

aquaculture in the next century

opportunities for growth challenges of sustainability

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In the last decade, aquaculture has been the only growth sector within fisheries and the prospects for continued growth appear excellent. Global per capita seafood consumption has been rising steadily since 1969, but landings from the capture fisheries reached a plateau in 1989, leaving aquaculture as the primary source of seafood production to meet this increasing demand.

A substantial portion of the global increase in aquaculture production has come from coastal environments, but as the human population grows and expands its involvement in the coastal zones, there will be increasing pressure to share the coastal resources among multiple users. In this environment some of our existing aquaculture practices will not be sustainable in their present form, but those that are designed to accommodate multiple resource use could grow rapidly. Examples range from the traditional farming systems in Southeast Asia, which benefit the community at large as well as the aquaculturists themselves, to modern high-tech recirculation systems.

As the aquaculture industry grows, conflicts over water use will intensify and competition will develop among users of the limited coastal resources.

At the recent AQUATECH '94 Conference in Sri Lanka, Imre Csavas of the Regional FAO Office in Bangkok projected global seafood demand and aquaculture production.⁽¹⁾ Demand was calculated by multiplying human population projections by expected per capita seafood consumption. According to the UN, the human population of 5 billion in 1990 will increase to 8 billion by 2025. By assuming that global per capita seafood consumption would remain close to the current level of 14 kg for the next 30 years, Csavas calculated that seafood demand in the years 2000, 2010, and 2025 would be 84, 97 and 115 million tonnes, respectively.⁽¹⁾

Fisheries landings peaked in 1989 at 89.7 million tonnes and have since fluctuated near this level, indicating the world fisheries stocks are being harvested at close to their maximum sustainable yield. Market demand for aquaculture products can be expected to increase as fisheries output stabilizes. The human-food portion of this fisheries harvest is some 60 million tonnes, so aquaculture demand should be close to 22-24, 35-37 and 52-55 million tonnes in the years 2000, 2010, and 2025, respectively.^(1,2) However, aquaculture may be unable to service this demand, and shortfalls could range from 1-3 million tonnes in the year 2000 to 9-13 million tonnes in 2025.

Impending changes

Aquaculture is entering a new era, one in which resource and environmental concerns will play a much larger role in decision making. Although human population increase will create a growing market for aquaculture products, it will also generate competition for scarce natural resources and accelerate environmental degradation because, unfortunately, per capita consumption of resources is also increasing. Groundwater, land, feed, and energy resources are likely to become more highly valued and tightly regulated. Aquaculture practices that are wasteful of resources will not be sustainable in the face of these shortages.

As the population expands, air, water, and land pollution will become more severe. Controls will be necessary to mitigate the greenhouse effect, acid rain, toxic waste accumulation and eutrophication of coastal waters, and aquaculture operations surely will face increasingly stringent discharge regulations. Not even recirculating systems will be immune, because the solid waste they generate (about 0.4 kg per kg of product) will be subject to regulation.

The aquaculture industry has recently

tamination by aquaculture species. These steps will protect the environment and safeguard the aquaculture industry.

These anticipated restrictions should be viewed by the aquaculture industry not as constraints to development but as challenges wherein aquaculture may find new opportunities. Scenarios can be envisaged where the aquaculture industry could become a stabilizing element in an integrated, ecosystem-oriented production strategy.

Resource management failures

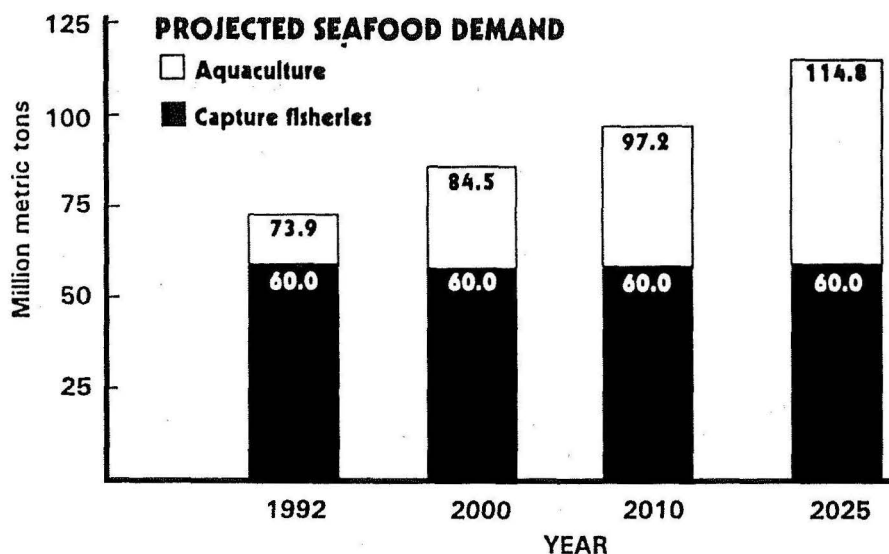
Sustainability will become a familiar term to those of us in the aquaculture industry. The concept, simple and intuitive, refers to management practices that will not degrade the environment. Sustainability models were developed as early as 1849⁽³⁾ to maximize economic benefits from forest management. The outcome of efforts to manage open access resources such as marine fisheries and common property resources such as forest and irrigation systems has been dismal, and it has been argued that these failures were due to conflicting desires to satisfy unlimited consumption with limited resources.⁽³⁾ In the face of uncertainty, managers often err on the side of the exploiting industry rather than the resource. The tendency is to base harvest levels for a resource on periods of high production rather than periods of low production. In other words, an estimate of Maximum Sustainable Yield tends more toward "maximum" than "sustainable."

Ludwig and colleagues⁽⁴⁾ likened the exploitation of fluctuating resources to a ratchet. During good years the harvest quotas are increased, which encourage new investment. Then, when the resource returns to normal or below, the industry appeals to the government for help. Since jobs and investment are at stake, government subsidies are made available. This combination results in the stock being continually overharvested.

Resource management issues are not easily resolved by science. Even simple ecosystems can not yet be predicted with confidence, and significant new knowledge accumulates slowly. In addition, political and economical factors must be considered, and these are often more fundamental than the scientific is

The capture fisheries of the world are being harvested at close to their maximum sustainable yield.

experienced several spectacular failures due to disease outbreaks. In some cases, practices that contributed to the impressive growth of the industry (e.g., the shrimp culture strategies used in Thailand, China and Taiwan) profited through the unilateral exploitation of resources and, therefore, thrived at the expense of others. If modern aquaculture is to survive, it will have to become more compatible with other users of resources and with the environment. Tighter regulations will be needed to prevent, for example, introduction and transmission of disease organisms. Additional regulations may be needed to protect native organisms from introduced diseases and from genetic con-



sues. Science can advise the political process about what is physically and biologically possible, but the final decisions must balance these considerations against conflicting political and economic interests.

Accountability

One fundamental lesson that emerges from the history of failures in resource management is that lack of user accountability leads to resource failure. Resources suffer the tragedy of the commons: that which belongs to all is cared for by none. The world fishery stocks will not be restored until harvest limits are defined and rigorously enforced. In some areas, accountability has been established by restricting access and allocating individual transferable quotas, but this is a disputed and politically difficult step, especially in developing countries.

Some argue that overexploitation of resources is the result of human greed, but we tend to agree with Lee⁽⁵⁾ that it is a rational response to a mismatch in accountability. Lee's classic example of a spatial mismatch is a shepherd who takes good care of his sheep, which he owns, but overexploits the pasture land, which he does not own. The shepherd's interest is to profit from the sheep, even though the land may be damaged. An analogy in the marine environment would be shrimp farms using an estuary for flow-through water supply. No single farm would degrade the water quality of the entire estuary, but collectively they might. The solution to accountability mismatches of this

type is a comprehensive plan to control resource use.⁽⁵⁾

Conflicts and management plans

Conflicts concerning aquaculture use of natural resources are likely to arise more frequently in the future. It is important that aquaculturists anticipate these issues and help find solutions. All stakeholders should be involved in the decision process. In some enlightened areas, this process is already underway. For example, the National Aquaculture Association of Honduras (ANDAH) is working to avoid environmental and pollution problems in the Gulf of Fonseca, an estuarine system with limited tidal flushing, by supporting a self-limiting moratorium on expansion of the shrimp culture industry in the Gulf area until the results of environmental impact studies are available.⁽⁶⁾ Large-scale examples can be cited from South-East Asia where accelerated economic growth in several countries has resulted in over-exploitation of natural resources and land-use conflicts among various interest groups. The negative impacts of this development have been especially noticeable in coastal areas where aquaculture is one of the most important growth sectors.^(7,8) The economic benefits of the extensive coral reef areas and mangrove belts were recognized at an early date, and human settlements expanded rapidly. Today, over 70% of the population of the region lives in coastal areas where resources are heavily exploited,⁽⁹⁾ and there is an urgent need for

Projected demand for food grade seafood (industrial fish and seaweed excluded), assuming plateau of capture fisheries at 60 million tonnes (adapted from Csavas⁽¹¹⁾)

an integrated, interdisciplinary, multisectoral approach in the development of management plans for these coastal areas.^(10,11)

To promote sustainable economic development in the ASEAN region, a program was initiated to develop Coastal Resource Management (CRM) strategies. This goal can be achieved by:

- documenting and disseminating information on the ways that coastal resources are being developed for economic purposes;
- suggesting technical approaches to the resolution of conflicts arising from multiple use of the coastal resources, including aquaculture; and
- encouraging various agencies to adopt multisectoral planning in coastal areas.

In this context, aquaculture is an integral part of the development and management plan, and many of the issues will have direct implications for aquaculture. In many regions aquaculture has been promoted without adequate consideration of site selection criteria and the interactions that are likely to occur with other resource users. However, the situation is changing. Awareness of the interactions between aquaculture and the environment, whether coastal or inland, has grown appreciably in recent years.

Among the environmental hazards that affect coastal aquaculture along the coasts of the ASEAN CZM project, oil contamination resulting from tanker accidents and routine tank cleaning by the shipping industry are among the worst. There is an urgent need to regulate and stringently control marine transportation systems and waste discharge from other industries to safeguard the aquaculture industry and artisanal fisheries. Present measures are not sufficient and the damage costs are seldom covered by those who cause the problems. It will not be possible to enforce more stringent regulations on aquacul-

Can aquaculture production keep pace with projected demand?

ture until those human and industrial activities that endanger aquaculture are also more tightly controlled.

Lack of government agency interaction is a major deficiency in most of the coastal projects where the aquaculture industry is involved. The success of coastal area management projects depends on bringing the scientists, resource managers, and planners together so as to "sensitize" policymakers on the need for a sustainable management plan. Greater political commitment to integrated planning is required, and aquaculture is an important component which needs as much safeguarding and control as the other sectors.

Future planning may focus on development areas where institutional linkages are weak and coastal aquaculture development may be one of those areas because many of the newcomers to the aquaculture industry, as well as local authorities, suffer from lack of expertise, inappropriate advice on site selection, inadequate evaluation of market opportunities and product diversification, and lack of evaluation of the development in relation to other national and international competitors.

Of course, the challenge of sustainability runs far deeper than aquaculture. The historic 1992 Earth Summit in Rio identified many issues, including climate change, biodiversity, and forest protection, which require concerted international action. Global resource use must be reduced to a level at which the environment can remain stable and healthy. Non-renewable resource exploitation must eventually be reduced to zero, and renewable resource utilization must be reduced to a sustainable level which includes a margin of safety.⁽⁴⁾ In the long term, major changes in energy, transportation, and food systems will be required.

More appropriate management plans also have to be developed to control the impact of aquaculture (for example, regulating biological oxygen demand). How much can the receiving ecosystem assimilate? This quantity is often re-



ferred to as the critical load.⁽¹²⁾ Critical loads are estimated based on dose-response relationships of sensitive indicator organisms, but other factors such as relationships among ecosystem components and inherent variability among and within ecosystems should be considered. Obviously, this is a complex and imprecise task. The following principles should be followed for decision making where uncertainty exists:⁽³⁾

- consider a variety of hypotheses;
- favor actions that are robust to uncertainties and reversible;
- probe and experiment, monitor results;
- update assessments and policy accordingly.

Once a regulatory limit is in place, how can aquaculture operations comply? Most pollution abatement strategies involve application of "end-of-pipe" treatments such as filters or sedimentation ponds, but such methods are often inadequate. For example, models of acid deposition from the burning of fossil fuels in Europe indicate that some areas will exceed critical loads in the year 2000, even if the maximum feasible air pollution abatement technologies are implemented. The solution is to reduce pollution at the source. In the case of acid deposition, this means improving end-use energy efficiency and switching from fossil fuel to renewable energy sources.⁽¹²⁾ In the case of aquaculture effluents, the sustainable solution will likely involve a combina-

tion of end-of-pipe effluent treatment and reduction of nutrients at the source through improved feeds, genetically improved stocks, polyculture, etc. The effluent can also be considered a resource that can be utilized in other production processes, including other forms of aquaculture (for example, fish pond or shrimp pond effluents can be used as nutrient sources in shellfish culture systems or integrated with agricultural production systems such as rice-fields).

Future production

In light of anticipated constraints, how might aquaculture satisfy the seafood demands of an expanding population? Nine of every ten persons now being added to the world's population are living in developing countries. This will probably force the mix of global aquaculture products toward the less expensive herbivorous fishes such as carp and tilapia.

Csavas⁽¹³⁾ evaluated inland aquaculture production of various countries based on production per internal renewable freshwater resource (measured as tonnes of production per cubic kilometre of annual precipitation minus annual evapotranspiration). Using this index he found that Thailand and China currently produce between 1 and 2 thousand tonnes of freshwater fish per cubic kilometre of their internal renewable freshwater resources, whereas the global average is only 2 hundred tonnes. Such calculations have to be viewed

with caution because of the regional differences in their validity, but there is certainly scope for a significant increase in production from renewable freshwater resources. As with the coastal environment, integration with other resource users may be essential to achieve a major increase in production per unit of available renewable water resource.

With the increasing pressure on groundwater resources, it is unlikely that production methods which require constant pumping of groundwater will survive in the long term. The trout industry has already stabilized in many areas because of groundwater limitations. Modern, high-tech culture systems based on recirculation should become more attractive with tightening constraints on water use and will certainly play a greater role in future food production. Although water treatment systems are costly, they may be designed to contribute to the overall production process. Aquacultural wastes are a valuable source of nutrients that can be recycled, especially in agriculture systems where such nutrients are needed. An example is the incorporation of hydroponics or aeroponics into the treatment process of recycled aquaculture waste waters to produce fruit and vegetable crops. This can make the aquacultural production process more cost-effective, provide a degree of product diversification, and create opportunities to share resources with otherwise competing industries such as agriculture.

Estuarine production systems for salmon, other marine fish, and shrimp have potential for much additional growth, but tighter regulations are needed to prevent the typical scenario of success followed by overdevelopment. Allowances must be made for appropriate buffer areas to absorb discarded wastes.⁽¹⁴⁾ This is urgently needed in the shrimp farming industry to prevent collapses like those that occurred in Taiwan and China. Additional disease diagnostic and prevention methods are also needed.

Of the world's total water volume, about 95% is in the oceans. Thus, it seems likely that aquaculture will ultimately respond to increasing limitations on coastal and land-based sites by developing systems to produce high-value marine fish in the open ocean. Ocean aquaculture may include ocean ranching, stock enhancement and offshore netpens. Some success has been achieved in this regard, but more practical and economic systems are needed. Also,

considering that all high-value marine fish are carnivores, alternatives to fish meal must be found. Fish meal supplies are limited and unlikely to increase. Thus, fish meal will become more costly, and its use in diets must be reduced in favor of alternative protein sources.

Even simple ecosystems can not be predicted with confidence

Demand for aquaculture products is projected to remain high because landings from capture fisheries appear to have reached their limit. Aquaculture remains as the only means of producing the seafood supply that will be required by the growing human population. However, even if aquaculture continues the high rate of growth it achieved in the last decade, it will still fall short of projected demands for seafood in the years 2000, 2010, and 2025. One of the constraints to future growth will be the environmental sustainability issues. Aquaculturists can minimize the impact of future conflicts and sustainability issues by reducing resource requirements, minimizing environmental impacts and participating in regulatory coalitions.

Because of the importance of sustainable practices for aquaculture, the World Aquaculture Society, in conjunction with the Network of Aquaculture Centers of Asia (NACA), will host a Special Session on "Policy for Sustainable Aquaculture" at the World Aquaculture '96 conference in Bangkok. The objective will be to identify current global

sustainability issues, review policy experiences and promising new approaches, and develop a set of recommended policies for the future. Researchers, producers, and government officials are invited to participate in this landmark session.⁽¹⁵⁾

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