

What are the effects on the host?

Mortalities in larvae and postlarvae, reaching up to nearly 100%.

What are the preventive measures?

Prevent the entry of luminous bacteria into the hatchery by using ultraviolet-irradiated water or by employing a series of filtration equipment (sandfilters, filter bags, cartridge filters, 0.45 micron pore-sized microfilter, etc.) and chlorination procedures (detailed next page).

Adhere to strict sanitation procedures prior to and during the larval stages.

Use only previously chlorinated water during spawning and rearing to ensure a clean environment for newly hatched and developing larvae.

Siphon out sediments and debris from the tank bottom since these could serve as substrates for bacterial growth.

Disinfect infected stock before finally discarding them followed by a complete clean-up and disinfection of hatchery paraphernalia after every larval rearing period.

What is the treatment?

Change 80-90% of the water daily.

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Procedure for disinfecting rearing water using calcium hypochlorite (70% chlorine activity)

(1) Using Table 1, dissolve the required amount of powder for a desired volume of water in a small volume of water (500 ml). For example, if the water volume is 0.5 ton or 500 liters and the desired concentration is 15 ppm, the amount of calcium hypochlorite needed is 10.7 g.

The amount of calcium hypo-chlorite may be multiplied by different factors to obtain other chlorine concentrations. Ex: To obtain 400 ppm chlorine solution in 1 ton water, multiply 28.6 g by 20 or 14.3 by 40. (1 ton = 1,000 liters.)

(2) Fill the tank with the desired volume of water, then add the dissolved calcium hypochlorite solution.

(3) Keep chlorinated water for at least 12 hours, up to 24 hours, then check the residual chlorine level using portable kits available in the market. Neutralize remaining chlorine with equal amount of sodium thiosulfate ($Na_2S_2O_3$) before using the water.

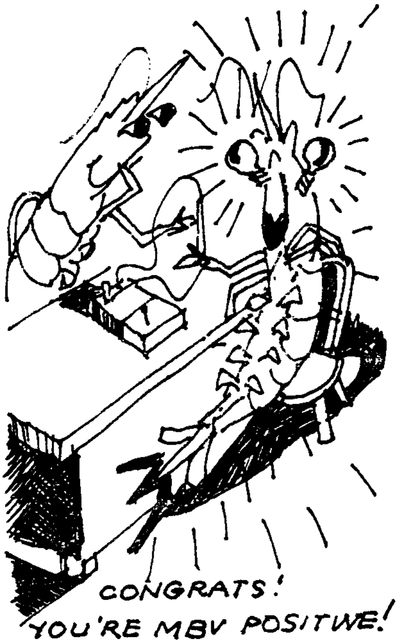
(4) If using ordinary household bleach (Purex, Chlorox, etc. with 5% available chlorine), use Table 2 to determine the amount of bleach to be used for a desired volume of water, then follow steps 2 and 3 above.

TABLE 1 Guide for determining the amount of calcium hypochlorite (g) to be used for water disinfection.

Volume of water (ton)	Chlorine concentration			
	5ppm	10 ppm	15 ppm	20 ppm
0.25	1.8	3.6	5.4	7.2
0.50	3.6	7.1	10.7	14.3
1.0	7.1	14.3	21.4	28.6
2.0	14.3	28.6	42.9	57.1
3.0	21.4	42.9	64.3	85.7
5.0	35.7	71.4	107.1	142.9
10.0	71.4	142.9	214.3	285.7

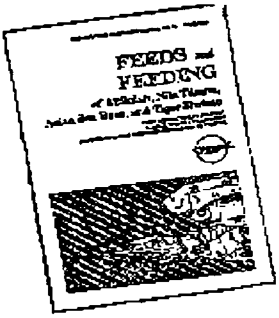
TABLE 2 Guide for determining the amount of bleach (ml) for water disinfection.

Volume of water (ton)	Chlorine concentration			
	5 ppm	10 ppm	15 ppm	20 ppm
0.25	25	50	75	100
0.50	50	100	150	200
1.0	100	200	300	400
2.0	200	400	600	800
3.0	300	600	900	1,200
5.0	500	1,000	1,500	2,000
10.0	1,000	2,000	3,000	4,000



Reference: **Diseases of Penaeid Shrimps in the Philippines.** Aquaculture Extension Manual No. 16, May 1990. SEAFDEC Aquaculture Department, Tigbauan, Iloilo, Philippines.

SEAFDEC/AQD News



Bestselling manual

In about six months after its publication in June 1994, the manual on ***Feeds and Feeding of Milkfish, Nile Tilapia, Asian Sea Bass, and Tiger Shrimp*** went out of print. The bestseller is written by the Feed Development Section of SEAFDEC/AQD and discusses nutrient requirements, sources and characteristics of feedstuffs, feed formulation, practical feed formulations, processing and preparation of feeds, storage and quality control of feeds, and feeding management. The technology extended in the manual is based largely on the research efforts of SEAFDEC/AQD in the last 20 years. The second printing has 500 new copies.

Three other manuals — ***Farming Prawns and Shrimps*** by FD Apud et al. 1983, ***Biology and Culture of Sea Bass*** by P Kungvankij et al. 1986, and ***Important Fish and Shrimp Fry in Philippine Coastal Waters*** by TU Bagarinao et al. 1986 — have been reprinted and may also be ordered from SALES/ CIRCULATION, SEAFDEC/ AQD. See contact address below.

Second International Conference on the Culture of Penaeid Prawns & Shrimps

14-17 May 1996
Iloilo City, Philippines

Review researches of the past decade, identify research gaps, and propose strategies to make the shrimp industry sustainable. Emphasis will be on genetic resources, environmental impact, emerging grow-out and culture techniques, and socio-economic and management aspects of culture operations. Shrimp physiology, nutrition, and diseases will also be discussed.

Registrations received before 15 January 1996 are discounted. Contact: SECRETARIAT, SICCPPS, SEAFDEC/AQD.

Training courses for 1996

TENTATIVE SKED

Aquaculture Management	26 Mar - 24 Apr
Fish Health Management	16 Apr - 28 May
Marine Fish Hatchery	3 June - 23 July
Coastal Aquaculture	31 July - 27 Sept
Freshwater Aquaculture	5 Sept - 16 Oct
Shrimp Hatchery Operation	1 Oct - 20 Nov
Fish Nutrition	23 Oct - 3 Dec

For application forms and further information, please contact: TRAINING AND INFORMATION, SEAFDEC/AQD.

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Light at the end of the tunnel

by E. LEDESMA

Better life through aquaculture