SUSTAINABLE AQUACULTURE: CONCEPT OR PRACTICE

William A. Wurts
Aquaculture, Cooperative Extension Program, Kentucky State University, USA

Keywords: sustainable, aquaculture, pond, dynamics, biomass, carrying-capacity, plankton, harvest, ecosystem, management, eutrophication

Contents

1. Sustainability
2. The Origins and Evolution of Aquaculture
3. Green and Blue Revolutions
4. Sustainable Aquaculture Practice
5. Dynamics of Intensive Culture Ponds
6. Reduced Stocking and Feeding
7. Harvesting Plankton to Recycle Nutrients and Improve Sustainability
8. Economics and Social Considerations
9. Managing Global Ecosystems
Glossary
Bibliography
Biographical Sketch

UNESCO – EOLSS SAMPLE CHAPTERS

Summary

This chapter discusses the concept of sustainability as well as current and potential aquaculture practices. Much of the debate and discussion about sustainable aquaculture has addressed definitions, policy and legislation rather than actual farm practices. Aquaculture arose from small flooded depressions and has progressed to high yields and intensive, self-contained units where the producer has complete control over the production environment. The rapid advancement of aquaculture over the past few decades has raised concerns that this "Blue Revolution" may mirror the Green Revolution of agriculture. Intensive production carries an environmental and often a social cost. Sustainable practices should integrate social, economic and environmental concerns. Several practices that could be viewed as sustainable have been developed and conducted in developing nations. These approaches attempt to integrate aquaculture with indigenous agriculture as well as the local communities, their cultures and the natural environment. In general, these approaches do not tax environmental carrying capacity, deplete resources or negatively impact sensitive local and regional ecosystems. Ideally sustainable aquaculture augments the environment and benefits the resident farm communities.

Wastes that result from the high stocking densities and heavy feeding rates of intensive aquaculture push the production unit beyond its (biological) environmental carrying capacity. This necessitates the use of energy and mechanization to maintain acceptable water quality. However, low-input production technologies presently exist for several aquatic species. They require little more than fertilization, limited feeding and reduced stocking densities. The culture environment is managed at or below its carrying

capacity. This type of production is often referred to as extensive aquaculture. As long as supplies of animals for stocking and formulated feeds remain un-interrupted and clean water is available, these practices can be sustained indefinitely. Ultimately, future sustainable technologies should fully integrate and exploit environmental productivity while minimizing or eliminating the ecological footprint.

1. Sustainability

Aquaculture is the management and/or cultivation of aquatic plants and animals for recreation, food and profit. Over the past decade, sustainable aquaculture has become a trendy topic. There has been much debate and considerable discussion about what it is and how it should be done. To a large extent, the dialogue has focused on global policy as well as national and international legislation. What is sustainable aquaculture?

The United States Farm Bill of 1990 defined sustainability as maintaining profitability, using non-renewable resources efficiently, supplying food and fiber needs, enhancing renewable resources and improving the quality of life in rural areas. The Food and Agriculture Organization of the United Nations described sustainable growth as "the management and conservation of the natural resource base, and the orientation of technological and institutional change in such a manner as to ensure attainment and continued satisfaction of human needs for present and future generations. Such sustainable development conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable, and socially acceptable." Bardach in 1997 argued that obstacles to the future growth of aquaculture "will be economical as much as social, and environmental as technical." A survey conducted by Caffey and co-workers in 1998 in the Southeastern United States defined indicators of sustainable aquaculture that could be measured. They fell into three categories: social, environmental, and economic. In 1999, Boyd commented that "environmental management" was the issue that is central to sustainable aquaculture. Stickney stated in 2000, "Sustainability involves the establishment of production systems that can exist, at least theoretically, in perpetuity." Costa-Pierce proffered a concept in 2002 termed ecological aquaculture. He suggested that the evolution and development of aquaculture must be in harmony with the environment and global ecosystems as well as human cultures and communities.

Some have argued that the term sustainability should be discarded altogether. In 1995, Boyd and Tucker stated that aquaculture is not truly sustainable because it is dependent on external feed, chemical and energy inputs. In the year 2000, Wurts recommended that the sustainable aquaculture concept serve as a catalyst, embracing as many different perspectives as possible. We can only defy entropy for a moment on the galactic time scale. The second law of thermodynamics tells us that the universal trend is from organization to randomness, order to chaos. Life on this planet can be sustained for a brief interlude.

2. The Origins and Evolution of Aquaculture

Beveridge and Little provide an insightful discussion about the origins of fish farming. Neither archaeological artifacts nor physical remains of a culture pond from the past

UNESCO – EOLSS SAMPLE CHAPTERS

exist to guide us to the true birthplace of aquaculture. How would we recognize the relics if they existed? We can only speculate about how humans first began to farm aquatic animals. It is likely that water from floods and rain filled depressions in the land, and water was trapped for prolonged periods, months or years. Such small impoundments might have been used by early human communities as a water supply for drinking and later perhaps, for crop irrigation. The first aquaculture pond may have been little more than a place to keep a few live animals after a fishing trip. If more fish were captured than could be immediately consumed, it would have been advantageous to maintain them alive for consumption over the next few days. Or, fish became isolated in these temporary ponds when floodwaters receded. Next would be the collection and management of desired species. The environment would be enhanced to ensure growth and eventually the proliferation of these stocked aquatic animals. This might have included fertilization with agricultural wastes and food scraps as well as stocking appropriate combinations of predator and prey. In due course, manual excavation of land and the construction of earthen berms or levees would be developed. Water would be pumped into ponds or diverted from streams and rivers rather than collecting rainfall. Controlled spawning and rearing of juveniles for pond stocking and management would follow. Finally, rearing juveniles of a single species and offering highly specialized feeds formulated to promote good growth and meet all nutritional requirements would arise. Eventually stocking densities would increase to the point where crop biomass would exceed the carrying capacity of the pond environment.

To go beyond this, technical interventions such as water exchange, aeration, and biological filtration must be introduced. Current high yield, intensive practices are energy dependent and rely heavily on nutritionally complete, commercially formulated feeds. In an attempt to control all environmental conditions and produce the greatest yield in the least space possible, high-tech aquaculturists have crowded high value aquatic species into “recirculating aquaculture systems.” At this level, production has become completely self-contained within insulated buildings furnished with tanks, pumps, aeration, sterilization systems, particle filters, carbon dioxide strippers, oxygen generators, heaters and biofiltration units. This approach is entirely dependent upon environmental manipulation; requires external energy, feed, and chemical inputs; and must exchange 5 % to 10 % of the total water volume daily to maintain adequate water quality. Waste effluents are discharged with routine maintenance of recirculating systems or during harvest of production ponds. As production practices become more intensive, the ecological footprint increases concomitantly.

3. Green and Blue Revolutions

The Green Revolution refers to the rapid development and industrialization of agriculture over the last century, in the United States and other nations employing advanced farming technologies. Crop and livestock production moved from small, family owned and operated farms to operations controlled or managed by large corporate conglomerates. Farm practices were streamlined with the immediate objective of achieving maximum profit over the shortest period of time. Farms became heavily mechanized and dependent on fossil fuels as well as chemical additives to generate larger yields in the smallest area possible. The trend was to cultivate a single species rather than a variety of crops. However with this expedient, short-term

UNESCO – EOLSS SAMPLE CHAPTERS

approach, the environment and the family farm suffered. Farms were managed more for immediate gain rather than resource stewardship. The resources of a specific locale or community were often developed and consumed while the profits and social benefits were exported to other regions or countries. If the assets were depleted, the original communities and their resources were often diminished overall, rather than enhanced.

The rapid growth and development of aquaculture over the last few decades has been termed the Blue Revolution. Critics of the blue revolution embrace the notion that aquaculture, rather than alleviating world hunger, may well be following in the footsteps of industrialized agriculture. Production systems have moved from managing the environment to enhance natural pond productivity or stocking low densities with moderate feed applications to intensive commercial practices. Intensive aquaculture is characterized by many of the hallmarks of industrialized farming: high stocking densities and feed inputs, single species cultivation, centralized production, high nutrient loads in discharge effluents, mechanization (aeration, feed blowers, tractor powered harvest equipment, water quality testing), large energy inputs and dependency on electricity and petroleum based fuels, pushing harvests beyond natural carrying capacities, and managing resources for short term profits. Relative to agriculture, aquaculture is still in its infancy. It has been hoped that sustainable and ecological technologies will eventually prevail to re-direct aquaculture and circumvent a new iteration of the green revolution.

-
-
-

TO ACCESS ALL THE **15 PAGES** OF THIS CHAPTER,
Visit: http://www.eolss.net/Eolss-sampleAllChapter.aspx

Bibliography

Bardach, J.E. (1997). *Sustainable Aquaculture*, 251p. J. E. Bardach (Ed.). John Wiley and Sons, Inc. [This book examines aquaculture from many sides, focusing on food supplies and sustainability].

Beveridge, M.C.M. and D.C. Little. (2002). The history of aquaculture in traditional societies. In: B. A. Costa-Pierce (Ed.). *Ecological Aquaculture, the Evolution of the Blue Revolution*, pp. 145-160. Blackwell Science Ltd., Blackwell Publishing Company. [This book chapter discusses the possible origins of aquaculture and the history of its development].

Boyd, C.E. (1999). Aquaculture sustainability and environmental issues. World Aquaculture, 30(2): pp. 10-13, 71-72. [This article provides insights into the causes of environmental problems in aquaculture and potential solutions].

Boyd, C.E. and C.S. Tucker. (1995). Sustainability of channel catfish farming. World Aquaculture, 26(3): pp. 45-53. [This article presents an overview of the US channel catfish industry and its sustainability]

Brummett, R.E. and Costa-Pierce, B.A. (2002). Village based aquaculture ecosystems as a model for sustainable aquaculture development in sub-Saharan Africa. In: B. A. Costa-Pierce (Ed.). *Ecological Aquaculture, the Evolution of the Blue Revolution*, pp. 145-160. Blackwell Science Ltd., Blackwell Publishing Company. [This book chapter reports on the progress of developing village-based practices for integrating aquaculture ecosystems with other farm enterprises in Southern Africa].

Caffey, R.H., R.F. Kazmierczak, R.P. Romaire, and J.W. Avault. (1998). Indicators of aquaculture sustainability: a Delphi survey. Presented at World Aquaculture '98; Las Vegas, NV -- The international triennial conference and exposition of the World Aquaculture Society, the National Shellfisheries Association and the Fish Culture Section of the American Fisheries Society. Book of Abstracts, p. 91. [This conference presentation and abstract discussed a survey conducted to identify and define measurable indicators for sustainable aquaculture in the Southeastern United States].

Costa-Pierce, B.A. (2002). In: B. A. Costa-Pierce (Ed.). *Ecological Aquaculture, the Evolution of the Blue Revolution.* Blackwell Science Ltd., Blackwell Publishing Company. 382p. [This book provides a collection of discussions about the global development of aquaculture that is both socially and ecologically/environmentally sustainable, addressing practices that range from artisanal to high technology].

FAO. (1991). Environment and sustainability in fisheries. COFI/91/3. Document presented at the 19th Session of the Committee on Fisheries, April 1-12. Food and Agriculture Organization of the United Nations, Rome. 23p. [This report provides a definition of sustainability that was presented at a meeting of the Food and Agriculture Organization of the United Nations].

Fitzgerald, W.J. (2002). Silvofisheries: integrated mangrove forest aquaculture systems. In: *Ecological Aquaculture, the Evolution of the Blue Revolution*, pp. 161-262. Blackwell Science Ltd., Blackwell Publishing Company. [This book chapter describes the impacts of aquaculture on mangrove ecosystems and approaches developed to integrate aquaculture and mangrove restoration, and mitigate environmental degradation in these crucial estuarine zones].

McVey, J.P., R.R. Stickney, Yarish, C. and Chopin, T. (2002). Aquatic polyculture and balanced ecosystem management: new paradigms for seafood production. In: R.R. Stickney and J.P. McVey (Eds.). *Responsible Marine Aquaculture*. CABI publishing, CAB International. [This book chapter discusses heightened concerns about the sustainability of aquaculture, implications for the marine environment and fisheries, and balancing approaches to minimize impacts].

Perschbacher, P.W. (1995). Algal management in intensive channel catfish production trials. *World Aquaculture*, 26(3): 65-68. [This article addresses phytoplankton populations and the implications for pond management of intensive aquaculture].

Rakocy, J. E. (2002). An integrated fish and field crop system for arid areas. In: B. A. Costa-Pierce (Ed.). *Ecological Aquaculture, the Evolution of the Blue Revolution*, pp. 263-. Blackwell Science Ltd., Blackwell Publishing Company. [This book chapter describes tank-culture technologies developed in the Virgin Islands for water conservation in areas with limited water supplies].

Stickney, R.R. (2000). Sustainable aquaculture. pp. 917-919, In: R.R. Stickney (Ed.). *Encyclopedia of Aquaculture*. John Wiley & Sons, New York. [This is a concise, general discussion about the concept of sustainability in aquaculture].

Tucker, C.S. (1996). The ecology of channel catfish culture ponds in northwest Mississippi. Reviews in Fisheries Science, 4(1): 1-55. [This article provides a comprehensive review of the biological and chemical environment of channel catfish ponds in the Delta area of Mississippi, emphasizing the impacts of phytoplankton communities and their metabolism].

U.S. Bureau of the Census, International Data Base. (2006). Total midyear population for the world: 1950-2050. Internet site: *http://www.census.gov/ipc/www/worldpop.html* (2006). [This internet website provides current estimates of the global population].

Wurts, W.A. (2000). Sustainable aquaculture in the twenty-first century. *Reviews in Fisheries Science*, 8(2): 141-150. [This article examines the concepts, variables, and potential factors that relate to the sustainability of aquaculture practices].

Wurts, W.A. (2004). Small-scale and home-use channel catfish farming in Kentucky. *World Aquaculture*, 35(3): 8-9. [This article discusses practical approaches for small-scale farmers and those with limited resources to produce channel catfish by reducing inputs].

Wurts, W.A. (2006). Low-input shrimp *Macrobrachium rosenbergii* farming in Kentucky. *World Aquaculture*, 38(4): 44-49. [This article describes production practices developed in the field for

UNESCO – EOLSS
SAMPLE CHAPTERS

freshwater shrimp production using fertilization, reduced feed inputs and limited technology]

Biographical Sketch

William A. Wurts received his doctorate from Texas A&M University in 1987. Research and academics focused on aquaculture, physiology and growth biology. He received his Master of Agriculture in Fisheries Science from Texas A&M University in 1981. Dr. Wurts studied graduate medical sciences at the University of Texas Southwestern Medical School in Dallas from 1975-1978. He earned a Bachelor of Arts with Highest Honors from the University of Texas at Austin (1975) and was awarded memberships in the Phi Beta Kappa and Phi Kappa Phi academic honors societies. Recent work focused on feeding practices, stabilizing water quality, and low-input, small-scale and home-use aquaculture. Past research included applied physiology with marine, freshwater, and euryhaline species as well as effects of hardness and alkalinity on copper toxicity to aquatic life. He has developed several technologies for the aquaculture industry.

As Senior State Specialist for Aquaculture at Kentucky State University, he provides education and consultation for Cooperative Extension professionals, producers, and the public about aquaculture and water quality management. He designs, plans, and conducts field research and on-farm demonstrations. His programs collaboratively facilitate the development of an aquaculture industry with the University of Kentucky Cooperative Extension Service, government agencies, and other organizations. Areas of specialization include aquaculture, applied physiology, aquatic biochemistry/chemistry, ecosystem management, production biology and nutrition. Interests encompass sustainable aquaculture, growth biology, pond dynamics, improving systems efficiency, and waste nutrient recapture through polyculture.

UNESCO – EOLSS
SAMPLE CHAPTERS