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Science and future of aquaculture

Aquaculture Department, Southeast Asian Fisheries Development Center

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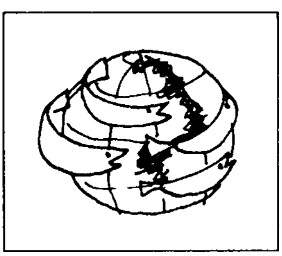
Special Feature

SCIENCE and the future of AQUACULTURE

The year's end always makes people aware that the next year is something yet to behold. The astute aquaculturist will have to be more attentive to the application of existing technologies in order to achieve new breakthroughs in production and profits. This issue's special feature focuses on technologies -- biological and physical -- that will make an impact in and eventually direct future aquaculture systems. Lest technology's ultimate aim -- better quality of life -- be forgotten, the views of former SEAFDEC/AQD Chief Dr. Flor Lacanilao are also presented.

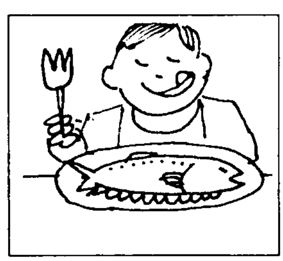
Biological technology

The biological sciences in general and biotechnology in particular will play an increasing role in aquaculture. The trend will be driven by international competition and consumer preferences. The R and D that will be conducted will vary according to the stage of development of the particular aquaculture species in relation to the market. With new species, the emphasis is often on basic culture through the life cycle. Species that have entered the market undergo a rapid research with emphasis on solving production problems and increasing survival and growth. In species whose production in some areas of the world has leveled off, the emphasis is on increasing production efficiency.

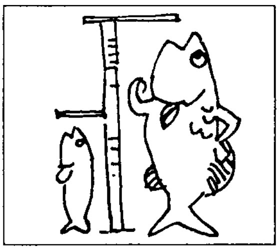


New species. Given that there are over 20 000 species of fish on earth and over 15 000 species of mollusc many of which are sought as food items, it is expected that aquaculture researchers constantly test new species for culture. The selection of a new species is usually associated with strong market demand linked with high value and a limitation of natural stocks. Consumer demand for high quality aquaculture products in Japan, Western Europe, and North America based on perceived health benefits and lifestyle factors is expected to continue. This demand will lead to the economic feasibility of culturing additional species. In the culture of tropical freshwater fish, certain carps, tilapias, and catfish predominate. But recent years have seen the emergence of aquaculture of other indigenous species. Examples are the culture of the pacu *Colossoma* sp. and other indigenous fishes in Brazil, and the culture of the indigenous carp *Puntius gonionotus* in Thailand.

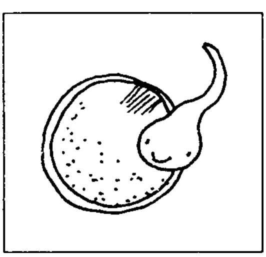
Nutrition. Future research on nutrition is expected to focus on (1) the search for alternative protein and lipid sources for making cost-effective feeds for high production; (2) nutritional requirements of cultured species and ingredient digestibility of feeds, and (3) the optimization of quality and nutritional value at harvest. The latter topic has become very important in light of the benefits of omega 3 polyunsaturated fatty acids (PUFA) in human health. These health benefits



have led to increased fish consumption. Thus, it must be ensured that fish products from aquaculture contain satisfactory levels of PUFA. A recent comparison has shown that the lipids of wild catfish contain 27.6% omega 3 PUFA compared to 10.2% in farmed catfish. When expressed as the omega 3 to omega 6 ratio, the ratio in wild catfish is 2.5 versus 0.6 in cultured catfish. There is a clear need to develop finishing diets that will optimize nutritional value as well as physical quality at harvest.

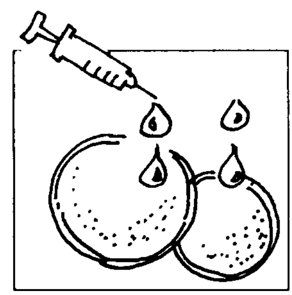


Growth. In animal husbandry, reduction of the production cycle through increased growth rates has, for economic reasons, always been a key area for genetic and endocrine research. The relatively long production cycles of cultured animals currently range up to several years. Genetic selection has resulted in significant improvements in growth rates. Endocrine techniques that could vastly improve growth rates are also currently under development. Results to date indicate that the hormone somatotropin (from the pituitary gland) is the most promising factor for growth acceleration. Mammalian and bird somatotropins produced from biotechnology can accelerate growth of Pacific salmon, both the freshwater juveniles and the seawater grow-out stage. Initial success has also been achieved in the catfish. In the future, research will focus on four areas: (1) efficient methods of administration of somatotropin by implant, the oral route, or by immersion; (2) development of somatotropin analogs having a higher potency; (3) development of fish somatotropins by biotechnology; and (4) further investigation of other growth factors.



Gene banks. While the technology now exists to cryopreserve fish spermatozoa, the concept of gene banks has, to date, been little utilized in aquaculture. In the future, gene banks can be used for: (1) indefinite storage of genetic information from wild strains of a variety of species for incorporation in breeding programs and development of genomic libraries; (2) storage of spermatozoa from selectively bred fish for use in future crosses; (3) storage of gametes for the production of monosex stocks; (4) the storage of sperm from one breeding season to the next to increase the effective size of the breeding population and thus reduce inbreeding; (5) the maintenance of control lines in selective breeding programs; (6) the development of interspecific crosses.

Transgenic fish. Transgenic fish are produced by the introduction of foreign DNA into the egg or embryo in such a manner that it is incorporated into the genome. Mice developing from eggs microinjected with the growth hormone gene grew faster and larger than normal mice. There has followed a surge of research to develop transgenic fish with enhanced production characteristics. In research conducted to date, a DNA sequence has been microinjected into goldfish, and fusion and growth hormone genes into rainbow trout. The presence of somatotropin and accelerated growth in individual second generation transgenic carp has been demonstrated.

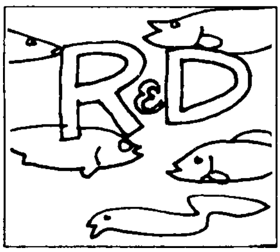


While the emphasis to date has been on the development of fast-growing strains of transgenic fish, research is also underway on freezing resistance in Atlantic salmon. Future research will focus on the improvement of such factors as flesh color, external appearance, disease resistance, fatty acid content, and ability to utilize low-cost dietary ingredients. It may also be possible to produce sterile fish by expressing in the gonad a gene that prevents gonad development.

Production characteristics influenced by single genes are the most likely to be improved by the development of transgenic fish, whereas characteristics regulated by multiple genes are more amenable to selective breeding.

Integration of biological technologies. There is a need for integration in aquaculture R & D, either of research from separate disciplines to solve major problems, or of several technologies into production systems. An example of the former is the investigation of the role of genetics, nutrition, and stress in the disease susceptability of cultured organisms. An example of the latter is the integration of endocrine and genetic technologies to produce monosex populations.

In the case of production systems for coho salmon, studies on the production of age 0 smolts, and of sterile age 1+ smolts were conducted separately. Androgen treatment interferes with smoltification. Thus, when the two procedures were integrated at the pilot production level it was necessary to time the androgen treatment, temperature, and photoperiod manipulation to avoid negative interaction.

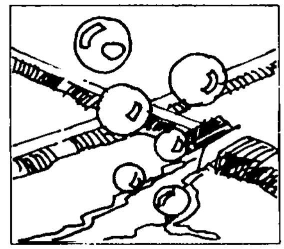


Physical technologies

Oxygen and aeration. The aeration of ponds has increased yields as much as 30-fold. The application of oxygen in raceway or tank culture has increased production easily by a factor of 7 to 10 and almost all conventional fish farms could double production through the proper application of the newer types of oxygen injection systems.

Oxyen is now readily available either as liquid oxygen as supplied by the major producers or it can be generated on location by new modern and efficient oxygen generating equipment. The key requirement for oxygen generation is a dependable supply of electricity.

New methods of oxygen injection include pressure systems which produce super saturated water and/or tiny microbubbles. Containerized mixing devices known as packed columns operate very efficiently with little or no energy required. These new devices transfer oxygen into water at efficiencies ranging from 80 to 95%. Past technology only provided transfer efficiency of 30 to 60%, substantially increasing cost of oxygen supplementation.

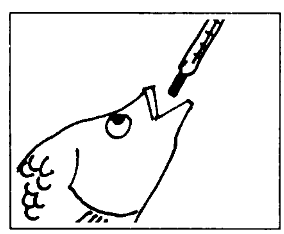


Benefits from oxygen supplementation include nitrogen stripping, substantially increased stocking densities hence yields, improved fish health, less medication, and improved feed conversions.

Superoxides of oxygen. By treating with either electrical or photochemical energy, oxygen molecules are transformed into superoxides of oxygen which have very powerful oxidizing properties. These superoxides, properly introduced into aquaculture systems, can act as sterilant and oxidant. Benefits include significant reduction in bacterial numbers in water supplies; the oxidation of unionized ammonia to less toxic nitrates; the oxidation of organics including harmful chemicals and agents which induce off flavors; and a reduction in surface tension. Successful applications of superoxides include oyster depuration, effluent treatment in recycling systems, and reduction of virus and improved survival of shrimp larvae in hatcheries.

Temperature management. Since the metabolic rate and growth of cold-blooded animals is determined by temperature and each species has its own preferred temperature at which it performs the best, temperature management in aquatic systems will receive more attention. Oxygen supplementation allows the animal to grow faster at higher temperatures which were previously thought to be harmful.

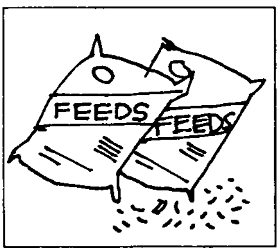
The principles of thermal engineering are well established. Heat pumps and heat exchangers are readily available. The challenge will be to use the best available technologies in a cost-effective manner to take advantage of the economic potentials derived from proper temperature control.



Effluent management. The single most important resource for aquaculture development is water. This resource, if properly managed, is renewable. Because it is in the best interests of the aquaculture industry to protect this resource, we anticipate that the industry will respond positively and constructively to manage effluent water. The only option to voluntary action will be regulated compliance.

The single most important source of water pollution is feed, either as wasted uneaten feed or as metabolites produced by fish from consumed feeds.

Emphasis in feed formulation will shift from cost optimization to "precision formulating" such that feed conversion efficiency is high. Less nitrogen, phosphorus, and organic substances will go into pond water. High digestibilities result in less wastes and lower oxygen demand. These new feeds will cost more, but will be cost-effective compared to other methods of effluent management.

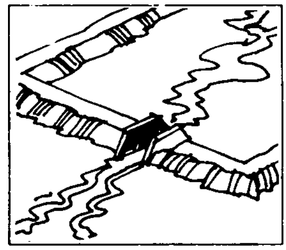


New and improved devices and techniques to settle, suck, spin, filter, and/or float out settlable and suspended solids are constantly appearing in the market. Removal efficiencies are being improved. A new filtration device reports the removal of about 90% of suspended solids, 80% of the phosphorus, and 40% of the nitrogen.

Dissolved solids can be removed biologically using biofiltration technology or through the addition of waste converting bacteria, a new tool that has tremendous potential. The chemical oxidation of organics using superoxides is also a viable alternative. Imagine potable water from fish farms.

Through the application of these new technologies, more farms will use recycle systems. Although the technologies for effective effluent management exist, what is lacking is the economic analysis and demonstration of the proper linkage of these technologies in typical farming operations.

Handling, grading, and counting. Inventory management must be done properly for any business to succeed. It is now possible to move, grade, sort, and count aquatic animals accurately and safely. The need to count is of primary importance and new products and technologies are appearing each year to perform this process faster and more efficiently.

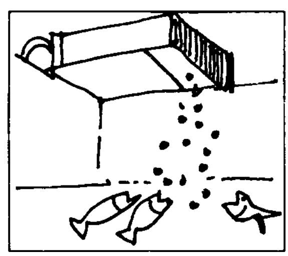


The ultimate objective is to count animals in their natural environment without handling them. We are not quite there yet, but there is no reason why this problem can't be solved.

Feeding systems. There are feeders and feeding systems available for almost every application and the challenge becomes finding the best suited for current and future needs.

Stand alone type feeders such as demand feeders or those powered by mechanical springs, rechargeable batteries, or solar power will be very popular because they are highly dependable, very flexible, and more affordable.

In those farming operations where highly controlled and managed production is an operating standard, mechanical type feeders linked to control systems will be preferred. Another advantage of program controlled feeding is that water quality parameters are maintained within more narrow ranges. This in turn can affect the design and cost of effluent management systems.

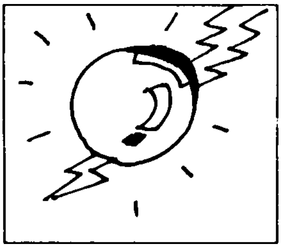


An electronic demand feeder will soon be available. Regulating feed supply based on animal behavior is a very sound principle. Electronics allows for precision adjustment, monitoring, and feed delivery control. This device will be invaluable in research.

Computerization. The degree of computerization will depend on whether the business is a fish farm or a fish factory, the former being influenced by more natural environmental factors whereas the latter would be completely and environmentally managed and controlled.

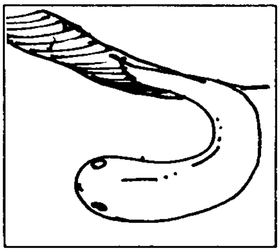
Certainly, the computer will play an expanded role in the area of research and development as it has a tremendous capacity to collect and assimilate data.

Bioelectronics. In the future, it is possible to monitor fish physiology and fish health through sensing devices attached to a sample of the population. The electronic transmissions allow prediction of animal conditions and responses before visual and diagnostic observations could be made. Robotics, lasers, fiberoptics, super conductors, and high-tech ceramics have not been included although most assuredly, they will be part of the technology of the future.



Conclusions. Environmental constraints plus the more effective applications of new technologies will move aquaculture development towards land-based systems. These systems permit more control and predictability and allow more intensive culture operations to succeed. These systems will not be highly sophisticated or complicated but instead will concentrate on good design, simplicity of operation, and effective management. Regardless of what system is used, they all must focus on producing high-quality, very desirable products for the consumer market.

Water reuse and recycling systems will develop more rapidly due to increased interest and promotion. The agricultural community is looking for and certainly needs complimentary enterprises to support strugglling agribusinesses. Agriculture farmers understand animal husbandry, they are creative and they are willing to test these new systems. Water recycling systems will be used near fish markets to allow prompt delivery of live or fresh products to consumers.



Another opportunity for aquaculture is to link the aquatic animal systems with plant culture. This provides the benefit of greater nutrient utilization with practically no effluent problems.

It would be well for all of us to heed the advice of a world famous scientist who commented "Imagination is more important than knowledge." His name? Albert Einstein.

Sources: (1) E.M. Donaldson. 1988. *Science and the future of aquaculture.* p. 299-309; (2) T.R. Zeigler. 1988. *Aquaculture technology in the future.* p. 311-315. In: **Aquaculture International Congress Proceedings**; British Columbia, Canada; 6-9 Sept. 1988.

Technology and the environment

There is no question that research plays a role in developing the aquaculture industry in the region. This was seen in the utilization of research by the shrimp industry. The fast development of aquaculture in Southeast Asia is exemplified by shrimp culture, particularly in Thailand, Indonesia, and the Philippines. Thailand's shrimp aquaculture production, for example, has grown from 12,000 tons in 1986 to over 110,000 tons in 1991.

However, the uncontrolled spread of shrimp farming has resulted in massive environmental deterioration. In the Philippines, the negative consequences are that: (1) the benefits of shrimp aquaculture do not trickle down to the poor people in the area, (2) intensive shrimp farming marginalizes small-scale fishermen, (3) the culture system does not generate desirable alternative employment for displaced fishermen, and (4) large-scale shrimp culture compromises the local environment, resulting in salinization of arable land, lowering of groundwater level, pollution of coastal areas, and health hazards. In effect, the coastal folk bear the social costs of large-scale aquaculture development, including loss of traditional livelihood for the fishing community, ejection from their residence site, and degradation of natural coastal resources. Add to this the social conflict resulting from resource use, that is, the fish culturists as against the fishermen.