Op-Ed

The Blue Revolution: A global ecological perspective

JANE LUBCHENCO[1]

Make no mistake: the Blue Revolution has begun and is needed. What remains to be seen is how this revolution will play out. Will aquaculture repeat the mistakes of or learn from the global expansion and intensification of agriculture? Will aquaculture help achieve the United Nations' Millennium Development Goals of eradicating poverty and hunger while ensuring environmental sustainability? Will aquaculture meet the challenge of becoming sustainable while growing exponentially? Answers to these queries will be markedly affected by trajectories set today. Economic, social and ecological perspectives are all needed to frame the issues and guide the decisions.

Much has been made of the need for aquaculture to expand in order to help supply food to an increasing human population. Close to six billion people were alive on Earth at the beginning of this century. Current estimates project around nine billion people by 2050, and a (welcome) leveling off of the rate of growth, with between nine and 10 billion by 2100. Feeding half again as many mouths as are alive today is a daunting prospect. One billion people already rely on seafood as an important source of protein. Globally an average of 16 kg of seafood is consumed per person per year, and the FAO projects this to increase to 19-21 kg/person/year by 2030 (UNFAO 2002). One third of today's total world food fish supply is from aquaculture. With capture fisheries on the decline, there is no doubt that aquaculture will play an increasing and key role in providing protein for a significant fraction of the world's population in this century.

As important as aquaculture might be to world food supply, the industry is not a humanitarian enterprise, but a diverse suite of large and small businesses with the primary goal of providing products that consumers want at competitive prices. The same is true for traditional agriculture. The challenges have been to provide the best possible product at the lowest possible price while still making a profit. The global need for more food provides both new opportunities but also new and considerable challenges. Meeting these new challenges should entail learning from the mistakes of agriculture, for example industrial poultry production. Although the modern poultry industry has succeeded in producing enormous amounts of cheap chicken, it has also brought some significant problems with eutrophication, heavy reliance on antibiotics and food safety problems. Anticipating and minimizing these kinds of problems will be cheaper and smarter in the long run.

Aquaculture is indeed growing more rapidly than all other animal food-producing sectors, increasing at an average compounded rate of 9.2 percent per year since 1970, compared to, for example, 2.8 percent for terrestrial farmed meat production systems. Although all forms of aquaculture are increasing, exceptionally high growth rates have occurred in salmon and shrimp farming. Their growth reflects increased consumer demand, especially in developed nations, driven by increased consumer awareness of the health and nutrition benefits of seafood, increased standardization and availability of products and cheaper prices. The growth also reflects advances in production techniques that allow growers to raise more fish or shrimp more efficiently.

This growth and the increasing awareness of environmental and social impacts are presenting new challenges to the aquacultural enterprise, mirroring similar issues that have arisen for agriculture and other sectors. Many of these issues are not new to the aquaculture community (and many have been discussed in this publication, for example by Costa-Pierce 2002), but they are also being discussed by a broader group of stakeholders and interested parties, including other scientists, consumers and regulators. One important set of issues concerns the interrelated consequences of (1) the additional land or sea transformation required for expansion and (2) the additional inputs and outputs associated with growth or intensification. The importance of addressing the consequences of both of these topics will only increase as aquaculture expands, diversifies and intensifies. There are critically important economic, social and ecological aspects to each of these two topics. I focus primarily on the ecological perspectives.

Adequate consideration of the consequences of additional land or sea transformation and additional inputs used or outputs produced needs to be cast in a global context. Humans have always modified the landscape, but the scales, rates and kinds of changes are now different than at any other time in human history (Lubchenco 1998, National Research Council 1999). When there were many fewer people with less sophisticated tools, the impact of alterations was minimal at the global scale. As the human enterprise has grown and changed, so too has its impact. Human activities collectively now determine most global patterns and processes, including the area occupied by different ecosystems, the chemical composition of the atmosphere and both fresh and coastal waters, rates of many biogeochemical cycles (for example that of nitrogen), the amount and distribution of surface freshwater, rates of species endangerment and extinction, rates of introduction of exotic species, and the structure and functioning of ecosystems (Vitousek et al. 1997). Indeed, humans have altered the physical structure, chemistry, biology and ecological functioning of virtually the entire planet.

Interdisciplinary teams of scientists are now documenting that these alterations in turn affect human well-being directly and indirectly, at local to global scales, through the goods and services provided by ecosystems (Dasgupta 2001, Daily and Ellison 2002, Millennium Ecosystem Assessment 2003). The natural world has always provided a wealth of benefits that people have simply taken for granted or ignored. However, as land is converted or fragmented, as species are lost, as biogeochemical cycles are altered, or as introduced species and disease eliminate native species, the functioning of natural ecosystems is being disrupted and the delivery of services from those ecosystem is compromised. As more and more ecosystem services are lost, people are beginning to pay more attention to them and to alternative ways of meeting human needs without losing critically important services.

"Ecosystem services" refers to the benefits people obtain from ecosystems. All ecosystems provide services, but they vary from one ecosystem to another. Forests, grasslands, cultivated systems (agriculture and aquaculture), mangroves, coral reefs, large marine ecosystems and urban ecosystems all provide different ecosystem services that result from the interactions of the plants, animals and microbes within that system. Four types of ecosystem services are recognized: provisioning services such as the provision of food, fuel wood and water; regulating services such as regulation of floods, coastal erosion, drought, land degradation and disease; support services such as soil formation and nutrient cycling; and cultural services such as recreational, spiritual, religious and other nonmaterial benefits (Millennium Ecosystem Assessment 2003). Some of these services are local (the provision of pollinators), others regional (flood control) and others global (climate regulation).

A growing population means not only greater demand for food, but also a greater demand for all ecosystem services. There is beginning to be a much more conscious consideration of the trade-offs involved in different possible uses of ecosystems. For example, a country might increase its food supply by converting a forest to agriculture, but in doing so, it decreases the supply of services that may be of equal or greater importance, such as clean water, timber, ecotourism destinations, or flood regulation and drought control (Millennium Ecosystem Assessment 2003). Adequate understanding of the trade-offs associated with different options is invaluable in choosing among alternatives.

These trade-offs are at the heart of some of the new challenges to the Blue Revolution. Constructing an aquaculture facility, for example, may involve transforming land, coastal or ocean waters, with food to be produced, but at the loss of a host of other ecosystem services. For example, mangroves might be transformed to shrimp ponds. Historically, the benefits of producing food, a lucrative export commodity and jobs would have been the primary considerations. Now, however, those benefits need to be weighed against the loss of other services the mangroves provide. Mangrove ecosystem services include the provision of critical nursery habitat, the provision of food and fuel wood, detoxification and sequestration of pollutants, trapping of sediment that would otherwise smother downstream coral reefs, protection of shoreline from erosion by waves and storms, and more. If only a small fraction of mangroves is converted to other purposes, the remaining mangrove system can likely provide most of the goods and services needed. If, however, a significant fraction of mangroves is transformed, many of the ecosystem goods and services will be lost or impaired. In view of the fact that significant amounts of mangroves around the world have already been transformed for coastal development, shrimp ponds and agriculture, additional transformation is likely to result in significant additional losses of ecosystem services.

The above example focuses on the ecological aspects of transforming land or ocean ecosystems. The second topic presenting new challenges to the Blue Revolution entails rethinking the ecological and social consequences of inputs to and outputs from an aquacultural operation. For example, one major input into fish farming operations is feed. The removal of massive amounts of small pelagic fishes from oceanic ecosystems to provide fish meal, fish oil (and also chicken and pig feed and pet food) has consequences not only to marine mammals, seabirds and larger fishes that would ordinarily feed on the small pelagic fishes, but also to the functioning of the oceanic ecosystem and its provision of goods and services. Suggestions that aquacultural use of feed to grow fish is a more efficient use of that feed than growing fish in the ocean completely misses the point that ocean ecosystems provide more than just fish to be consumed. Significant progress has already been made in improving the feed conversion rations (per fish) for come carnivorous species like salmon, and these trends are expected to continue. This benefit may be offset, however, if the aggregate number of fish if increasing at a faster rate. In addition, many of the new carnivorous species being farmed or ranched (bluefin tuna, for example) demand much high feed inputs per pound of fish output. Alternative feeds (for aquaculture as well as livestock and pets) — for example from cereals or soybeans — may hold promise and research into their use should be strongly encouraged.

Another major input for some kinds of aquaculture are individuals of the species to be raised. If the life cycle cannot be completed in captivity, eggs, larvae or young must be captured from natural habitats and their removal may entail consequences to that ecosystem. Depending on the scale of collection, this impact may be minimal or substantial.

In a similar fashion, the ecological and social consequences of discharges from aquacultural operations need to be part of the equation. These outputs include nutrient and chemical pollution (including antibiotics, persistent organic pollutants and other compounds), diseases and escapes of non-native species. Each of these outputs has the potential to disrupt the functioning of the adjacent ecosystem and many also impact human health as well. Assessment of the amount and kind of discharges that are minimally disruptive are needed. And again, conscious decisions about the tradeoffs associated with the benefits and costs of creation, expansion or intensification of the operation need to be made.

Knowledge about these ecosystem connections between aquaculture and the ecosystems that support it is one of the core elements required for achieving sustainability. Sustainable aquaculture will require the integration of ecological, social and economic tradeoffs. Simply producing the best product at the cheapest prices regardless of the environmental or social consequences is not sustainable. Minimizing the consequences of land or sea transformation, minimizing the inputs and outputs as well as their consequences needs to be part of the equations as well. There is no doubt that the tradeoffs are challenging to evaluate and make, but therein lies opportunity.

Different kinds of aquaculture face different challenges in becoming sustainable. In general, the easiest pathway to sustainability will lie in the farming of low trophic-level species such as filter-feeding shellfish and herbivorous invertebrates and fishes (unless they are fed diets more suited to carnivorous species) the farming of native species and genotypes; the raising of species in a fashion that requires minimal transformation of an existing ecosystem and polyculture operations or closed-containment systems that recycle waste products internally. Shellfish aquaculture where native species are raised may already be close to ecologically sustainable, depending on the specifics of the operation. The most difficult challenges appear to be in the farming of non-native carnivorous fishes that require substantial feed inputs and release excessive nutrients, disease and invasive species. Many of these species are also the ones with the greatest current market value, and therein lies the challenge.

As aquaculture communities take seriously the challenges of becoming sustainable, the adoption of Codes of Conduct, Best Management Practices, and a focus on a Triple-Bottom Line are all useful vehicles as long as there is adequate transparency and verification. In parallel to these new directions within the industry, increasing recognition of the importance of aquaculture to the health and well being of people around the world is resulting in more attention on the part of consumers and governments. Increasing demand on the part of consumers for sustainably raised food is creating new markets and new opportunities. Increasing awareness on the part of governments may result in new incentives or regulations focusing on environmental and social aspects. The emerging recognition of the interconnectedness between aquaculture and the larger biogeophysical and socioeconomic worlds is both the challenge and the opportunity of the Blue Revolution. As a consumer and a lover of seafood, the sooner the Blue Revolution goes green, the better.

Note

[1]Jane Lubchenco is on the faculty in the Department of Zoology, Oregon State University, Corvallis, Oregon USA 97331-2914. She can be contacted via e-mail at lubchenj@bcc.orst.edu. Dr. Lubchenco will be presenting one of the opening addresses at Aquaculture '04.

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