ECONOMICS OF AQUACULTURE

David Whitmarsh
CEMARE, University of Portsmouth, UK

J.C. Seijo
Universidad Marista de Mérida, México

Keywords: Aquaculture, externalities, environmental cost, food security, indicators, polyculture, reference points, rural development

Contents

Summary

Aquaculture has contributed substantially to world fish supplies, but alongside this there has been growing concern about the environmental impact of many of the practices employed in fish farming. This chapter reviews the role and potential of global aquaculture, highlighting the benefits that the industry has delivered as well as the costs engendered through pollution and habitat degradation. Prospects for a truly 'sustainable' aquaculture, and how the experiences of the past may provide a roadmap for the future, are discussed.

1. Introduction

Over the past four decades, the growth of aquaculture – the farming of fish and aquatic organisms – can truly be described as a success story which has brought with it significant benefits for producing countries. These include increased food supplies, support for rural livelihoods, and the generation of foreign exchange earnings.

Consumers have also been beneficiaries, as anyone who has lately bought farmed salmon or shrimp can testify; both these food items are widely available in supermarkets and considerably cheaper than 20 years ago. But there is a dark side to this development, at least in the view of many environmentalists and other critics. Aquaculture, it is claimed, is fundamentally unsustainable. That it is destructive of critical natural habitat, creates pollution through the release of chemicals and organic effluent, and jeopardises global food security by depleting stocks of wild caught fish which are used in aquaculture feed. Others would go further and insist that, where economic benefits have come from aquaculture, in many Developing Countries these have largely been appropriated by the wealthy few with little evidence that poverty has been alleviated.

In this chapter we consider both the positive and negative aspects of aquaculture, looking at the way the industry has responded to economic pressures and how the various conflicts likely to emerge as a result of future growth can be resolved. We start by presenting an overview of world aquaculture, and then go on to consider in closer detail its role in economic development and food security. Particular attention is given to the use of indicators and reference points in the management and sustainable development of small-scale rural aquaculture. The theme of sustainability is considered from another aspect in the section which follows, where we examine the external costs associated with the environmental impacts of aquaculture and ways in which such costs can be 'internalised'. In the concluding section we look at the prospects for aquaculture in the new millennium and consider how the challenge posed by growing demand and rising prices can be met without encountering the problems that have been witnessed in the past.

2. An overview of World aquaculture

The practice of growing edible fish in enclosures goes back many centuries, but the production methods which characterise the modern aquaculture industry have largely been developed since the 1960s. Commonly used systems include brackishwater or marine ponds (e.g. for shrimp), sea cages (e.g. for salmon, sea bass and sea bream), rafts and long lines (e.g. for molluscan shellfish such as mussels). Recent trends indicate a move to more offshore locations for some types of mariculture, as well as growing interest in the feasibility of land-based production systems for certain high value species (e.g. abalone). There are two features that are central to aquaculture and which distinguish it from capture fisheries: husbandry, which relates to the stewardship over the production process; and ownership, which defines the entitlement to benefits from the resource. These characteristics have been fundamental to the success of aquaculture, and indeed if we consider what has occurred within capture fisheries in recent years it is clear that the problems of this sector are in part attributable to the fact that 'husbandry' as such is impractical and ownership rights have been difficult to establish.

The contrasting development of capture fisheries and aquaculture is shown in Figure 1. Global supplies from the catching sector increased rapidly throughout the 1950s and 1960s, growing at some 6% p.a., but since that time the rate of increase has been more modest. The levelling off which has occurred in recent years is a reflection of the fact

that most fishing areas have reached their maximum potential, while in some cases (e.g. demersal fish caught in the NE Atlantic), landings have fallen as a result of over-exploitation and catch restrictions. A very different picture emerges with aquaculture, which over the same period has grown consistently rapidly and now accounts for just under 40% of total world supplies of fish and other aquatic organisms.

Let us look at this in a little more detail. Aquaculture development has been heavily concentrated in Asia (Figure 2), which currently accounts for over 90% of production.

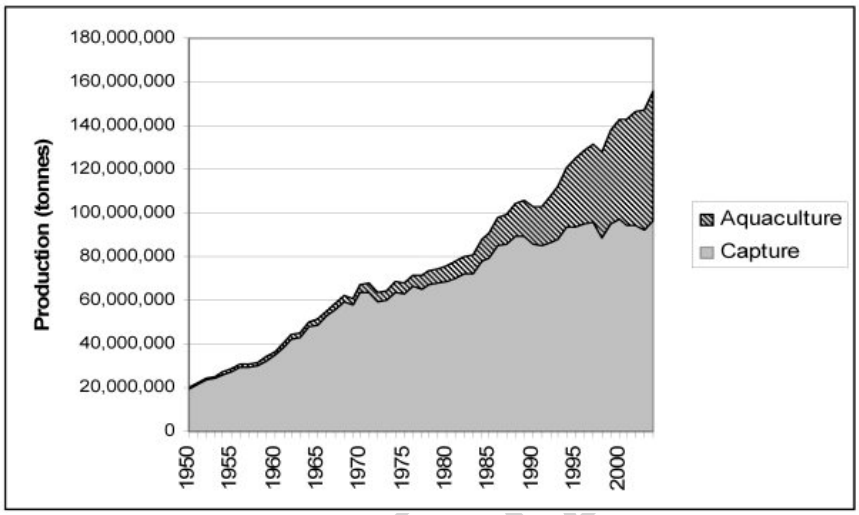

Figure 1: Production from aquaculture and capture fisheries (Source: FAO database)

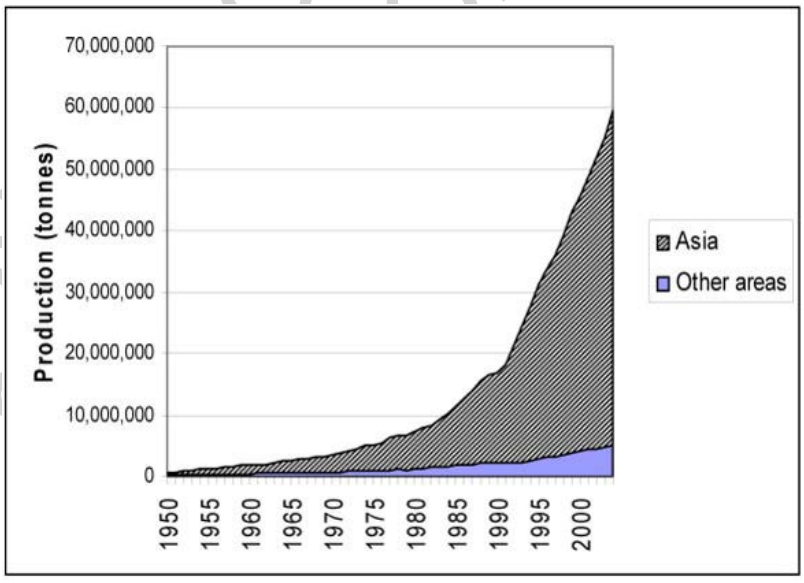

Figure 2: Growth of aquaculture in Asia and the rest of the World (Source: FAO database)

Nine of the top ten aquaculture producing countries are Asian, with China alone in 2004 contributing $36 billion worth of farmed aquatic production out of a World total of $70 billion (Table 1). Growth of aquaculture has been especially prominent in Developing

Countries (Figure 3), which in 2004 together produced over $58 billion of production (Table 2).

Country	Tonnes Inland waters	Tonnes Marine waters	Tonnes Total	$USM Inland waters	$USM Marine waters	$USM Total	% of world
Bangladesh	856,708	58,044	914,752	1,168	195	1,363	2
Chile	5,640	689,053	694,693	24	2,791	2,815	4
China	18,960,292	22,369,316	41,329,608	21,251	14,746	35,997	51
India	2,351,968	120,367	2,472,335	2,218	719	2,936	4
Indonesia	796,520	672,092	1,468,612	892	1,271	2,163	3
Japan	45,852	1,214,958	1,260,810	460	3,781	4,242	6
South Korea	25,299	927,557	952,856	147	1,065	1,212	2
Philippines	405,427	1,311,601	1,717,028	421	374	795	1
Thailand	365,501	807,365	1,172,866	350	1,237	1,587	2
Viet Nam	767,813	460,804	1,228,617	1,186	1,273	2,459	3

Table 1: Top ten World aquaculture producers in 2004
(*Source:* FAO database)

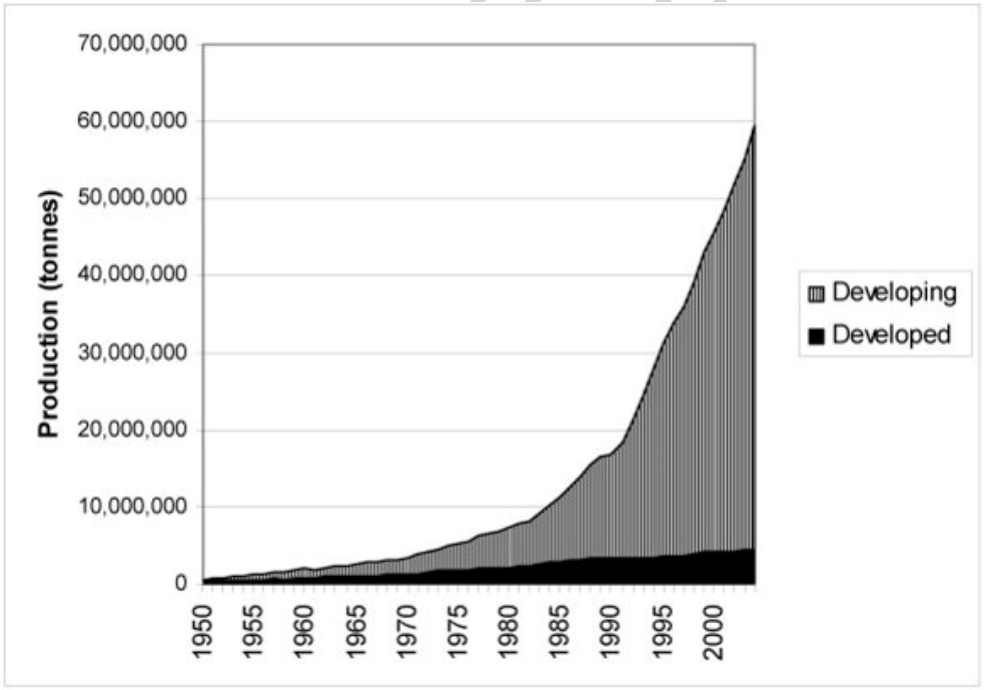

Figure 3: Growth of aquaculture in developed and developing countries
(*Source:* FAO database)

Product group	Developed	Developing	Developed	Developing
	Quantity [tonnes]	Quantity [tonnes]	Value [$USM]	Value [$USM]

Aquatic plants	487,487	13,439,580	1,038	5,771
Crustaceans	42,587	3,637,166	124	14,237
Diadromous fishes	1,329,162	1,522,353	4,314	4,032
Freshwater fishes	571,947	23,294,594	1,179	23,445
Marine fishes	393,347	1,053,636	2,900	2,052
Miscellaneous aquatic animal products	0	13,021	0	137
Miscellaneous aquatic animals	15,251	365,482	9	1,231
Molluscs	1,575,788	11,667,043	2,095	7,739
Total	4,415,569	54,992,875	11,659	58,643

Table 2: Aquaculture production from Developed and Developing countries in 2004 by main product group (*Source:* FAO database)

Much of this is traded internationally, a fact which underlines the importance of aquaculture as a generator of foreign currency and a driver of economic growth. Amongst the Developed Countries, Europe is the largest continental producer in terms of quantity and value, with Norway standing out as the leading nation (Table 3).

	Quantity	**Value**	**Value**
	Tonnes	**$USM**	**€ M**
Denmark	42,252	130	104
France	243,907	655	527
Germany	57,233	171	138
Greece	97,068	366	294
Ireland	58,359	121	98
Italy	117,786	365	294
Norway	637,993	1,688	1,359
Russian Federation	110,018	302	243
Spain	363,181	432	348
United Kingdom	207,203	593	478
Other countries	303,683	760	612
Total	2,238,683	5,584	4,495

Table 3: European aquaculture production, 2004 (Source: FAO database)

Several factors have contributed to the development of aquaculture. Increasing population and rising per capita incomes have maintained the buoyancy of world markets for fisheries products, but the growing inability of capture fisheries to satisfy this demand has meant that the gap has had to be filled by farmed production. Global scarcity in particular seafood markets has caused prices in real terms to rise substantially, making it increasingly attractive to look for ways of sourcing supplies from aquaculture. On the supply side, technological change across a wide range of areas – notably in hatchery production, nutrition, disease control and selective breeding – has increased productivity and lowered unit costs. Technical innovation and expanding

demand have also helped to diversify the range of organisms that can be profitably cultivated, such that at the present time over 200 species of aquatic animals and plants are commercially grown compared to little more than 70 in 1950. Policy measures have given additional impetus to aquaculture development, and though the regulations which are nowadays applied to fish farming have become increasingly onerous to many producers, governments in general have been supportive of aquaculture and have encouraged its growth through financial incentives.

The picture we obtain is of an industry which has grown in response to commercial opportunity, in the process contributing significantly to World food supplies. It is salutary to consider briefly the market dynamics which has accompanied this, and how it has affected the distribution of economic benefits. For some farmed species the volume of production has been great enough to cause a significant drop in price, a situation illustrated by what has happened in the European markets for farmed salmon, sea bass and sea bream as well as in Asian markets for shrimp. Consumers have obviously benefited from this, but producers have found themselves facing narrower profit margins and the choice of either quitting the market or cutting costs in order to stay in business. For export-oriented Developing Countries the implications are considerable, since it means that much of the economic surplus generated by aquaculture is being appropriated by their overseas trading partners in the form of cheaper supplies. While aquaculture growth has undoubtedly produced significant benefits in the form of poverty alleviation and food security, as we shall see shortly, the wider trade effects should not be overlooked.

-
-
-

Bibliography

Bailly, D. and Willmann, R. 2001. Promoting sustainable aquaculture through economic and other incentives. In Subasinghe RP et al. (eds.) Aquaculture in the Third Millenium. Technical Proceedings of the Conference on Aquaculture in the Third Millenium, Bangkok, Thailand, 2025 February 2000. pp 95-101, NACA, Bangkok and FAO, Rome. [Examines the scope for achieving environmental sustainability in aquaculture through economic incentives, contrasting their use with the traditional 'command and control' approach to environmental management]

Barbier, E.B. and Cox, M. 2004. An economic analysis of shrimp farm expansion and mangrove conversion in Thailand. *Land Economics* 80: 389-407 [Presents a detailed analysis of the factors influencing mangrove conversion to shrimp farming]

Burbridge, P., Hendrick, V., Roth, E. and Rosenthal, H. 2001. Social and economic policy issues relevant to marine aquaculture. *Journal of Applied Icthyology* 17: 194-206 [Provides a useful discussion of the positive and negative effects of aquaculture development and how these can be incorporated into policy]

Dey, M.M. and M. Ahmed. 2005. Aquaculture-food and livelihoods for the poor in Asia: a brief overview of the issues. *Aquaculture Economics and Management*. 9:1-10 [Demonstrates the broader role which aquaculture can play in tackling food insecurity and poverty in developing countries]

Edwards, P.; D.C. Little & H. Demaine (Eds.). 1993. *Rural Aquaculture.* CABI Publishing. 358p. [Highlights aquaculture's role as a provider of protein in less developed countries and its potential to sustain rural livelihoods]

FAO. 2006. State of World Aquaculture. FAO Fisheries Technical Paper, 500:134p. [Describes the current global status of aquaculture and analyses the development trends underlying this]

Haylor, G. and S. Bland. 2001. Integrating aquaculture into rural development in coastal and inland areas. In: R.P. Subasinghe, P. Bueno, M.J. Phillips, C. Hough, S.E. McGladdery & J.R. Arthur, (eds). Technical proceedings of the Conference on Aquaculture in the Third Millenieum, Bangkok, Thaila, 20-25 February 2000. pp 73-81. [Highlights the role of aquaculture in rural development, and considers the steps needed to ensure sound governance and stakeholder participation]

Martínez, J.A. y J.C Seijo. 2001a. Economics of risk and uncertainty of alternative water exchange and aeration rates in semi-intensive shrimp culture systems. *J. Aquaculture Economics & Management.* 5(3/4):129-146. [Constructs a bioeconomic model to compare the economic performance of two alternative systems for shrimp production]

Muir J, Bruger C, Young J, Stewart J. 1999. The solution to pollution ? The value and limitations of environmental economics in guiding aquaculture development. Aquaculture Economics and Management 3: 43-57 [Reviews the major techniques for valuing the externalities of aquaculture, and considers how these can be more effectively incorporated into aquaculture planning and decision-making]

Neiland, A.E., Soley, N., Varley, J.B. and Whitmarsh, D.J. 2001. Shrimp aquaculture: economic perspectives for policy development. *Marine Policy* 25: 265 – 279 [Provides an overview of shrimp aquaculture and the issues that need to be considered by policy-makers in ensuring the sustainability of the industry]

Sathirathai, S. and Barbier, E.B. 2001. Valuing mangrove conservation in Southern Thailand. *Contemporary Economic Policy* 19: 109-122 [Presents a detailed analysis of the financial and economic returns from converting mangroves to shrimp ponds compared with the benefits of conservation]

Seijo, J.C. 2004. Risk of exceeding bioeconomic limit reference points in shrimp aquaculture systems. *Aquaculture Economics and Management* 8(3/4):201-212. [Presents a classification of indicators and reference points for aquaculture production systems, and analyses the probability of exceeding LRPs under alternative harvest timing decisions]

Soley, N., Neiland, A. and Nowell, D. 1994. An economic approach to pollution control in aquaculture. *Marine Pollution Bulletin* 28(3): 170-177 [Shows how economics can provide a framework for understanding pollution externalities in cage aquaculture, and offers a range of policy options for dealing with the pollution problem]

Whitmarsh, D. and Wattage, P. 2006. Public attitudes towards the environmental impact of salmon aquaculture in Scotland. *European Environment* 16(2): 108 – 121

[Reports the results of a public attitude survey aimed at establishing the importance attached to the environmental performance of salmon aquaculture in Scotland]

World Bank 2006. *Aquaculture: Changing the Face of the Waters. Meeting the Promise and Challenge of Sustainable Aquaculture.* Report 36622 – GLB [Provides information and guidance to decision-makers on sustainable aquaculture, and highlights the key issues and challenges for the future]

Biographical Sketches

David Whitmarsh is Professor of Marine Resource Management in the Department of Economics, University of Portsmouth. He teaches on a range of undergraduate and postgraduate courses within the Department, and supervises doctoral students attached to the CEMARE research group. His specialist expertise is in the economics of the marine environment, and over the past 30 years he has undertaken both theoretical and applied research in this area. Academic journals he has published in include *Land Economics*, *Journal of Economic Education*, *Project Appraisal*, *Marine Policy*, *Marine Pollution*

Bulletin, *Marine Resource Economics*, *Environmental Conservation* and *European Environment*. He has worked on research projects and participated in meetings and conferences sponsored by a number of international agencies, notably the European Commission (EC), the Organisation for Economic Cooperation and Development (OECD) and the United Nations Food and Agriculture Organisation (FAO). Other professional activities have involved advisory work for the UK Department of Trade and Industry (DTI), HM Treasury, the UK Environment Agency and the UK House of Commons Agriculture Committee.

Juan Carlos Seijo is Professor of the School of Natural Resources, Marist University of Merida where he was University Rector from 1996 to 2004. He received his MSc. (1979) and Ph.D. (1986) degrees in Resource Economics from Michigan State University. He has taught for 20 years graduate and undergraduate courses in Fisheries and Aquaculture Bioeconomics. His academic work has been published in scientific journals that include *Marine Resource Economics*, *Journal of Aquaculture Economics and Management*, *Fisheries Research*, *Philosophical Transactions of the Royal Society*, among others. He is author of two books in his field of specialization. He has taught specialized courses in bioeconomics organized by FAO and UNESCO in Chile, Uruguay, Peru, Colombia, Venezuela, Panama, Guatemala, Cuba, and Trinidad, and has participated in Expert Consultations invited by FAO in Lysekil, Sweden (1995), Australia (1998), Rome (2000), Mauricio (2003), and Cambodia (2004). He has been guest and visiting professor in the Ocean University of Taiwan (Keelung), Center for Marine Studies of the University of Delaware, and the Institute of Aquaculture of the University of Stirling. He is currently Chairman of the Scientific Advisory Group of WECAFC (West Central Atlantic Fisheries Commission), and Board member of the North American Association of Fisheries Economists (NAAFE).