Aquacultural Engineering Society News

AES News, Spring 1998, Vol. 1, No. 1

Letter From Your President

This issue of our newsletter comes to you in our new professionally printed two-color format. Beginning with this issue, we will also be including a reprint of the AES series of engineering-oriented articles appearing in and provided courtesy of *Aquaculture Magazine*. This newsletter contains the first article in the series, which is a review of aquaculture recirculation systems written by Tom Losordo.

The AES has also entered into an agreement with Capamara Communications to provide Editorial Advisory Board members for a new aquaculture trade magazine called *Recirc Today,* which will be released this July. According to the Editorial Advisory Board, "the new magazine will contain concise accounts, written in a low-tech language, of biological and technical progress in the theory, design, use, and functioning of recirculating systems and their component parts, and in the recycling of resources within integrated farming systems." AES members will receive the first year of *Recirc Today* for free.

Our 1998 joint WAS/AES meeting in Las Vegas was another success. AES hosted three days of technical and workshop sessions, all of which were well attended. The AES received $5,300 from WAS for our participation. In addition, AES was presented with a check for $5,725 at the Las Vegas meeting for our participation in the *Fourth International Symposium on Tilapia in Aquaculture* (ISTA IV) held in Orlando in November of 1997. These AES revenues will go towards improving the society's member services (e.g., upgrading the newsletter), off-setting the high costs of AES mailings, and bolstering the society's revolving fund.

Our next meeting will be in Roanoke, Virginia, July 16-19, 1998, as part of the *Second International Conference on Recirculating Aquaculture.* Mike Timmons is coordinating the AES sessions. The AES has two one-half day sessions devoted to contributed presentations, and two one-half day sessions of invited presentations on biological filters and feeds in recirculating systems.

For more details on the AES, visit our website at: www.cals.cornell.edu/dept/aben/aes.

Dave Brune,
AES President

Inside:

Aquaculture Magazine Articles

The AES, in cooperation with *Aquaculture Magazine,* has created a column devoted to presenting a broad range of up-to-date information on aquacultural engineering. The articles will be authored by members of the AES. To "kick off" the AES column, we have elected to review the status and future of recirculating aquaculture production systems. This review will be released in a three-part series. The first article was written by Tom Losordo and will explore issues that are important to evaluating the place that recirculating systems have in commercial aquaculture production. The second article, also by Tom Losordo, will review the status of tank-based water reuse systems in North America and Europe. The third article will address how water recirculation technology is finding it's way into outdoor pond and tank production systems. *Aquaculture Magazine* has given the AES permission to reprint this series of articles within the *AES News* and the first article is reprinted inside.

Jaw-Kai Wang,
AES Publications Editor

Recirculating Aquaculture Production Systems: The Status And Future, Part 1

By Thomas M. Losordo • North Carolina State University

WHAT IS A RECIRCULATING SYSTEM?

Recirculating aquaculture production systems have attracted immense interest world-wide. In general, recirculating systems are production systems that utilize water more than once in the same tank with some degree of waste treatment and water renovation in between. The most common measurement of degree of water recycling is usually the percentage of the total system volume that is replaced per day. In most systems, some water is discharged each day as a by-product of the maintenance of the water treatment system, such as backwashing of solids-capturing filters. The amount of water used in a recirculating system (% volume exchanged per day) is usually a function of some limiting factor. In the extreme case, if seawater is not available for the inland production of marine organisms, the system must be considered nearly closed with virtually no replacement of the system volume with new seawater. On the other hand, if water is recycled to conserve heat only, then the percentage of water exchanged per day may vary with the season. In almost all cases, a completely closed system is more difficult to operate and maintain than one that replaces 5 percent of the system volume or more per day.

Proponents of recirculating production systems cite numerous advantages of these systems. With high production intensities these systems require only a small amount of land area (not including that needed for waste disposal). As such, these compact units can be located close to large population centers (cities) where land would be prohibitively expensive for building larger, less intensive pond based production systems. Proponents also claim that recirculating systems provide a higher degree of control of the environment in which the crop is being grown. This feature allows for the culture of warmwater species in a cold environment or visa-versa; or marine species grown hundreds of miles from the nearest sea in an urban warehouse! Proponents have also stated that recirculating systems are more environmentally friendly than other types of aquaculture systems.

Recirculating systems have detractors as well. The most common negative statement about these systems is that they are not an economically viable way to grow fish. In general, the capital cost of these systems, measured as money invested per unit of annual fish production is higher than other traditional aquaculture production systems. Detractors point to the numerous business failures using this type of technology and wonder whether these systems are even technically feasible.

The realities of today's recirculating aquaculture systems, as with most issues, lies somewhere in between these two extreme views. This article is intended as a starting point in the exploration of some of these important issues related to tank based recirculating production systems. The author seeks to dispel some misconceptions — both positive and negative — about recirculating aquaculture technology. Part II of this series will review the current status of recirculating production systems.

PRODUCTION INTENSITY AND WASTE GENERATION

Like other aquaculture production systems, fish production in recirculating systems generates waste. Wastes produced due to fish excretion and uneaten food initially appear in fish tanks and are removed either through the liquid waste or sludge waste stream. Generally, in tank systems, the fish culturist can observe fish activity and control feeding and monitor fish growth more closely than in ponds or net pens. Because of this, the culturist can more easily track fish inventories, minimize wasted feed and more closely adjust the daily feed amount to either the fish appetite or some percentage of body weight. Some newer tank drain technologies allow for the rapid collection of solid waste (either faeces or feed) as they are generated within a tank. Using these technologies, the culturist can stop feeding the fish when uneaten feed appears in the outlet flow of the tank. More recently, equipment and computer software have been developed to monitor the outflow pipe from tanks or net pens. The computer discerns wasted feed from faeces and, with a control circuit, can modify feed rates immediately and automatically.

Additionally, in tank based systems, wastes can generally be more easily collected and concentrated. However, if this concentrated waste is not treated and disposed of properly, nothing is gained and, in-fact, the system becomes a "point source" of waste, which actually has more potential for localized pollution impact than other less intensive systems. Pond systems, in most cases, discharge little water and in almost all cases, provide some amount of internal "natural" waste treatment. In essence, a pond is a biological filter that converts nitrogen to both algae and nitrogen gas through a bacterial denitrification step occurring in the mud in the bottom of the pond. Tank base systems have no such natural waste treatment process, and all waste collection and treatment must be planned for and designed into the system. Data from a large scale (450 metric tonne, 1 million pounds annually) commercial recirculating fish production facility shows that approximately 20% of the feed added to the system will come out (on a dry wt. basis) as sludge. Putting that into perspective, a facility feeding 3,000 pounds of feed per day will produce 600 pounds of waste sludge per day (dry weight). At a sludge concentration of 15% (dry wt. solids) that would translate into a liquid sludge production volume of 480 gallons per day. The 480 gallons of sludge would contain approximately 28 pounds of total nitrogen, of which 70% is organic and 30% is inorganic, and 59.5 pounds of total phosphorus.

Recirculating systems also tend to concentrate dissolved nutrients such as nitrate. In general, a system that replaces less than 10% of the system volume per day, with no active denitrification system, will have nitrate-nitrogen concentrations in the culture tank well in excess of 100 mg / L and total phosphorus concentrations in excess of 20 mg-P / L.

Waters receiving these nutrients should be highly resistant to eutrophica-

tion. Although treatment of recirculating wastewater to control nitrogen level is technologically feasible and is being talked about and implemented more often in the recirculating systems, phosphorus removal is cost prohibitive. Efforts in North America and Europe are currently focused on the reduction of phosphorus levels in feeds as a means of controlling phosphorus in aquacultural effluents.

Additionally, marine systems pose a special problem with regard to sludge treatment or disposal. Marine systems may generate organic sludge with a high concentration of salt. Treatment and disposal of aquaculture sludge is currently done through either the city sewer systems in urban environments or through land and crop application in more rural settings.

There has been a great deal of interest in fish production systems that are linked to greenhouse plant or vegetable culture. However, matching plant waste utilization to fish waste generation is not an easy task. In reviewing the available data in the literature, it appears that aerial requirements for plant production are significantly greater than the culture area for the production of fish. In intensive production systems with fish culture densities at or above 70 kg / m^3 (0.58 lb./gal), the ratio of plant culture area to fish culture area is approximately 40 : 1. As such, in integrated systems where plants are used to utilize wastes, fish culture densities tend to be lower than in systems producing fish alone. To maintain high fish stocking densities in integrated aquaculture / vegetable culture systems, the addition of some form of traditional biofiltration is required. Additionally, from a marketing viewpoint, because of the large volume of plants produced, the horticulture products usually become the primary crop.

THE ISSUE OF CONTROL AND WATER QUALITY

When one hears about recirculating tank systems, the phrase "controlled environment aquaculture" is not far behind. Because most recirculating systems are tank based with no bottom substrate for bacterial growth, there are very few natural water treatment processes ongoing within these systems. Virtually all water treatment (except for some passive nitrification and denitrification) and water quality control processes must be designed into recirculating tank systems and are the responsibility of the operator. Nature has little or no role in this type of aquaculture. While this is positive in a well designed and operated system, it can be just as big a negative in a poorly designed or overloaded recirculating system. The basic "unit processes" required for tank based recirculating aquaculture are listed in Figure 1, while some of the more common components used for solids removal are shown in Figure 2.

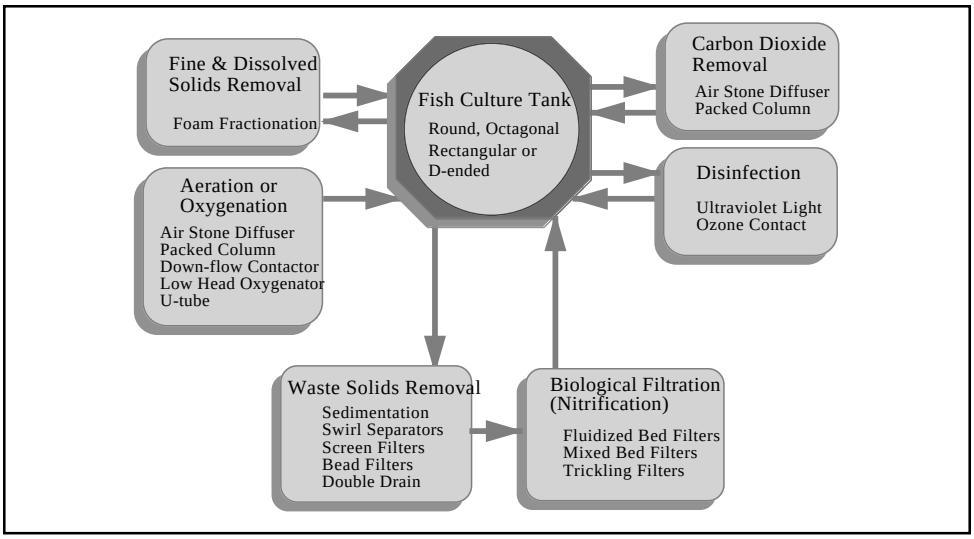

Figure 1. Required unit processes and some typical components used in recirculating aquaculture production systems.

In a well designed and operated recirculating system that is neither overstocked nor overfed, some aspects of water quality can be controlled precisely. For example, if the oxygen concentration in a tank is low, the operator or a linked computer system, can adjust a valve and add more oxygen to the tank, if the capacity is available. Similarly, if the pH of the system moves outside of the optimal range, chemicals can be added manually or automatically to bring the pH within the optimum operating limits. Additionally, in systems where biofiltration is operated as

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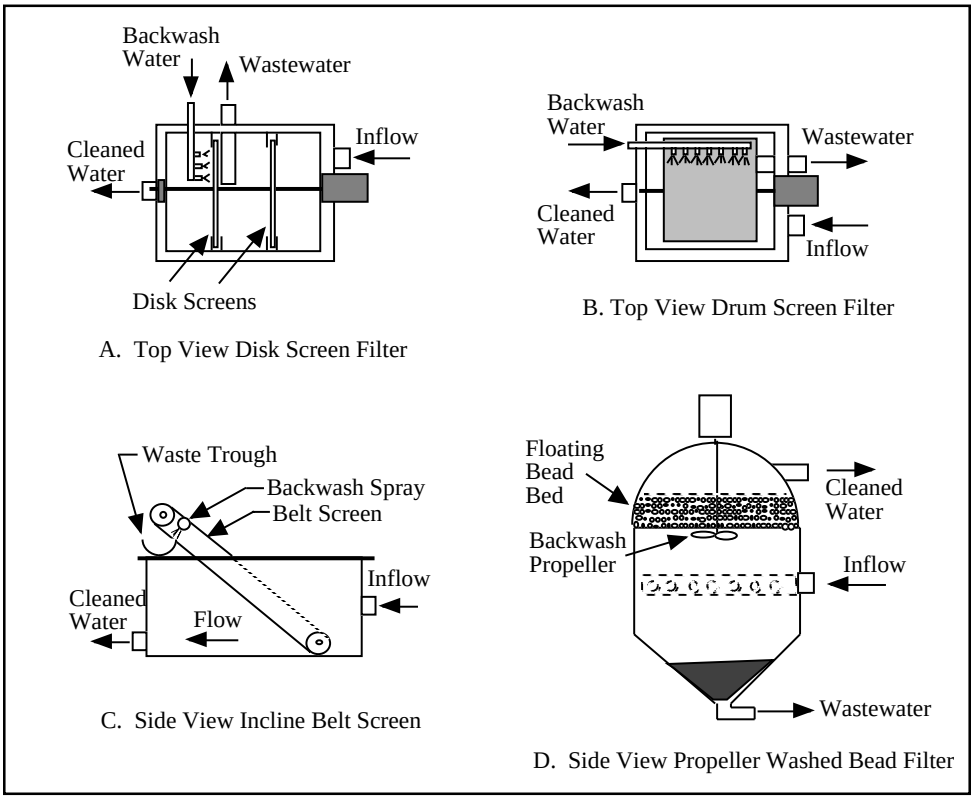

Figure 2. Screen filters and bead filters are commonly used components for removing waste solids from recirculating aquaculture production systems.

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a common water treatment unit for many tanks, if ammonia in one tank becomes a problem, the flow can be increased to that specific tank, and the ammonia level can be brought under control (if the flow or filter capacity is available).

However, a reality of commercial aquaculture is that most producers seek to improve the economic bottom line of their operation by intensification of production. That is, systems are operated at the upper level of their design limits. Operated in this way, any aquaculture system — pond, flow-through tank or recirculating system — may not be very forgiving of mistakes by the operator. In recirculating systems these problems can be magnified. Intensive recirculating production systems tend to have high rates of oxygen utilization. Respiration by the fish, bacteria in the biofilter (if submerged), and bacteria floating in the water column (referred to as BOD) can produce very high rates of oxygen consumption. Where crops can be lost to oxygen depletion overnight in pond production systems, heavily stocked and fed recirculating systems can be lost in a matter of a half hour if there is an interruption in the flow (liquid or gas) that brings oxygen to the culture tank, and emergency procedures are not in place or do not function properly.

So as one can see, there are always trade-offs. With recirculating systems you have the potential to gain more control of the environment, however, if the system is not well designed, or the design capacity is exceeded, rapid and disastrous consequences can occur.

THE ECONOMICS OF RECIRCULATING SYSTEMS

Recirculating systems shouldn't be dismissed "out of hand" as not being economically viable. There are numerous examples of successful operations worldwide. When one compares the cost of fish production to pond production systems, some interesting results are found.

For the most part, the variable costs of fish production (feed, fingerling, electricity and labor cost) in recirculating systems are not much different from other production technologies. While pond culture systems require large amounts of electricity for aeration during the summer months (at least 1 kW / acre of pond), recirculating systems usually have a lower and more even electrical load over the entire year. Although it may appear that recirculating systems require more labor than pond systems (monitoring, upkeep and maintenance), if the nightly labor for checking dissolved oxygen in ponds, moving emergency aerators around, and harvesting are taken into account, the differences may be found to be minimal. In fact, feed costs can actually be less in recirculating systems than for pond or net pen based systems. Tank production systems generally produce a better feed conversion ratio. Given that feed costs are the largest variable cost item in fish farming, attention in feeding could yield a major economic advantage for the careful recirculating system producer.

If all this is true, then why so many economic failures in recirculating systems aquaculture? The answer is usually related to the high initial investment in many of these systems. Comparing the productive capacity per dollar of investment, many of these failed recirculating systems have cost more than other fish production methods. Pond production systems in the southeastern United States have investment costs of between $1.00 and $2.00 per pound of annual production, including land, construction, and equipment (Dunning, 1995). In other words, a farm with ponds capable of producing 100,000 pounds of fish per year costs between $100,000 and $200,000 initial investment. Alternatively, in the past, it has not been uncommon to hear of a "turnkey" recirculating system with the same production capacity costing the owner upwards of $400,000. That's $4.00 invested per pound of annual production. From the results of the North Carolina Fish Barn project, we have estimated that a production system, including land and building, should cost between $2.00 - $2.75 per pound of annual production capacity. Keep in mind that over-designed and unnecessarily expensive systems may have a debt service that translates immediately into economic problems from the start. On the other hand, under-designed systems may never achieve their design production levels and experience cash flow problems.

Entrepreneurs who are currently successful in recirculating fish production have managed to build systems that produce fish intensively and consistently while minimizing debt. That is, these entrepreneurs have managed to keep the investment costs down while operating an efficient and reliable system. Many of these producers have had modest beginnings, starting with a well researched prototype system, and expanding as their markets and capital have allowed. Many of these successful fish producers are selling into high value markets, usually live fish, that pay top dollar for premium quality product. We will report on some of these systems as we review the status of the industry in Part II of this series.

RECIRCULATING SYSTEMS IN THE 21st CENTURY

In earlier years of recirculating systems development (late 1960s through the early 1980s), ammonia-nitrogen toxicity control and oxygen addition were topics focused upon in recirculating aquaculture research. As production intensified and more experience was gained in the late 1980s and early 1990s, the impact of waste solids within the system became more widely recognized as an important design factor. Development efforts refocused on the rapid and efficient removal of waste solids which is a key to the reduction of component size for biofiltration and oxygenation. As intensities have further intensified in the 1990's, carbon dioxide control has also surfaced as an important issue. However, in a recent meeting of industry, government, and academic experts in this field, the consensus was that technology must become more cost effective to be implemented on a wider scale. Two points that came to the "top of the list" for doing so were the development of systems that improved production per unit of investment, and improved feeds that are tailored to recirculating systems and the crops being produced.

As this decade closes, the challenge to engineers, biologists, and economists continues to be to create systems that produce more product for less investment while maintaining process and production reliability. While many seek to measure success by increased stocking intensity, a more appropriate measure may be increased annual production per unit of capital investment. Realize that this may mean lighter stocking rates but moving product more quickly through the system. Combine this unit of measure with the

efficient utilization of resources (labor, energy, and feed), and a winning combination should be found.

As mentioned earlier, one of the largest variable cost items in aquaculture is feed. Issues related to aquaculture feeds will become increasingly important as feed constituents become more expensive and environmental regulations restrict the discharge of wastes. Improved feeds can mean better water quality within the system, reduced size of water renovation components, and can have a significant impact on the "bottom line". Better feeds should also mean less waste in the form of sludge and inorganic nutrients.

Additionally, a healthy dose of public education is also needed. All too often operators and investors new to this field have implemented plans without understanding the basics of the business or technologies. The same mistakes are often made over and over again by hopeful aquaculturists and, when the design problems are finally corrected by some internal R & D, the extra development costs often make the systems economically non-competitive.

While this manuscript has highlighted both positive and negative aspects of recirculating systems, the author is strongly convinced that cost effective and environmentally friendly systems will allow recirculating aquaculture production systems to move into the next century and take a successful place within the aquaculture industry world-wide.

REFERENCES

Dunning, R. 1995. *Aquaculture in North Carolina: Catfish, inputs, outputs and economics.* North Carolina Department of Agriculture. Raleigh, NC, USA.

Dunning, R. 1995. *Aquaculture in North Carolina: Hybrid striped bass, inputs, outputs and economics.* North Carolina Department of Agriculture. Raleigh, NC, USA.

Losordo, T.M., M. Masser, and J. Rakocy. 1992. *Recirculating aquaculture tank production systems: An overview of critical considerations.* Publication No. 451, United States Department of Agriculture, Southern Regional Aquaculture Center, Stoneville, Mississippi, USA.

New Magazine: *Recirc Today*

Recirc Today is an new aquaculture technology magazine specializing in the subject of water recirculation and treatment. It will feature original articles and extended summaries of published papers covering all aspects of recirculation theory and technology. The magazine will appeal to all people in the aquaculture recirculation field — farmers, research scientists, engineers, manufacturers, and suppliers. The magazine will focus on bringing concise accounts in low-tech language of biological and technical progress in the theory, design, use, and functioning of high-tech water recirculation systems and their component parts, and in the recycling of resources within integrated farming systems. It will also provide a venue for manufacturers and suppliers to advertise their products directly to a knowledgeable and discriminating public, where all can benefit from current advances in the field.

The aim of *Recirc Today* is to provide a forum for exchanging information on water recirculation in aquaculture. The authority for statements and claims made is the sole responsibility of contributors. Reference to named products or technologies does not imply endorsement or recommendation by either the editors and publisher of the magazine or of the Aquaculture Engineering Society.

Recirc Today welcomes articles which meet the overall objectives of the magazine and are prepared in accordance with the Guide for Authors.

GUIDE TO CONTRIBUTORS

Recirc Today welcomes short articles dealing with all aspects of fresh and salt water recirculation and treatment related even loosely to aquaculture, or the performance and physiology of cultured organisms in recirculation systems. They may be original summary or review articles, or extended abstracts of refereed papers previously published in scientific or technical journals. Such abstracts will include the title, authorship and full citation of the original article.

Titles should be as short as possible and clearly related to the subject of the article.

Authors should be fully identified, including parent firm or institution and current mailing addresses. Phone numbers and e-mail addresses may be included.

Text should be concise and not exceed 1000 words. Shorter articles or news items are also welcome. Terminology should allow comprehension by readers lacking advanced scientific or technical training. Where appropriate, editorial assistance will be available to aid authors in achieving necessary brevity and clarity.

In the interest of readability, no references will be cited in the text, thus authority for statements and claims made will be the responsibility of the author. Authors may include a limited reading list as part of the text.

Photographs should be glossy and with good contrast and should be prepared so that they can be reproduced without reduction. Line drawings should be in black ink and formatted so that details will be clear after reduction. Originals are preferred and will be returned to the author. Each illustration should be clearly identified on the back with the illustration number and the title and author of the paper. Tables should be typed on separate sheets and may be re-formatted to fit within the column dimensions. Captions for photographs, figures and tables should be included in the text.

Copy may be submitted typed, double-spaced, on one side of the paper, and may be accompanied by a 3.5 inch floppy disc containing the text in a current word processing language such as Word Perfect or MS Word, in either Macintosh or IBM formats. By prior arrangement, copy may be submitted electronically.

An original and two copies of articles submitted for consideration for publication should be sent to David J. Scarratt, Editor, *Recirc Today.* PO. Box 1564, Halifax, N.S. Canada, B3J 2Y3. Phone: (902) 423 6955; Fax: (902) 423 2720; e-mail: scarratt@ns.sympatico.ca

UPCOMING MEETINGS

Second International Conference On Recirculating Aquaculture

Virginia Tech and the AES (among others) will be hosting the *Second International Conference on Recirculating Aquaculture*, July 16-19 at the Hotel Roanoke Conference Center in Roanoke, Virginia, USA. The Conference will feature renowned experts from around the world who will share their practical experience in recirculating aquaculture. (See Section Schedule, page 7.)

Symposium topics will include the most recent developments in fish health, including isolation and quarantine issues. Small scale systems operators will share their success and failure stories in recirculating systems, while conversations will take place by leading experts on denitrification. Presentations will be given on practical options for treating waste, and the role that automation can and should play in recirculating systems. There will be a focus on the economic principles needed to establish and sustain recirculating aquaculture.

Additional highlights will include three sessions by the Aquacultural Engineering Society on feeds for recirculating aquaculture systems; biofiltration; and system design, construction, and operation; as well as a day-long session by The Freshwater Institute on the intensification of coldwater fish production.

Please contact Dr. George Libey for further information:

540-231-6805 (ph)
540-231-9293 (fax)
rakestra@vt.edu (email)

Aquaculture America '99

The AES will be holding our Annual Meeting at *Aquaculture America '99*, January 27-30, which is the US Chapter of the World Aquaculture Society's Annual Meeting in the Tampa (Florida) Convention Center. The AES will sponsor at least one technical session and one producer oriented session at *Aquaculture America '99*. The deadline for contributing high quality, 1-page, extended abstracts for oral or poster presentation is July 31, 1998. For more information, contact: *Aquaculture America '99*, Conference Manager, 21710 7th Place West, Bothell, WA 98021 USA; 425-485-6682 (ph); 425-483-6319 (fax); worldaqua@aol.com (e-mail).

Cornell 4th Annual Aquaculture Water Reuse Systems Short Course

This four and 1/2 day short course (a Saturday tour ends at noon) is intended to give a thorough coverage of the design, operation and management of water reuse systems for fin fish. Limited coverage will be given to engineering economics. The course will be taught by members of the Cornell Aquaculture Program and outside experts. A combination of "hands on" experiences with classroom presentations will be offered (8:30 am-5:00 pm). At the conclusion of the workshop, individuals should be able to design their own water reuse systems and have a fundamental knowledge of the principles influencing design decisions. The following topics will be addressed:

- system carrying capacity (oxygen and ammonia constraints)
- space and volume requirements
- flow requirements
- fluid mechanics, pressure losses
- nitrification principles, filter design, and water chemistry
- system design
- alarm and power backup systems
- group presentations of design projects

The cost of the short course is $650 and covers handouts, travel from campus housing to site and daily breakfasts, lunches, and banquet dinner. Enrollment is limited and a $200 deposit is required by May 23, 1998. For more information contact: Dr. Michael B. Timmons (Ag & Biological Engineering, Riley-Robb Hall, Cornell University, Ithaca, NY 14853) 607 255 2801 (ph); 607 255 4080 (FAX); mbt3@cornell.edu (email).

Aquaculture Europe '98

The next international conference to be organized by the European Aquaculture Society (EAS) will take place in Bordeaux, France, October 7-10, 1998. The key topic will be "aquaculture and water: fish culture, shellfish culture, and water usage." The 3-day conference will consist of oral and poster papers, selected and case study papers, poster sessions, and technical excursions. Workshops are also being offered on recirculation technology, larval rearing in fish and shellfish, and co-management of production basins in fish and shellfish culture. The AES is co-sponsoring a special one day workshop on recirculation systems that will be run complimentary to the scientific session addressing this topic. The workshop will include presentations on various aspects of recirculating aquaculture by international experts, producers, and designers of commercial recirculation systems. Raul Piedrahita is coordinating the AES involvement. Interested contributors to the conference are invited to submit an extended abstract in camera ready form (1 original and 3 copies) to the EAS conference secretariat prior to June 1, 1998. For more information or to submit an abstract, contact: European Aquaculture Society, EAS Secretariat, Slijkensesteenweg 4, B-8400 Oostende, Belgium; +32-59-32 38 59 (ph); 32-59-32 10 05 (fax); or eas@unicall.be (email).

US Trout Farmer's Association Annual Meeting

The US Trout Farmer's Association and Idaho Aquaculture Association will hold their mid-year convention and trade show at Canyon Springs Hotel and Western Plaza Hotel in Twin Falls, Idaho, on October 8-10, 1998. The program will highlight environment, water quality, waste management, marketing/promotion, and quality assurance. A special panel session on extruded feeds-cost vs. benefits will also be held. The trade show will be open October 8 and 9. For more information, contact USTFA at 304-728-2167 (ph), 304-728-2196 (fax), ustfa@intrepid.net (e-mail), or 111 W. Washington Street, Suite 1, Charles Town, WV 25414-1529.

AES Conferences and Workshops

The AES is designed to be a low overhead society and as such will endeavor to hold its annual meeting in conjunction with other related societies (e.g. WAS, AFS, ASAE, etc.) in order to reduce member travel costs and enable members to attend as many professional meetings as possible. The majority of society business will be conducted at the society's annual meeting.

Second International Conference on Recirculating Aquaculture--Session Schedule

Friday, July 17

SYMPOSIUM 1 - Isolation and Quarantine (morning)

- *Biosecurity: Principles and Practices in the Commercial Poultry Industry* (6 pages). F. William Pierson
- *Common Chemicals For Cleaning and Disinfecting Aquaculture Facilities* (13 pages).George J. Flick, Jr.
- *Isolation and Quarantine - Practical Considerations* (2 pages). George S. Libey
- *Biosecurity and Fish Health Monitoring for Aquaculture Facilities* (3 pages). Stephen A. Smith

SYMPOSIUM 2 - Small Scale Systems (morning)

- *Recirculating Aquaculture Systems as a Teaching Tool* (2 pages). Brian L. Nerrie
- *The Aqua-Manna Experience* (6 pages). James E. Bradley and William G. Blythe
- *IT WORKED, BUT...A Short, Abridged History of Shenandoah Waters* (8 pages).William K. Stackhouse
- *Critical Considerations for Greenhouse Tilapia Production* (7 pages). Steve Abernathy and C. Greg Lutz

AES TECH SESSION - Feeds for Recirculating Aquaculture System (morning)

- *The Importance of Feed to the Economic Success of the System* (4 pages). Todd F. Powless
- *Digestibility Issues of Feeds for Water Recirculating Systems* (5 pages). Mark W. LaVorgna
- *Selection of Pelleted, Expanded and Extruded Feeds* (4 pages). Bob Robinson
- *Formulating Feed for Tilapia Reared in Recirculating Systems* (8 pages). Paul D. Maugle

SYMPOSIUM 3 - Automation (afternoon)

- *The Use of Process Control Software for the Monitoring and Control of Aquaculture Systems* (11 pages). Phillip G. Lee
- *Water Quality - Types of Analyses and the Equipment Used* (10 pages). Norman Barma
- *Various Types of Meters and Transmitters for Use in Aquaculture, Their Proper Placement, Maintenance and Operation* (no paper). Randy Lovell
- *Communication Between Production Systems and the Aquaculturist via Sensor Interrogation, Networking and the Internet* (no paper). Rick Kris

SYMPOSIUM 4 - Waste Management (afternoon)

- *Settling Basin Design and Performance* (no paper). Daniel Stechey
- *Constructed Wetlands for Water Treatment in Aquaculture* (8 pages), Michael J. Massingill, Elisabeth Kasckow, Rodney J. Chamberlain, James M. Carlberg, and Jon C. Van Olst
- *Aquaculture Sludge Composting Demonstration Project* (no paper). James Shelton
- *An Integrated Approach to Aquaculture Waste Management in Flowing Water Systems* (11 pages). Steven T. Summerfelt

AES TECH SESSION - Biofiltration (afternoon)

- *Biological Filters: Trickling and RBC Design* (28 pages). John N. Hochheimer and Fred Wheaton
- *Sizing and Management of Floating Bead Bioclarifiers* (23 pages). Ronald F. Malone, Lance E. Beecher, and Aurelio A. DeLosReyes, Jr.
- *Application of Fluidized-Sand Biofilters to Aquaculture* (13 pages). Michael B. Timmons and Steven T. Summerfelt
- *Comparative Performance of Biofilm Reactor Types: Application of Steady-State Biofilm Kinetics* (3 pages). Barnaby Watten, Michael B. Timmons, Brian J. Vinci, and Steven T. Summerfelt
- *Immediate and Stable Nitrification in Biofilters by Microbial Manipulations* (6 pages). Ami Horowitz and Sarah Horowitz

POSTER PRESENTATIONS (displayed all day)

- *Determination of the Primary Ammonia Removal Design Criteria for Biological Filters* (1 page). Catherine A. Wells and Fredrick W. Wheaton
- *In-Situ Passive Waste Removal in Circular Fish Culture Tanks* (1 page). J. D. McMillian, F. W. Wheaton, and J.M. Ebeling
- *A Prototype Tilapia/Hydoponic Greenhouse Recirculating Production System for Institutional Application* (2 pages). Scott H. Newton, Jimmy Mullins, George S. Libey, and Mark Kidd
- *The Speedy Text to Identify Optimal Growth Temperature for Aquatic-Animals* (3 pages). X. Miao, K.W. Zheng, and X.Y. Jing

Saturday, July 18

SYMPOSIUM 5 - Business Management and Economics (morning)

- *Investment and Management Aspects of Owner/Operator Scale Greenhouse Tilapia Systems* (8 pages). C. Greg Lutz and Kenneth J. Roberts
- *Economic Analysis of Land-Based Summer Flounder Aquaculture Systems Under Uncertainty* (1 page). James L. Anderson and David Zucker
- *Strategic Management for Recirculating Aquaculture Systems* (no paper). Patrick O'Rourke
- *What Lenders Want: Financing Your Aquaculture Enterprise* (10 pages). Patricia F. Lacey

SYMPOSIUM 6 - International Recirculating Aquaculture Systems (morning)

- *Recirculating Aquaculture System in Japan* (5 pages). Haruo Honda
- *Recirculation Technologies in Norwegian Aquaculture* (9 pages). Björnar Eikebrokk and Yngue Ulgenes
- *Overview of Recirculating Aquaculture Systems in UK* (no paper). Bob Bawden
- *Recirculating Aquaculture Systems in Korea - Development of an Environmentally Friendly Aquaculture System, Intensive Bio-Production Korean (IBK) System* (8 pages). In-Bae Kim and Jae-Yoon Jo

AES TECH SESSION - Volunteered Presentations (all day)

- *Design of an Emergency Aeration System for Intensive Aquaculture Raceway Systems* (1 page). M. Bower, S. Diaz, M. Ellis, B. Marchionini, and A. Sheldon

(Continued on next page)

Second International Conference on Recirculating Aquaculture--Session Schedule

(Continued from previous page)

- *Development and Evaluation of a Feedback Control System for Dynamic Control of Dissolved Oxygen in Intensive Recirculating Aquaculture Systems* (2 pages). James M. Ebeling
- *Growth of Mercenaria Seed Clams in a Recirculating Nursery System Utilizing Computer-Control and Fluidization Technology* (1 page). Timothy J. Pfieffer and Kelly A. Rusch
- *Fish Health Management of Recirculating Systems* (2 pages). David Crosby
- *Application of Industrial Monitoring and Control for an Experimental Carbon Dioxide Stripper in a Recirculating Aquaculture System* (2 pages). Scott M. Tsukuda, James M. Ebeling, and Barnaby J. Watten
- *The Use of Commercial Probiotics in the Production of Marine Shrimp Under No Water Exchange* (3 pages). Tzachi M. Samocha, Addison L. Lawrence, Ami Horowitz, and Sarah Horowitz
- *A Study of Selected Fish Feed Binders: Effect on Generated Waste Quantity and Quality* (1 page). Fred Wheaton, S. Singh, J.H. Soars, and J.N. Hochheimer
- *Effect of Chemotherapeutants on Nitrification in Fluidized-Bed Biofilters in a Recycle Rainbow Trout Culture System* (1 page). M.F. Schwartz, G.L. Bullock, S.T. Summerfelt, J.A. Hankins, and J.A. Mathias
- *Water Quality Limitation of Fixed Film Biofilters for Recirculating Aquaculture Systems* (4 pages). Shulin Chen and Songming Zhu
- *Aquaculture Engineering Design of Tilapia Breeding System in a Freshwater Recirculating System* (1 page). Teodoro U. Abalos
- *Performance of a Prototype Zeolite Recirculating Aquaculture System* (2 pages). Harry Westers and Joseph T. Fuss
- *An Integrated Recirculating System for the Production of Oysters and Shrimp* (2 pages). Jaw-Kai Wang
- *Design and Construction of a Commercial Biosecure, Closed, Recirculating Shrimp Production System* (1 page). Phillip G. Lee, Phillip E. Turk, and Addison L. Lawrence
- *Procedure for Analyzing the Technical and Economic Risk of a Recirculating Aquaculture System* (2 pages). Kerry W. Tudor and Patrick D. O'Rourke
- *The Effect of Biological Air Purifying System with Aquatic Animal-Plant Integrated Greenhouse* (3 pages). S. R. Cui, X.W. Miao, B.H. Shao, and L.X. Fu
- *Integrating Hydroponic Plant Production with Recirculating System Aquaculture: Some Factors to Consider* (3 pages). James E. Rakocy
- *Ground Limestone as a Biofilter Media for Hybrid Stripped Bass Culture* (2 pages). Dale C. Honeyfield
- *Evaluation of an Aerated Floating Plastic Media Biofilter Within a Recirculating System Used to Produce Food-Size Yellow Perch* (1 page). Justin M. Balter, Craig Hall, Glenn Snapp, and Steven T. Summerfelt
- *Prediction and NMR Determination of Fluid Film Thickness and Velocity Distribution in Nitrifying Trickling Filters* (1 page). Valdis Krumins
- *The Chilean Aquaculture Industry and the Role Played by the Universidad Catolica Del Norte in its Development* (4 pages). German E. Merino

COLDWATER AQUACULTURE CONFERENCE (all day)

- *Comparison of Aquaculture and Broiler Production Systems* (10 pages). Michael B. Timmons and Paul W. Aho
- *Alternative Species Production: Potential of Arctic Char* (no paper) Julie Delabbio
- *The Pacific Northwest Experience with Production Intensification Through Recirculation* (9 pages). Sean Wilton and Rocky Boschman
- *The European Experience with Production Intensification* (18 pages). James Muir
- *The Impact of Fish Handling Equipment* (1 page). Louie Owens
- *Trends in Feeds and Feeding Strategies* (4 pages). Thomas Zeigler and J. Alan Johnson
- *Effluent Management: Overview of the European Experience* (12 pages). Asbjorn Bergheim and Simon J. Cripps
- *The Importance of Biosecurity in Intensive Culture* (8 pages). Julie Bebak
- *Culture Tank Designs to Increase Profitability* (10 pages). Steven T. Summerfelt, Michael B. Timmons, and Barnaby J. Watten
- *Value-Added Market Opportunities for Small and Medium Scale Businesses* (7 pages) Howard M. Johnson

SYMPOSIUM 7 - Aquatic Animal Health (afternoon)

- *Shellfish Diseases and Their Management in Commercial Recirculating Systems* (2 pages). Ralph Elston
- *Diseases of Flatfish* (8 pages). S. W. Feist
- *Chemotherapeutics and Treatment Calculations Used in Aquaculture* (5 pages). Stephen A. Smith
- *Potential Zoonotic Infections in Cultured Foodfish* (9 pages). Jeffrey C. Wolf

SYMPOSIUM 8 - Denitrification (afternoon)

- *Biological Denitrification Using Upflow Biofiltration in Recirculating Aquaculture Systems: Pilot-Scale Experience and Implications for Full-Scale* (8 pages). Jennifer B. Phillips and Nancy G. Love
- *Denitrification in Recirculating Aquaculture Systems: From Biochemistry to Biofilter* (9 pages). Jaap van Rijn and Yoran Barak
- *Nitrite Accumulation in Denitrification Systems - The Role of Dissolved Oxygen and Substrate Limitation* (no paper). JoAnn Silverstein
- *Denitrification Using Upflow Biological Filtration - Engineering Aspects of the Technology* (no paper). Mervyn W. Bowen

The *First International Recirculating Conference* at the Hotel Roanoke, in July of 1996, was a huge success with more than 500 participants from 26 countries. The 1998 conference is expected to be even bigger and better!

Elsevier's Journal Aquacultural Engineering

Aquacultural Engineering is the only international journal to cover aquacultural engineering. Contents of the journal emphasize the design and development of effective aquacultural systems. The journal also provides scientists and other professionals with the latest basic research data and its application to the commercial operation of aquaculture facilities. This authoritative resource features both physical and biological research on freshwater and marine aquaculture systems in the following areas:

- Engineering and design of aquaculture facilities;
- Engineering-based research studies;
- Construction experience and techniques;
- In-service experience, commissioning, operation;
- Materials selection and their uses;
- Quantification of biological data and constraints.

Aquacultural Engineering papers are stringently peer-reviewed and the journal is maintained by an internationally recognized editorial board. A one-year subscription to the journal comes with AES membership.

There are now only two 1997 issues of *Aquacultural Engineering* that are overdue (vol. 17, nos. 3 & 4); Elsevier Science will print the remaining issues as soon as possible and the AES will mail the remaining 1997 journals to our journal receiving members as they arrive. We will also begin shipping the 1998 *Aquacultural Engineering* journals to our journal receiving members as they arrive. Thank you for being patient, especially the new 1998 members.

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The AES is looking for sponsors within the aquaculture industry to support the increased cost of producing the *AES News*. The sponsors listed below have donated generously to support the AES. For this donation, the AES will be inserting a one-page product literature sheet in one of the newsletter mailings, and list the vendor as an AES supporter in four consecutive newsletters. Please contact one of the *AES News* Co-Editors if you would like to be a sponsor.

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The **Aquacultural Engineering Society** was founded in 1993 to provide a forum for addressing engineering problems related to aquaculture. Its membership is open to engineers and non-engineers engaged in the culture, processing, and/or distribution of aquatic organisms or their by-products. The AES serves as an authoritative source of engineering information and support to the aquaculture industry. Working with other aquacultural groups and societies, the AES brings people together to discuss new ideas and technologies of benefit to the aquacultural community as a whole.

AES Members receive a one-year subscription to the journal Aquacultural Engineering, updated membership directories, and the AES News.

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Order AES and Other Aquaculture Conference Proceedings From NRAES

The Northeast Regional Agricultural Engineering Service (NRAES) has maintained a strong partnership with the AES since we were founded in 1993. To date, the NRAES has published the conference proceedings for every major AES meeting (when proceedings were produced). Many in the aquaculture industry have come to appreciate the quality and relatively low price of these valuable proceedings, and they are a real asset to the AES. The collection of aquaculture and aquacultural engineering related conference proceedings offered by NRAES includes:

Engineering Aspects of Intensive Aquaculture , NRAES-49, $38

This publication is the proceedings from an aquaculture symposium held at Cornell University in April 1991 and includes twenty-three papers presented at the symposium. The papers cover topics on closed systems, system design considerations, water quality, and engineering and management considerations. This publication can serve as a basic primer for engineers, biologists, researchers, consultants, or extension agents with an interest in aquaculture. (348 pages).

Aquacultural Engineering and Waste Management , NRAES-90, $35

This publication is the proceedings from the Aquaculture Expo VIII and Aquaculture in the Mid-Atlantic Conference held June 24-28, 1995. Topics covered in the twenty-one papers include engineering design; control systems; culture systems; techniques and design; waste treatment and control; and aquaculture effluent and waste management. This proceedings will be useful to engineers, biologists, researchers, consultants, or extension agents who desire detailed information on aquaculture systems (384 pages).

Successes and Failures in Commercial Recirculating Aquaculture, 2 volumes, NRAES-98, $65

This proceedings is from an international conference held in July 1996. The conference featured experts with practical experience in the industry and was designed for individuals in industry, government, and academia who are planning to become involved with commercial-scale recirculating aquaculture. Fifty-six papers are included in the two-volume proceedings. Topics include fish health and welfare, business plans and management, food safety issues, system design and management, waste and by-product recovery, and shellfish and fish production. Papers presented during two open sessions are also included (656 pages).

Advances in Aquacultural Engineering, NRAES-105, $40

This publication is the proceedings from the AES technical sessions at the Fourth International Symposium on Tilapia in Aquaculture (ISTA4), held November 9-12, 1997, in Orlando, Florida. Thirty papers are included and are divided into four sections: water quality, computer applications and control, design and management of intensive aquaculture production systems, and biofiltration systems and water quality control. The information in this proceedings will be invaluable for any person with an interest in aquacultural engineering or with a need for engineering support (393 pages).

Tilapia Aquaculture, 2 volumes, NRAES-106, $48

This publication is the proceedings of the Fourth International Symposium on Tilapia in Aquaculture (ISTA4), held November 9-12, 1997, in Orlando, Florida. Seventy-two papers are included within 12 separate sections: nutrition, genetics, growth, reproduction, production systems, role of tilapia in development, industry reviews, economics and marketing, physiology and disease, computer systems and monitoring technology, sex determination and sex reversal, and aquaculture in Israel. ISTA4 is the fourth in a series of meetings that have brought together scientists, farmers, and seafood buyers from around the world to provide complete and up-to-date information regarding tilapia (808 pages).

Marketing and Shipping Live Aquatic Products, NRAES-107, $65

This publication is the proceedings of an October 1996 conference addressing strategies and issues involved in the marketing and shipping of live aquatic animals. Forty-nine papers are included in the proceedings. Papers discuss animal welfare, environmental issues, shellfish, finfish, ornamentals, holding and transport, and marketing and regulatory issues. Information in this proceedings will help improve harvesting, handling, packaging, and shipping technology; identify new business opportunities; provide broader selections for consumers; develop humane handling strategies; and ensure food safety (288 pages).

Prices do not include postage and handling. Please contact NRAES to place an order, for postage and handling charges, and for updated pricing:

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AES Newsletter

The *AES News* is printed quarterly by the Aquacultural Engineering Society. You can receive the *AES News* by joining the Aquacultural Engineering Society. If you would like to discuss the contents of the *News*, or, if you would like to contribute information to the *News*, please contact either of the two Co-Editors:

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Aquacultural Engineering Position Announcement

The United States Department Of Interior, United States Geological Survey has a term appointment for a *General Engineer* (GS-0801-12, Announcement No. H-98-194) in the Biological Resources Division at the Leetown Science Center (LSC) in Leetown, West Virginia.

The person selected for this position must:

- Serve as a research engineer in the Restoration Technology Group at LSC with particular emphasis in environmental engineering and fish culture;
- Develop new methods/technologies for restoring degraded Appalachian streams and rivers impacted by mining, other forms of development, or invasion of exotic species;
- Develop new methods/technologies to support fish propagation within the National Fish Hatchery system;
- Prepare scientific publications and presentations;
- Offer technical assistance to client bureaus as needed.

Desireable characteristics:

- Knowledge of basic and advanced engineering principles.
- Knowledge of design and application of computer based instrumentation systems.
- Ability to communicate results verbally and in writing.
- Knowledge of research methods, good laboratory practices, and statistics.
- Knowledge of aquatic biology, fisheries, or fish culture principles.
- Ability to develop computer models simulating equipment/process performance.
- Knowledge of water chemistry and water chemistry analyses.

Contact Dr. Barnaby Watten (Barnaby_watten@usgs.gov) for more information about the position.

For information on applying for this position, contact the Personnel Office, U.S. Geological Survey, Recruitment And Placement Branch, Room 1a315, 12201 Sunrise Valley Drive, Ms-601, Reston, Va 20192 (or phone 703-648-6131). Applications must be received in the Personnel Office by June 1, 1998. The USGS is an Equal Opportunity Employer.

Carbon Dioxide Control in Intensive Aquaculture

Carbon dioxide control in intensive recirculating aquaculture systems is an important consideration in the design of commercial-scale systems and in systems where high carbon dioxide levels have contributed to adverse fish health. Both situations present the problem of maximizing carbon dioxide removal from the water column and venting it into the atmosphere at minimal cost. Current intensive aquaculture techniques have exacerbated potential carbon dioxide problems due to common usage of pure oxygen absorption equipment. Such systems may not provide adequate gas exchange for stripping of carbon dioxide to prevent carbon dioxide accumulation to toxic levels. Additionally, pure oxygen absorption units support higher fish densities, which also increases the total carbon dioxide production within the system and increases the potential for carbon dioxide problems.

Efforts to address the increasing concern for carbon dioxide control in intensive aquaculture operations resulted in the development of an interactive computer design tool, Carbon Dioxide Control version 2.1, to provide side by side comparison of various dissolved carbon dioxide control strategies. Carbon Dioxide Control version 2.1 is based on mathematical models of carbon dioxide control strategies and provides for economic and feasibility comparisons between all options. It requires an Intel microprocessor-based PC or compatible (486 or higher recommended) with a color monitor, 3.5" floppy disk drive, 640K RAM, and DOS 3.3 or higher.

Carbon Dioxide Control in Intensive Aquaculture software and user's guide was written by Brian J. Vinci, Cornell University; Michael B. Timmons, Cornell University; Steven T. Summerfelt, The Conservation Fund's Freshwater Institute; and Barnaby J. Watten, U.S. Geological Survey.

To order a copy of the computer software and user's guide, please contact: NRAES, Cooperative Extension, 152 Riley-Robb Hall, Ithaca, New York 14853-5701; phone (607) 255-7654; fax (607) 254-8770; or email at nraes@cornell.edu.

Five Reasons to Become an AES Member

1. *Build your knowledge*

By receiving 8 issues per year of the journal *Aquacultural Engineering*, you will be able to increase your knowledge of what's going on in the design and development of effective aquacultural systems for marine and freshwater facilities. You will also receive the *AES News*, a free subscription to the new trade magazine *Recirc Today* (in 1998 only), and ordering information on past and future AES publications.

2. *Build a professional network*

By attending the numerous workshops and conferences sponsored by AES, you can stay abreast of current aquacultural engineering applications and solutions, and expand your network of colleagues and professional contacts within the industry. The *AES News* will keep you informed about upcoming aquacultural events.

3. *Build your profession*

By being a part of an international organization working to improve, foster, and enhance development of the aquacultural engineering profession, you as an individual will benefit from the efforts of the membership as a whole.

4. *Build your credibility*

By joining a growing international society, you will be demonstrating your commitment to the industry and your proactive stance towards perpetuating its growth.

5. *Build your expertise*

By participating in AES scheduled conferences and events where the latest technologies are presented and discussed, you will increase your knowledge base and boost your professional development.

Membership Dues

The AES is still collecting 1998 membership dues. If you have not already joined the AES for 1998, you can still join and receive eight issues (two 1998 volumes) of the journal *Aquacultural Engineering*, *the AES News*, the AES Member Directory, and one year of complimentary copies of the new trade magazine *Recirc Today*.

For more information on the AES, visit the AES web page at: http://www.cals.cornell.edu/dept/aben/aes/

To join the AES, please fill out the following information and send with payment to: Steve Summerfelt, c/o Freshwater Institute, P. O. Box 1746, Shepherdstown, WV, 25443, USA. Make cheques payable to the Aquacultural Engineering Society. You do not have to provide education information to become a member.

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