1 INTRODUCTION

1.1 Coastal aquaculture in global fisheries context

The growth of aquaculture in coastal and inland waters is one of the success stories of global food production. Demand for fisheries products continues to increase to meet the needs of consumers, reflecting recognition of the dietary benefits of fish and shellfish in both developed and developing countries. The oceans of the world have a finite supply of environmental goods and services available to support human activities and needs. While the world's population continues to grow, the supply of seafood products from marine capture fisheries may be reaching its limit. In fact, global production from capture fisheries has levelled off, and most of the main fishing areas have reached their maximum potential (FAO Fisheries and Aquaculture Department, 2007). In some areas, overfishing and other factors have resulted in a decline in stocks and landings.

Aquaculture has developed to help bridge the growing gap between what the capture fisheries can supply and the growing global demand for fisheries products (Figure 1.1; Table 1.1).

A wide and ever increasing variety of species is produced, and aquaculture maintains its position as one of the fastest growing food production systems. In fact, aquaculture continues to grow more rapidly than all other animal food-producing sectors, with an average annual growth rate for the world of 8.8 percent per year since 1970, compared with only 1.2 percent for capture fisheries and 2.8 percent for terrestrial farmed meat production systems (FAO Fisheries and Aquaculture Department, 2007).

The 2005 contribution of aquaculture to the world aquatic production was about 62.9 million tonnes (excluding aquatic plants). FAO projections (FAO, 2004), indicate that to maintain the current level of per capita consumption, global aquaculture production will need to reach 80 million tonnes by 2050.

Most aquaculture production of fish, crustaceans and molluscs continues to occur in freshwater environments (56.6% by quantity and 50.1% by value). Mariculture contributes 36.0% of production quantity and 33.6% of the total value. While much of the marine production consists of high-value finfish, there is also a large amount of relatively low-priced shellfish such as mussels. Although brackish-water production represented only 7.4% of production quantity in 2004, it contributed 16.3% of the total value, reflecting the prominence of high-value crustaceans and finfish (FAO Fisheries Department, 2006). There can be little question that coastal

Figure 1.1: Capture fisheries and aquaculture contributions to global food-fish supply 1970 - 2005. AQ share triangles) represent the growing relative share of aquaculture contribution (percent) to total food-fish supply (Subasinghe and Lowther 2007; pers. comm. based on FAO FishStat Plus 2007 data available at: http://www.fao.org/fishery/topic/16073).

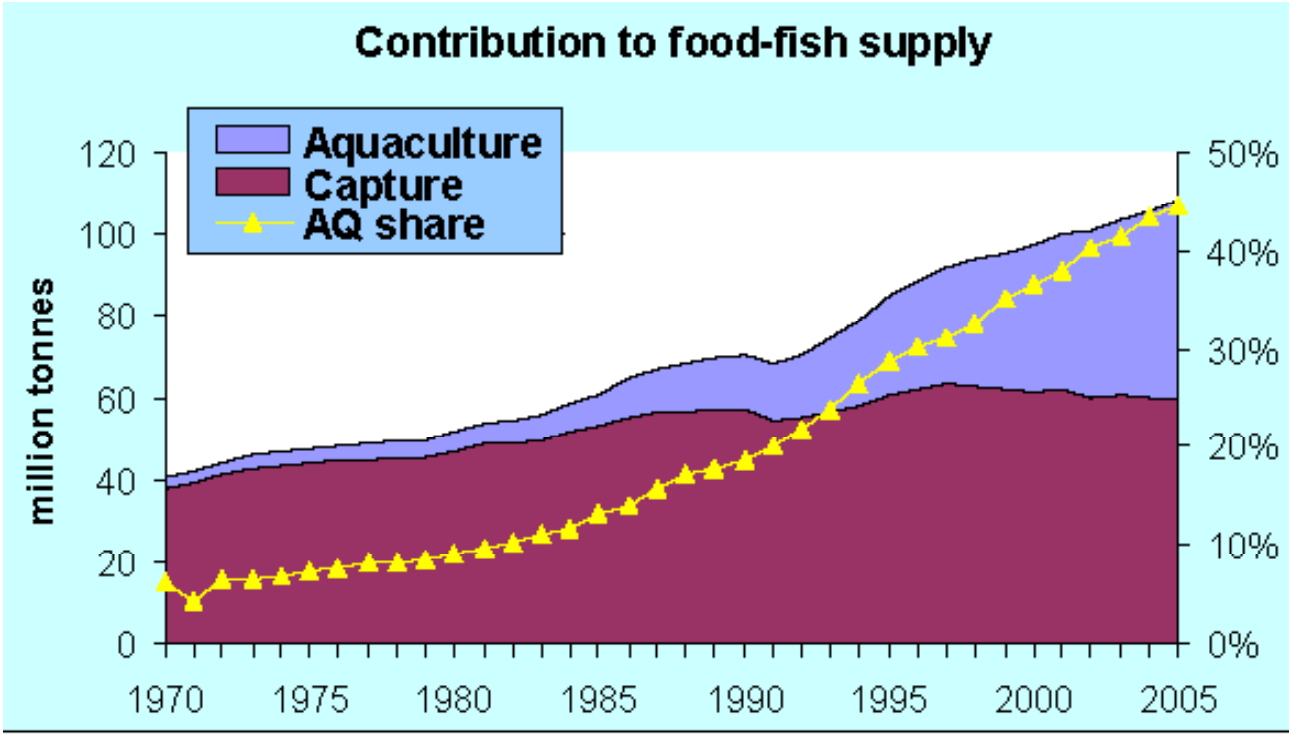
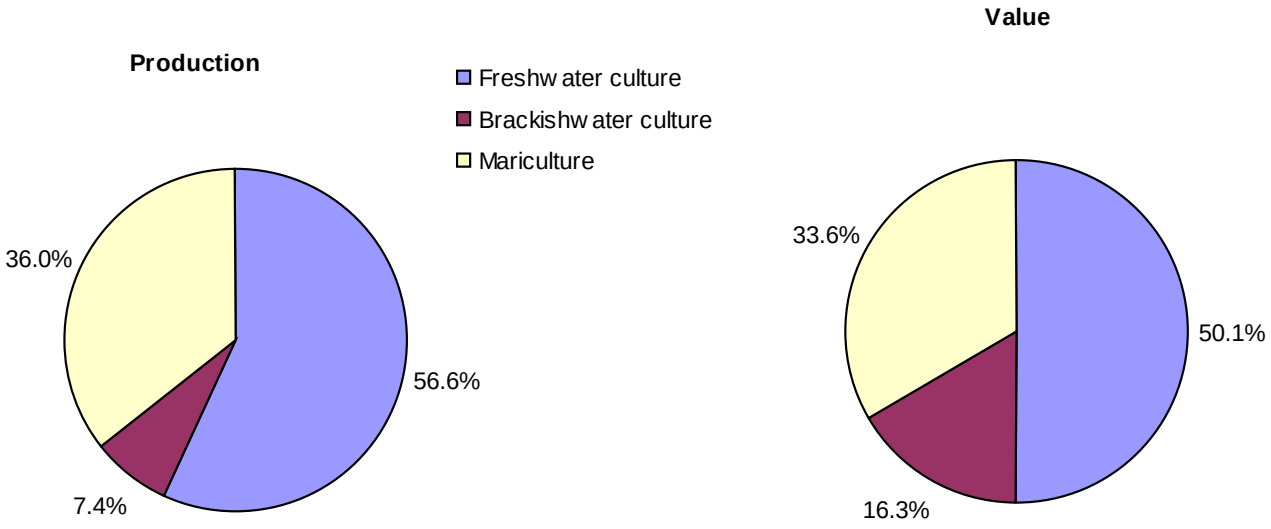


Table 1.1 : World fisheries and aquaculture production and utilization 2000-2005 (FAO Fisheries and Aquaculture Department, 2007).

	2000	2001	2002	2003	2004	2005[1]
	(Million tonnes)					
PRODUCTION						
INLAND						
Capture	8.8	8.9	8.8	9.0	9.2	9.6
Aquaculture	21.2	22.5	23.9	25.4	27.2	28.9
Total inland	**30.0**	**31.4**	**32.7**	**34.4**	**36.4**	**38.5**
MARINE						
Capture	84.6	84.2	84.5	81.5	85.8	84.2
Aquaculture	14.3	15.4	16.5	17.3	18.3	18.9
Total marine	**101.1**	**99.6**	**101.0**	**98.8**	**104.1**	**103.1**
TOTAL CAPTURE	95.6	93.1	93.3	90.5	95.0	93.8
TOTAL AQUACULTURE	35.5	37.9	40.4	42.7	45.5	47.8
TOTAL WORLD FISHERIES	**131.1**	**131.0**	**133.7**	**133.2**	**140.5**	**141.6**
UTILIZATION						
Human consumption	96.9	99.7	100.2	102.7	105.6	107.2
Non-food uses	34.2	31.3	33.5	30.5	34.8	34.4
Population (billions)	6.1	6.1	6.2	6.3	6.4	6.5
Per capita food fish supply (*kg*)	16.0	16.2	16.1	16.3	16.6	16.6

Note: Excluding aquatic plants.
[1] Preliminary estimate

Figure 1.2 : Proportional global production and value of combined fish crustaceans and mollusc aquaculture by environment for 2004 (Source: FAO Fisheries and Aquaculture Department, 2007).



aquaculture, including brackishwater aquaculture and mariculture, is a significant part of worldwide seafood production and that it will continue to be so for the foreseeable future (Figure 1.2).

Aquaculture is a highly diverse activity in terms of the species grown, scale and intensity of operation, technology and management practices. It ranges from small-scale 'back-yard' ponds and hatcheries, to major high technology industrial operations employing thousands of people and numerous individual sites, each producing several thousand tonnes per year. The range of scale, species and technology means that aquaculture can be viewed on the one hand by aid agencies as a useful tool for poverty alleviation, and on the other by large financial institutions as a sound investment area for commercial growth. This diversity can create particular difficulties when drafting regulations or guidelines to apply uniformly across the board.

The recent dramatic growth in coastal aquaculture activity on commercial scales has been concentrated in a few parts of the world, where conditions are particularly suitable for the growth of high value species for local consumption or export. Atlantic salmon production, for example, has developed rapidly in the sheltered cool temperate fjordic environments of Norway, Chile, Scotland and western Canada, whereas tropical shrimp production has developed in coastal areas of tropical Asia and Latin America. The arrival of a relatively new industry to such areas has given rise to concerns and conflicts. The establishment of aquaculture sites may restrict the options available for use of the space that they occupy. This can lead to conflicts with other stakeholders in the coastal zone, such as fishermen, who may see their freedom of action limited.

Environmental impacts and interactions of coastal aquaculture can be particularly contentious. While methods for monitoring local effects of aquaculture (for example, the effects of particulate organic waste on the seabed, or the effects of nutrient release on the availability of nutrients in the surrounding water body) are now well established, other areas of interactions, such as the genetic interactions between escaped animals and wild stocks continue to be hotly debated.

It is these areas, where aquaculture may have the potential to lead to undesirable changes in the surrounding environment and its living resources, which are the focus of this report. Effective management of aquaculture requires understanding of the probability that hazards (such as wastes, or escaped animals) arising from proposed aquaculture developments will lead to consequences that are considered unacceptable in the local or international contexts within which the development would occur. Objective analysis of the ecological risks concerned will facilitate effective allocation of resources to mitigation measures and an open, transparent and even-handed approach to management.

1.2 The scope of this report

As with all other human activities in coastal areas, there are environmental changes associated with coastal aquaculture. The nature of these changes and how to monitor them have been discussed in international science in support of environmental management since the 1980s (for example, Chua *et al*. 1989; Cholik and Poernomo 1987; Ackefors and Enell 1990; Gowen and Bradbury 1987; Hakanson *et al*. 1988; FAO/NACA 1995; Iwama 1991; Kapetsky 1982; Makinen *et al*. 1991; Black 2001; Hargrave 2005; Hambrey and Southall 2002; Mahmood 1987; ICES 1988, 1999, 2002, 2003, 2004, 2005, 2006; GESAMP 1991, 1996, 1997, 2001; Munday *et al* 1992; Nash *et al*. 2005; Pillay 1992; Pullin 1989; Pullin *et al*. 1993; Videau and Merceron 1992).

This report presents a model of ecological risk analysis for coastal aquaculture and guidelines for its application which:

- is structured to fit into a broader decision making environment which combines social and economic values with science-based predictions of environmental changes and effects;
- is pre-adapted to enhance the role of risk communication and risk management in the context of transparency;
- can operate in an open and transparent manner to incorporate information from the broad array supplied by scientists from government, academic, industry, and stakeholder organisations, and the public; and,
- explicitly recognises that many of the environmental changes associated with aquaculture activities can also arise from other coastal activities such as industrial and urban development, tourism, agriculture, fishing and stock enhancement.

The report emphasises the dynamics of risk communication, providing guidelines for communicating risk to environmental managers, stakeholders and the public. To validate the proposed approach to environmental risk analysis, this document presents six trial case studies which use the approach to illustrate its strengths and weaknesses.

The risk assessment protocols in this report are constructed as part of a sustainable development tool (Risk Analysis) which was designed to work hand in hand with risk communication in a decision-making environment that took account of the precautionary principle. The open and transparent application of the risk assessment protocols, and the explicitly documented uncertainty in predicting the outcomes of the interactions of coastal aquaculture with the environment created specific requirements for the methodology. Objectives and principles were developed for the application of the environmental risk assessment and risk communication protocols.

It is recognised that international risk protocols already exist in some other disciplines. For example, the World Animal Health Organisation's import risk analysis protocol which focuses on aquatic animal diseases (OIE 2006), and the international principles and guidelines for the conduct of microbiological risk assessments, as developed by the FAO/WHO Codex Alimentarius Commission (1999). Sumner *et al*. (2004) give an introduction to the application of seafood risk assesmment in the fish industry. This report describes an approach to environmental risk assessment and communication that complements, rather than replaces, those protocols, focusing specifically on coastal aquaculture.

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