Title:

Regional Review on Status and Trends in Aquaculture Development in North America: Canada and the United States of America — 2010

ISBN:

978-92-5-106895-3

Author:

Olin, Paul G., California Sea Grant
Smith, James, Fisheries and Oceans Canada
Nabi, Rashed, Fisheries and Oceans Canada

Publication Date:

01-13-2012

Series:

Extension Publications

Permalink:

http://escholarship.org/uc/item/1946b7nm

Original Citation:

Olin, P., Smith, J. and Nabi, R.Regional Review on Status and Trends in Aquaculture Development in North America – 2010FAO Fisheries and Aquaculture Circular No. 1061/2. Rome, FAO. 2011. 84 pp.

Published Web Location:

http://www.fao.org/docrep/014/i2163e/i2163e00.pdf

Keywords:

aquaculture, production, value, Canada, United States

Abstract:

The aquaculture industry in North America produced 644 213 tonnes of product in 2008 with an estimated value of US$1.6 billion. This represents an annual percentage increase over the previous decade of 1.8 percent by volume and 4.5 percent in value. The finfish industry is at the forefront of the aquaculture sector, led by production of Atlantic salmon in Canada and channel catfish in the United States of America.

There is potential for significant increases in North American production and both the Canadian and United States governments have projections for expansion of their aquaculture industries. Canada estimates that by 2020 production in Canada could exceed 308 000 tonnes with a farmgate value of US$1.6 billion. The United States Department of Commerce estimates that domestic aquaculture production in the United States of America has the potential to increase in value from US$1 billion to more than US$3 billion by 2025. Future significant growth in the North American aquaculture industry will require policies and regulations that protect the environment while ensuring the economic viability of the sector in an increasingly competitive international arena.

ISSN 2070-6065

REGIONAL REVIEW ON STATUS AND TRENDS IN AQUACULTURE DEVELOPMENT IN NORTH AMERICA: CANADA AND THE UNITED STATES OF AMERICA — 2010

Cover: *Cage farming in Canada.* Photo courtesy of Marine Harvest. J. Aguilar-Manjarrez, S. Borghesi and P. Olin.

Copies of FAO publications can be requested from:
Sales and Marketing Group
Office of Knowledge Exchange, Research and Extension
Food and Agriculture Organization
of the United Nations
E-mail: publications-sales@fao.org
Fax: +39 06 57053360
Web site: www.fao.org/icatalog/inter-e.htm

FAO Fisheries and Aquaculture Circular No. 1061/2 FIRA/C1061/2 (En)

Regional Review on Status and Trends in Aquaculture Development in North America: Canada and the United States of America — 2010

by

Paul G. Olin
California Sea Grant
Scripps Institution of Oceanography
University of California San Diego
United States of America

James Smith
Aquaculture Management Directorate
Fisheries and Oceans Canada
Canada

Rashed Nabi
Aquaculture Management Directorate
Fisheries and Oceans Canada
Canada

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
ROME, 2011

E-ISBN 978-92-5-106895-3 (PDF)

PREPARATION OF THIS DOCUMENT

The present Regional Review on Status and Trends in Aquaculture Development in North America was prepared as a collaborative effort of FAO's Aquaculture Service (FIRA) and Paul Olin, James Smith and Rashed Nabi. The document was compiled and edited by Paul Olin.

The authors greatly appreciate the contributions by the following experts: Ruth Salmon, Executive Director, Canadian Aquaculture Industry Alliance; Sherry Sadler, Project Manager, Canadian Aquaculture Industry Alliance; Angela Bexten, Assistant Director, Global Fisheries and Marine Governance Bureau, Fisheries and Oceans Canada; and Gloria Falk, Team Leader, Aquaculture Management Directorate, Fisheries and Oceans Canada.

Additional contributions were provided by FAO colleagues, in particular José Aguilar-Manjarrez of FAO's Aquaculture Service (FIRA) and Devin Bartley, Marine and Inland Fisheries Service (FIRF). Xiaowei Zhou from FAO's Statistics and Information Service (FIPS) prepared the FAO aquaculture statistics presented in this review. Danielle Rizcallah and Lei Chen (FIRA) assisted in the completion of the final layout and formatting to standard FAO editorial guidelines.

Olin, P., Smith, J. and Nabi, R.
Regional Review on Status and Trends in Aquaculture Development in North America – 2010
FAO Fisheries and Aquaculture Circular No. 1061/2. Rome, FAO. 2011. 84 pp.

ABSTRACT

The aquaculture industry in North America produced 644 213 tonnes of product in 2008 with an estimated value of US$1.6 billion. This represents an annual percentage increase over the previous decade of 1.8 percent by volume and 4.5 percent in value. The finfish industry is at the forefront of the aquaculture sector, led by production of Atlantic salmon in Canada and channel catfish in the United States of America.

There is potential for significant increases in North American production and both the Canadian and United States governments have projections for expansion of their aquaculture industries. Canada estimates that by 2020 production in Canada could exceed 308 000 tonnes with a farmgate value of US$1.6 billion. The United States Department of Commerce estimates that domestic aquaculture production in the United States of America has the potential to increase in value from US$1 billion to more than US$3 billion by 2025. Future significant growth in the North American aquaculture industry will require policies and regulations that protect the environment while ensuring the economic viability of the sector in an increasingly competitive international arena.

CONTENTS

TABLES

FIGURES

ACRONYMS AND ABBREVIATIONS

AAC	Aquaculture Association of Canada
ACRDP	Aquaculture Collaborative Research and Development Program
AIMAP	Aquaculture Innovation and Market Access Program
AIT	American Institute in Taiwan
ANA	Aquaculture Network for the Americas
APEC	Asia-Pacific Economic Cooperation
APFIC	Asia-Pacific Fishery Commission
APHIS	Animal Plant Health Inspection Service
APR	annual percentage rate
BCP	USDA Business and Cooperative Programs
BCSFA	British Columbia Salmon Farmers Association
BMP	best management practice
CAIA	Canadian Aquaculture Industry Alliance
CEAA	Canadian Environmental Assessment Act
CEPA	Canadian Environmental Protection Act
CFIA	Canadian Food Inspection Agency
COFI	Committee on Fisheries
CMSP	coastal and marine spatial planning
CSAS	Canadian Science Advisory Secretariat
CSREES	Cooperative State Research, Education and Extension Service
CSSP	Canadian Shellfish Sanitation Program
DFO	Fisheries and Oceans Canada
EPA	Environmental Protection Agency
FAEM	Framework for Aquaculture Environmental Management
FAR	focus area report
FCR	feed conversion ratio
FDA	Food and Drug Administration (United States of America)
FMP	fishery management plan

FSA	USDA Farm Service Agency
FWG	APEC Fisheries Working Group
G-20	Group of Twenty Finance Ministers and Central Bank Governors
GDP	gross domestic product
GMO	genetically modified organism
HACCP	Hazard Analysis Critical Control Point
HADD	harmful alteration, disruption or destruction
I&T	introductions and transfers
ICES	International Council for the Exploration of the Sea
IMTA	integrated multitrophic aquaculture
ISA	infectious salmon anaemia
ISSC	Interstate Shellfish Sanitation Conference
JPA	Joint Project Agreement
MBP	molluscan broodstock programme
MICNA	Mussel Industry Council of North America
MOU	memorandum of understanding
NAA	National Aquaculture Association
NAAHP	National Aquatic Animal Health Program
NACA	Network of Aquaculture Centres in Asia-Pacific
NASCO	North Atlantic Salmon Conservation Organization
NASO	National Aquaculture Sector Overview
nei	not elsewhere included
NEPA	National Environmental Policy Act
NGO	non-governmental organization
NIFA	National Institute of Food and Agriculture
NMAI	National Marine Aquaculture Initiative
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOP	National Organic Program
NOSB	National Organic Standards Board
NPDES	National Pollutant Discharge Elimination System
NSSP	National Shellfish Sanitation Program
NWPA	Navigable Water Protection Act
OECD	Organisation for Economic Co-operation and Development
OIE	World Organisation for Animal Health
PICES	North Pacific Marine Science Organization
QMP	Quality Management Program
R&D	research and development
SBIR	Small Business Innovation Research
TCI	The Catfish Institute
TECRO	Taipei Economic and Cultural Representative Office
USFWS	United States Fish and Wildlife Service

USDA	United States Department of Agriculture
VMAC	Veterinary Medicine Advisory Committee
WAS	World Aquaculture Society
WTO	World Trade Organization

EXECUTIVE SUMMARY

Social and economic background of the region

This circular covers the status and trends in aquaculture development in North America, including the nations of Canada and the United States of America. Both countries are interested in expanding aquaculture production to increase domestic supplies and create export opportunities. Canada and the United States of America are both high-income industrialized nations with the natural resources and investment capital to expand aquaculture production significantly.

FAO has projected the need for an additional 1.3–1.4 million tonnes of seafood annually to keep up with projected global consumption. In North America, current levels of per capita consumption of seafood are about 8 kg, and with the population expected to add 52 million people by 2025, about 416 000 tonnes of additional seafood will be required to meet demand. The United States Food and Drug Administration is recommending people double their seafood consumption to take advantage of the numerous health benefits associated with seafood, particularly cardiovascular health benefits derived from consuming species high in omega-3 fatty acids. If this occurs, then demand for aquaculture products could increase even more dramatically in the region.

The North American population of 335 million is highly educated and largely urban, with 45 percent of Canadians living in six major cities and 84 percent of people in the United States of America residing in urban centres. The population is young with 20 percent under the age of 15 years and 12 percent over 65 years. Median annual income levels have risen steadily in the last decade, and in Canada household income was US$66 000 in 2007 while that in the United States of America was US$50 000.

In the United States of America, the services sector dominates the economy, representing 80 percent of its gross domestic product (GDP) of US$13.2 trillion; Canadian GDP in 2007 was US$1.3 trillion. While the economies of Canada and the United States of America derive their growth and GDP mainly from the service and manufacturing sectors, primary sector industries, such as agriculture (including aquaculture) are important, especially in a regional context. In Canada, aquaculture in 2008 accounted for about 5 percent of the US$155 billion value of the agriculture sector; while in the United States of America, aquaculture sales of US$937 million are less than 1 percent of the US$276 billion value of the agriculture sector.

General characteristics of the sector

Global capture fisheries are not anticipated to increase for the foreseeable future, and it is generally recognized that future increased demand for seafood will be met by expanded aquaculture production. To meet this growing demand, the aquaculture sector in North America has evolved into two broad industry types: finfish production, which is dominated by salmon, catfish and to a lesser degree trout; and shellfish production, primarily oysters, mussels and clams. The finfish industry is placed at the forefront of the sector led by production of salmon in Canada and channel catfish in the United States of America. By the 1990s, in Canada, finfish aquaculture had jumped from 30 to 70 percent of the total as a result of the rapid increase in production of Atlantic salmon on both the Atlantic and Pacific coasts. In contrast, in the United States of America, freshwater catfish remains the dominant aquaculture species, representing 65 percent of finfish value in 2007, or almost twice the value of all other primary finfish species produced. Catfish production increased by 44 million tonnes between 1998 and 2003, but then declined in 2008 to levels seen a decade earlier. Shellfish production increased steadily during the decade from 1997 to 2007, with Canadian blue mussel production expanding from 11 570 tonnes to 23 692 tonnes valued at US$35.5 million. Shellfish production in the United States of America saw steady increases, with production roughly doubling for Manila clams, northern quahogs, red swamp crawfish, and American cupped oysters.

Future significant growth in the North American aquaculture industry will probably follow the successful model provided by the Atlantic salmon industry in Canada, with new technologies enabling net-pen culture to move further offshore, and by the Canadian blue mussel industry employing new technologies to create industry sectors. Both Canada and the United States of America have ample areas for this expansion, and the Canadian salmon example and pilot projects in the United States of America with cobia, Atlantic cod, moi and amberjack demonstrate the viability of the net-pen approach. However, in some regions, there is considerable opposition to net-pen finfish culture, and whether a significant industry sector develops will depend on the establishment of a regulatory regime that ensures environmental protection while enabling the economic viability of aquaculture ventures.

North American production and value

North American aquaculture production in 2008 was 644 213 tonnes, valued at US$1.6 billion, up from 536 169 tonnes in 1998 for an annual percentage rate (APR) of 1.8 percent for the decade. While the United States production of 500 114 tonnes eclipsed Canadian production of 144 099 tonnes, Canadian production increased much more rapidly with an APR of 4.7 percent compared with an APR of 1.2 percent for the United States of America. While production in the United States of America is higher, the roughly comparable value of the aquaculture sector in Canada and the United States of America, despite the disparity in tonnes produced, reflects the higher value of Canada’s primary product of Atlantic salmon relative to channel catfish, the primary species produced in the United States of America. In addition to Atlantic salmon and channel catfish, both Canada and the United States of America have successful shellfish farming ventures producing primarily Pacific and eastern oysters and blue mussels.

Resources, Services and Technologies

Canada is the second-largest country in the world, with a total area of almost 10 million km^2 while the United States of America is slightly smaller at 9.6 million km^2 (with a land area of 9 158 960 km^2 and a water surface area of 470 131 km^2). The coastline of the United States of America is 19 924 km. Canada’s coastline is much longer at 202 080 km, and its total land mass is 9 984 670 km^2 with a water surface area of 891 163 km^2. Canada’s long coastline of 243 042 km represents 25 percent of the world’s coastline. Canada’s three million lakes and rivers also contain 16 percent of the world’s freshwater, and, combined, these natural resources provide an abundance of potentially suitable sites for supporting both marine and freshwater aquaculture (Natural Resources Canada, 2009).

Unlike Canada, much of the coastline of the United States of America is well developed and competition for space in the coastal and nearshore environment creates user group conflicts. This is recognized as a challenge and a number of agencies and non-governmental organizations (NGOs) are supporting comprehensive coastal marine spatial planning as a tool to reduce these conflicts. Further restrictions on access to coastal and nearshore waters is posed by the creation of marine sanctuaries. In addition to the difficulty in accessing coastal land and waters in the United States of America, there are very few areas with unallocated freshwater to support significant, new, land-based freshwater aquaculture facilities. It is for these reasons that the industry and government agencies of the United States of America are looking towards expansion of the sector in nearshore and offshore waters.

The North American service sector is well developed with ready access to feeds, fingerlings, seedstock, and veterinary services. Domestically manufactured feeds supply most farms raising Atlantic salmon and channel catfish. Concerns over the use and future limitations of fishmeal and fish oil as feed ingredients have spawned alternative feeds initiatives to identify suitable alternate feed ingredients. Hatcheries supply eggs and fingerlings to growers of catfish, salmon and trout. Shellfish hatcheries produce Pacific and eastern oyster seed, while mussel growers primarily collect seed from natural sets or purchase hatchery seed.

Biotechnology and DNA analysis are increasingly used to select for production traits, such as fast growth and disease resistance. This is an area of active research in Canada and the United States of

America. While there is much promise in these technologies, there are currently no genetically modified organisms being used in aquaculture production.

Culture systems for finfish include cages and net pens deployed in reservoirs or coastal waters, and land-based systems including ponds, raceways and recirculating systems. Shellfish culture employs bottom culture and off-bottom culture using longlines. Salmon are cultured primarily in gravity net pens and channel catfish are grown almost exclusively in freshwater ponds. The use of submersible net pens is showing promise in new applications further offshore in less protected waters.

Health management and biosecurity are high priorities for producers, and regulatory agencies in Canada and the United States of America have recently adopted or are developing national aquatic animal health plans. Canada has been successful with its plan, and salmon farmers have not seen a recurrence of the outbreak of infectious salmon anaemia that caused considerable Atlantic salmon losses earlier in the decade. The plan being developed by multiple agencies in the United States of America was finalized in 2010.

Aquaculture and Environment

Canada and the United States of America have well-established regulatory and environmental NGO communities that demand sustainable aquaculture practices that protect natural resources. As a result, the industries have developed environmental policies and codes of practice that protect the environment in which they operate. Opposition to aquaculture development has hindered industry development in the past and continues to do so today. Any new aquaculture ventures in North America will be required to perform comprehensive environmental review and monitoring to ensure that proposed operations are sustainable and compatible with water quality and natural resource protection. Inherent in this process is a focus on ecosystem-based management and environmental approaches to aquaculture. Integrated multitrophic aquaculture is being investigated as one technique to enhance environmental compatibility.

Markets and Trade

Almost 60 percent of Canada’s aquaculture products are sold to export markets in some 20 countries. The largest export market for Canada is the United States of America, which consumed 96 percent of sales in 2007 (consisting primarily of Atlantic salmon and blue mussels). The total value of Canadian exports was US$613 million in 2007.

The industry in the United States of America markets most aquaculture products domestically, and United States consumers imported 83 percent of seafoods consumed in 2008, worth a record US$14.2 billion. The primary export market for channel catfish is Canada, which accounts for 71 percent of United States exports, worth US$2.1 million. Canada is also the largest importer of trout from the United States of America, accounting for 67 percent of United States exports, worth US$1.6 million.

It is imperative that seafood-exporting countries have a comprehensive and stringent food safety programme, and the Canadian programme is overseen by the Canadian Food Inspection Agency, while that in the United States of America is overseen by the United States Food and Drug Administration and the National Oceanic and Atmospheric Administration (NOAA) Seafood Inspection Program. The seafood safety programmes of both countries are recognized as models throughout the world.

Contribution of aquaculture to food security, social and economic development

Direct and indirect employment in North American aquaculture was estimated at 54 171 jobs in 2007, up from 40 212 in 1998, for an APR gain of 2.9 percent. Aquaculture represents a very small segment of North American agricultural production. However, on a regional basis, it is extremely important to some communities in both Canada and the United States of America. This is especially true in Atlantic

Canada, British Columbia, and the southeastern United States of America. According to an unpublished study by Fisheries and Oceans Canada (DFO), Canadian finfish and shellfish operations together employ 5 100 people and create another 9 600 jobs further downstream in supply and service industries. In the United States of America, total direct and indirect employment in aquaculture was estimated at 39 471 in 2007, up by 6 087 from 33 384 jobs in 1998.

External pressures on the sector

The North American aquaculture industry has adapted well to animal health challenges in the past and will continue to do so in the future. Other external pressures related to climate change, global warming, sea-level rise, severe storms and ocean acidification will all require adaptive management and flexibility to respond to different scenarios and challenges as they emerge and play out.

Significant challenges resulting from globalization and competition face North American producers where higher wages and benefits reduce margins. Advanced technologies, increasing automation and aggressive marketing will all be needed in order to remain competitive in a global market..

The role of shared information: research, training extension and networking

The need for scientific research remains critical to enhance the growth and diversity of North American aquaculture. From the early days of development, the DFO has played the lead role in research and technology transfer in Canada, while this responsibility in the United States of America is shared by the United States Department of Agriculture and the NOAA. Federal state and provincial government research facilities are dedicated to research on new species development, selective breeding to improve broodstock performance and seed quality, enhanced growout technologies, health management, and improved husbandry, nutrition and feeds. Federal research provides a sound science and technology base for innovations in the industry, and collaborations with the extensive network of universities and state and provincial researchers, coupled with extension expertise in both countries, expand the reach of this research. Development and commercialization of new technologies in the culture of catfish, salmon, oysters and mussels, and the success of these industries are largely the result of past and ongoing government support through collaborations with industry, academia and extension. When applied to new species with promising culture potential, this research and extension capacity should facilitate industry expansion.

Governance and management of the sector

In North America, aquaculture is managed by a combination of federal, provincial, state and local authorities. In the last decade, governments in both Canada and the United States of America have made concerted efforts to improve aquaculture governance and increase financial support for research and development. These have included: creation of national policies, strategic plans to support expansion, identification of priority goals and research topics, and efforts to establish national legislation addressing aquaculture. These efforts should improve regulation of the industry, balancing the needs to protect the environment, sustain fisheries and enable a competitive industry to flourish. This will all be essential to counter well-funded opposition groups if the sector is to expand.

Implementation of the Bangkok Declaration

Canada and the United States of America have observed growth in the aquaculture sector in the last decade but they envision a more robust industry with greater production and product diversity. Both governments have created national aquaculture development plans in keeping with guidance provided in the 2000 Bangkok Declaration and Strategy. Efforts to develop the sector's full potential and increase global seafood supplies have been pursued more aggressively in recent years to create a regulatory regime supporting industry expansion and to accelerate the rate of growth. The industry is being developed in a sustainable fashion in keeping with principles of ecosystem-based management and in accordance with the FAO Code of Conduct for Responsible Fisheries.

1. SOCIAL AND ECONOMIC BACKGROUND OF THE REGION

This circular covers the status and trends in aquaculture development in North America, including the nations of Canada and the United States of America. Both countries are interested in expanding aquaculture production to increase domestic supplies and create export opportunities. Canada and the United States of America are both high-income industrialized nations and members of the Organisation for Economic Co-operation and Development (OECD), and the Group of Twenty Finance Ministers and Central Bank Governors (G-20).

In 2007, the North American population reached 335 million. Canada's population of 33 million creates an average density of 3.5 people/km^2 (Population Reference Bureau, 2007). The United States of America is more heavily populated, with 302 million residents creating an average population density almost ten times that of Canada at 31 people/km^2 (United States of America Census Bureau, 2009).

More than 61 percent of Canadians live in the central provinces of Ontario and Quebec. Five Canadian provinces along the Atlantic and Pacific coast make up only 20 percent of the total population. Vast northern areas comprise 39 percent of Canada's total area but have only 0.3 percent of its population. In the United States of America, one-third of the population is located in the southern region of the country. Seven states have populations exceeding 10 million, including California (37 million), Florida (18), Illinois (12), Michigan (10), New York (19), Pennsylvania (12), and Texas (24 million). Overall, in the United States of America, slightly more than 50 million people reside in rural areas and more than 250 million are urban dwellers. Canada's population is similarly concentrated in urban areas, with 45 percent living in six major cities. Almost 90 percent of the growth occurs in the large urban areas, whereas population size in the rural regions is declining.

North America's population is young, with 20 percent under the age of 15 years and 12 percent over the age of 65 years. The population of the region is growing and is expected to increase by 38 percent by mid-2050 to 462 million. This overall growth masks a difference between the United States of America and Canada where fertility rates are 2.1 and 1.5, respectively (Table 1). The Canadian population is ageing as a result of decreasing fertility rates and longer life expectancy.

According to a Canadian projection, by the 2030s the working-age population could decline from 70 percent to 60 percent of the overall population, leading to a situation where older people leaving the workforce will outnumber younger people entering. The population in the Atlantic region is ageing owing to outmigration of young adults. This demographic trend presents many challenges for younger industries such as aquaculture with regard to employee retention, knowledge transfer, continuing education and training.

Over the last decade in the United States of America the number of people in the workforce over age 16 has remained fairly constant at around 66 percent of the population. United States of America employment projections for the 2006–16 decade call for 15.6 million new jobs, an increase of 10 percent. This is slightly less than the 15.9 million jobs, or 12 percent, created during the 1996–2006 decade. The labor force filling these jobs is becoming more racially and ethnically diverse and is projected to grow more slowly than in the past. This slowdown in the growth of the labor force is primarily due to the aging and retiring of baby boomers.

Male employees dominate the aquaculture workforce, accounting for more than 72 percent of Canadian jobs in the sector. Because the majority of the on-farm jobs are physically challenging and are located in remote and isolated areas often involving vessel operations, it is easier for the industry to attract more men than women, who comprise 28 percent of the total workforce. Some female employees work at large corporate farms as skilled professionals, such as veterinarians, biologists or communication specialists, but many are employed in semi-skilled jobs ranging from laboratory technician to accounting. Given the physical nature of on-farm jobs, which are more frequently available than office-based jobs, it is not clear whether the sector will achieve a gender balance in the near future.

Recent statistics on gender-based occupation in United States of America aquaculture are incomplete. Overall, women's role in the general workforce has been increasing since the 1950s. According to the United States of America Census Bureau, it is likely in 2009 that there was a shift in gender balance in the United States workforce with more women working than men.

In United States agriculture generally, many of the farms operated by women are small-scale farms, earning less than US$50 000 annually. Women-operated farms are generally smaller, both in sales and size, than male-operated farms, and female operators control a relatively small share of the resources used in agricultural production. Like most households with small farms, households of female operators rely heavily on off-farm income. Largely because of low farm earnings, the average total household income of female-operator households is less than the average for male-operator households and below the average for all households in the United States of America.

North America now has a better educated population and qualified workforce than a decade ago. According to the 2006 census, 60 percent of Canadian adults had a post-secondary education, with 23 percent holding a university degree and the remainder having a diploma or certificate. North American women holding a university or college diploma outnumber men. In the United States of America in 2007, 84 percent of students completed secondary education, 54 percent had some post-secondary education and 24 percent held a bachelor's or higher-level diploma (OECD, 2007).

Table 1: North American components of population growth, 2007.

Location	Population (Millions)	Male (Millions)	Female (Millions)	Fertility Rate	Population Projection 2025 (Millions)	Population Projection 2050 (Millions)
Canada	33	16.5	16.8	1.5	37.6	41.6
United States of America	302	148.7	152.9	2.1	349.4	419.9
North America	335	165.2	169.7	2	38.7	461.5

Source: Population Reference Bureau, 2007.

North American's income levels continue to climb from previous years. In 2007, median after-tax income for Canadian families with two or more persons rose 19 percent from 1998 to US$66 435. In the same period, the prevalence of low-income families declined from 10.1 percent to 5.8 percent (Statistics Canada, 2009a). The income increase was consistent with the economic growth, as measured by the real gross domestic product (GDP), which rose 2.7 percent in 2007. This expansion, until it was hit by the current recession, also matched a rise in employment, with unemployment falling to a low of 6.0 percent. Before the recent economic downturn, real GDP grew at a rate of 2.7 percent. Canada's GDP reached US$1.3 trillion dollars in 2007, up 12 percent from 2003 (Table 2).

In 2007, the median annual household income in the United States of America rose 1.3 percent to US$50 233 (United States of America Census Bureau, 2009). Men continue to earn more than women, and men who worked full time, year-round saw incomes climb between 2006 and 2007 from US$43 460 to US$45 113. For women, the corresponding increase was from US$33 437 to US$35 102.

Although the economies of Canada and the United States of America derive their growth and GDP mainly from the service and manufacturing sectors, primary sector industries such as agriculture (including aquaculture) are important, especially in a regional context. One-quarter of Canadian exports are primary goods, and many areas in the country rely on this sector for employment and income. In 2006, the agriculture sector generated US$155 billion in consumer sales in Canada, exported more than US$36 billion in agriculture and food products including seafood, and contributed about US$8 billion to Canada's overall trade surplus (AAFC, 2009). Aquaculture accounts for only about 5 percent of this sector but plays an important role, providing diverse opportunities and generating income in coastal and remote communities. Moreover, with its continuous growth, aquaculture is emerging as a distinct technology-based subsector in the Canadian economy.

In the United States of America, the services sector dominates the economy, representing 80 percent of the country's GDP of US$14.1 trillion. Manufacturing follows with 19 percent and agriculture trails at 1.2 percent. In 2007, the United States of America exported US$82 billion in agricultural products while importing US$70 billion, generating an agricultural trade surplus of US$12 billion. The value of United States aquaculture production in 2007 was US$945 million, less than 1 percent of the US$276 billion value of the agriculture sector.

Table 2: North American gross domestic product (GDP), growth and employment.

2007	Canada	United States of America
Gross National Product	US$1.3 trillion	US$13.4 trillion
Gross Domestic Product	US$1.3 trillion	US$13.2 trillion
GDP growth rate	2.7%	5.22%
Unemployment rate	6%	4.6%
Average income	US$66 435	US$50 233

Source: Statistics Canada, 2009b.

While the economies of both Canada and the United States of America showed modest growth entering 2007, they have since been constrained by the economic downturn and recession. The steep rise in oil costs has reverberated through the North American economy. Inadequate investment in economic infrastructure, the high costs of medical care and pensions for an ageing population, and stagnation in family income in the lower economic groups present challenges for future growth. The global economic downturn, the subprime mortgage crisis, investment bank failures, falling home prices and tight credit pushed both the United States of America and Canada into recession by mid-2008.

2. GENERAL CHARACTERISTICS OF THE SECTOR

2.1 Status and Trends

Global capture fisheries are not anticipated to increase for the foreseeable future and it is generally recognized that aquaculture must meet future increasing demands for seafood (FAO, 2009a). To meet this growing demand, the aquaculture sector in North America has evolved into two broad industry types: finfish production, which is dominated by salmon, catfish and to a lesser degree trout; and shellfish production, primarily oysters, mussels and clams. The finfish industry is placed at the forefront of the sector led by production of salmon in Canada and channel catfish in the United States of America. By the 1990s, Canadian finfish aquaculture jumped from 30 to 70 percent of the total owing to the rapid increase in production of Atlantic salmon on both the Atlantic and Pacific coasts. In contrast, in the United States of America, freshwater catfish remains the dominant aquaculture species, representing 65 percent of finfish value in 2007, or almost twice the value of all other primary finfish species produced. Catfish production increased by 44 000 tonnes between 1998 and 2003, but then declined in 2007 to levels seen a decade earlier. Shellfish production in the United States of America saw steady increases, with production roughly doubling for Manila clams, northern quahogs, red swamp crawfish, and American cupped oysters.

Future significant growth in the North American aquaculture industry will probably follow the successful model provided by the Atlantic salmon industry in Canada, with new technologies enabling net-pen culture to move further offshore, and by the Canadian blue mussel industry employing new technologies to create industry sectors. Both Canada and the United States of America have ample areas for this expansion, and the Canadian salmon example and pilot projects in the United States of America with cobia, Atlantic cod, moi and amberjack demonstrate the viability of the net-pen approach. However, in some regions, there is considerable opposition to net-pen finfish culture, and whether a significant industry sector develops will depend on the establishment of a regulatory regime that ensures environmental protection while enabling the economic viability of aquaculture ventures.

2.2 North American production and value

North American aquaculture production in 2008 was 644 213 tonnes, up from 536 169 tonnes in 1998 for an annual percentage rate (APR) of 1.8 percent for the period (Figure 1). While United States production of 500 114 tonnes eclipsed Canadian production of 144 099 tonnes (Figure 2), Canadian production increased much more rapidly with an APR of 4.7 percent, compared with the United States APR of 1.2 percent. While United States production is higher, the roughly comparable value of the aquaculture sector in Canada and the United States of America, despite the disparity in tonnes produced, reflects the higher value of Canada’s primary product of Atlantic salmon relative to channel catfish, the primary species produced in the United States of America (Figure 3). Channel catfish is the highest volume species produced in North America, followed by Atlantic salmon, American cupped oysters, red swamp crawfish, and Pacific oysters (Figure 4). There has been considerable variability in production quantity in the sector from year to year and between the two countries. Canada experienced a high APR of 24 percent in 1999 while the APR for the United States of America peaked at 11 percent in 2004 (Figure 5). The industry also experienced years of significant contraction, with a Canadian low APR of –14 percent in 2004 and a low APR of –15 percent in the United States of America in 2005. This highly variable rate of growth can be seen in both production and value (Figures 5 and 6). The relative quantity and value of species produced in Canada and the United States of America can be seen in Figures 7 and 8.

The value of North America’s 644 213 tonnes of aquaculture production was US$1.6 billion in 2008, up from US$1 billion in 1998, for an APR of 4.5 percent over the decade (Figure 1). The 2008 value of the Canadian industry production of 144 099 tonnes increased dramatically during this period, almost tripling from US$267 million in 1998 to US$686 million in 2008 (with an APR of 9.9 percent). From year to year, the change in value of the Canadian industry varied widely with a low APR of –15 percent in 2002 followed three years later by a high APR of 46 percent in 2005 (Figure 6). The value of United States aquaculture products increased 20 percent from US$781 million in 1998 to US$937 million in 2008, reflecting an APR of 1.8 percent over the decade. The United States industry also experienced a contraction in 2002 with an APR of –10 percent, followed the next year by a high APR of 12.5 percent (Figure 6). Annual fluctuations in APR are generally caused by variables such as widespread disease issues, new market opportunities, fluctuating currency exchange rates or competition in the marketplace. Differences between the two countries usually result from increases or declines in a species predominately cultured in only one country, i.e. Atlantic salmon in Canada or channel catfish in the United States of America.

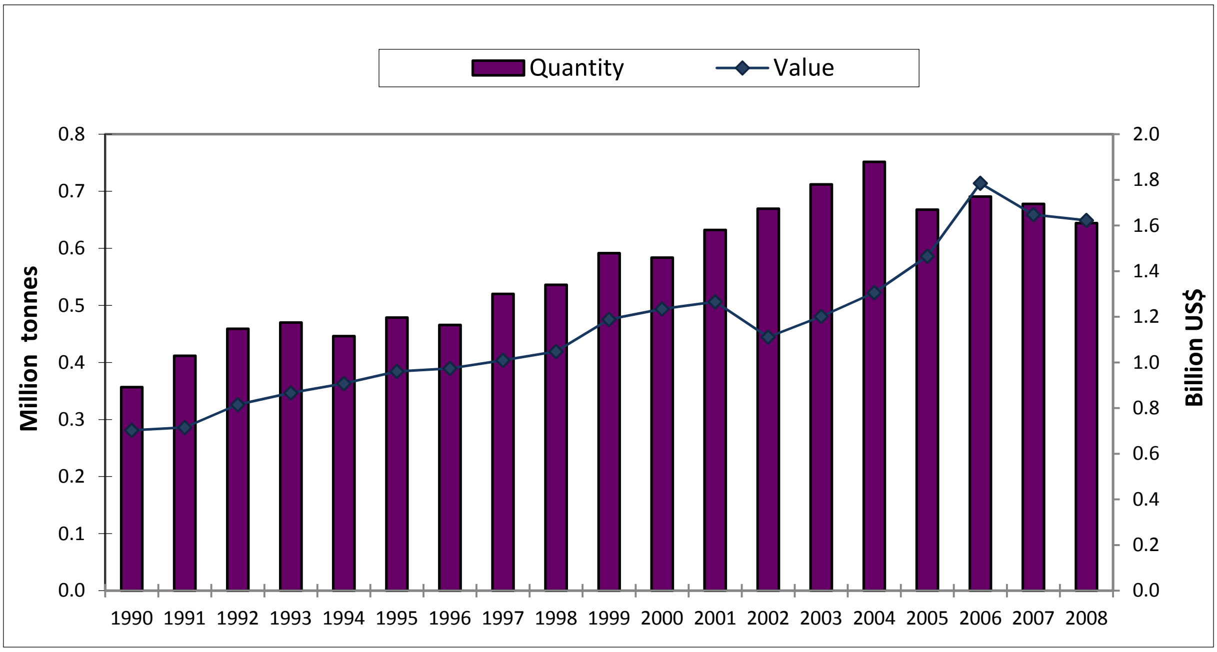

Figure 1: Aquaculture production and value in North America.
Source: FAO FishStat Plus, 2010.

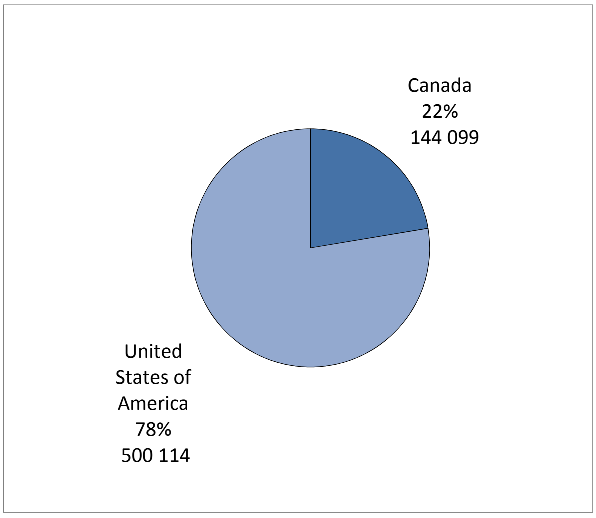

Figure 2: Aquaculture production by country in North America in 2008, tonnes.
Source: FAO FishStat Plus, 2010.

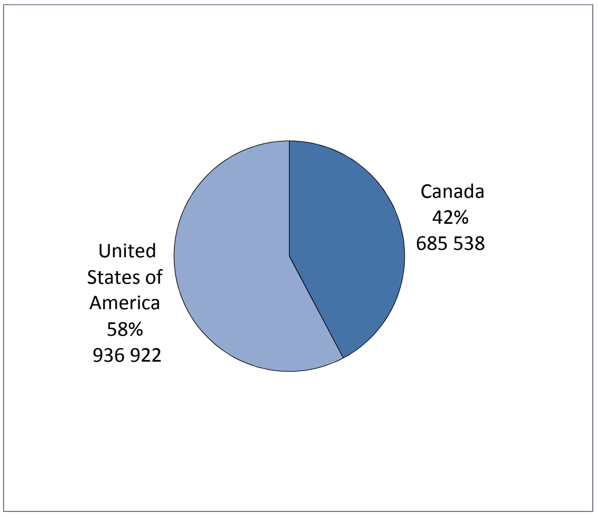

Figure 3: Aquaculture production value by country in North America in 2008, US$1 000.
Source: FAO FishStat Plus, 2010.

About 90 percent of Canada's aquaculture production is in marine waters. Although small in scale at 10 percent of the total, freshwater aquaculture takes place in all of Canada's ten provinces.

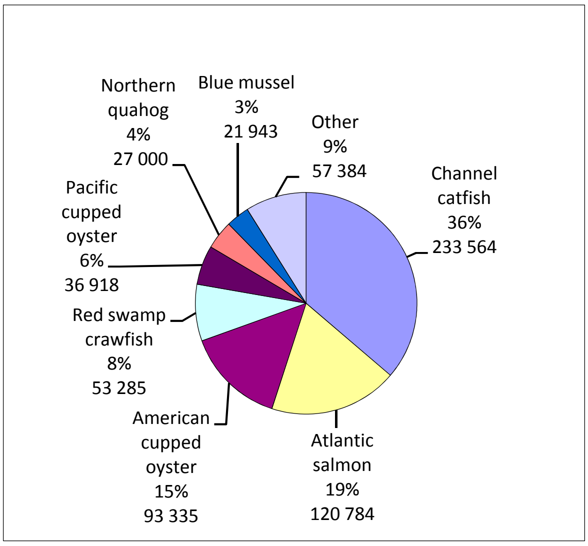

Figure 4: Major aquaculture species in North America in 2008, tonnes.
Source: FAO FishStat Plus, 2010.

2.3 Canadian production and value

Canadian aquaculture production increased 58 percent from 91 046 tonnes in 1998 to 144 099 tonnes in 2008. The corresponding value increased from US$266 910 million to US$685 538 million. Production volume peaked in 2002, reaching 172 046 tonnes, valued at US$396 525, but fell in the following years when salmon production declined owing to an outbreak of infectious salmon anaemia (ISA).

In 2007, British Columbia produced 47 percent of the total production or 80 430 tonnes. On the Atlantic Coast, New Brunswick held the highest share of salmon production (26 percent), followed by Prince Edward Island (12 percent), Nova Scotia (6 percent), and Newfoundland (5 percent). In the period, the share of central Canada (Ontario and Quebec) and the Prairie provinces (Saskatchewan, Manitoba and Alberta) fell by half to 3.5 percent and less than 1 percent, respectively.

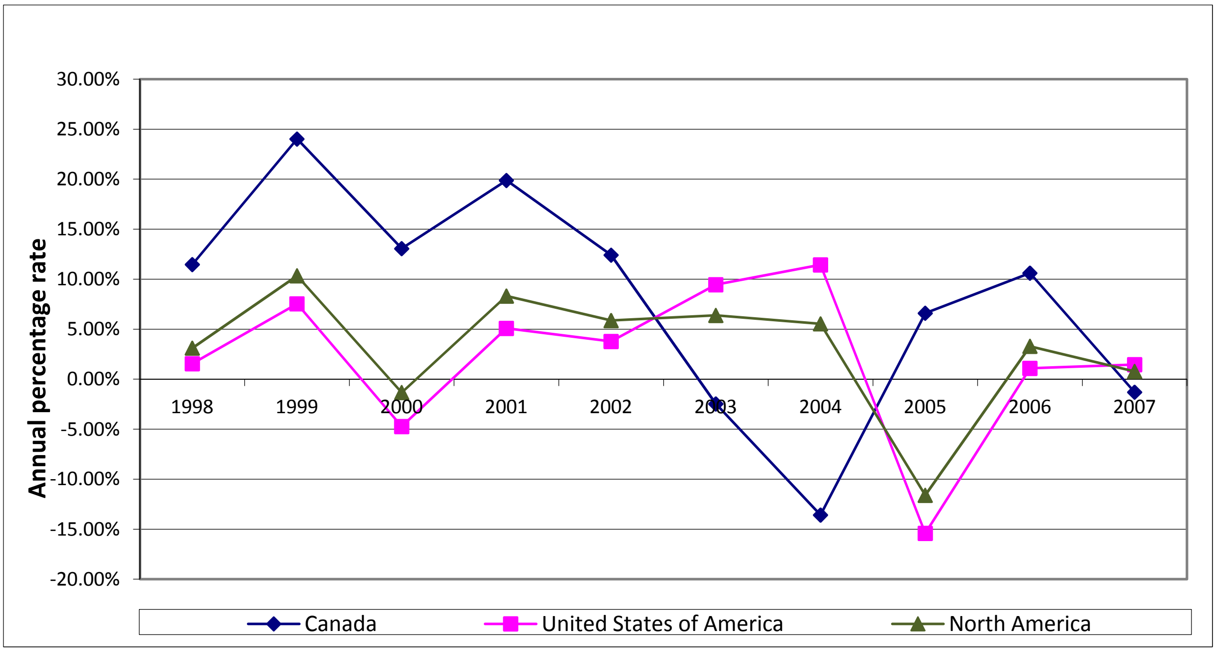

Figure 5: Annual percentage rate in aquaculture production in North America, 1997–2007.
Source: FAO FishStat Plus, 2009.

Finfish production has grown at an APR of 7.4 percent in the past decade, more than doubling from 63 918 tonnes in 1997 to 129 949 tonnes in 2007. The value of finfish represented over 90 percent of the total value and increased from US$498 million to US$824 million. Finfish include salmon, trout and a few other marine and freshwater species.

The share of shellfish production has been smaller but it contributes significantly to the stability and diversity of the sector. Shellfish production has grown at a higher rate, 8.2 percent, than finfish and more than doubled to 39 365 tonnes in the past decade. However, its production level in 1997 was three and a half times lower than finfish, making it difficult for the industry to keep pace with the growth in finfish production. The value of the production in that period increased from US$36 million to US$75 million. Shellfish include primarily mussels, and to a lesser degree, oysters, clams, scallops, and other species. Production is concentrated in the Atlantic provinces and, in 2007, 76 percent of the total shellfish production came from Newfoundland and Labrador, Prince Edward Island, Nova Scotia, and New Brunswick, with the rest being unevenly distributed between British Columbia (22 percent) and Quebec (2 percent).

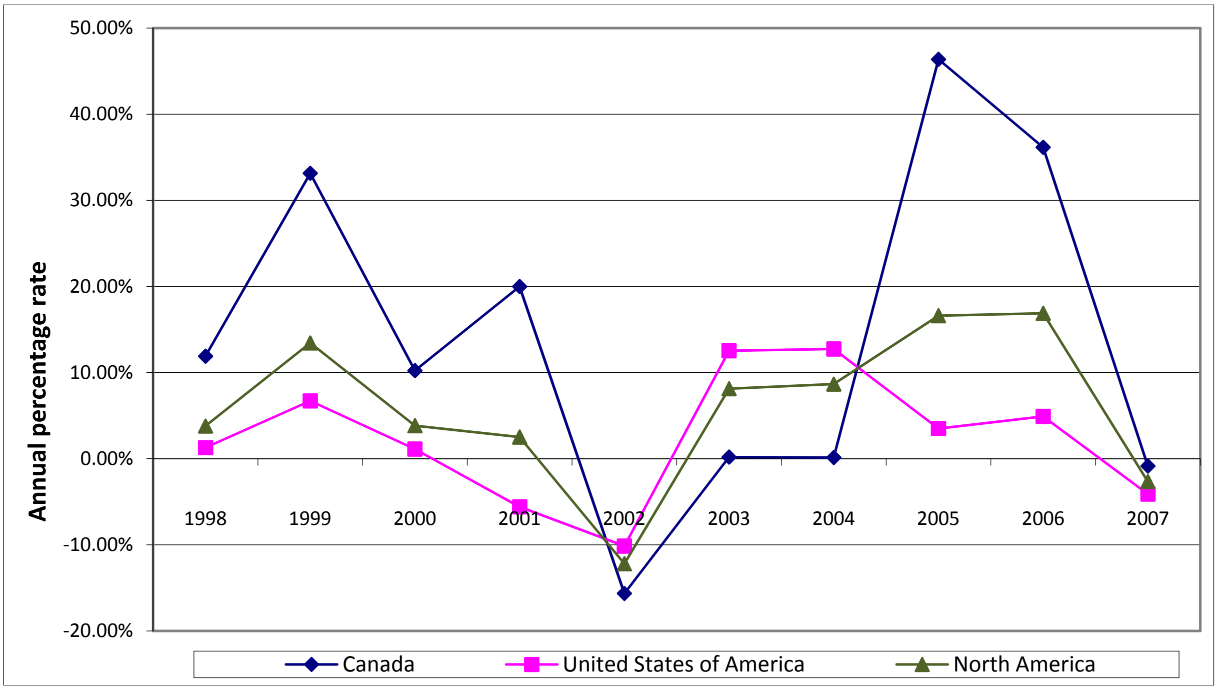

Figure 6: Annual percentage change in aquaculture value in North America, 1997–2007.
Source: FAO FishStat Plus, 2009.

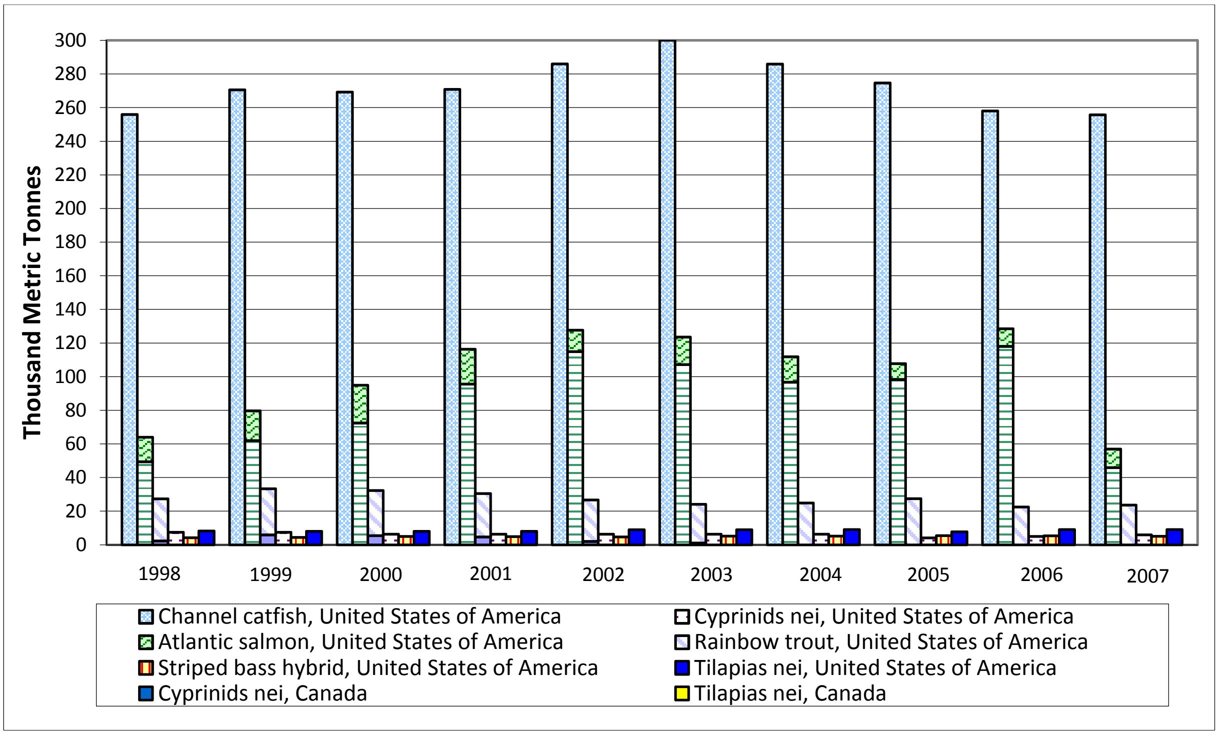

Figure 7: Fish production in Canada and the United States of America, 1998–2007.
Source: FAO FishStat Plus, 2009.
Notes: For Canadian production data on trout in years 2004–2007 refer to Table 4 with data from Statistics Canada.
nei = not elsewhere included.

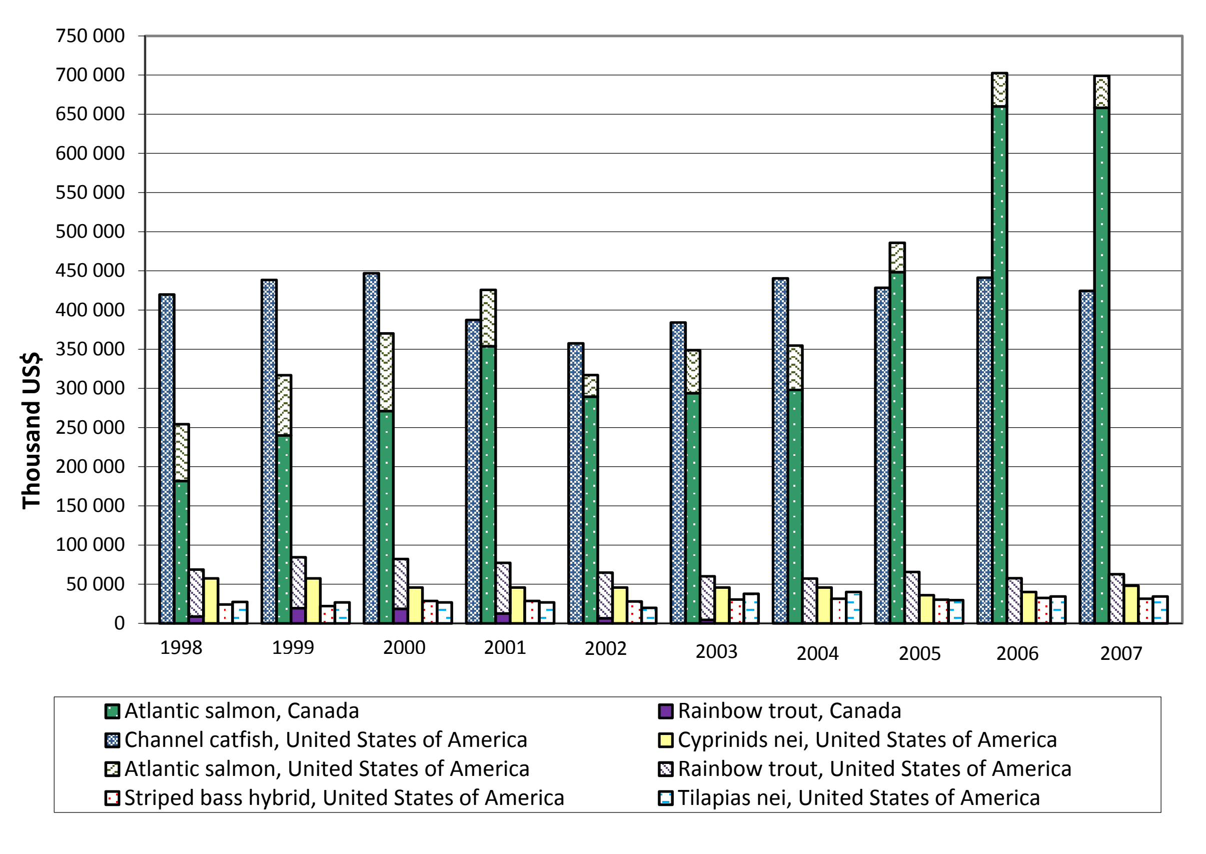

Figure 8: Fish value in Canada and the United States of America by species, 1998–2007.
Source: FAO FishStat Plus, 2009.
Note: nei = not elsewhere included.

For a long period, salmon, mussels, oysters and trout have been top species in Canadian aquaculture (Figure 9).

The North American salmon aquaculture industry is dominated by Canadian production at more than 90 percent. Salmon operations are large and vertically integrated (GSGislason and Associates Ltd, 2004). The integration comprises all four phases of the aquaculture value chain: hatchery, growout, processing and marketing. There is a large presence of Norwegian transnational companies involved with salmon farming in British Columbia on the Pacific coast. In contrast, on the Atlantic coast, where the industry began, it is still largely controlled by a small number of Canadian-owned and -operated companies.

In the last few years, there has been major consolidation in the salmon industry and the mergers had a short-term negative effect on overall production (Statistics Canada, 2009c). The consolidation has reduced the salmon industry to some five companies that control the majority of production (GSGislason and Associates Ltd, 2004; Price Waterhouse Coopers, 2008). This consolidation has resulted in economies of scale and the benefits to be derived from vertical integration from broodstock to market.

The Canadian trout industry operating in inland freshwaters was characterized by a large number of small operators. In the last decade, however, a smaller cluster of cage operators has emerged in Ontario that control 80 percent of the total trout production today. About 85 percent of the operations have capacity to produce less than 10 tonnes a year. The larger operations can produce about 1 000 tonnes a year. Unlike salmon, all trout operations are Canadian investments.

The shellfish industry is also characterized by local ownership. The industry structure is polarized between mussels and other species but represents a lower level of vertical integration than the salmon industry. About 60 percent of the mussel operations may be grouped as large with an average annual production of 1 800 tonnes; the smaller operations produce less than 40 tonnes a year.

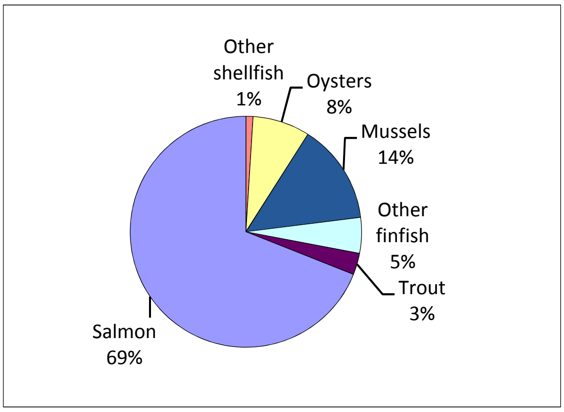

Figure 9: Canadian aquaculture production by species, 2007.
Source: FAO FishStat Plus, 2009.

Canadian aquaculture utilizes four types of culture methods: cage culture, land-based culture, off-bottom culture, and bottom culture. Cages are used by salmon growers in marine water and trout growers in freshwater. Freshwater cages are similar to the marine cages. Rainbow trout growers utilize this method in Lake Huron in Ontario and Lake Diefenbaker in Saskatchewan.

Land-based methods are used for growing trout and other finfish as well as in smolt production. The method consists of raceways, ponds or circular tanks that have a continuous flow of freshwater. The use of pumped water in these methods considerably drives up energy costs and thus greatly detracts from the competitiveness of the farm. Sufficient water availability in central and western Canada makes these regions suitable for such land-based technologies.

Bottom culture methods for shellfish farming were used extensively until the development of off-bottom culture methods in the 1970s. Oyster growers use a variety of culturing techniques that accommodate local growing conditions and local aquaculture customs. Oyster culture techniques include bottom culture, rack, and bag systems.

Off-bottom culture methods have generally replaced bottom culture methods because of the relative efficiency of the former. Mussel growers on the Atlantic and Pacific coasts use off-bottom culture. Longlines are the most common system in use on the Atlantic coast (DFO, 2003). On the Pacific coast, both longlines and raft systems are in use. Where conditions are reasonably calm and protected, rafts may be the most suitable system (British Columbia Shellfish Growers Association, 2008). Geographical coordinates for principal growing areas can be found in the FAO 2005 North American regional review (Olin, 2006).

The dominance of Canadian salmon and United States catfish and oyster production and their relative contribution to the overall North American production and value for each species are readily seen in Figures 7, 8, 10 and 11.

2.3.1 Salmon

Salmon farming began in the early 1970s when farmers focused their efforts on two Pacific salmon species, coho (*Oncorhynchus kisutch*) and chinook (*Oncorhynchus tshawytscha).* The focus soon shifted to Atlantic salmon (*Salmo salar*) which could grow faster than Pacific salmon in saltwater and withstand higher densities in cages. The successful farming of Atlantic salmon first took place in New Brunswick in 1979. However, it subsequently became more widespread in British Columbia. Atlantic salmon is not native to British Columbia; eggs of this species were first imported in British Columbia in 1984 from Scotland, the United Kingdom, and, later, juveniles were imported from Washington, the United States of America. Now, operators on both coasts produce juveniles from broodstock at their own hatcheries. As in other salmon farming regions, Canada's salmon farmers grow primarily Atlantic salmon. The share of coho and chinook salmon is small but stable at about 10 percent.

Salmon sets the production trend in Canadian aquaculture, accounting for 70 percent of the total aquaculture production and over 80 percent of the value. Production has grown at an annual average rate of 7.5 percent in the past decade, but the overall growth has been considerably constrained by environmental, regulatory and site restrictions in British Columbia, and disease outbreaks on both coasts. Canada ranks as the fourth-largest salmon producing country, holding a production share of 8 percent, but trails far behind the leading producers (Norway, 43 percent, and Chile, 35 percent). After experiencing declines for several years since 2002, production trended upward again, reaching 104 075 tonnes in 2008 (Table 3). However, this level of production was still more than 22 000 tonnes lower than the 2002 level, when Canadian salmon production peaked. The value of the total salmon production increased from US$236 million in 1987 to US$625 million in 2008. Average farmgate prices for salmon have been stable about US$5.4/kg for most of the past decade, but producers began to receive higher prices from 2005 when limited supply drove up world salmon prices.

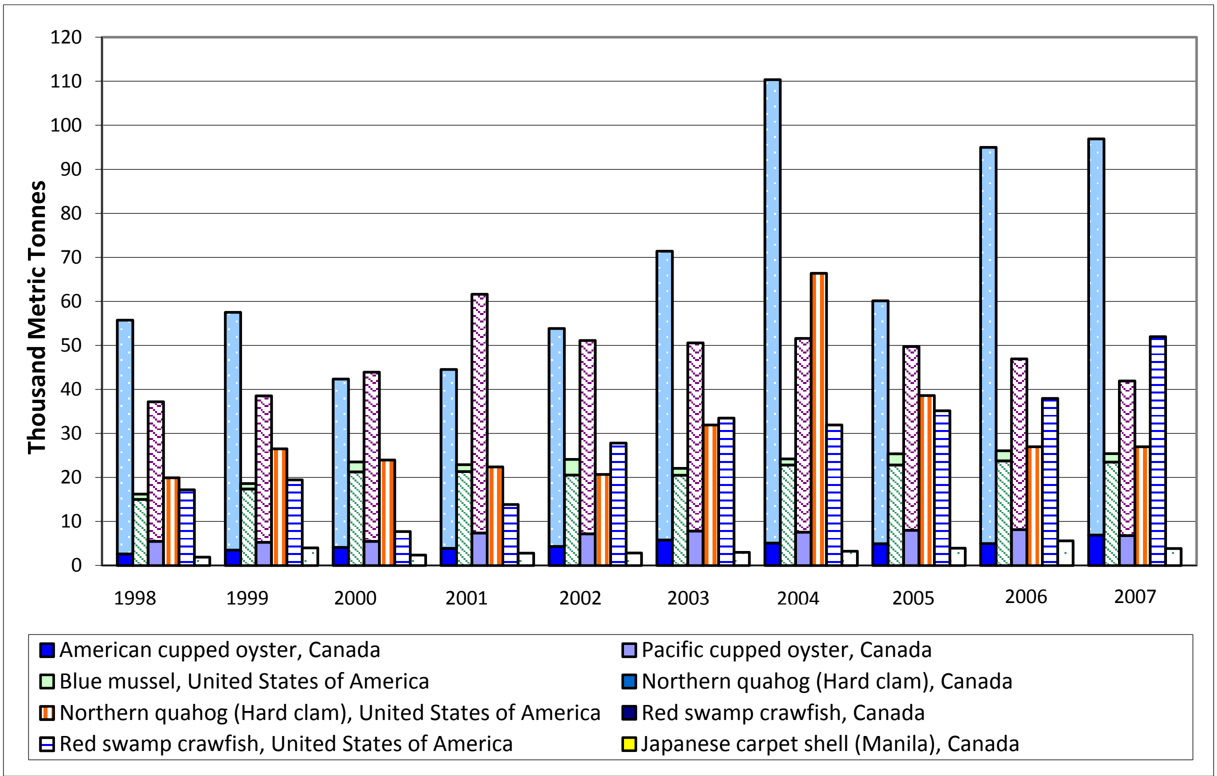

Figure 10: Invertebrate production in Canada and the United States of America, 1998–2007.
Source: FAO FishStat Plus, 2009.

Table 3: Salmon production tonnes by province/region.

Year	British Columbia	New Brunswick	Other Atlantic provinces	Total
1997	36 465	18 585	1 725	56 775
1998	42 200	14 232	2 186	58 618
1999	49 700	22 000	1 190	72 890
2000	49 700	22 000	1 190	72 890
2001	68 000	33 900	3 706	105 606
2002	84 200	38 900	3 221	126 321
2003	65 411	33 100	1 450	99 961
2004	55 646	35 000	-	90 646
2005	63 370	35 000	-	98 370
2006	70 181	35 000	12 880	118 061
2007	71 370	39 000	6 936	117 306
2008	73 265	26 000	4 810	104 075

Source: Statistics Canada, 2009c.

Most salmon production took place in British Columbia, followed by New Brunswick at 61 and 33 percent respectively. Two other Atlantic provinces, Newfoundland and Labrador, and Nova Scotia contributed the rest (Table 3). In the past two years, production in these two provinces has increased markedly as a result of new investments.

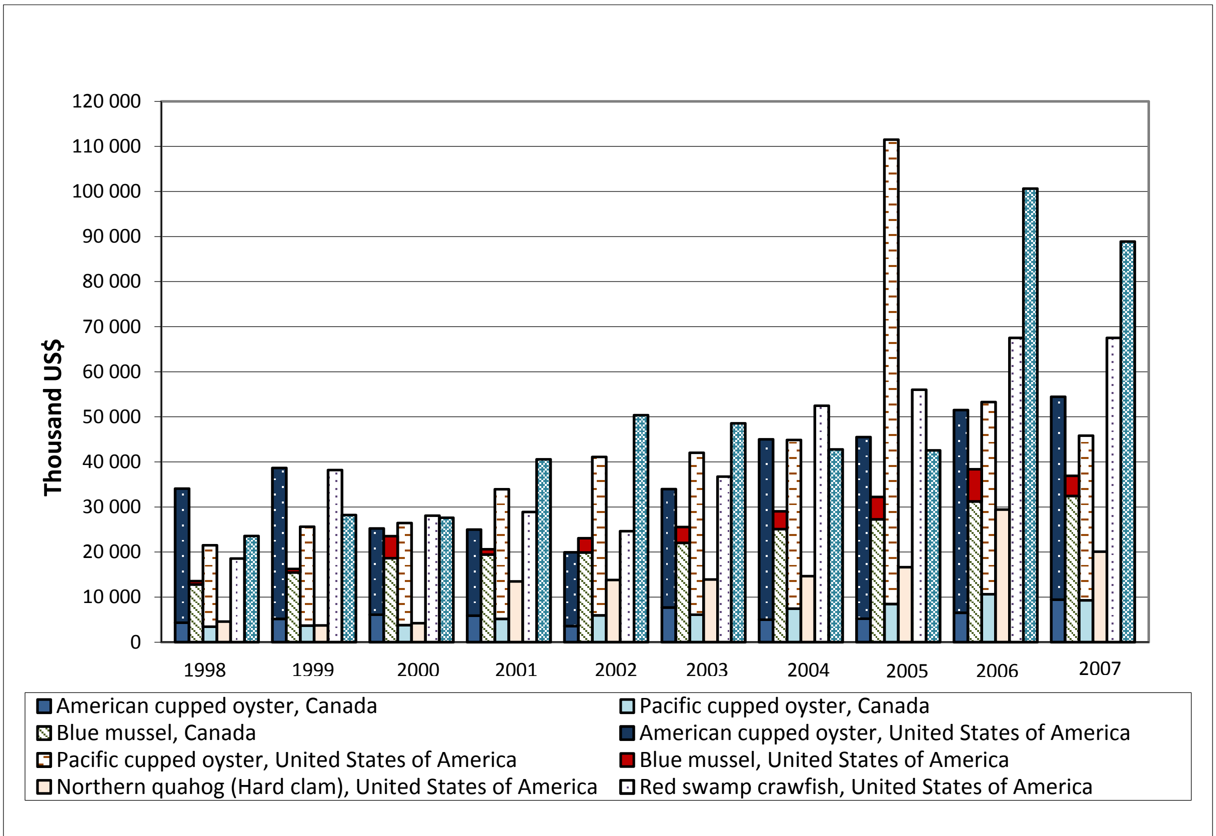

Figure 11: Invertebrate value in Canada and the United States of America by species, 1998–2007. *Source:* FAO FishStat Plus, 2009.

2.3.2 Trout

Trout farming represents the oldest finfish aquaculture in Canada. Rainbow trout (*Oncorhynchus mykiss*) farming exists all across Canada, whereas in the United States of America it is concentrated in Idaho (where 82 percent of production took place in 2007). Trout were introduced on the Atlantic coast and in central Canada between the late nineteenth and early twentieth century. Introductions were originally to enhance stock for recreational fisheries. Today, most farmed trout is produced for human consumption, although a portion of it is still allocated to recreational fisheries. Brook trout is a native species to Canada and is widely distributed in the lake and rivers systems of the country. However, the farming of brook trout is largely limited to central Canada. It is in greater demand for recreational sport fishing than for human consumption. About 65 percent of its production is allocated to enhancement and recreational fisheries, with the rest for human consumption.

Trout represented 3 percent of total Canadian production in 2007 (Figure 8). Between 1997 and 2002, trout production increased from 6 574 tonnes to 7 601 tonnes, but since then has declined. In 2008, rainbow trout and brook trout together represented 5 865 tonnes in Canada (Table 4), valued at US$35 million. In the United States of America, the trout industry generated US$63 million in 2007, up slightly from US$60 million in 1998. In Canada, trout consistently commands a high market price, which averaged US$5.4/kg for rainbow trout and US$10.07/kg for brook trout in 2007.

In the last 20 years, many small land-based trout operations in Ontario have either gone out of business or reduced their production. While Ontario's land-based trout operations contributed 50 percent of total production in 1987, they now contribute less than 20 percent. About half of total farmed rainbow trout production in Ontario comes from two large cage culture operations while the remaining cage culture production is split among 5–6 producers

Quebec's land-based trout industry contributes about 19 percent of total trout production, mainly for restocking recreational fisheries. Trout production for consumption has decreased in Quebec over the past decade but production for restocking in private recreational fisheries increased from 644 tonnes in 1997 to 858 tonnes in 2007.

Table 4: Canadian Trout production, 1997–2008, in tonnes.

	Ontario	Quebec	Others	Total
1997	3 275	1 311	1 988	6 574
1998	3 580	1 480	1 547	6 607
1999	3 850	2 139	1 539	7 528
2000	4 000	1 690	1 532	7 222
2001	4 135	1 463	1 655	7 253
2002	4 650	1 371	1 580	7 601
2003	4 200	1 092	696	5 988
2004	4 000	1 155	525	5 680
2005	4 075	1 210	482	5 767
2006	3 800	1 269	113	5 182
2007	4 100	1 401	256	5 757
2008	4 260	325	1 280	5 865

Source: Statistics Canada, 2009c.

2.3.3 Mussels

The blue mussel (*Mytilus edulis*) is the second-most important species in Canadian aquaculture in terms of production and value. It is farmed on both the Atlantic and Pacific coasts, but the Atlantic province of Prince Edward Island supplies more than 72 percent of the production.

Mussels account for 14 percent of total Canadian aquaculture production. The industry experienced significant growth between 1997 and 2001, when production increased from 11 570 tonnes to 21 566 tonnes. Production then fluctuated, reaching 23 692 tonnes in 2007 valued at US$30.9 million. Despite growing demand for mussels in the global market, the average farmgate price has been stable at about US$1.40/kg throughout the decade and, consequently, the relative value of the industry remains low.

Prince Edward Island contributed 17 234 tonnes of the total production, distantly followed by Newfoundland and Labrador (13.4 percent). Other contributing provinces included Quebec, British Columbia, Nova Scotia and New Brunswick.

2.3.4 Oysters

Oysters have been harvested in Canada for centuries, but farming began in the 1950s. Today, the majority of oysters sold in the market are supplied by aquaculture. Growers on the Atlantic coast farm the native American oyster (*Crassostrea virginica*), and growers in British Columbia farm the Pacific oyster (*Crassostrea gigas*). The Pacific oyster is non-indigenous, having been brought to British Columbia from Japan in the 1940s. The development of off-bottom growing technology in the 1980s has increased productivity, transforming oyster culture from ranching to agribusiness.

Farmers in British Columbia produce 60 percent of the oysters grown. Production grew steadily and increased from 5 631 tonnes in 1997 to 13 711 tonnes in 2007, with a corresponding increase in value from US$9.2 million to US$18 million.

2.4 United States of America production and value

The aquaculture industry in the United States of America continues to be dominated by culture of the channel catfish (*Italurus punctatus*), which represented 67 percent of finfish production valued at US$425 million in 2007 (Figure 12).

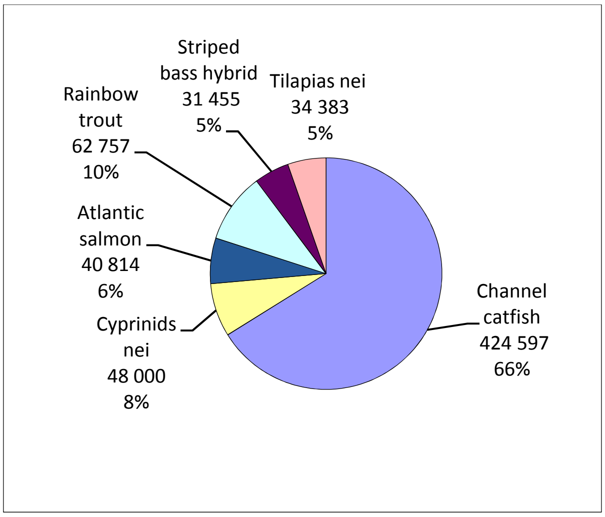

Figure 12: Value of United States of America primary fish value in 2007, US$1 000.
Source: FAO FishStat Plus, 2009.
Note: nei = not elsewhere included.

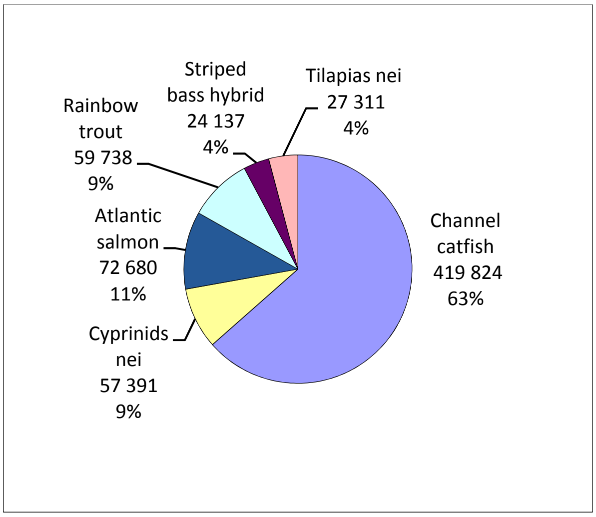

Figure 13: Value of the United States of America primary fish value in 1998, US$1 000.
Source: FAO FishStat Plus, 2009.
Note: nei = not elsewhere included.

Production peaked in 2003 and then declined to about the level of 1998 (Figure 7). Other species that combined with channel catfish comprise 90 percent of United States finfish production include rainbow trout (O*ncorhynchus mykiss*), Atlantic salmon (*Salmo salar*), tilapia (*Oreochromis* and *Tilapia* spp.), cyprinids, and hybrid striped bass (*Morone saxatilis x M. chrysops*). The volume APR for all these species ranged between 2 and –2.4 percent for the decade. The value of these species changed little over the decade with the exception of Atlantic salmon, which declined in value from US$73 million in 1998 to US$41 million in 2007 (Figures 12 and 13). United States finfish production changed very little over the decade, with an average total volume APR of –0.17 percent for the sector (Figures 14 and 15). The only finfish exhibiting much change in production levels throughout the decade was Atlantic salmon, which experienced peak production of 22 000 tonnes in 2000, only to fall to 11 000 tonnes in 2007 (Figure 16). In this instance, competition from other producers, endangered species concerns, and opposition groups all contributed to the decline. High energy costs, rising prices for feed, high labour costs, and increasing competition from other regions have all constrained growth in the finfish sector.

2.4.1 Channel Catfish

Channel catfish farming in the United States of America began in the 1960s with the first processing plant built by a partnership of growers in 1967, followed by construction of the first feed mill by a farmers cooperative in 2001. These developments provided the infrastructure to support significant industry expansion, and from 1982 to 2002 the pond area approximately doubled and production increased sixfold. In 2003, American catfish production peaked at 300 000 tonnes, representing 64 percent of total North American production worth US$384 million. Since then, production has declined although revenue has increased with production of 256 000 tonnes generating US$425 million in sales in 2007. In 2008, this decline in production reversed and there was a 2.7 percent increase in processing. Even so, the number of catfish operations in Alabama, Arkansas, Louisiana and Mississippi decreased by 75 farms in 2008 to 638, a drop of 10.5 percent from 2007. Harvest yields vary considerably but the industry average is 4 000 kg/ha (Tucker *et al*., 2004).

The number of catfish processing facilities has varied over time as processing plants have been built, closed, restarted and sold. Since a peak in 1990, the number of catfish processors has fluctuated between 25 and 28. There are four multiplant processors with capacities greater than 22 680 tonnes/year, 12 with capacities between 4 500 and 22 680 tonnes/year and 3 with capacities of 4 500 tonnes/year. These, combined with the very small facilities, comprised a total processing capacity of 306 628 tonnes of live weight catfish in 2000. The large processors are members of The Catfish Institute (TCI). As of 2006, there were 15 certified TCI processors responsible for processing more than 90 percent of the United States farm-raised catfish.

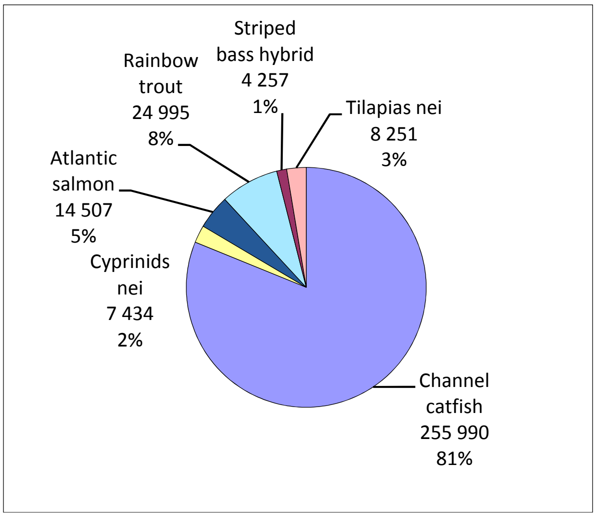

Figure 14: United States of America primary finish production volume in 1998, tonnes.
Source: FAO FishStat Plus, 2009.
Note: nei = not elsewhere included.

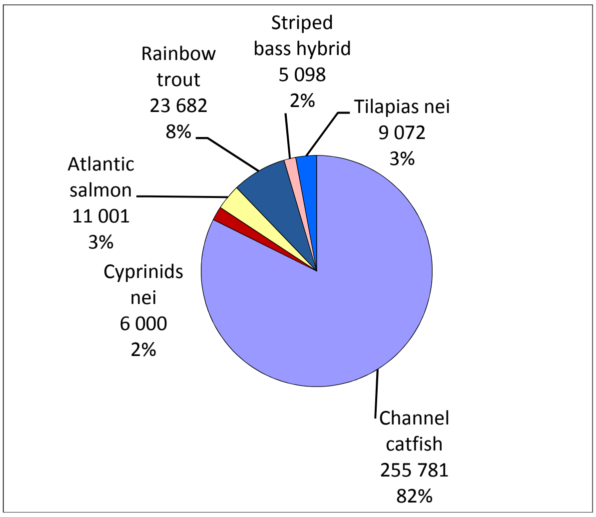

Figure 15: United States of America primary finfish production volume in 2007, tonnes.
Source: FAO FishStat Plus, 2009.
Note: nei = not elsewhere included.

The industry has been faced with a number of serious challenges during the past decade, primarily in the form of competition with *Pangasius* imports from Asia, and escalating feed prices as corn is diverted for ethanol production, resulting in increased feed costs. Imports of frozen *Pangasius* fillets increased 21.1 percent in 2008 and now account for 49.8 percent of fillet products sold. Catfish feed prices rose 34.2 percent between 2007 and 2008, rising from US$289/tonne to US$388/tonne.

Since 2002, the catfish industry has seen a 25 percent decrease in water surface area being farmed, and the number of farms has dropped 31 percent by 381 operations. Declines by primary producing states and value can be seen in Table 5. The average price of catfish was US$1.69/kg in 2007, which rose slightly to US$1.71/kg in 2008.

Table 5: Declines in catfish farm surface area and production in the United States of America.

State	Lost production Area (ha)	Decline (%)	Production 2002 (US$1 000)	Production 2008 (US$1 000)
Alabama	2 226	22.5	76 045	93 254
Arkansas	5 261	36.1	56 380	64 263
Louisiana	2 954	54.9	15 812	11 883
Mississippi	13 152	28.8	243 226	206 288

Source: USDA NASS, 2009.

2.4.2 *Shellfish production*

The shellfish sector has three major producing regions in the United States of America: one centred in the northeast, a second on the Pacific coast (primarily in the Pacific Northwest), and the third encompassing the Gulf of Mexico. Production varies annually, but the three regions each account for about one-third of United States oyster production.

Oyster production evolved in North America from localized fisheries established by indigenous people and European settlers. These early growers managed fisheries with transplantation of shellstock from one region to another, and finally into hatchery-based field growout where hatchery seed are outplanted into coastal embayments using a variety of growout techniques. These include oyster seed on cultch grown on the bottom, and on stakes, tubes and lines. Cultchless seed are typically marketed as a half-shell product following growout in bags on the bottom, in floating bags, or on racks. Production is highly variable and is dependent on the culture system, temperature and productivity of growing waters.

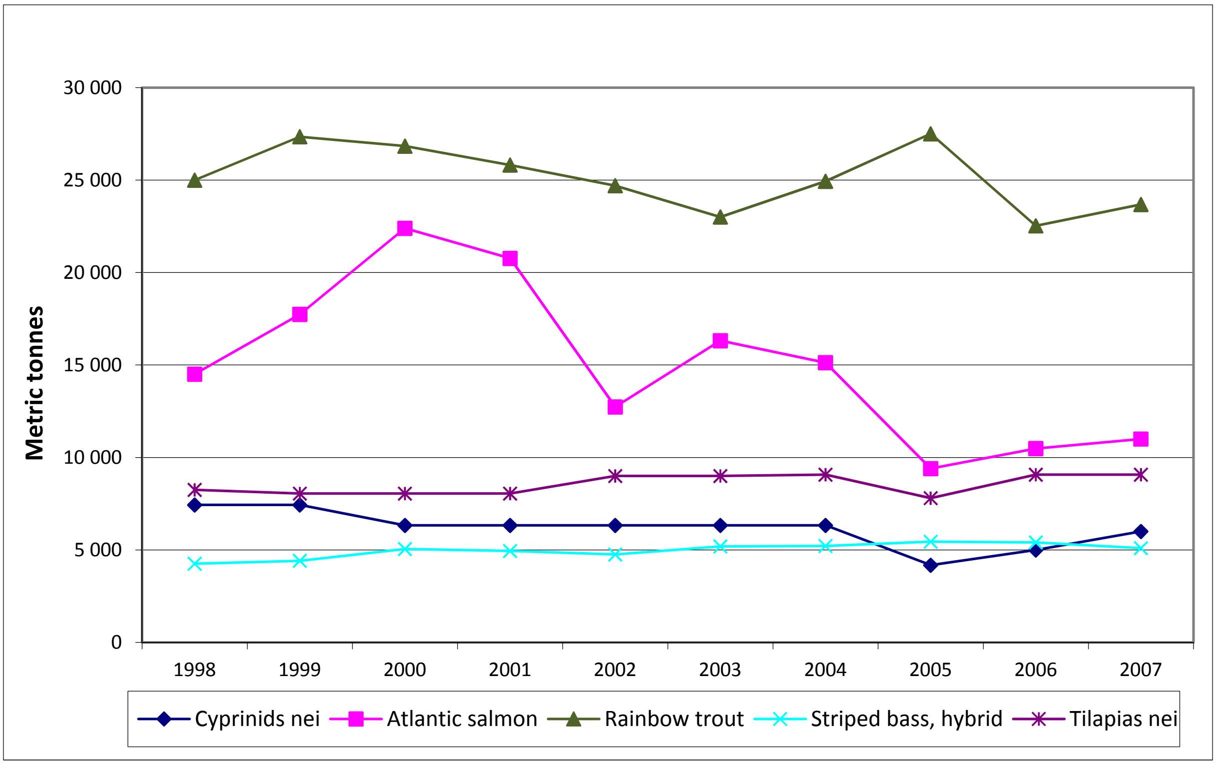

Figure 16: Value of United States of America finfish volume production for the period 1998–2007, tonnes.
Source: FAO FishStat Plus, 2009.
Note: nei = not elsewhere included.

The primary species cultured in the northeast and Gulf of Mexico region is the native American cupped oyster (*Crassostrea virginica*). The Pacific industry relies largely on the non-indigenous Pacific cupped oyster (*Crassostrea gigas*), originally imported from Japan in the early 1900s. Early importations of seed and shellstock to the Pacific resulted in the inadvertent introductions of predatory oyster drills from Japanese waters and the eastern Atlantic.

The United States shellfish industry has fared better than the finfish sector in the last decade and the importance of the United States contribution of oysters, crawfish, hard clams and Manila clams to North American production is evident (Figure 10). Overall, production of invertebrates in the United States of America rose from 125 000 tonnes to 210 000 tonnes for an APR of 7.8 percent between 1998 and 2007. Production of Manila clams increased dramatically over the decade, rising in value from US$4.6 million to just over US$20 million. Significant increases are also noted for hard clams, with production increasing from 20 000 tonnes to 27 000 tonnes, for an APR of 3.4 percent. In 2007, production of red swamp crawfish, and American cupped oysters increased at APRs of 13 percent, and 6 percent to 52 000 tonnes and 90 000 tonnes, worth US$89 million and US$49 million, respectively (Figures 17 and 18). Production of American cupped oysters and hard clams both peaked in 2004 at 105 000 tonnes and 66 000 tonnes, valued at US$40 million and US$52 million, respectively. There was a significant decline in American oyster production in 2005 in the aftermath of hurricane Katrina. Production numbers and value of the Pacific oyster in 2007 of 42 000 tonnes worth US$45.8 million are probably under-reported as industry estimates are almost double that (B. Dewey, personal communication, 2010).

While production of all species of shellfish increased across the board (Figure 18), as a share of the total production, American oysters remained at 42 percent, red swamp crawfish rose from 14 to 25 percent, and the Pacific oyster dropped from 25 to 17 percent (Figures 19 and 20). The value of production of red swamp crawfish increased from 25 to 33 percent of the total and hard clams increased from 19 to 26 percent (Figures 21 and 22).

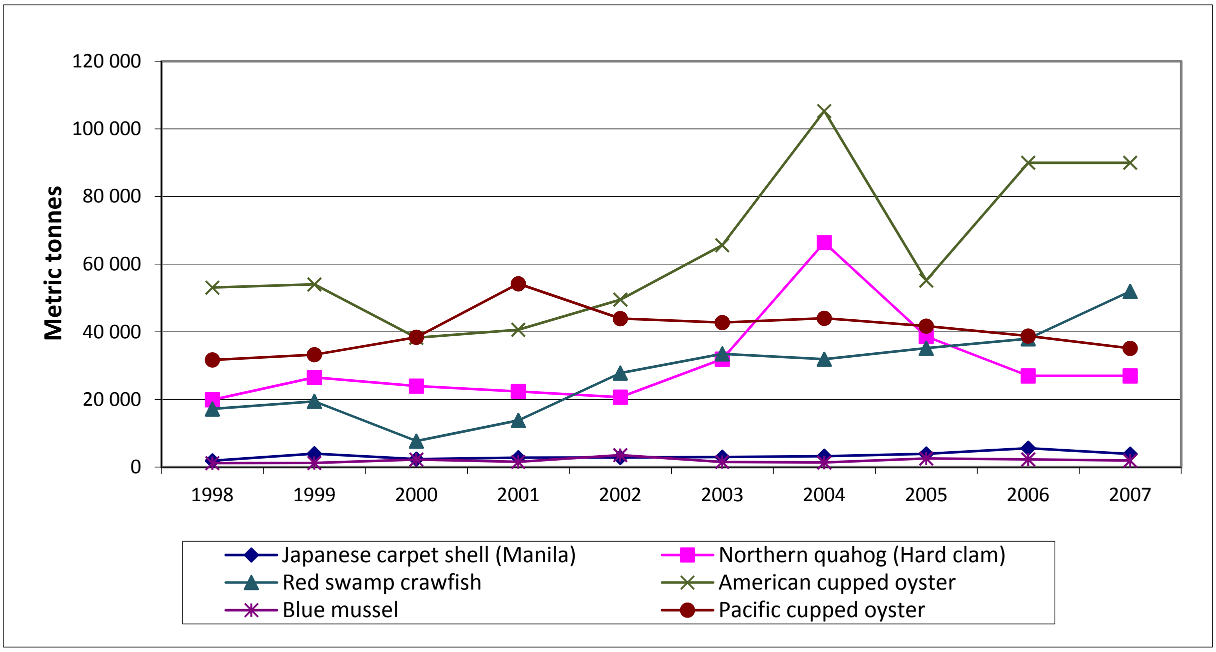

Figure 17: United States of America invertebrate production for the period 1998–2007, tonnes.
Source: FAO FishStat Plus, 2009.

Continued increases in shellfish production in the United States of America will require concerted efforts to maintain and improve coastal water quality. Many once-productive shellfish-growing regions have experienced harvest restrictions or closures as a result of declining water quality. Poor water quality coupled with significant disease losses, probably associated with water quality, continue to affect the sector. There is a strong desire to see improvements in water quality and the Clean Water Act provides a legal mandate to do so. Shellfish aquaculture could expand significantly as new growing areas are identified through improvements in water quality or as new deep-water culture techniques are adopted.

One encouraging new species on the shellfish scene in the Pacific Northwest is the geoduck clam (*Panopea abrupta*). Commanding high prices as a live product throughout Asia, this clam is being grown intertidally in the State of Washington. Although the industry is still small, it has been very successful. Live geoduck clams are well received in the marketplace but their culture has generated considerable opposition from groups concerned about environmental impacts owing to the visibility of intertidal culture gear and disruption of sediments during harvest.

In the United States of America, many coastal regions are heavily developed or protected, and there is increasing competition for access to coastal areas for aquaculture. This limited coastal access and finite freshwater resources inland are significant constraints to further industry development of any magnitude. While there are 133 312 km of coastline, there are few areas with protected waters and this dictates that any significant growth in aquaculture production will probably occur in offshore areas.

2.5 Salient issues and success stories

In North America, the Canadian industry experienced considerable growth, expanding by 54 percent, while the industry in the United States of America expanded by only 17 percent from 1998 to 2007. This expansion in Canada resulted from development of industry sectors raising new species, principally Atlantic salmon and blue mussels.

A strategic action planning exercise coordinated by the DFO shows that, with immediate action, Canadian aquaculture production could increase by about 8 percent to 214 000 tonnes by 2013, generating a farmgate value of US$1.2 billion. By 2020, production could exceed 308 000 tonnes and generate a total farmgate value in excess of US$1.6 billion.

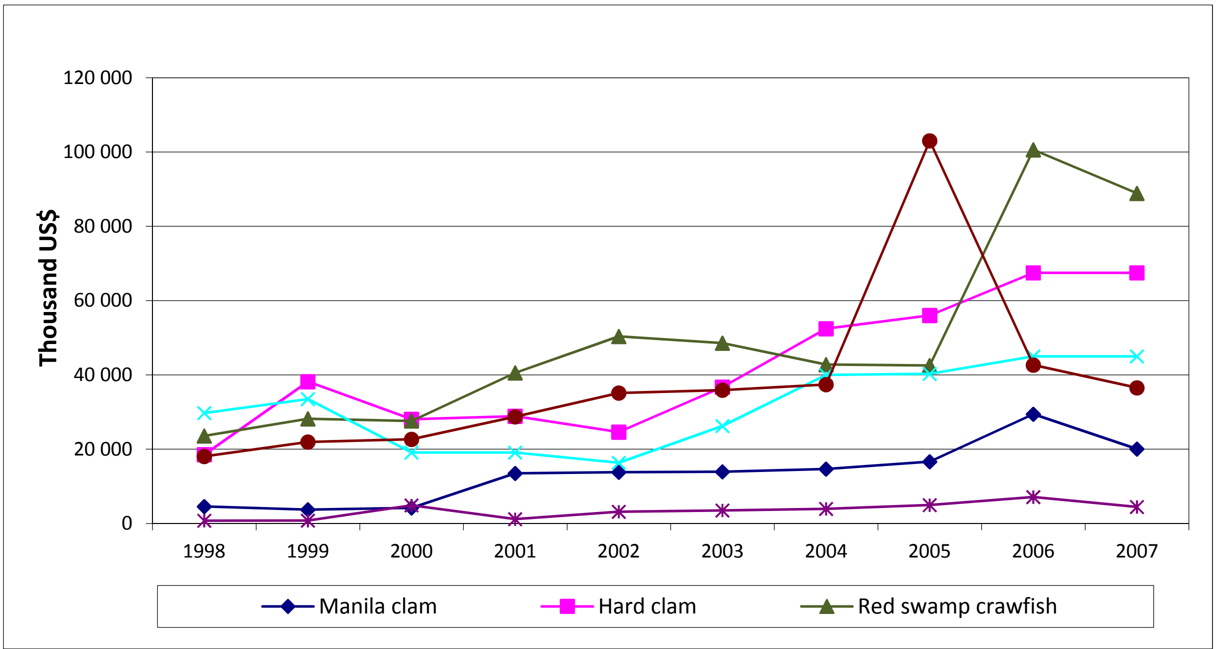

Figure 18: United States of America invertebrate value for the period 1998–2007, US$1 000.
Source: FAO FishStat Plus, 2009.

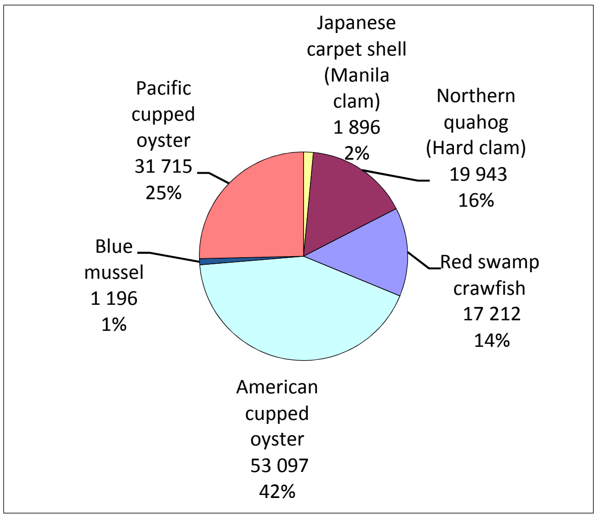

Figure 19: United States of America invertebrate production volume in 1998, tonnes.
Source: FAO FishStat Plus, 2009.

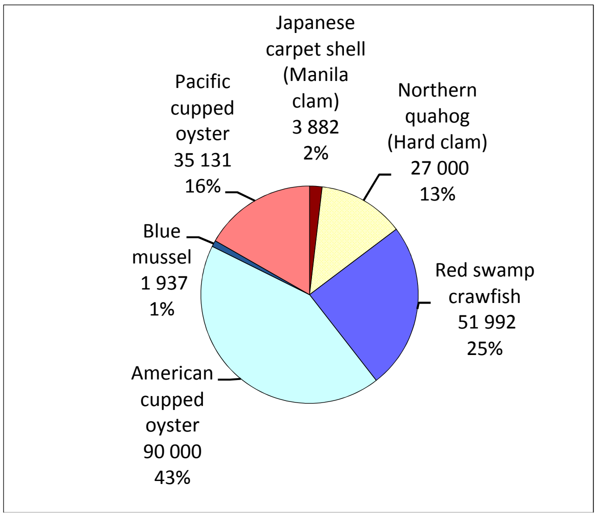

Figure 20: United States of America invertebrate production volume in 2007, tonnes.
Source: FAO FishStat Plus, 2009.

There is significant potential to increase commercial aquaculture production in the United States of America using today's technology (NOAA, 2007). Preliminary production estimates by the NOAA indicate that domestic aquaculture production of all species could increase from about 0.5 million tonnes annually to 1.5 million tonnes per year by 2025. The additional production could include 760 000 tonnes from finfish aquaculture, 47 000 tonnes from crustacean production, and 245 000 tonnes from mollusc production. Of the 760 000 tonnes of finfish aquaculture, 590 000 tonnes could come from marine finfish aquaculture (Nash, 2004).

2.6 The way forward

In 2006, the NOAA Aquaculture Program drafted a ten-year plan for aquaculture to identify the agency's vision and plans for development of marine aquaculture in the United States of America (NOAA, 2007). The plan was adopted by the NOAA in 2007 to guide a broad, national initiative for marine aquaculture based on the following four goals:

- a comprehensive regulatory program for marine aquaculture;
- development of commercial marine aquaculture and replenishment of wild stocks;
- public understanding of marine aquaculture;
- increased collaboration and cooperation with international partners.

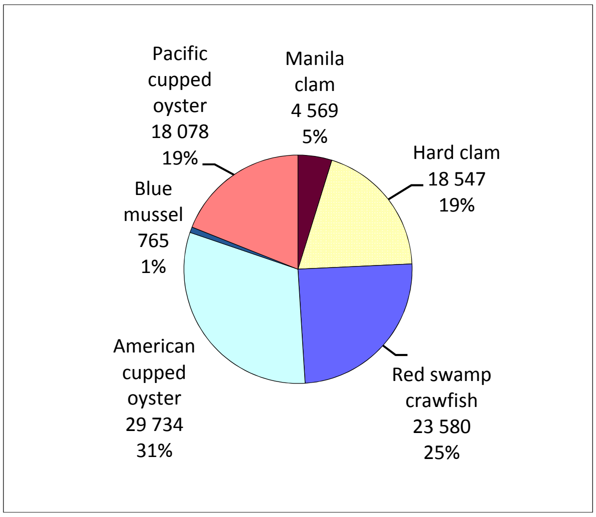

Figure 21: United States of America invertebrate production value in 1998, US$1 000.
Source: FAO FishStat Plus, 2009.

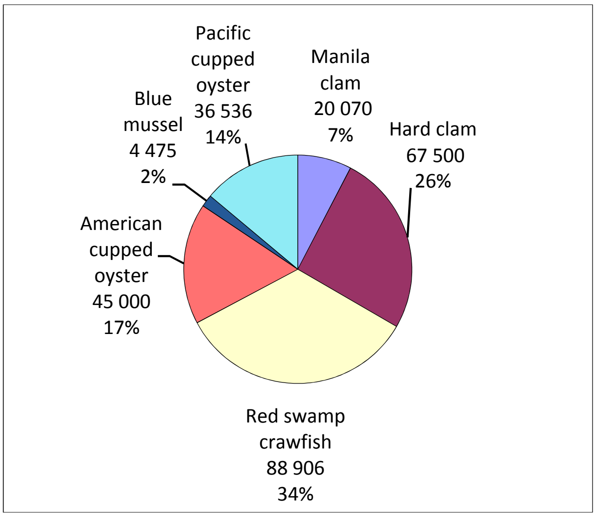

Figure 22: United States of America invertebrate production value in 2007, US$1 000.
Source: FAO FishStat Plus, 2009.

In 2008, the National Institute of Standards and Technology and the NOAA convened a workshop titled Overcoming Technical Barriers to the Sustainable Development of Competitive Marine Aquaculture in the United States of America. The purpose of the workshop was to identify areas for expansion of the aquaculture industry and technological impediments to doing so. Four major areas of opportunity were identified, along with the technology necessary to capitalize on them, as follows:

- shellfish aquaculture;
- cage culture of marine finfish;
- land-based culture of marine finfish;
- biofloc-based culture of marine shrimp.

Of these four priorities, culture of marine finfish has the greatest potential to contribute significantly to future increases in aquaculture production. In order to capitalize on the marine finfish sector for which Atlantic salmon has provided such a good model, there is a need to identify new species with the potential for domestication and to overcome activist opposition to net-pen culture in marine waters.

There is considerable interest in the United States of America in developing culture technology for a number of new species, including southern flounder, red drum, Atlantic cod, halibut, wolffish, yellowtail flounder, witch flounder, yellowtail, cobia, yellowfin tuna and pompano. In particular, cobia is viewed as a leading candidate for significant expansion of ocean net-pen culture with the development of fingerling production capacity and extraordinary growth rates of up to 6 kg in one year. One pilot-scale facility is now raising cobia near Puerto Rico, and two facilities are using ocean net pens in Hawaiian waters raising Hawaiian yellowtail and moi. The University of New Hampshire's Atlantic Marine Aquaculture Centre has piloted culture of Atlantic cod, haddock, halibut and flounder. There is also a project supported by the Hubbs Sea World Research Institute seeking permitting to develop an ocean cage production operation in southern California raising Pacific yellowtail, striped bass and white seabass.

Similarly, in Canada, a number of marine and freshwater finfish species are farmed at a low level, with some at the developmental stage and some at a point where there is a need for market development. They hold great potential for diversification of the sector and this diversification is crucial for significant industry expansion. They include, among others, Atlantic cod, Atlantic halibut, haddock, tilapia, sturgeon, and Arctic char (Table 6). A small number of producers specialize in these species but markets for these products are undeveloped and production techniques at higher volumes have not emerged. Their combined production has fluctuated over time with no clear trend. In 2006, their production fell 27 percent to 9 171 tonnes from an all-time high of 12 621 tonnes in 2005.

Table 6: Different species farmed in Canada.

Status	Finfish Marine	Finfish Freshwater	Shellfish	Plants
Commercial	Atlantic salmon Coho salmon Chinook salmon Steelhead	Rainbow trout Brook trout	Blue mussels Oysters Clams Scallops Geoduck	
Developmental	Atlantic cod Atlantic halibut Haddock Atlantic wolfish Eel Sablefish	Tilapia Sturgeon Arctic char Walleye Yellow perch Grass carp American Eel Brown trout Tiger trout	Quahog Sea urchin Sea cucumber Soft shell clams Bay scallops	Kelp Seaweed

Source: DFO, 2009.

The lack of a regulatory structure for net-pen farming in coastal waters of the United States of America has long been recognized as a serious impediment to anyone seeking a lease or trying to secure financing for an ocean-based farm. This need is recognized by federal agencies and is a primary goal in the NOAA's ten-year plan. Recently, however, the Gulf of Mexico Fishery Management Council has developed a fishery management plan (FMP) for regulating offshore aquaculture in the Gulf of Mexico. In turn, the NOAA has recently announced its intention of developing a comprehensive national policy for sustainable marine aquaculture, providing a framework for addressing aquaculture activity in federal waters. When this occurs, and presuming lease terms and the regulatory regime are reasonable from an economic and biological perspective, it should open the door for investment and industry development. The next step would then be to develop and expand marine finfish hatchery capacity to supply this nascent industry.

3. RESOURCES, SERVICES AND TECHNOLOGIES

3.1 Status and trends

3.1.1 Land and water

North America is bordered on the east and west by the Atlantic Ocean and the Pacific Ocean, respectively. Canada shares its northern border with the Arctic Ocean and to the south with the United States of America. The United States of America shares its southern border with the Gulf of Mexico and the country of Mexico. The Great Lakes are located on the shared border between Canada and the United States of America.

Canada is the second-largest country in the world, comprising almost 10 million km^2. The United States of America is slightly smaller at 9.6 million km^2, for a land area of 9 158 960 km^2 and a water surface area of 470 131 km^2, with a coastline of 19 924 km (Central Intelligence Agency, 2009). The Canadian coastline is much longer at 202 080 km, and the country's total land area is 9 984 670 km^2 with a water surface area of 891 163 km^2. Canada's long coastline of 243 042 km represents 25 percent of the world's total. Canada's 3 000 000 lakes and rivers also contain 16 percent of the world's freshwater; and combined, these natural resources provide an abundance of potentially suitable sites for supporting both marine and freshwater aquaculture.

Unlike Canada, much of the United States coastline is well developed and competition for space in the coastal and nearshore environment creates user-group conflicts. This is recognized as a challenge and a number of agencies and NGOs are supporting marine spatial planning as a tool to reduce these conflicts. Further restrictions on access to coastal and nearshore waters result from creation of marine sanctuaries. In addition to the difficulty in accessing coastal land and waters in the United States of America, there are very few areas with unallocated water to support significant, new, land-based freshwater aquaculture facilities. It is for these reasons that the United States industry and government agencies are looking towards expansion of the sector in nearshore and offshore waters.

There are regional centres of production in Canada but aquaculture occurs in all ten of its provinces and the Yukon Territory. Regional centres are found in the marine environment in the Province of British Columbia on the Pacific coast and in the Provinces of New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland and Labrador on the Atlantic coast. Marine aquaculture in these two regions accounts for more than 90 percent of total production (FAO FishStat Plus, 2009). Freshwater aquaculture is unevenly distributed between land-based and lake-based culture, with the former concentrated in central Canada.

The National Agricultural Statistics Service of the United States Department of Agriculture (USDA) conducted the second census of United States aquaculture in 2005. There were 4 309 aquaculture farms in 2005, with 281 new farms having started operations in the preceding five years. Despite this overall increase, farms producing foodfish fell to 1 847, a decrease of 321 since 1998, which reflects the increasing costs and competition facing the foodfish sector. In contrast, farming of shellfish and sport fish increased. Between 1998 and 2005, 88 new crustacean farms brought the total to 925, the number of mollusc farms almost doubled from 535 to 980, and farms producing sport fish for recreational anglers increased from 204 to 303. Production is centred in the southeast, where the channel catfish industry is located, and where Florida is a leading producer of ornamental fish. States with the highest number of farms include Louisiana (873), Mississippi (403), Alabama (215), Arkansas (211), and Florida (359).

Almost 50 percent of United States farms use fresh groundwater for production, and this number rose slightly from 1 925 to 2 018 between 1998 and 2005. On-farm surface water was also used as a source of water by 1 314 farms in 2005, down slightly from 1 454 in 1998. Saltwater was used by 1 200 farms in 2005, up from 815 in 1998, reflecting the growth in the shellfish sector during this time.

Freshwater aquaculture on private lands involved 3 127 farms using 147 945 ha in 2005, while leased land used in freshwater production in 2005 covered 52 366 ha, or 24 percent of the freshwater surface area under production. Leased land is primarily in Louisiana, Minnesota, Mississippi and Arkansas, which combined account for 94 percent of leased freshwater production. Data on primary states involved in freshwater production and production trends between 1998 and 2005 can be seen in Table 7.

Table 7: Freshwater farming in the United States of America – area and primary states involved, 1998–2005.

Area	2005		1998	
	Farms	Hectares	Farms	Hectares
United States of America	3 127	147 945	3 252	129 800
Alabama	213	10 260	259	8 861
Arkansas	211	24 741	222	22 628
Louisiana	738	42 350	681	27 787
Minnesota	77	16 602	36	14 669
Mississippi	403	41 643	419	43 785

Source: USDA, 1998, 2005.

In 2005, 1 203 farms in the United States of America used 132 534 ha for saltwater aquaculture production, up significantly from 779 farms using 107 306 ha in 1998. In similar fashion, the number of leased saltwater farms increased from 478 in 1998 to 779 in 2005 and the area increased from 28 471 acres (11 522 ha) to 107 302 ha during the same period. The primary states involved can be seen in Table 8.

Table 8: Saltwater farming in the United States of America – area and primary states involved, 1998–2005.

Area	2005		1998	
	Farms	Hectares	Farms	Hectares
United States of America	1 203	132 534	779	107 306
California	22	2 429	16	800
Connecticut	27	25 480	15	14 721
Louisiana	135	87 322	n/a	n/a
Massachusetts	140	448	96	210
New Jersey	70	1 807	14	567
Oregon	21	981	9	793
Texas	19	984	10	699
Virginia	122	5 023	238	1 740
Washington	175	5 370	66	4 715

Source: USDA, 1998, 2005.

Culture practices vary widely depending on the species being raised, but the vast majority of finfish culture takes place in embankment ponds for catfish, raceways for trout and ocean net pens for Atlantic salmon. In the United States of America, 54 percent of farms use ponds and 10 percent utilize flow-through raceways or tanks. Recirculating systems are used by 10 percent of farms, primarily raising tilapia, sturgeon and hybrid striped bass. These recirculating systems have significantly higher production costs and products are often sold at a premium price into live fish markets. Cages in ponds or larger waterbodies are used by only 4 percent of United States growers.

Shellfish aquaculture producers employ a wide variety of gear, but oysters are predominantly grown on cultch both subtidally and in the intertidal zone, or in plastic mesh bags on intertidal mudflats. Clams are grown in plastic mesh bags or seeded in intertidal areas, while mussels are seeded on longlines.

3.1.2 Seed

The North American aquaculture industry has better access to seed supplies than a decade ago. In 2004, Canada issued more than 200 licences for commercial hatchery operations, only 14 of which were for shellfish. The major salmon companies have their own broodstock and land-based smolt production facilities. Some smaller farms may operate hatcheries, but in most cases they rely on other hatcheries for supplies. The industry does not import smolts or broodstock but it occasionally imports eggs from Iceland (British Columbia Salmon Farmer Association, 2009). The trout industry relies on egg imports from the United States of America but it also purchase fingerlings from local hatcheries. Smaller trout operators sometimes encounter difficulties in obtaining a timely supply of fingerlings. Access to wild stock for aquaculture broodstock is an emerging policy issue in British Columbia, but for minor species the DFO provides access to wild stocks for broodstock by scientific licence to assist industry development (GSGislason and Associates Ltd, 2004). On the Atlantic coast, salmon hatcheries have developed their own broodstock and no longer rely on wild stocks.

United States catfish growers rely on domestic hatchery production for eggs, fry and fingerlings. Most of the larger operations have their own hatcheries and supply fry to smaller producers. There are 184 farms that supply catfish fry and fingerlings and 39 providing eggs to the industry. Tilapia hatcheries are operated by 28 farms that provide fry and fingerlings to the industry, which primarily produces and markets fish into lucrative live markets. With the recent downturn in the catfish industry, some hatcheries have curtailed or ceased operations until feed prices and markets stabilize and growers have confidence in their ability to produce a profitable crop. Trout eggs are produced by 24 farms, and 111 operations produce fry and fingerlings.

Canadian mussel growers obtain seed from their own collection efforts although a small proportion of them (about 5 percent in Prince Edward Island) buy seed from fishers (DFO, 2003). Many growers also opt to obtain a licence to collect seed on their own lease. They can attach the seed collectors to the backline, which usually gives a relatively uniform size distribution of seed. The collectors can be made from all sorts of materials such as old rope, Italian socking material, nylon bags and Vexar mesh. There are reports that a newer fuzz rope and artificial seaweed that have been on the market for about seven years greatly enhance seed collection. Whatever the material used, the collectors are usually hung on the lines just before the spat are expected to settle in the summer.

A recent development has been the production of triploid mussel seed. They do not spawn so it is possible to ship them all year. Triploids continue to grow through the winter, although at a reduced rate, and so they have a better growing condition compared with diploids. They appear to attach more firmly to the culture ropes reducing stock losses. Triploids are also reputed to have smoother, less grainy meat (BCSGA, 2008). A significant proportion of other shellfish seed are imported, and the growers have reliable access to import markets.

American oyster growers on the Pacific coast rely primarily on hatchery production of diploid and triploid seed, and there are 14 farms in operation producing larvae and seed. Some coastal embayments on the Pacific coast experience natural sets of the introduced Pacific oyster, but these are unpredictable and have been infrequent in recent years. Recently, the industry on the Pacific coast has experienced significant mortality of hatchery seed as a result of bacterial outbreaks of *Vibrio tubiashii*, which can cause catastrophic mortality in larval culture. Over a three-year period, hatchery operators have managed to identify protocols that have enabled them to resume production, primarily through management of pH levels and biosecurity protocols. This is one case where climate change and resulting ocean acidification could be optimizing conditions for proliferation of pathogenic bacteria while compromising resistance in affected oysters.

Oyster growers in the northeast of the United States of America and in the Gulf of Mexico region producing the native American oyster rely on a combination of natural set and hatchery production, and there are 27 hatcheries producing larvae and seed. Farmers of hard clams rely on hatcheries and natural sets, and there are 46 farms that produce hard clam larvae and seed. Manila clam producers rely almost entirely on hatchery seed, and there are seven operations that produce larvae and seed.

3.1.3. Biotechnology

Aquatic biotechnology involves combining science and technology applied to aquatic organisms to develop and apply innovative tools to conserve aquatic ecosystems, enhance production, protect species at risk, and detect and treat disease in fish. Genomic research includes efforts to understand the function and structure of genes.

The industry greatly benefits from aquaculture biotechnology and genomics research. Canada and the United States of America both have advanced research programmes and are known internationally as having some of the world's safest and most effective science-based regulatory systems for biotechnology. Products are subject to rigorous standards and scientific risk assessment for potential health and environmental impact under the Canadian Environmental Protection Act. The United States Food and Drug Administration (FDA) has higher regulatory standards for transgenic fish than for other foods and has authority through the United States of America Food and Drug Act. Applicants to commercialize a transgenic organism must prove efficacy claims and meet safety criteria in the areas of human consumption, animal welfare, and environmental safety. Environmental risk assessment at the FDA is governed by the National Environmental Policy Act (NEPA), and the regulations implementing NEPA have been adopted by the Council on Environmental Quality and by the FDA: "FDA considers harm to the environment to include not only toxicity to environmental organisms but also environmental effects other than toxicity, such as lasting effects on ecological community dynamics."

About two dozen Canadian companies operate in the field of aquatic biotechnology. Aquaculture is the main sector of application of aquatic biotechnology and comprises development of genetically modified organisms (GMOs), mainly salmon (coho salmon, Atlantic salmon). It is important to note, however, that there is currently no production of genetically modified salmon for human consumption in either Canada or the United States of America. Studies are also being conducted to develop vaccines, to improve phenotypic traits through artificial selection using conventional genetic approaches, to improve reproductive technologies, to develop a cleaner industry, and to develop diagnostic tools for fish diseases (Heimstra and Davidson, 2009). In aquatic biotechnology research in 2005, Canada ranked second both for the expected impact of its scientific papers and its specialization in the field. The areas of major importance for Canada in this field are aquaculture, in particular enhancement of fish performance, molecular ecology to study wild populations, and biomonitoring of aquatic ecosystems (Campbell *et al*., 2005).

Unlike in other areas of biotechnology in Canada, the field of aquatic biotechnology has a strong presence of government departments along with universities. Leading federal departments include the DFO and Environment Canada, and leading universities include the University of Waterloo, University of Guelph, University of British Columbia and University of Laval. In 2007–08, the DFO allocated US$3.6 million for developing and adopting leading-edge genomics and biotechnology tools (DFO, 2008a).

The DFO and industry collaborate in DNA analysis that will help to improve broodstock. In Pacific and Atlantic salmon aquaculture, DNA analysis is used to monitor loss in genetic diversity in aquaculture strains and to distinguish wild from cultured salmon found in the same waterway. Similar analysis is used in the United States of America in catfish, trout, sturgeon, striped bass and tilapia to maintain genetic diversity in cultured populations. Stock enhancement programmes for marine finfish, such as white seabass, also use genetic markers to preserve genetic variability and ensure an effective breeding population. Biotechnology is able to increase fish and shellfish growth, improve their reproductive potential, strengthen disease resistance, and increase their ability to endure adverse environmental conditions. Additional sets of genetic markers are being developed in the DFO and in large genome projects for Atlantic salmon and halibut that will enable identification of fish carrying superior quantitative trait loci for genes controlling traits such as disease resistance and rapid growth.

The DFO is using molecular genetics to produce larger shellfish at a faster rate and with more reliable quality. In the United States of America, a molluscan broodstock programme (MBP) has been under way at Oregon State University's Hatfield Marine Science Center since 1996. After one generation of selection, this MBP has achieved an average increase in yield per generation of 9.5 percent (whole live weight) compared with yields of families from unselected broodstock (Langdon *et al*., 2003). The west coast oyster industry has made extensive use of MBP broodstock and plans to continue this in the future. The MBP is currently focusing on selecting for yield – the sum effect of both survival and growth. Future characteristics to be selected include larval survival, shell colour and shape, and mantle colour. The MBP is funded as a special project through the USDA Cooperative State Research, Education and Extension Service (CSREES).

As noted above, no transgenic fish have been approved for commercial use, consumption or release in North America. However, Aquabounty Technologies has developed a transgenic AquAdvantage™ Atlantic salmon with twice the growth rate of other salmon that has been under regulatory review by the FDA for more than a decade. The review process used by the FDA on the AquAdvantage™ salmon involved the Veterinary Medicine Advisory Committee (VMAC), a body of scientists both in and outside of government who advise the Commissioner of Food and Drugs in discharging responsibilities as they relate to helping to ensure public and animal health. The VMAC published a 180-page report in 2010 summarizing its scientific review and the basic conclusions were that the AquAdvantage™ salmon was safe, was nutritionally comparable with other Atlantic salmon, and was not a threat to the environment.

The DFO has developed transgenic fish in contained facilities only for use in environmental and human health risk assessments in support of regulatory responsibilities. Its scientists are conducting risk assessment research on genetically engineered fish in secure, contained, land-based facilities. Risk assessment research is being conducted on salmon that have been genetically engineered for enhancement of certain production traits such as growth rate and cold tolerance. Because genetically engineered fish could be developed for aquaculture and could enter the food chain or interact with wild species in the environment, intensive research is required to enhance the ability to assess potential risks to humans or other aquatic species and their habitat.

3.1.4 Feed

Finfish producers in North America rely on domestic production of formulated feeds and the primary industry sectors supplied are Atlantic salmon in Canada and the channel catfish in the United States of America. Imports are negligible except for a small amount of speciality feeds imported from Europe. In Canada, about 90 percent of the total feed is supplied to the salmon industry, 6–9 percent to trout and the rest to other finfish. There is little variation in this pattern between the Atlantic and Pacific coasts.

Eight transnational and Canadian feed companies now operate in Canada, with mergers and consolidation over the past few years having reduced the number. According to a 2007 industry estimate, those companies together produced more than 200 000 tonnes of feed. Of this total, 56 percent was produced in British Columbia.

In the United States of America, all catfish feeds are domestically produced. Catfish growers are increasingly concerned about escalating feed prices as higher prices for soybeans and corn have driven prices up from an average of US$216/tonne in 1998 to US$289/tonne in 2007. In 2008, 92 percent of catfish feed was delivered to four southern states in the heart of the Delta Region (Table 9). Prices are expected to drop somewhat in the future as demand for corn for bioethanol fuels lessens and prices drop.

Over the years, the feed conversion ratio (FCR) in salmon net-pen culture has improved as a result of improved feed quality, greater feeding efficiency and the introduction of automatic feeders. Technological innovation has been a driving force for Canadian feed producers. They have implemented the use of extrusion technology, which produces superior-quality pellets compared with the steam pelleting process used previously. The manufacturing process is being reviewed to reduce overall energy consumption per unit of production including product transport, grinding, mixing, extrusion and drying. Another area of innovation includes feed efficiency, which focuses on utilizing less fishmeal and fish oil and, thereby, reducing the environmental impacts of feed use.

Table 9: Catfish feed utilization in the United States of America 2008, tonnes.

Area	2004	2008
Alabama	184 838	173 983
Arkansas	106 708	80 856
Louisiana	35 161	15 362
Mississippi	320 085	311 768
Other states	27 914	43 636

Source: USDA, 2009.

Fishmeal and fish oil are important feed ingredients for many cultured aquatic species, and they are also used in land-based animal agriculture. While the fisheries that supply fishmeal and fish oil have been harvested sustainably for many decades, there is general agreement that while commercial fisheries can supply today's need for fishmeal, there will be insufficient supplies to support continued growth of the aquaculture industry using fishmeal and fish oil at current levels. This consideration and the relatively high costs for these limited fishery-based ingredients have given rise to concerted efforts to identify feed ingredients to augment or replace fishmeal and fish oil in finfish and crustacean diets. Considerable progress has been made already, and the ratio of wild fish input via formulated feeds to total farmed fish output has fallen by more than one-third from 1.04 in 1995 to 0.63 in 2007 (Naylor *et al*., 2009).

In response to this need, the NOAA and the USDA have created an Alternative Feeds Initiative whose purpose is to identify alternative dietary ingredients that will reduce the amount of fishmeal and fish oil contained in aquaculture feeds while maintaining the important human health benefits of farmed seafood. This initiative combines the research expertise within the NOAA, the USDA's Agricultural Research Service and the CSREES, and researchers in academia to identify alternative protein and oil sources for aquaculture feeds. This initiative will help reduce pressure on fish populations harvested for fishmeal, develop cost-effective diets using less fishmeal and fish oil, and maintain the health benefits derived from eating seafood high in omega-3 fatty acids.

3.1.5 Culture technologies

Aquaculture producers in North America use the following types of culture methods:

- cage and net pen culture;
- land-based culture in ponds, raceways, and recirculating systems;
- off-bottom culture;
- bottom culture.

Cage culture: Cages and net pens are used primarily by salmon growers in North American marine waters and by Canadian trout growers in freshwater. Cages are used in the United States of America to a lesser degree for catfish and tilapia in larger reservoirs. There is a nascent industry using cages and net pens in Hawaii to culture moi (*Polydactylus sexfilis*), also known as Pacific threadfin, and Seriola rivoliana, known locally in Hawaii as kahala. A private firm is culturing cobia (*Rachycentron canadum*) on a lease off Puerto Rico. The University of New Hampshire maintains an open Ocean Aquaculture Program and it has successfully grown summer flounder, cod, haddock and halibut in cages moored at its open-ocean site.

Marine cage culture: Marine cage culture methods are employed mainly for farming salmon. Almost all of the cages used in Canada can be classified as gravity-type cages (Masser and Bridger, 2007). Marine cages are moored as a group, or flotilla, typically within submerged grid mooring systems.

These grids frequently provide upwards of eight mooring lines connected to each cage to maintain its position within the grid. In the United States of America, similar gravity cages are used to culture salmon, but submersible Sea Station™ net pens are used in the farming of cobia, moi and kahala.

Salmon smolts are stocked into marine cages from freshwater hatcheries. In these cages, the smolts are nurtured and fed for 18–24 months until reaching a harvestable size. The use of automatic feeders that incorporate the use of underwater cameras to monitor feeding behaviour and control feed delivery helps to ensure adequate feed is provided while minimizing loss and water quality impacts from uneaten feed.

Freshwater cage culture: Freshwater cages similar to those used for salmon are used by rainbow trout growers in Georgian Bay in Lake Huron in Ontario and in Lake Diefenbaker in Saskatchewan. The number of cages per operation or company in freshwater is smaller than that for marine cages. The smallest operation consists of six cages with a production of 160–180 tonnes/year. Operations smaller than this do not appear to be economically viable. A wide variety of smaller cages is used on a small scale in ponds and reservoirs to grow catfish, tilapia, hybrid striped bass, perch and other species.

Land-based culture: Land-based methods are used for growing trout and other finfish. The method consists of raceways, ponds or circular tanks that have a continuous flow of freshwater, or a recirculating system with filters for water treatment. The use of pumped water in these systems considerably drives up energy costs and thus greatly detracts from the competitiveness of the farm. However, in many locations in central and western Canada and in the midwestern United States of America, land-based methods are the only available methods for freshwater aquaculture.

Bottom culture: Bottom culture methods were used most extensively for oyster culture until the development of off-bottom culture methods in the 1970s. Oyster growers use a variety of culturing techniques that accommodate local growing conditions and local aquaculture customs. Oyster culture techniques vary regionally and include bottom culture, rack, and bag systems.

Off-bottom culture: In mussel culture, off-bottom methods have largely replaced bottom culture methods because of their increased efficiency. Mussel growers on the Atlantic and Pacific coasts use off-bottom culture. When compared with wild-harvested mussels, farmed mussels deliver twice as many mussels per kilogram, as well as meat yields that are usually 3–4 times higher (DFO, 2003). Longlines are the most common system in use on the east coast. On the west coast, both longlines and raft systems are in use. Where conditions are reasonably calm and protected, rafts may be the most suitable system.

Mussel growers obtain seed either from fishers or through their own spat collection efforts. Oyster, scallop and clam growers buy seed from hatcheries, which have a reliable supply.

3.1.6 Aquatic animal health support

The Canadian industry and provincial governments intensified their collaboration in health management after the outbreak of infectious diseases in the early 2000s and developed successful biosecurity policies and programmes. The industry associations have collaborated by developing best management practices (BMPs) that cover aspects of farm operation ranging from design and operation to environmental monitoring, health management, and record-keeping. Individual companies strictly observe the protocols that they have developed together with provincial and federal agencies.

In Canada, aquaculture biosecurity measures are enforced by the Canadian Food Inspection Agency (CFIA), which develops standards, protocols and strategies. When disease outbreaks are suspected or detected abroad, the CFIA, in collaboration with the Canada Border Service Agency, implements import restrictions. The CFIA has well-planned laboratory biosecurity and biocontainment protocols and procedures aimed at protecting the safety of the food supply, plants and animals. These protocols and procedures follow internationally recognized standards for safely handling animal pathogens.

Since 2005, the CFIA, in collaboration with the DFO, has been implementing the National Aquatic Animal Health Program (NAAHP) to bring Canada into line with standards set by the World Organisation for Animal Health (OIE) (CFIA, 2009). The NAAHP is a science-based regulatory programme for aquatic animal diseases and is delivered under the Health of Animals Act. Two key components of NAAHP are: (i) emergency response plans that clearly delineate respective roles and responsibilities should a regulated pathogen of concern be detected or a disease outbreak occur; and (ii) domestic disease control measures to prevent spread of disease within Canada and support export attestations and import controls (NAAHP, 2009). The DFO's national reference laboratories provide quality diagnostic testing for reportable diseases and provide confirmatory diagnostic testing.

The regulations used to deliver the NAAHP under the Health of Animals Act have more direct relevance to terrestrial animals than to aquatic animals. Regulatory amendments are under way to address the inadequacy of the regulations and to support the delivery of the NAAHP for aquatic animals. A domestic disease control framework is also being developed to control the spread of listed diseases within Canada and to create an emergency response infrastructure (CFIA, 2009).

The United States of America has a programme similar to that in Canada, which is also evolving in response to disease outbreaks and the need for better aquatic animal health management.

Recent disease outbreaks in North America have highlighted the need for comprehensive aquatic animal health programs. Outbreaks of ISA, viral haemorrhagic septicaemia, and spring viraemia of carp in private North American aquaculture operations have resulted in losses of more than US$10 million.

In the United States of America, the need for a comprehensive national aquatic animal health plan has long been identified as a high priority issue by the Federal Joint Subcommittee on Aquaculture. In 2001, the federal agencies responsible for managing the health of aquatic animals began to develop a national aquatic animal health plan. Those agencies are the USDA through the Animal and Plant Health Inspection Service (APHIS), the United States Department of Commerce through the NOAA Fisheries Service, and the United States Department of the Interior through the United States Fish and Wildlife Service (USFWS). The process involved extensive engagement with stakeholders and resulted in a draft plan in 2008 (NOAA, 2008). Following review and revision in 2009, the plan was scheduled for implementation in 2010.

The task force that developed the plan used a number of international instruments to establish four principles around which the plan was created to ensure that elements in the plan met the standards of the World Trade Organization (WTO) and the OIE. Those instruments included:

- the OIE Aquatic Animal Health Code (2002);
- a business case in support of a national aquatic animal health program;
- salmonid disease control policy of the fisheries comanagers of Washington Department of Fish and Wildlife;
- manual of procedures for the implementation of the Asia regional technical guidelines on health management for the responsible movement of live aquatic animals (FAO/Network of Aquaculture Centres in Asia Pacific [NACA]).

The plan further established as its four main goals the following:

- support aquaculture as a viable business activity in the United States of America;
- protect our nation's farmed and wild aquatic resources from the unwanted introduction or spread of devastating infectious diseases;
- provide for effective interstate and international trade;
- meet the national and international legal obligations of the United States of America.

The Plan identifies the following agencies as having primary authority for aquatic animal health management.

Animal and Plant Health Inspection Service (APHIS): This is the lead agency for preventing, controlling and eliminating aquatic animal diseases and for providing federal oversight to health programmes in livestock. Authority of the USDA for aquatic animals is found in the Animal Health Protection Act. In regard to private commercial aquaculture, the United States Secretary of Agriculture has authority to regulate imports, exports and interstate commerce of all animals should they pose a risk to other livestock.

The APHIS is also the federal agency responsible for licensing domestic manufacturers of veterinary biological materials, such as vaccines, and issues permits allowing biologics from other countries to be imported into the United States of America. The APHIS, in coordination with other federal, state, and private entities, is the United States agency responsible for reporting the occurrence of certain notifiable aquatic animal pathogens to the OIE in Paris, France. The APHIS works closely with animal health programmes managed by the states for both cultured and wild aquatic organisms. Regulations vary from state to state but most have health protection regulations, field health services, extension specialists, and diagnostic and inspection laboratories for testing for diseases and pathogens.

National Marine Fisheries Service (NOAA Fisheries): Several laws give the NOAA Fisheries responsibility and authority over activities affecting aquatic animal health, but one in particular addresses aquaculture directly. The National Aquaculture Act (NAA) directs the United States Secretaries of Commerce, the Interior and Agriculture to develop, periodically review and revise, and implement an aquaculture programme. It also directs the Secretaries to undertake a continuing assessment of aquaculture. These authorities enable the NOAA Fisheries to engage in aquaculture fish health management.

United States of America Fish and Wildlife Service (USFWS): Its primary authority in aquatic animal health derives from the Lacey Act. This prohibits the possession or importation of any animal or plant, including pathogens deemed to be injurious to human beings, wildlife or wildlife resources, or to the interests of agriculture, horticulture, forestry, or to wildlife or the wildlife resources of the United States of America.

Environmental Protection Agency (EPA): The EPA is authorized to regulate aquaculture operations under the Clean Water Act. This law gives the EPA the authority to require a National Pollutant Discharge Elimination System (NPDES) permit for aquaculture effluent discharges in the United States of America.

Health and Human Services Food and Drug Administration (FDA): The Food, Drug and Cosmetic Act gives the FDA the responsibility for ensuring that all food is safe and wholesome to eat. The FDA also holds regulatory authority for approval of drugs other than biologics for use on aquatic animals.

In addition to these agencies, the USDA operates two aquatic animal health research laboratories whose mission is to meet the needs for continued growth of the catfish industry and to increase its profitability. Biological control strategies are being developed that will prevent large economic losses in the catfish industry caused by diseases and parasites. The specific research objectives of the prevention programme are development of vaccines, rapid diagnostic tests, and development of fish diets that will enhance resistance to infectious bacteria and parasites.

3.1.7 Capital

Access to capital varies significantly among the various segments of the industry. The large and vertically integrated salmon industry enjoys secure access to traditional lending markets. Other segments of the industry face difficulties in attracting investors owing to a combination of business risk factors and regulatory complexity (New Brunswick Aquaculture Summit, 2009). Difficulties in obtaining operating capital occur particularly during long growout periods. Many growers also fail to meet the high standards of history and business management practices demanded by lending agencies (GSGislason and Associates Ltd, 2004).

Various government mechanisms are in place to assist smaller companies with start-up and operating capital. Farm Credit Canada, a federal crown corporation, has been assisting smaller operators with loans since 1995. The Atlantic Canada Opportunity Agency, a federal regional economic development agency, provides a repayable loan. The provincial governments of the Atlantic provinces offer both start-up and working capital with low interest rates.

The Unites States aquaculture industry has been slow to develop in part owing to the difficulty in accessing capital for investment purposes. A statutory change to the federal Fisheries Finance Assistance Program allowed aquaculture facilities to benefit from this NOAA fisheries loan programme.

The USDA Farm Service Agency (FSA) makes farm ownership and operating loans to family-size farmers and ranchers who cannot obtain commercial credit from a bank, farm credit system institution, or other lender. Aquaculture producers can qualify for these FSA loans, which can be used to purchase land, livestock, equipment, feed, seed and supplies. The FSA loans can also be used to construct buildings or make farm improvements.

The federal government of the United States of America operates the Small Business Innovation Research (SBIR) programme in a number of federal departments including the USDA and the Department of Commerce. While not providing operating capital per se, research proposals are reviewed and competitively awarded grants are made to qualified small businesses to support high-quality research. Research supported by the SBIR programme is targeted at solving problems to make domestic aquaculture more competitive and enhance knowledge of commercially important freshwater and marine fish, plants and shellfish.

The objectives of the SBIR Program are to:

- stimulate technological innovations in the private sector;
- strengthen the role of small businesses in meeting federal research and development needs;
- increase private sector commercialization of innovations derived from federally supported research and development efforts;
- foster and encourage participation by women-owned and socially and economically disadvantaged small business firms in technological innovations.

3.1.8 Insurance

Limited aquaculture insurance has been available to Canadian aquaculture businesses since the mid-1970s. Insurance can be purchased directly from two companies based in the United Kingdom that are licensed to underwrite in Canada. Alternatively, producers can insure themselves with local brokers reinsured by the parent companies in the international insurance market. Transnational producers cover Canadian subsidiaries under their group insurance facilities (Van Anrooy *et al*., 2006). In the past, coverage was limited to finfish but the market has now been extended conservatively to cover shellfish. Smaller enterprises still tend not to buy insurance because of high premiums and limited coverage.

Insurance is offered under the property insurance business line, which means that the insurance provider must register under the Canadian Insurance Companies Act and offer guaranties and trustees accordingly. Aquaculture insurance in Canada is classified as business insurance. Foreign insurers therefore require a licence before they can underwrite aquaculture business, including aquaculture stock.

Aquaculture insurance has also been available in the United States of America since the mid-1970s. However, unlike in Canada, coverage targeted at catfish has been patchy as a result of the variable production levels and disease problems that led to insuring terms and conditions from underwriters that most farmers have not found acceptable (Van Anrooy *et al*., 2006). Attempts to establish insurance programmes for catfish farms have been largely unsuccessful. In contrast, many salmon, trout, striped bass and abalone operations are either covered or have purchased insurance from the private sector, and some shellfish operations are covered by the Federal Crop Insurance Program. Extensive shellfish and crawfish production systems are not considered insurable because of the relative lack of control of production variables.

While insurance programmes for catfish farmers have largely failed, growers would like a viable insurance option and have lobbied extensively to have aquaculture covered under the Agricultural Risk Protection Act. The key issue connected with such a development centres around the premiums, the coverage, and whether the programme is actually an insurance programme or a subsidy.

The actual number of policies in effect in the United States of America is likely to be less than 100, and given that there are slightly more than 4 000 farms, only 2.5 percent of the industry has crop insurance. The coverage offered to North American producers varies from “all risks” to “named perils”, with rates and coverage individually established for each insurance applicant.

Aquaculture insurers in North America will provide coverage on species reared in most intensive and semi-intensive aquaculture systems. Examples include marine cages, longlines, freshwater ponds, greenwater tanks, and raceway and recirculation systems. Hatchery and nursery operations also qualify for insurance, but extensive production systems generally do not. Two companies from the United States of America have provided aquaculture insurance policies, but since 2005 only one is still active. Lloyd’s of London is licensed to offer insurance in all 50 states of the United States of America.

Generally, aquaculture insurance providers in the United States of America use site surveys by knowledgeable professionals to assess the physical risks inherent in aquaculture production systems. This is true especially in cases involving marine sites, sites that use extensive pumping and aeration technology, and those that rely on sophisticated alarm systems owing to the production density and inherent risk. In addition, site surveys seek to confirm that farm management understands the inherent risks and takes steps to minimize them. The potential for storm damage, disease losses and operational failures are all important parts of the risk evaluation and/or management process.

3.2 Salient issues and success stories

Farmed fish are fed small, extruded, nutrient-dense, dry pellets. Feed must meet the nutritional requirements of healthy growing fish and it constitutes the most significant cost in operating a fish farm. In 2007, Canadian researchers completed a three-year, multipartner, research pilot to study Canadian farmed trout fed with a high-energy, low-phosphorous feed developed by the Danish aquaculture industry, and newly formulated high-performance feeds developed by Canadian companies.

The study examined whether the feed provided a better FCR and reduced phosphorous waste as compared with traditional domestic trout feeds used by Canadian fish growers. Small-scale feed trials were held under controlled laboratory conditions and at eight larger-scale commercial fish farms across Canada.

Both the Danish and the newly formulated Canadian feeds performed beyond expectations. There was an overall reduction in phosphorous output by 36 percent. Although the new feeds are more expensive, the improved FCR reduced overall feed costs. The new feeds significantly improve fish growth and reduce phosphorous loading in effluent water.

In the United States of America, aquaculture nutrition researchers have also focused efforts on seeking ways to reduce phosphorous inputs to surface waters from trout culture operations. Trout producers in Idaho were under increasing pressure from the EPA under the NPDES discharge permitting system to reduce phosphorous pollution. A very successful multiyear research programme funded by the USDA Western Regional Aquaculture Center resulted in development of low-phosphorous feeds that provide a better FCR and reduce phosphorus waste as compared with traditional domestic trout feeds. The new feeds significantly improve fish growth and reduce the environmental footprint of trout production.

3.3 The way forward

It is evident that the ability of aquaculture industry to expand globally will require less reliance on finite supplies of fishmeal and fish oil, and the development of alternative ingredients. Levels of fishmeal and fish oil in salmon feeds have already been significantly reduced both as a percentage of the feed and through reduced feeding rates and better FCRs. The Aquaculture Feeds Initiative of the NOAA Fisheries and research being conducted in North America is certain to reduce the reliance of industry on fishmeal and fish oil. Alternative feed ingredients, nutrition research and applications of biotechnology are all tools that will support these efforts in the future.

With the fairly rapid global spread of Atlantic salmon farming over the last decade, it seems likely that in the future new species and culture technologies will follow that successful model. There is an impressive list of new species of interest in North America, and as mentioned above, it is likely that some of these species will be successfully commercialized in the coming decades. A number of species have demonstrated their adaptability to being cultured in large sea cages and, as hatcheries gear up production sufficiently for stocking these cages, this industry sector is capable of considerable growth. Atlantic cod, sablefish and cobia all come to mind as promising species for commercialization in the near future using established net-pen technologies.

4. AQUACULTURE AND THE ENVIRONMENT

4.1 Status and trends

4.1.1 General environmental conditions

Canada and the United States of America have stringent environmental regulations such that there are few environmental problems generally associated with the aquaculture sector. This was not always the case and water quality problems originating with excess nutrients and organic enrichment have historically been challenges the industry has successfully met. Regulatory regimes permitting effluent discharge such as the NPDES in the United States of America have required the industry to meet stringent discharge standards. In many cases, such as with pond culture of catfish and shrimp, a principal strategy employed was to reduce discharge and use on-site ponds for water treatment and subsequent reuse.

Indeed, pond culture of catfish provides a good example of an industry developing water management and reuse strategies to improve environmental quality. Farmed catfish were originally placed in a precautionary category by the Monterey Bay Aquarium's Seafood Watch Program, but following an educational effort on the part of the industry and increased awareness of the environmentally sustainable practices employed by the industry, catfish was moved up to the Best Choice category. United States farm-raised catfish land top honours as an environmentally friendly product in the fish and seafood category.

Major environmental watch groups including the National Audubon Society and the Environmental Defense Fund list United States farm-raised catfish as one of the most environmentally friendly choices for consumers seeking seafood when shopping or dining out. Environmental groups consider United States farm-raised catfish production ecofriendly, in part owing to the use of native species, low water use compared with other types of aquaculture, low fishmeal use in feed, and low pollution discharge.

Historical concerns about fish escapes and excessive antibiotic use have been largely addressed through improved net-pen designs and the development of vaccines to prevent disease. The NPDES permits address water quality concerns and proper siting and/or fallowing of net-pen culture sites are effective techniques to maintain environmental quality.

Farmed shellfish receive high rankings for the minimal environmental impacts observed when culturing filter-feeding bivalve shellfish. Ecosystem services provided by cultured shellfish can have positive net impacts through water filtration and provision of habitat once provided by native shellfish whose populations have declined dramatically in many areas such as Chesapeake Bay.

4.1.2 Health management

Canada's approach to health management is holistic, taking into consideration how health management decisions enable sustainable development and use of oceans and freshwater systems. In the United States of America, a similar approach is being taken and a guiding principle within the NOAA is ecosystem-based management, that is, taking into consideration ecosystem-based effects of aquaculture operations and management decisions. This approach is in parallel with others outlined in the Convention on Biological Diversity and the FAO Code of Conduct for Responsible Fisheries (FAO, 1995; Soto *et al*., 2008).

In the context of fish health, Canada and the United States of America are not unlike other countries and face considerable challenges in aquaculture because farmed species can live in close proximity to one another and to similar wild species. Chemicals, pathogens and animals can easily be transported or move about in aquatic environments. Wild fish communities are potentially affected by aquaculture operations, including activities specifically related to health management. For example, treatments and application methods for sea lice on farmed Atlantic salmon must take into consideration potential environmental effects prior to application.

Environmental assessments, monitoring and surveillance activities are a fundamental part of any treatment plan, and this is recognized in Canada and the United States of America. In an effort to make judicious aquatic animal health management decisions, the DFO formed a multistakeholder National Working Group on Fish Health Management in Aquaculture in 2008. In 2009, the NOAA Fisheries released a draft National Aquatic Animal Health Plan for the United States of America, which will be implemented to provide a comprehensive framework for animal health management.

A focus of both the Canadian and United States efforts is to advance the sustainability of aquaculture by addressing key fish health management constraints for sustainable aquaculture development in North America. The Canadian expert group specifically aims to enhance the tools available to deal effectively with certain infectious diseases and to begin to overcome regulatory, scientific and coordination barriers. The group undertook an exercise to identify top priority diseases for Canadian aquaculture and found that the issues of greatest concern are sea lice, bacterial kidney disease, and other bacterial pathogens. This priority shortlist and specific action plans for accessing selected therapeutants related to the identified issues formed the basis of work for the group in 2008–09. Work to facilitate access to therapeutants already approved for use in other jurisdictions is also under way. Success has been achieved in facilitating the registration of SLICE®, and AlphaMax™. Both therapeutants have been approved by Health Canada to treat sea lice on salmon farms. Research and experiments including monitoring and surveillance of results from different treatments have been undertaken. The group is leading the way to identify adequate and responsible integrated health management plans and environmental BMPs, working closely with the DFO, Health Canada, industry, and the CFIA.

In the United States of America, regulatory approval for aquaculture drugs rests with the FDA, while the APHIS is responsible for regulating biologics. The approval process takes into consideration efficacy and potential environmental effects, and the EPA is involved at this level of review. Generally, there are three categories that drugs for aquatic species fall into: (i) approved; (ii) considered to be of low regulatory priority; and (iii) fish colour enhancers. Below are listed FDA-approved aquaculture drugs with their approved sources, species and withdrawal times.

- **Aquaflor® Type A Medicated Article (Florfenicol):** Supplied by Schering-Plough Animal Health Corporation, for the control of mortality owing to enteric septicaemia of catfish. The tolerance for florfenicol amine (the marker residue) in muscle (the target tissue) is 1 ppm.
- **Chorionic Gonadotropin:** Supplied by Intervet Inc., may be used as an aid in improving spawning function in male and female brood finfish (21 CFR 522.1081).
- **Formalin solution:** Supplied by Natchez Animal Supply Co. or Argent Laboratories, may only be used in salmon, trout, catfish, largemouth bass, and bluegill for the control of protozoa and monogenetic trematodes, and on the eggs of salmon, trout and pike (esocids) for control of fungi of the family Saprolegniaceae (21 CFR 529.1030).
- **Formalin solution:** Supplied by Western Chemical Inc., may be used to control: external protozoa and monogenetic trematodes on all finfish species; external protozoan parasites on shrimp; and fungi of the family Saprolegniaceae on the eggs of all finfish species (21 CFR 529.1030).
- **Tricaine methanesulfonate (MS-222):** Supplied by Argent Laboratories and Western Chemical Inc., may only be used in the families Ictaluridae (catfish), Salmonidae (salmon and trout), Esocidae (pike), and Percidae (perch) when the fish is intended to be used for food. It may not be used within 21 days of harvesting fish for food. In other fish and in cold-blooded animals, the drug should be limited to hatchery or laboratory use (21 CFR 529.2503).
- **Oxytetracycline:** For feed use, supplied by Pfizer Inc., may only be used in salmonids, catfish, and lobster. Withdrawal times are: marking in Pacific salmon, 7 days; disease control

in salmonids, 21 days; catfish, 21 days; lobster, 30 days (21 CFR 558.450). Oxytetracycline tolerance in the flesh is 2.0 ppm (21 CFR 556.500).

- **Sulfamerazine:** Supplied by Roche Vitamins Inc., may only be used in trout. It may not be used within 21 days of harvest (21 CFR 558.582). Sulfamerazine tolerance in the flesh is zero (21 CFR 556.660). Note: this product is currently not marketed.
- **Sulfadimethoxine/ormetoprim combination:** Supplied by Roche Vitamins Inc., may only be used in salmonids and catfish. Withdrawal times are: salmonids, 42 days; catfish, 3 days (21 CFR 558.575). Sulfadimethoxine/ormetoprim combination tolerance in the flesh is 0.1 ppm for both drugs (21 CFR 556.640) (FDA, 2001).

The FDA's Center for Veterinary Medicine has identified a number of "low regulatory priority aquaculture drugs". The FDA is unlikely to object to the use of low regulatory priority substances if the following conditions are met: (i) the substances are used for the stated indications; (ii) the substances are used at the prescribed levels; (iii) the substances are used according to good management practices; (iv) the product is of an appropriate grade for use in food animals; and (v) there is not likely to be an adverse effect on the environment. The following list identifies these compounds and provides their indicated use and usage levels.

Low regulatory priority substances

- **Acetic acid:** Used in a 1 000–2 000 ppm dip for 1–10 minutes as a parasitide for fish.
- **Calcium chloride:** Used to increase water calcium concentration to ensure proper egg hardening. Dosages used would be those necessary to raise calcium concentration to 1–20 ppm $CaCO_3$. Used up to 150 ppm indefinitely to increase the hardness of water for holding and transporting fish in order to enable fish to maintain osmotic balance.
- **Calcium oxide:** Used as an external protozoacide for fingerlings to adult fish at a concentration of 2 000 mg/litre for 5 seconds.
- **Carbon dioxide gas:** Used for aesthetic purposes in cold, cool, and warm water fish.
- **Fuller's earth:** Used to reduce the adhesiveness of fish eggs to improve hatchability.
- **Garlic (whole form):** Used for control of helminth and sea lice infestations of marine salmonids at all life stages.
- **Hydrogen peroxide:** Used at 250–500 mg/litre to control fungi on all species and life states of fish, including eggs.
- **Ice:** Used to reduce metabolic rate of fish during transport.
- **Magnesium sulphate:** Used to treat external monogenic trematode infestations and external crustacean infestations in fish at all life stages. Used in all freshwater species. Fish are immersed in a 30 000 mg $MgSO_4$/litre and 7 000 mg NaCl/litre solutions for 5–10 minutes.
- **Onion (whole form):** Used to treat external crustacean parasites, and to deter sea lice from infesting external surface of salmonids at all life stages.
- **Papain:** Used in a 0.2 percent solution to remove the gelatinous matrix of fish egg masses in order to improve hatchability and decrease the incidence of disease.
- **Potassium chloride:** Used as an aid in osmoregulation; relieves stress and prevents shock. Dosages used would be those necessary to increase chloride ion concentration to 10–2 000 mg/litre.
- **Povidone iodine:** Used in a 100 ppm solution for 10 minutes as an egg surface disinfectant during and after water hardening.
- **Sodium bicarbonate:** Used at 142–642 ppm for 5 minutes as a means of introducing carbon dioxide into the water to anaesthetize fish.
- **Sodium chloride:** Used in a 0.5–1.0 percent solution for an indefinite period as an osmoregulatory aid for the relief of stress and prevention of shock; and in a 3 percent solution for 10–30 minutes as a parasitide.
- **Sodium sulphite:** Used in a 15 percent solution for 5–8 minutes to treat eggs in order to improve their hatchability.

- **Thiamine hydrochloride:** Used to prevent or treat thiamine deficiency in salmonids. Eggs are immersed in an aqueous solution of up to 100 ppm for up to four hours during water hardening. Sac fry are immersed in an aqueous solution of up to 1 000 ppm for up to one hour.
- **Urea and tannic acid:** Used to denature the adhesive component of fish eggs at concentrations of 15 g urea and 20 g NaCl/5 litres of water for about 6 minutes, followed by a separate solution of 0.75 g tannic acid/5 litres of water for an additional 6 minutes. These amounts will treat about 400 000 eggs.

Fish color enhancers as micro-nutrients

- **Astaxanthin:** Used as a feed additive at no more than 80 mg/kg (72 g/tone [907 kg]) of finished feed to enhance the pink to orange-red colour of the flesh of salmonid fish, and to provide essential micronutrients.
- **Canthaxanthin:** Used as a feed additive at no more than 80 ppm to enhance the pink to orange-red colour of the flesh of salmonid fish, and to provide essential micronutrients.

4.1.3 Alien species

The use of introduced species in agriculture has a long and beneficial history. California has a highly productive agriculture industry generating US$38 billion/year that is entirely based on introduced species. Certainly, the risks associated with introducing aquatic species are greater than introductions into terrestrial ecosystems, but nonetheless, the use of non-native species should not be entirely ruled out. It could be argued that the use of the alien Atlantic salmon in British Columbia in fact presents less risk to native Pacific salmon than would culture of chinook or coho. Any risks associated with farmed fish influencing genetic variability in wild populations when using alien species are avoided. The current level of concern about the use of alien species has a valid basis, but thorough risk assessments should enable the industry to continue to evaluate new alien species for their culture potential and make informed decisions based on science. Both Canada and the United States of America have a regulatory regime in place to address valid concerns.

The movement of fish in Canada is regulated under the National Code on Introductions and Transfers (I&T) of Aquatic Organisms. This code came into effect in 2003 and is intended to protect aquatic ecosystems as well as to minimize genetic, ecosystem and disease effects while encouraging responsible use of aquatic resources. It requires the submission of a detailed application to provincial ministry officials responsible for aquaculture for each introduction and transfer of aquatic organisms.

In the United States of America, interstate movement of fish is regulated by individual state statutes except when a species is judged to be injurious, in which case the federal Lacey Act is invoked by the USFWS of the Department of the Interior. The USFWS also has jurisdiction for all imported fish entering the country under permit.

Aquaculture is the most common reason for I&T. The species most often introduced are established aquaculture species such as salmon, trout, oysters or mussels (Tim Carey and Associates, 2005). Under Canadian regulations, every application for I&T is scrutinized to address the following three major biological:

- ecological effects, such as competition for food, space, spawning areas, alteration of habitat, and predation on indigenous organisms;
- genetic changes that will lessen the ability of local populations to survive;
- of fish disease agents, parasites and other accompanying organisms that will affect organisms, both wild and cultured, in receiving waters and their habitats.

Permitting of introductions of aquatic species into individual states within the United States of America is the responsibility of individual state wildlife agencies. Considerations vary but, in general, the major biological concerns identified above by the Canadian Code on I&T would probably be concerns that would need to be addressed in any permit application for I&T submitted to a state regulatory agency.

No introduction of a new aquatic animal species has recently been approved for release to natural waters (rivers, lakes and coastal waters) in Canada (Tim Carey and Associates, 2005). The importation of an Asian oyster (*Crassostrea ariakensis*) for introduction into the Chesapeake Bay was debated for nearly a decade before federal and state authorities ruled against it. The proposed introduction resulted from the near total collapse of the United States oyster populations in the region as a result of disease and declining water quality. The Asian oyster was resistant to disease and demonstrated good growth but the prevailing sentiment was to continue investing in habitat restoration and support the recovery of the native oyster.

In Canada and Maine where Atlantic salmon are farmed in net pens, fish escaping from cages have been an important environmental concern owing to their potential impact on wild fish. It is also a great concern of fish farm operators as escapes represent a financial loss. The DFO, provinces and the industry are constantly engaged in achieving “zero escape” of fish from cage facilities. While escape prevention and mitigation is a shared federal-provincial regulatory responsibility, the DFO uses a variety of regulatory, monitoring and scientific research tools for escape prevention.

Provincial regulations and operating guidelines require aquaculture operations to submit escape prevention and re-capture plans as well as to record and report any escapes. Actual and suspected escape reporting is a condition of holding an aquaculture licence. While escapes can still occur as a consequence of storms, equipment failure, predator damage and human error, the incidence of escapes has been reduced by orders of magnitude as a result of: improved farming techniques; good management; maintenance of nets; improved anchoring; increased provincial government regulation and monitoring; stricter guidelines for vessel operations near farms; and improved staff training. As a result, the number of escape events is much lower now (British Columbia, Ministry of Agriculture and Lands, 2009).

4.1.4 Integrated aquaculture

Integrated aquaculture is still in its developmental stage in Canada and is not practised to any degree in the United States of America. Scientists are still examining how effective the development of integrated aquaculture will be at increasing the production capacity of a site. One concept that is currently being examined is integrated multitrophic aquaculture (IMTA). This is the idea of growing finfish, shellfish and marine plants together for the benefit of all crops and the environment. Integrated multitrophic aquaculture is a collaboration between the DFO, academics and industry to evaluate the viability of combining fed aquaculture (e.g. finfish) with inorganic extractive (e.g. seaweed) and organic extractive (e.g. shellfish). It is an approach that uses the mussels and kelp to recycle nutrients and can lead to “greener” aquaculture practices by reducing nutrient loading and sedimentation. The culture of various species could also lead to economic gains for fish farmers. Many years of research have supported the idea that IMTA is environmentally sustainable, economically viable and socially acceptable.

An interdisciplinary team drawing from the University of New Brunswick at Saint John and the DFO is now developing an IMTA system at an industrial pilot scale by cocultivating Atlantic salmon, kelp and blue mussels at several aquaculture sites in the Bay of Fundy. A similar initiative is also under way in British Columbia. If successful, IMTA stands to improve the economics of aquaculture operations and also reduce their carbon footprint.

4.1.5 User conflicts

There are ongoing conflicts between aquaculture and traditional fisheries, real-estate developers, and recreational interests throughout North America. Commercial fishers view salmon operations as an encroachment into the prime coastal space and hold aquaculture responsible for environmental pollution leading to the decline of wild salmon stocks. Salmon stocks are in decline in many regions of North America except for Alaska, and these declines were in evidence long before salmon aquaculture appeared on the scene. Commercial fishers also resist the installation of any aquaculture gear that might interfere with fishing activities or result in entanglements. For a number of years, salmon aquaculture significantly depressed salmon prices as it became more of a commodity than a speciality item. Many salmon fishers saw revenue drop considerably as they entered markets seasonally in competition with farmed fish. This situation is no longer widespread as fishers have largely regained lost income through well-organized marketing, careful product handling and processing, and product differentiation.

Real-estate developers, some coastal residents and recreational interests have concerns that fish farms devalue waterfront property or degrade aesthetic values of recreational waters. Many aboriginal communities also voice similar opposition. These are value judgements and as coastlines become more developed and people unfamiliar with working waterfronts move into coastal areas these conflicts are likely to increase. Educational efforts to inform new residents about nearshore commercial activities and their importance to local communities can help to resolve or reduce some of these conflicts.

The industry has addressed many of the environmental concerns through gradual development of greener technology and the implementation of BMPs. Larger area management approaches, such as the bay management approach in the Bay of Fundy in New Brunswick, and integrated coastal zone management plans in British Columbia have further reduced user conflicts. In addition, public involvement of industry in festivals and activities such as promoting beach clean-ups place the industry in a good public light.

In the United States of America, shellfish growers actively educate the public about the environmental benefits of shellfish aquaculture, ranging from providing complex three-dimensional habitat that is used by a myriad of fish and invertebrates to improving water quality through filter feeding that increases water clarity with the potential to benefit submerged aquatic vegetation. One study in New England demonstrated that shellfish beds had biodiversity and species abundance comparable with that found in seagrass beds (DeAlteris, Kilpatrick and Rheault, 2004).

Generally, the effect of aquaculture on the environment is highly regulated in North America such that significant environmental impacts are negligible, especially when considered relative to other users of similar resources. Although there is no federal aquaculture act in Canada, the industry complies with a stringent regulatory process to address potential environmental impacts. The regulation of aquaculture planning principally relies on three pieces of legislation: the Fisheries Act, the Navigable Water Protection Act (NWPA), and the Canadian Environmental Assessment Act (CEAA). The Fisheries Act establishes a process for authorization or granting of a lease through a formal assessment of all new aquaculture applications. The two main provisions of the act applied to aquaculture include: (i) habitat protection; and (ii) pollution prevention. The provision of habitat protection prohibits any aquaculture activities that can result in "harmful alteration, disruption or destruction" (HADD) of habitat; the provision of pollution prevention prohibits the deposit of deleterious substances into waters frequented by fish. If the assessment determines that the proposed operation cannot avoid HADD, then it refers the application for further assessments.

All applications for suspension aquaculture undergo an assessment under the NWPA because these operations have the potential to "substantially interfere with navigation". The results of the assessments under the Fisheries Act and the NWPA are used to initiate an environmental assessment.

An environmental assessment under the CEAA ensures that the environmental effects of the aquaculture facilities within and outside of the proposed jurisdiction receive careful consideration. In addition, the environmental assessment encourages responsible authorities to take actions to promote sustainable development and thereby to achieve a healthy environment and economy.

An environmental assessment is also undertaken to comply with a few other pieces of legislation. They are: the Canadian Environmental Protection Act (CEPA), the Food and Drugs Act, the Pest Control Products Act, the Feed Act, and the recently introduced Species at Risk Act. The federal government must also assess the impact of the proposed aquaculture sites on a number of areas including native rights and land claims, migratory birds, resource utilization by other groups, and shellfish food safety.

The United States of America has a Federal Aquaculture Act pending and the four stated policies are to:

- support an offshore aquaculture industry that will produce food and other valuable products, protect wild stocks and the quality of marine ecosystems, and be compatible with other uses of the exclusive economic zone;
- encourage the development of environmentally responsible offshore aquaculture by authorizing offshore aquaculture operations and research;
- establish a permitting process for offshore aquaculture that encourages private investment in aquaculture operations and research, provides opportunity for public comment, and addresses the potential risks to and impacts (including cumulative impacts) on marine ecosystems, human health and safety, other ocean uses, and coastal communities from offshore aquaculture;
- promote, through public–private partnerships, research and development in marine aquaculture science, technology, and related social, economic, legal, and environmental management disciplines that will enable marine aquaculture operations to achieve operational objectives while protecting marine ecosystem quality.

Environmental protection and sustainability are central to each of the policy directives in the legislation. The environmental community is a powerful interest in the United States of America and any regulatory regime established will certainly protect the environment through the ecosystem-based management focus of NOAA Fisheries. The challenge is to design a regulatory regime that accomplishes two goals – fostering industry growth while ensuring environmental protection.

4.1.6 Public perception

Public perception in North America of the environmental performance of the aquaculture sector is still mixed. Generally, the sector receives criticisms in British Columbia (salmon farming zone); a neutral tone in central Canada (trout farming zone) and a positive rating in the provinces on the Atlantic coast (DFO, 2008b). People's perceptions are influenced by activism in British Columbia, where environmentalists and the media hold salmon farming responsible for declines in the Pacific salmon stock. However, recent polls show that people's perceptions are changing. According to a poll conducted in 2007, 65 percent of respondents said they supported the development of a sustainable salmon farming sector in British Columbia, and less than 1 percent identified salmon farming as the top environmental issue (BCSFA, 2007, 2009). These results complement an earlier survey commissioned by another independent poll, which showed that 60 percent of respondents believed salmon farming increased job opportunities and 41 percent said a benefit of salmon farming was that it resulted in less pressure on wild salmon stocks.

Another survey shows that United States seafood traders, key importers of Canadian products, hold Canadian aquaculture products in high esteem (Les Études de MarchéCréatec, 2007). The respondents believed that Canadians understood the importance of sustainability and took measures to maintain it despite competition. Many felt that the Canadian industry had environmental and sustainability concerns about "environmental balance".

4.2 Salient issues and success stories

In addressing environmental issues, it remains a challenge to separate science-based issues from those that are value-based. Issues such as water quality, escapes and the potential for disease transmission are issues that can be assessed and addressed through scientific inquiry. Indeed, the regulatory regimes in North America require these concerns to be identified and resolved. Value-based issues are much more complex to resolve and at times can be intractable. Differences of opinion about what constitutes a desirable view plane, commercial activities being conducted in public waters, and farming activities taking place on working waterfronts in transition are challenges and will continue to be so in the future.

There is generally a lack of comprehensive coordinated marine spatial planning in North America although considerable attention is being focused in this direction. Coastal and marine spatial planning (CMSP) is one of the nine priority objectives proposed in the interim report of the United States Interagency Ocean Policy Task Force (Interagency Ocean Policy Task Force, 2009). In the interim, marine spatial planning is being initiated on a regional basis in a number of areas and is being supported by state, provincial and federal governments. The Province of New Brunswick now has a mapping system for aquaculture that is accessible through the Internet. The DFO is the leasing and licensing authority in the Province of Prince Edward Island. A mapping system for Prince Edward Island is accessible through the Internet. Maps of aquaculture sites in British Columbia are available at ftp://gis.luco.gov.bc.ca/pub/coastal/aquaculture/. It is imperative that the aquaculture industry be present as CMSP becomes more widespread in order to ensure that their concerns are heard and opportunities for future growth are not lost.

A new Web site showing the locations of aquaculture sites and their characteristics is now available. The online National Aquaculture Sector Overview (NASO) map collection uses Google Maps and Google Earth technology to assist FAO Member Countries to inventory and monitor aquaculture. The collection is in its early stages but holds potential for use in a number of ways such as monitoring the status and trends of aquaculture development and addressing site selection and zoning issues. Each NASO map hosts a Google map showing the location of aquaculture sites and their characteristics at an administrative level and/or at an individual farm level, depending on the degree of aquaculture development, the resources available to complete the form and the compiler (www.fao.org/fishery/naso-maps/naso-maps/en). The NASO map for the United States of America of America is available online, while the NASO map for Canada will be made available in late-2011. The NASO map collection is coordinated by the Aquaculture Service of the FAO Fisheries and Aquaculture Department in close collaboration with FAO's Fisheries and Aquaculture Statistics and Information Service.

4.3 The way forward

The aquaculture industry was slow in mounting educational campaigns to counter some of the inaccurate information about the industry that was being promulgated by opposition groups. As in any newly developing industry, some of the opposition was generated by early industry practices and technologies that are that are no longer in use, precisely because they had unacceptable consequences. Open and transparent environmental impact assessments at both site and waterbody level to understand cumulative impacts and avoid adverse impacts are essential (Wilson, Magill and Black, 2009; FAO, 2009a). Educating the public about these issues, while acknowledging and improving problem areas, is the most promising approach to addressing public concerns and reducing negative perceptions.

5. MARKETS AND TRADE

5.1 Status and trends

5.1.1 Canadian markets and trade

Almost 60 percent of Canada's aquaculture products are sold in export markets in some 20 countries. The largest export market for Canada is the United States of America, which accounted for 96 percent of sales in 2007. Proximity to United States markets and lower transportation costs influence this market concentration. The major United States export destinations include Washington, Massachusetts, California, Maine and New York. Canadian aquaculture products are well accepted in American markets for their quality and wholesomeness. In Europe, Canada markets aquaculture products in France while in Asia, Japan and Taiwan Province of China stand out among a few other countries.

The total value of Canadian exports was US$480 million in 2007 (Statistics Canada, 2008a). Exports of aquaculture products from Canada have been consistently greater than aquaculture imports. Imports accounted for less than 4 percent of total aquaculture trade (Table 10).

Salmon and mussels are the two main export species. Salmon accounted for more than 89 percent of the total export value in 2007 at US$456 million. The bulk of the salmon export comprises fresh and frozen whole salmon. The share of value-added salmon products, such as fillet, has decreased over the years largely because Canadian exporters enjoy a comparative advantage in fresh and frozen products over their competitors. The share of fillets declined from 21 percent in 2000 to 9 percent in 2007.

Mussels are exported as partially cooked, smoked and pasteurized, but most are sold fresh in the shell. In 2007, the value of mussels exported increased to US$24 million, and more than 97 percent of this value was earned from the United States market.

Canada's domestic market for aquaculture is small, presumably owing to lower domestic fish consumption. Average per capita fish consumption in Canada has been stable at about 9.0 kg/year. The domestic markets are located in large cities as well as near the communities where aquaculture takes place.

Table 10: Canadian aquaculture trade balance, US$1 000.

Trade	2002	2003	2004	2005	2006	2007
Export	408 702	349 938	324 636	424 967	496 145	480 643
Import	16 418	24 667	27 593	23 561	19 260	20 941
Balance	392 284	325 271	297 043	401 406	476 885	459 702

Source: Statistics Canada (2008a).

5.1.2 United States of America markets and trade

People in the United States of America consumed 7.3 kg of seafood per person in 2008, down 0.1 kg from 2007. United States consumers spent an estimated US$70 billion on fishery products in 2008. Sales at restaurants, carry-outs and caterers of US$47 billion were more than double the US$22.7 billion in retail sales for consumption at home. Industrial fish products were valued at US$389 million.

In 2008, the United States of America imported 83 percent of the seafood it consumed, amounting to about 2 370 477 tonnes of seafood, 54 607 tonnes less than the quantity imported in 2007. Although total weight declined slightly from 2007, imports in 2008 were valued at a record US$14.2 billion, US$475 million more than 2007. The top species imported (by volume) include shrimp, tuna, salmon, groundfish, freshwater fish, crab and squid. Of these, shrimp and salmon are aquaculture products.

The United States of America exported 1 161 843 tonnes of seafood in 2008, valued at US$4 billion. The major fresh and frozen exports were salmon, surimi and lobsters; salmon was the major canned item exported.

Following an increasing trend through most of the decade, the value of United States of America seafood exports levelled off in 2008, while the value of imports continued a steady rise, further increasing the seafood trade deficit (Figure 23).

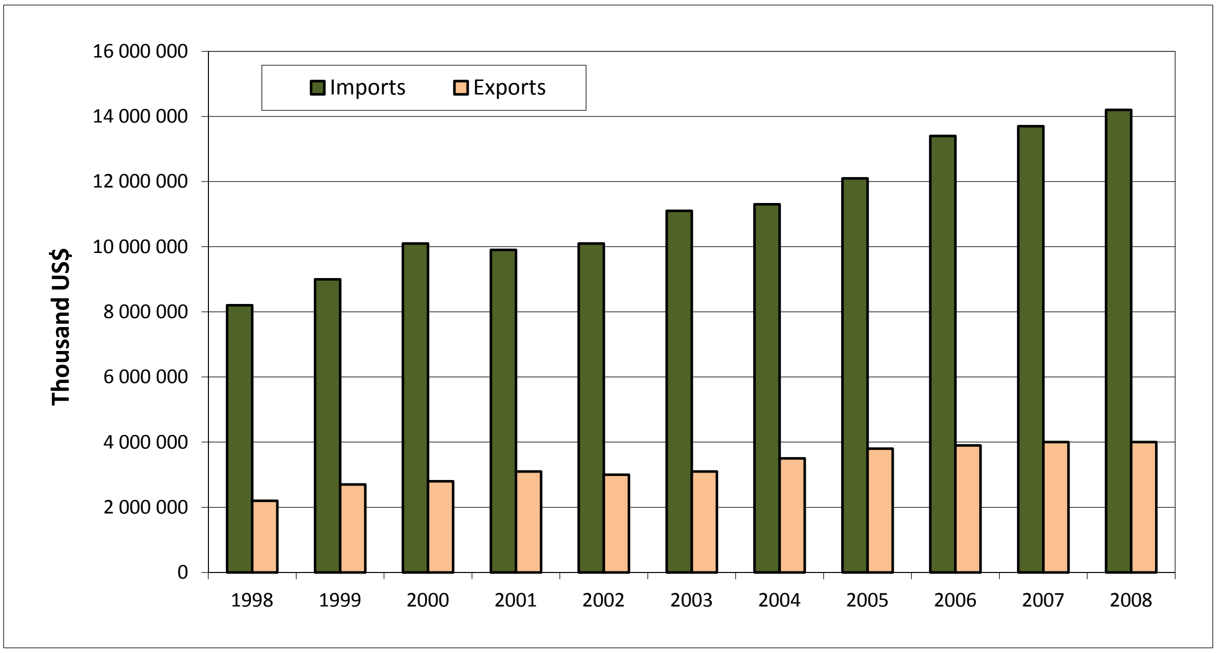

Figure 23: Value of United States of America seafood imports and exports, 1998–2008.
Source: NMFS 2009.

The top 10 seafood imports by value in 2008 were:

1. shrimp (fresh and frozen) US$4.1 billion (farmed);
2. salmon (fresh and frozen – fillets and steaks) US$1 billion;
3. freshwater fish (fresh and frozen – fillets and steaks) US$909 million (farmed);
4. crabs (fresh and frozen) US$721 million;
5. tuna (canned) US$661 million;
6. tuna (fresh and frozen – whole) US$602 million;
7. American lobster (fresh and frozen) US$592 million;
8. crabmeat (canned) US$547 million;
9. salmon (fresh and frozen – whole) US$516 million (farmed);
10. groundfish (fresh and frozen – fillets and steaks) US$442.4 million.

Despite a slight rise in the value of seafood imports in 2008, volume declined slightly for both imports and exports, a minor trend that followed a peak in 2006 (Figure 24).

China is the dominant exporter of seafood to the United States of America, supplying 22 percent or 519 348 tonnes in 2008, valued at US$2.2 billion. Following China in volume exports are Thailand and Canada with 15 and 13 percent, respectively (Figure 25). While Canada's export volume to the United States of America is 9 percent below that of China, the value is slightly higher at US$2.3 billion reflecting the high value of Canadian products, in particular farmed salmon (Figure 26). Similarly, Thailand exports 7 percent less seafood volume than China but earns 14 percent of total revenue compared with China's 15 percent, once again reflecting the relatively high value of Thailand's shrimp exports. Chile, Ecuador, Indonesia and Viet Nam account for 5, 4, 6 and 5 percent of total volume of American seafood imports, respectively.

The primary export market for fresh catfish fillets is Canada, which imported 71 percent of American exports valued at US$2.1 million in 2008. Other significant importers of fresh catfish fillets are the Netherlands and Germany at 15 and 8 percent of the market, respectively (Figure 27).

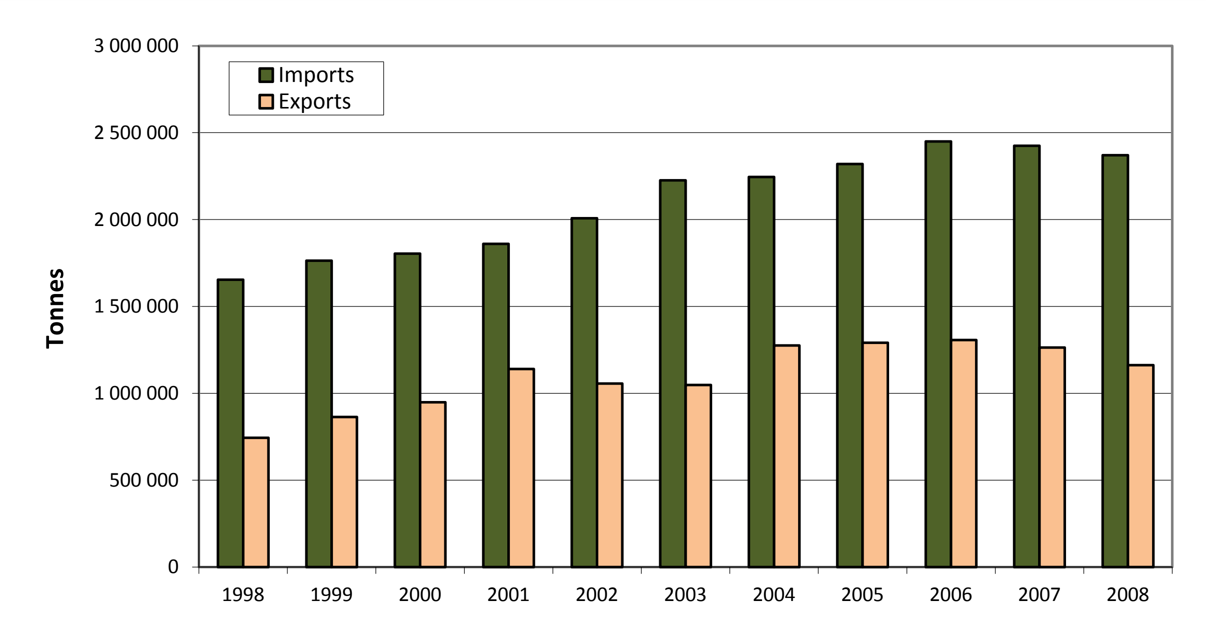

Figure 24: Volume of United States of America seafood imports and exports, 1998–2008.
Source: NMFS 2009.

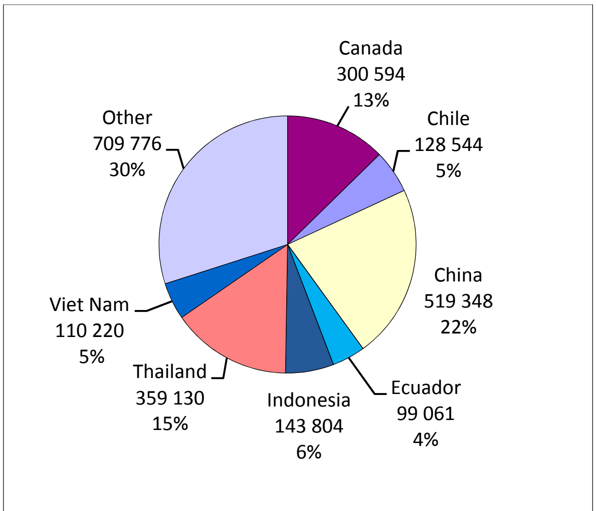

Figure 25: Primary exporters of seafood to the United States of America in 2008, tonnes.
Source: NMFS 2009.

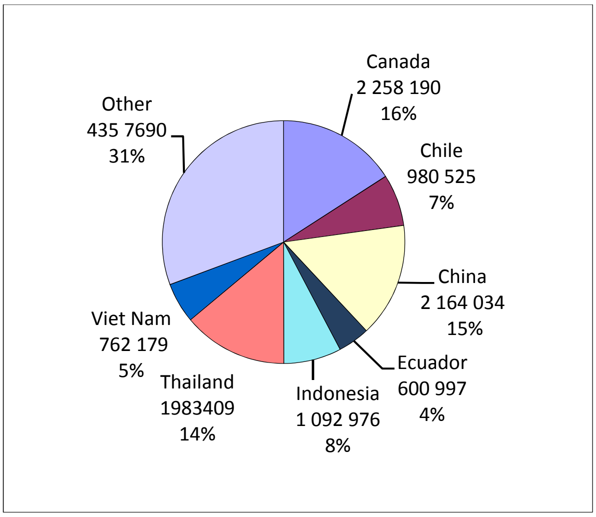

Figure 26: Value of United States of America imports by primary country in 2008, US$1 000.
Source: NMFS 2009.

Export of frozen catfish fillets is primarily to the Netherlands at 39 percent, followed by Mexico and Italy each with 16 percent. The total export value of frozen fillets is less than US$1 million (Figure 28).

A significant challenge for United States catfish farmers has been a flood of imports of other frozen catfish fillets, primarily *Pangasius* catfish from Viet Nam (Figure 29). These high-quality, inexpensive, imported frozen fillets have made markets extremely competitive. In 2002, state legislatures and the United States Congress ruled that the name catfish in marketing could only be used for native channel catfish of the genus *Ictalurus*. Importers responded by labelling their products *Pangasius*, basa and tra, and imports continued to climb. Later that year, tariffs were imposed on imported "catfish", alleging that Viet Nam was illegally selling the fish below cost.

United States trout farmers primarily export to Canada, which consumes 67 percent of exported trout valued at US$1.6 million. Four other countries account for 25 percent of exports (Figure 30).

Canada is also the largest market of United States farmed oyster exports, with 43 percent of market share worth US$8.9 million. China, Hong Kong Special Administrative Region is another primary export market for oysters, with a market share of 18 percent valued at US$3.7 million. Seven other countries collectively account for 28 percent of oyster exports(Figure 31).

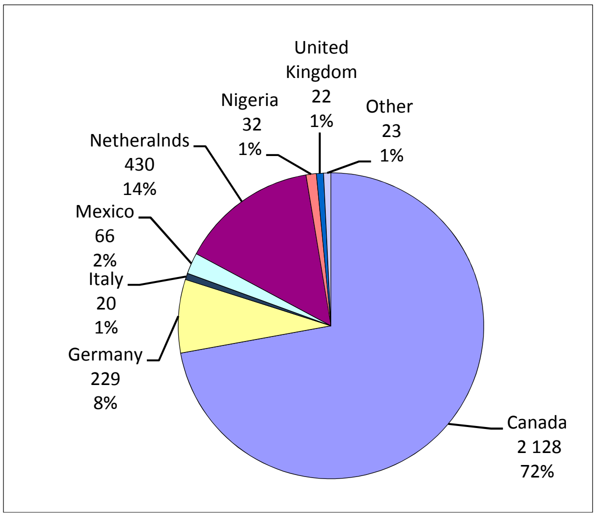

Figure 27: United States of America fresh catfish fillet export value in 2008, US$1 000.
Source: NMFS 2009.

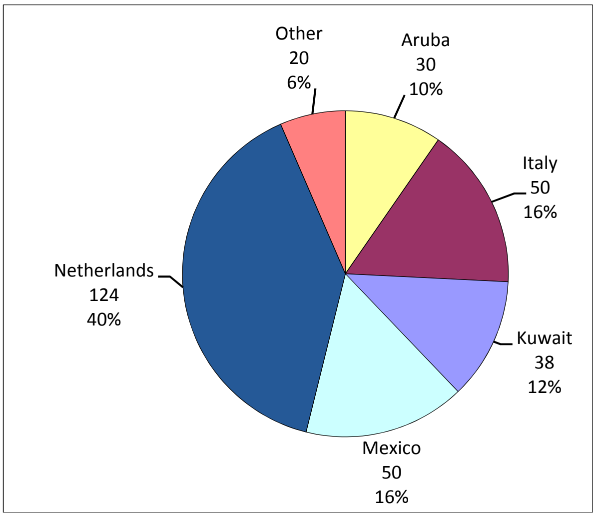

Figure 28: United States of America frozen catfish fillet export value in 2008, US$1 000.
Source: NMFS 2009.

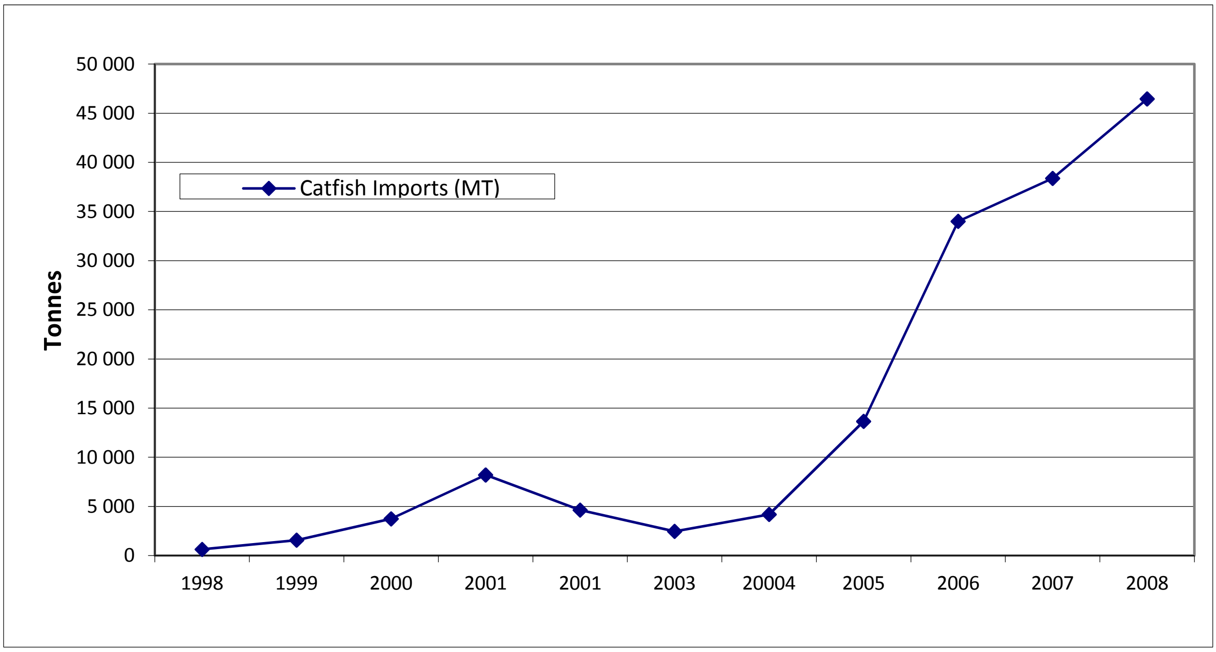

Figure 29: United States of America imports of frozen *Ictalurus*, *Pangasius* and *Siluriformes* catfish, 1998–2008.
Source: NMFS 2009.
Note: Data from February 2002 to July 2004 are under-reported as United States legislation at the time forbade labelling non-Ictaluridae fish as catfish, and thus Vietnamese basa and tra are excluded.

5.1.3 Food safety requirements

Food safety and food quality standards of fish and seafood exported from and imported into Canada are regulated by the CFIA. Principal legislation used for regulation includes the Federal Fish Inspection Act and Food and Drugs Act. The CFIA develops and verifies compliance with appropriate product and process standards that contribute to the acceptable quality, safety and identity of fish and seafood products.

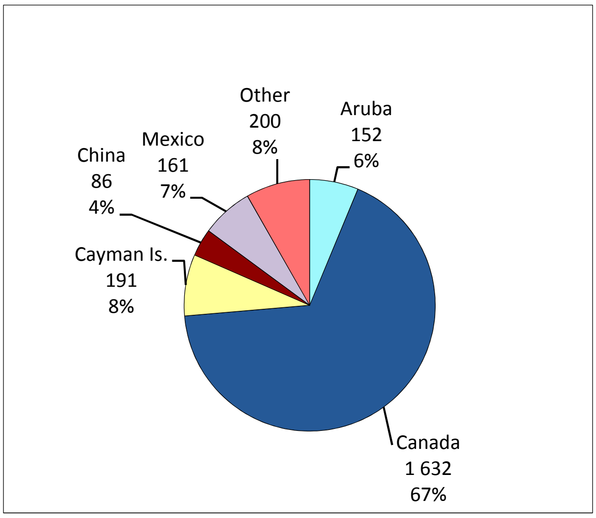

Figure 30: United States of America trout export value and primary destinations, US$1 000.
Source: NMFS 2009.

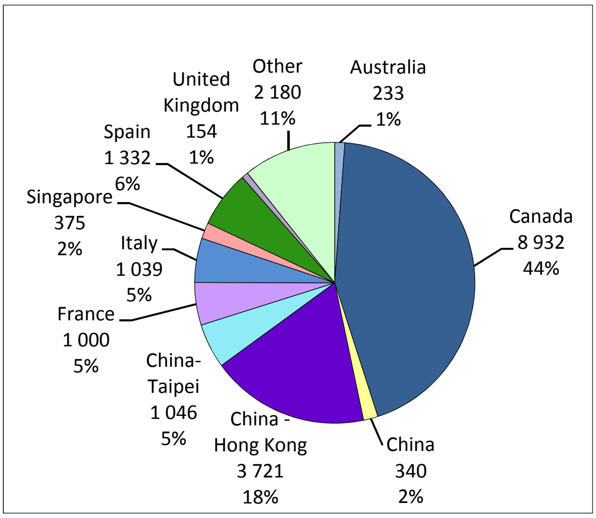

Figure 31: United States of America oyster export value and primary destinations for the period 1998-2008, US$1 000.
Source: NMFS 2009.

The Fish Inspection Regulations (Fish Inspection Act) require that all Canadian seafood products for export or interprovincial trade must originate from federally registered processing establishments. The processors involved in exports must also register themselves with the CFIA and have an in-plant Quality Management Program (QMP) in operation. The QMP, a regulatory-based in-plant quality control programme, which began in February 1992, is the world's first mandatory food inspection programme based on Hazard Analysis Critical Control Point (HACCP) principles to provide high-level assurance that fish and seafood products produced in Canada are safe and wholesome to eat. The QMP also deals with non-safety issues, including fish quality and federal regulatory requirements such as labelling. The QMP replaced a traditional food inspection programme, with federal inspectors inspecting fish plants and testing their products. The QMP was thoroughly re-designed between 1996 and 2000, with the active participation of the fish processing industry.

Along with promoting the production of safe and wholesome fish and seafood products for the protection of consumers, the QMP benefits fish processors in a number of ways. They include: a streamlined process for the certification of final products for export; the privilege of using the "Canada Inspected" logo on their products; and minimal government intrusion and intervention in their day-to-day operations. Moreover, because it incorporates the application of HACCP principles, the QMP has been effective in maintaining access to international markets at a time when many countries are introducing HACCP requirements for imported fish and seafood. This is important for Canada's fish processing industry, which is heavily export-oriented.

Inspectors from the CFIA perform compliance verification through a combination of audit and inspection activities to ensure that registered processors have implemented the QMP plan as designed and meet other regulatory requirements. By meeting this requirement, the establishments also ensure that they process fish in accordance with requirements of the Unites States FDA Seafood HACCP regulations. The CFIA maintains a list of Canadian establishments approved for export to the United States of America and any listed establishment must have a QMP.

The CFIA, in collaboration with Environment Canada and the DFO, also enforces separate safety policies and procedures for bivalve molluscan shellfish harvesting and processing under the Canadian Shellfish Sanitation Program (CSSP). The CSSP conforms to the standards of the United States National Shellfish Sanitation Program (NSSP) and the Interstate Shellfish Sanitation Conference (ISSC), which provide regulatory oversight of bivalve shellfish marketing and trade in the United States of America. Environment Canada monitors bacterial water quality in shellfish growing areas, and the DFO regulates the harvesting of shellfish in the areas that are labelled as either closed or prohibited based on the monitoring reports. The CFIA regulates certification, processing, packaging, labelling, storage, imports and exports. In addition, the CFIA maintain records for identification of growing waters and shellfish source, and tracks individual shellfish lots. If a grower fails to meet operating procedures and sanitary conditions, the CFIA may suspend operations or de-certify the farm.

Effort for inspecting imports is directed at foreign processors that have demonstrated a history of poor compliance with Canadian standards. The inspection of imported fish consists of the following four components:

- risk-based sampling of imported fish products assumed to be "good order";
- risk management of imported fish products that failed to meet Canadian requirements;
- risk management of imported fish products determined to present a potential risk;
- product monitoring and surveys.

International inspection efforts are minimized through the establishment of memoranda of understanding (MOUs) or mutual recognition agreements with other countries having reliable inspection systems.

Food safety and food quality standards for fish and seafood exported from and imported into the United States of America are regulated by the FDA and the NOAA’s Seafood Inspection Program. This FDA responsibility stems from initial food safety legislation in the United States of America through the Food and Drugs Act of 1906, the first of more than 200 laws that constitute one of the world’s most comprehensive and effective networks of public health and consumer protections. Legal authority for this responsibility today is derived from the Federal Food, Drug, and Cosmetic Act of 1938, which also authorized the FDA to ensure the safety of new drugs and issue standards for many food products. Today, the FDA regulates US$1 trillion worth of products a year and ensures the safety of all food except for meat, poultry and some egg products, which are regulated by the USDA.

The FDA has the authority to establish regulatory standards, inspect facilities and prosecute violations, but it is primarily an industry responsibility to comply with applicable regulations. The NOAA’s legal authority to support industry and ensure a safe seafood supply for United States consumers and export markets is based on the Agriculture Marketing Act and the Fish and Wildlife Act. Specific responsibilities of the two agencies with regard to seafood safety are laid down in an interagency MOU. The harvesting, processing and marketing of bivalve shellfish also falls under the regulatory purview of the FDA through the NSSP and ISSC (described above).

The regulations of the FDA are stipulated in the Food Code, which was revised in 2005 and most recently updated in 2009 (available at www.fda.gov/Food/FoodSafety/RetailFoodProtection/FoodCode/FoodCode2009/).

The FDA Food Code is a model code and reference document that provides a scientifically sound technical and legal basis for regulating the retail and food service segment of the food industry. It consists of practical, science-based guidance and manageable, enforceable provisions for mitigating known risks of foodborne illness. It serves as a model for state, city, county, tribal and industry sectors involved in the seafood trade that must comply with standards contained therein. These entities must comply with the federal guidelines but may independently adopt more restrictive measures. For example, California has its own California Retail Food Code, also adopted in 2009 (available at www.cdph.ca.gov/services/Documents/fdbRFC.pdf).

The FDA Food Code provides the foundation for a public-health-focused food safety framework to maintain a safe seafood supply. State, city, county, tribal and territorial agencies regulate more than 1 million restaurants, retail food stores and vending and food service operations in the United States of America. The model FDA Food Code provides the basis for many of their food statutes, regulations and ordinances, which in turn guide their licensing, inspection and enforcement activities.

While the FDA issues regulations to ensure seafood is safe, sanitary, wholesome and properly labelled, the NOAA Seafood Inspection Program works with the seafood industry domestically and overseas to help it comply with FDA food regulations and meet industry specifications. The NOAA is responsible for developing commercial-grade standards for wild-harvested seafood products, conducting inspections, and providing certification, grading, evaluation and analytical services to the industry. More than 30 percent of seafood sold in the United States of America is inspected under the NOAA's voluntary programme.

5.1.4 Certification, organic aquaculture

Although certification is not a regulatory condition for marketing aquaculture products in North America, the industry recognizes the marketing advantages some certifications can provide. Some large retail chains now require their suppliers to comply with ecocertification programmes. Standards and certification programmes are becoming increasingly important as a means for industry to appeal to consumers and objectively demonstrate their commitment and adherence to production excellence across a range of indicators. As mentioned above, many producers and industry sectors have adopted environmental codes of practice and BMPs to ensure food safety, demonstrate sustainability and reduce their environmental footprint.

There is currently no legal definition of what constitutes organic aquaculture in the United States of America. The legal mandate for making such a determination lies with the USDA and the National Organic Standards Board (NOSB), as part of the National Organic Program (NOP) under the authority of the Organic Foods Production Act of 1990. The NOSB established an Aquatic Task Force and Aquaculture Working Group in 2000 to examine key issues and formulate recommendations for submission to the USDA/NOP. The multitude of aquatic species cultured and the diversity of culture systems in use present significant challenges for establishing organic aquaculture standards. Some of these challenges include:

- evaluating production sites for meeting criteria for organic certification including nutrient loading, monitoring criteria, use of chemicals and therapeutants, and environmental interactions of cultured and wild species;
- establishing guidelines to control practices used in aquaculture to accommodate animal welfare in closed systems;
- induction of triploidy in fish and invertebrate species;
- origin of seed and fry to support fishery-based aquaculture wherein stocks are obtained from wild populations;
- the need for feed ingredients to come from organic sources and the fact that many fish species have a requirement for fishmeal and fish oil in their diets.

Currently, only one company in Canada holds ecocertification. The company offers ecocertified Atlantic salmon, certified under the internationally recognized Seafood Trust Eco Label. Another major company practises organic farming and raises only chinook (king) salmon. Its products are not yet certified as organic but it is working toward achieving organic certification.

The Canadian Aquaculture Industry Alliance (CAIA) has completed a gap analysis to help prepare the industry in establishing criteria for organic certification. In collaboration with the federal government and with support from International Food Quality Certification, the CAIA initiated the Canadian Aquaculture Standards Forum in 2008 to promote common understanding and capacity building in the industry with regard to standards and certification. The Aboriginal Aquaculture Association is also working toward developing an Aboriginal Certification of Environmental Sustainability Program.

5.1.5 Social organization in marketing

There are industry associations in all provinces and most states but they are generally not actively engaged in product marketing and the supply chain. Two exceptions to this are catfish in the United States of America and mussels in Canada. The channel catfish industry in the United States of America through the TCI engages in promotion and marketing of channel catfish. The Mussel Industry Council of North America (MICNA) oversees a marketing programme designed to increase the demand for mussels across North America (MICNA, 2009). Formed in 2008, the MICNA consists of mussel growers and processors from Atlantic Canada and Quebec as well as various industry associations. Industry associations representing other species are more engaged in helping industry to improve farm-level practices and in representing the industry in community, national and international forums.

5.1.6 Potential for increased demand for aquaculture products

FAO has projected the need for an additional 1.3–1.4 million tonnes of seafood annually to keep up with projected global consumption (FAO, 2009b). In North America, current levels of per capita consumption are about 8 kg and, with the population expected to increase by 52 million people by 2025, about 416 000 tonnes of additional seafood will be required in order to meet demand. The FDA is recommending people double their seafood consumption to take advantage of the numerous health benefits associated with seafood, particularly cardiovascular benefits derived from consuming species high in omega-3 fatty acids. If this occurs, then increased demand for aquaculture products could approach 1 million tonnes by 2025.

5.2 Salient issues and success stories

Canada and the United States of America have well-established domestic and export markets, and the main constraints to expanded trade are high production costs and competition in the international marketplace. Expansion of domestic markets should be a focus in North America as public health agencies are encouraging a doubling of seafood consumption to capitalize on the health benefits of increased seafood consumption. North America has a comprehensive HACCP-based food safety system that serves as a model in many other areas. This system and the recognized benefits of seafood consumption should be aggressively used as a marketing tool. Per capita seafood consumption in North America is below that of many other regions. Global increases in consumption of food fish will also occur in developing countries, where populations are growing and higher incomes allow increased consumption of high-value fisheries products (Delgado *et al*., 2003).

5.3 The way forward

Both capture fisheries and aquaculture have a unique marketing opportunity to build on the health benefits of seafood consumption as no other source of animal protein can. Considerable success has been achieved in this regard and, in addition, the industry has done a creditable job of establishing environmental policies and codes of practice. The sustainability of the industry needs to be capitalized on and effectively communicated, especially at this critical juncture where national policies on aquaculture development will soon be established.

Environmental and organic certifications are increasingly valued as marketing tools. Some Canadian companies are pursuing organic certification, and the USDA is in the midst of establishing criteria for organic certification of United States aquaculture products. This is a challenge in such a diverse industry but should enable some companies to capitalize on the marketing opportunities such certification can afford.

6. CONTRIBUTION OF AQUACULTURE TO FOOD SECURITY, SOCIAL AND ECONOMIC DEVELOPMENT

6.1 Status and trends

6.1.1 Aquaculture employment

Direct and indirect employment in North American aquaculture was estimated at 52 129 jobs in 2007, up from 40 212 in 1998 for an APR gain of 2.9 percent. Aquaculture represents a very small segment of North American agricultural production. However, on a regional basis it is extremely important to some communities in both Canada and the United States of America. Canadian aquaculture has grown faster than many established major field and fruit crops. In the seafood sector, the contribution of aquaculture has risen to 33 percent of the total Canadian seafood supply from capture fisheries and aquaculture combined, up from 23 percent in 1997.

Aquaculture plays a significant role in sustaining and revitalizing many declining coastal and rural communities in Canada. As a result of declines in resource-based industries, primarily timber and fisheries, these remote communities have been struggling to maintain economic stability and provide employment opportunities for youth. Farmed salmon is the largest food export of the Pacific province of British Columbia and the largest crop in the New Brunswick agrifood sector. The industry has given rise to a supply and service sector that is expanding to meet increased production demand, and resulting in increased private-sector technical and research capability. In order to be competitive, the industry is investing in advances in facilities, fish nutrition, fish health, species diversification, and genetics, all requiring high technology support. The sector has evolved with a growing demand for a specialized workforce, offering opportunities for many semi-skilled and highly qualified professionals. Aquaculture is a new source of year-round, better-paying jobs in many remote communities. On finfish farms, 80 percent of the jobs are full-time. Shellfish farming is characterized by some level of seasonality and as a result, many jobs on shellfish farms tend to be part-time.

According to an unpublished DFO study, Canadian finfish and shellfish operations together employ 5 100 people and create another 9 600 jobs further downstream in supply and service industries. Almost half of the employees are young and fall into the 21–35 year age group. Finfish operations, marine and freshwater combined, comprise only one-third of the total aquaculture operations but account for two-thirds of the total direct jobs. By contrast, shellfish production covers 43 percent of the operations but accounts for only one-quarter of the jobs. Of the total direct and indirect jobs, 53 percent are located in British Columbia on the Pacific coast and 25 percent in New Brunswick on the Atlantic coast, where farms are larger in size and predominantly characterized by vertical integration. Many small finfish and shellfish operations use unpaid family labour.

The aboriginal share of the workforce is growing and is currently at 6 percent. There are a number of successful aquaculture entrepreneurships that have created income and employment opportunities for aboriginal communities. Largely dependent on natural resources for their livelihoods, aboriginal people in Canada were hit hard by the decline in commercial capture fisheries and timber harvest. Aquaculture helped to generate income and create jobs in their own communities. One success story that has drawn considerable attention is the salmon farming venture of the Kitasoo First Nation in British Columbia in partnership with a transnational salmon company. Today, salmon farming provides 15 full-time equivalent jobs for Kitasoo First Nation members worth US$483 750 annually.

The Kitasoo have also constructed a plant processing 635 tonnes of farmed salmon each month, generating gross monthly revenues of US$2.4 million. Processing activities employ 30 full-time equivalent jobs at full operation, contributing about US$1.1 million in wages to the village economy.

In British Columbia, 21 First Nations are engaged in shellfish aquaculture activities and 14 First Nations are engaged in finfish aquaculture. First Nations in Ontario, Quebec and Atlantic Canada are also pursuing aquaculture initiatives.

Labour productivity varies significantly between the two segments of the sector. Finfish farming has achieved an average annual productivity level per employee of 45 tonnes in freshwater and 61 tonnes in marine waters, whereas in shellfish farming each employee produces 25 tonnes. The productivity is greater at large integrated farms than at small family-operated farms, which depend significantly on family and temporary or seasonal labour (British Columbia, 2003).

The sector now faces a growing labour shortage. Industry representatives report that, during harvest seasons, some aquaculture operators and processors on both coasts hire immigrant workers from the Philippines, Viet Nam, and other East Asian countries. Such hiring is more likely to take place in the shellfish industry, which is characterized by higher seasonal demand for farm hands.

The sector also faces internal competition for skilled people among regions and between the finfish and shellfish sectors. While this competition increases demand for skills training, it places small operators at a competitive disadvantage. Small producers using their limited resources to train employees run the risk of losing the skilled employees to larger farms. The more developed salmon industry in British Columbia can attract skilled people from the Atlantic coast as well as from the finfish industry in central Canada, but small operators in these regions cannot offer the same benefits as transnational corporations. The CAIA is a member of the recently established Canadian Agricultural Human Resource Council, which has a mandate to find solutions to the labour market constraints faced by the industry, so that the industry can remain competitive and profitable in the future. Some ongoing activities under that initiative include:

- industry-wide labour market inventory and needs assessment for producers;
- developing recruitment and retention programs for skilled labour;
- inventory of education and training programmes in Canada;
- description of on-farm occupations;
- new markets and future skills needs;
- communications and career awareness.

The two primary aquaculture sectors in North America have evolved in parallel fashion with regard to consolidation of a number of small farms over time into fewer and more efficient larger operations. This has occurred with channel catfish and salmon, and follows the model observed across the terrestrial agriculture sector. Even in the organic movement, which once held small farm status as part of its appeal, larger corporations are producing organic crops more efficiently and successfully competing in the marketplace. This evolution towards fewer and more efficient larger operations is driven largely by the need for economies of scale to lower production costs and remain competitive as production increases and aquaculture products make the transition from speciality products to commodities.

In United States aquaculture, total direct and indirect employment was estimated at 39 471 in 2007, up by 6 087 from 33 384 jobs in 1998. The United States aquaculture census, last conducted in 2005, provides detailed information on aquaculture employment by individual states. In the United States of America, aquaculture provided 10 519 direct jobs in aquaculture in 2005, of which 5 653 or 54 percent are more than 150 days/year (USDA ERS, 2006). There are 4 866 part-time or seasonal jobs with workers on the job fewer than 150 days/year. Operators of the 4 309 aquaculture farms in the United States of America work on average 30 hours/week, ranging from a high of 53 in Delaware to a low of 17 in Kentucky.

The importance of aquaculture employment to local economies varies considerably on a regional basis. The impact is greatest in the cluster of states in the southeast Delta region, which is the centre of the channel catfish industry. The three states of Arkansas, Louisiana and Mississippi provide jobs to 3 936 people or 37 percent of the nation's total direct employment in aquaculture (Table 11). These same three states generate US$56.4 million in payroll or 34 percent of the nation's total for aquaculture. With its dynamic shellfish sector raising primarily oysters and clams, Washington alone represents 15 percent of total aquaculture payroll at US$27.4 million with 1 284 positions equal to 12 percent of direct employment.

Table 11: States in the United States of America with aquaculture payroll exceeding US$10 million in 2005.

State	No. of Jobs >150 days	No. of Jobs <150 days	Payroll (US$1 000)
Arkansas	511	229	14 955
California	450	121	14 762
Florida	478	315	12 410
Louisiana	565	1,255	16 969
Mississippi	938	438	24 452
Washington	834	450	24 711
Sub-Total	3 776	2 808	108 259
United States of America Total	5 653	4 856	168 724

Source: USDA, 2005.

6.1.2 Seafood consumption

Aquaculture products are not a significant factor in providing food for poor people in North America. In fact, seafood consumption is highest among older and more affluent consumers. In general, successful aquacultured products are premium food items such as salmon, shrimp and oysters. One exception to this is imported frozen tilapia fillets, with imports to the United States of America rising from 16 tonnes selling at US$3.24/kg in 2003 to 88 tonnes worth US$3.10/kg in 2007. With the availability of these inexpensive tilapia imports, virtually all of the tilapia cultured in North America is sold as a live product to attract the premium price necessary to cover production costs.

Canadian per capita consumption of wild and farmed seafood combined was 9.4 kg (edible weight) in 2006. Per capita seafood consumption has been relatively stable since reaching a high of 9.8 kg in 2003. Canadians prefer fresh and frozen fish to processed fish. They also consume more shellfish than freshwater fish (Table 12).

The United States per capita consumption of fish and shellfish was 7.4 kg (edible meat) in 2007, about 2 kg/person less than that in Canada. This total was 0.1 kg less than the 7.3 kg consumed in 2006. Per capita consumption of fresh and frozen products was 5.5 kg, 0.1 kg less than in 2006. Fresh and frozen finfish accounted for 3 kg while fresh and frozen shellfish consumption was 2.5 kg per capita.

Table 12: Per capita seafood consumption in Canada, kg/person.

	2002	2003	2004	2005	2006
Fresh and frozen fish	4.01	4.43	3.94	4.04	4.09
Freshwater fish	0.43	0.53	0.51	0.47	0.50
Processed sea fish	2.96	2.81	2.74	2.90	2.87
Shellfish	2.17	2.03	1.93	1.90	1.89
Total	9.57	9.80	9.12	9.31	9.36

Source: Statistics Canada, 2008b.

Environmental and food safety research organizations identify many farmed aquatic species on their lists of the best seafood choices, including catfish, oysters, Arctic char, bay scallops, crayfish, trout, mussels, abalone, striped bass, tilapia, barramundi and clams. Growing demand for seafood at food service establishments and changing demographic composition are expected to increase demand for farmed fish. Non-conventional retailers and mass marketing by supermarkets are also popularizing farmed fish to domestic consumers who are concerned about healthy food. Between 1987 and 2006, consumption of shrimp in the United States of America increased by 92 percent, salmon consumption rose by 359 percent, and catfish went up by 63 percent. Most of this supply comes from farms and is a good indicator of continued increasing demand.

6.2 Salient issues and success stories

Both Canada and the United States of America have well-developed social protection networks with a number of special programmes for women and minorities. The United States workforce will become increasingly diverse in the next three decades, a shift that could bring changes in education, training and public policy.

By 2039, today's racial and ethnic minorities will become the majority of the workforce between the ages of 18 and 64 years. In 2050, the working-age population will be 30 percent Hispanic, 12 percent non-Hispanic black and 8 percent non-Hispanic Asian. Today, the breakdown is 15 percent Hispanic, 12 percent black and 5 percent Asian. As mentioned above, the percentage of women in the workforce is rising and will soon surpass men. Enhanced opportunities in education and training will help to ensure diversity in the North American population is reflected in that of the workforce.

While inequalities drawn along ethnic and gender lines exist in North America, considerable progress is being made to create greater opportunities for under-represented groups in food production. There is a multitude of opportunities for women as farmers, and increasingly new opportunities are emerging as scientists, teachers and leaders. Women are often at the forefront of research, bringing new discoveries and technologies to the agricultural industry, including the aquaculture sector.

6.3 The way forward

In North America, there a number of programmes supported by government and the private sector to assist women and minorities in obtaining an education and accessing professional development opportunities in agriculture, particularly in rural areas. Some of these include:

- Cooperative Service Reports from the USDA's Rural Business-Cooperative Service (www.rurdev.usda.gov/rbs/pub/service.htm). The goal of Rural Development, Business and Cooperative Programs (BCP) of the USDA is to promote viable business development in rural areas. By creating planning and funding partnerships with local entities, the BCP serves as a catalyst to create and preserve quality jobs and a sustainable environment.
- The USDA's Rural Empowerment Zones/Enterprise Communities Web site (www.rurdev.usda.gov/rbs/ezec/). The first priority in this USDA programme is to provide economic opportunities and jobs to sustain economically self-sufficient communities and support cooperatives. Opportunities for entrepreneurial initiatives, small business expansion, and training are all tools to provide economic stability in communities.
- The goal of the Cooperatives Program of USDA's Rural Development Program is to help rural residents form new cooperative businesses and improve the operations of existing cooperatives. To accomplish this, the Cooperatives Program provides technical assistance to cooperatives and those thinking of forming cooperatives. It also conducts cooperative-related research and produces information products to promote public understanding of cooperatives.
- USDA National Agricultural Library Services (www.nal.usda.gov). The USDA's National Agricultural Library brings a wealth of information on resources available to assist agricultural producers. One example is a new programme in partnership with The American Farm Bureau Federation to create a National Curriculum and Training Clearinghouse for Beginning Farmers and Ranchers. The clearinghouse is a component of the Beginning Farmer and Rancher Development Program, a competitive grant initiative that is part of the 2008 Farm Bill.
- The USDA home page (www.usda.gov) is the gateway to resources available to farmers and ranchers. Examples of grant programmes include the Value-Added Producer Grant Program, Beginning Farmer and Rancher Development Program, Rural Development Business Program, and opportunities for minority and limited-resource producers.
- Agriculture and Agri-Food Canada (www.agr.gc.ca). The home page for Agriculture and Agri-Food Canada contains valuable information on Canadian aquaculture, opportunities in

the industry, and a diversity of support programmes and initiatives for cooperatives and rural development.

6.3.1 Farmers clusters

Small farm clusters are organizations of farmers bound together by a desire to succeed through the mutual sharing of ideas, technologies, experience and new market opportunities. As small farms in North America face increased competition from larger producers, this sharing of information is seen as a way to increase competitiveness and enhance the sustainability of rural communities. The organic food industry started with many of these same precepts, but as market opportunities grew, agri-industry recognized the opportunities and much of the organic food in markets today is produced by large agribusinesses. While there is interest in farmers clusters among small agricultural producers, there has not been a significant expansion of the movement in North American aquaculture and there are no farmers clusters among aquaculture producers.

Agribusiness understands the efficiencies afforded by cooperation and collaboration, even when competing in the market place. Evidence of this is seen in the recently announced formation of three agriscience clusters supported by the Dairy Farmers of Canada, the Dairy Processors Association of Canada and the government. Each cluster will bring together industry, academic and government expertise to address issues in the areas of human nutrition and health, food safety and finding ways to reduce the carbon footprint of the dairy industry. Similar agriscience clusters could be successfully created around important issues involving aquaculture development, such as species diversification, hatchery technology, new feeds and environmental compatibility.

7. EXTERNAL PRESSURES ON THE SECTOR

7.1 Status and trends

7.1.1 Climate change

The impact of climate change on North American aquaculture is not yet fully known. Few research studies have been completed to demonstrate impacts scientifically, but many are under way. The four major effects of climate change (rising air and water temperatures, sea-level rise, ocean acidification, and extreme weather) will certainly affect aquaculture.

The Atlantic coast salmon industry has fully recovered from the ISA problem in the early 2000s, which may have been facilitated by ocean warming trends. Salmon farms in Chile have recently been severely affected by the spread of ISA, and resulting losses have spurred the industry to develop a comprehensive health management plan similar to that developed in Canada, which has successfully prevented further outbreaks.

Higher water temperatures are likely to alter the range, growth and distribution of many species – this carries both risks and benefits. Increased infectious disease with rising temperatures is a vulnerability of aquaculture. Climate warming may stimulate the growth of harmful algal blooms that can release toxins into the water and kill fish and shellfish. Because both cage-based finfish aquaculture and shellfish aquaculture occur in open water, they are susceptible to this increased toxicity. These blooms threaten shellfish populations, especially clams, through both lethal effects and chronic impacts (Natural Resources Canada, 2004). For cage-based aquaculture occurring in freshwater lakes and reservoirs, the impact of temperature rise will probably be greater for trout producers than for striped bass or tilapia growers given their higher thermal tolerance. Warming waters will increase availability of new sites on northern coastlines where cold temperatures currently restrict aquaculture (2We Associates Consulting Ltd., 2000). These changes will be gradual enough that growers should be able to adapt their operational and business plans in the near term. However, over a longer time frame in extreme cases they may be required to relocate or discontinue production.

7.1.2 Coastal storms

The frequency and severity of extreme weather seems to have increased on both the Pacific and Atlantic coasts, as anticipated by climate change models. Hurricanes Katrina and Rita in the Gulf of Mexico are good examples of this and demonstrate how shellfish aquaculture can be devastated both by loss of stocks and coastal infrastructure. The higher frequency and intensity of storms will cause more damage to shellfish gear and fish cage facilities. As a result, the costs of equipment design and replacement and of fish escape prevention will rise. The inflation in insurance premiums in recent years is evidence that greater uncertainty and risk as a consequence of extreme events will increase operating costs.

The aquaculture industry is generally confident of its ability to adapt to changing conditions related to gradually rising temperatures and sea levels, and believes that it may benefit from longer growing seasons and increased harvest areas. Of greater concern is the spectre of ocean acidification and how that may influence shell formation and affect filter-feeding shellfish.

7.1.3 Ocean acidification

Ocean acidification has the potential to alter ocean ecosystems drastically in a relatively brief time frame. Ocean acidification results from the buildup of carbon dioxide in the atmosphere, which then dissolves into seawater producing carbonic acid that drives down pH. Carbonate chemistry, which controls secretion of shell material made of $CaCO_3$ by marine invertebrates like corals and filter-feeding bivalves (such as oysters, clams and mussels), is also influenced by pH. Acidifying the ocean is particularly detrimental to these organisms and shell formation may be inhibited at reduced pH levels. This decline in ocean pH is largely the result of modern industrialization and the burning of fossil fuels since the industrial revolution. Researchers predict that this oceanic absorption of CO_2 from fossil fuels may result in larger pH changes in the next few centuries than observed in the past 800 000 years (Caldeira and Wickett, 2003).

The surface-water pH of oceans now averages 8.2 and has probably declined by 0.1 unit since the industrial revolution. Modellers predict that pH could continue dropping by another 0.3–0.4 units over the next century. At a pH of about 7.8, shell formation in many marine invertebrates is inhibited. This could result in major regime shifts in the world's marine ecosystems, imperilling shell-forming shellfish and plankton far sooner than generally anticipated.

Recent surveys of water quality off the Oregon coast in the Pacific northwest documented pH values of 7.8 in upwelled water that has probably been entrained in deep ocean currents, out of contact with the atmosphere for 50 years. The effects of this reduced pH, and potential links with oyster larval mortality resulting from *Vibrio tubiashii* flourishing in lower pH waters has been mentioned previously. In addition, anecdotal evidence from oyster hatcheries in the region links lower pH values to significant larval mortalities in hatcheries, without *V. tubiashii* as a causative agent. In oyster larvae, which must form a shell to grow and survive, the reduced pH environment and potential inability to secrete calcium carbonate may provide an explanation for observed mortalities correlated with reductions in pH. Research is ongoing to investigate these mortalities and document their cause.

While this scenario is regional at this time, systematic monitoring of the pH of the oceans has not occurred to a large degree and this should be a priority. The economic impact of ocean acidification on shellfish aquaculture in the United States of America could be significant. Shellfish harvest in the United States of America is projected to decline by between 10 and 25 percent in the next 60 years (Cooley and Doney, 2009). Currently, shellfish sales generate about US$750 million per year, nearly 20 percent of total fisheries revenue. By 2060, it is calculated that between US$75 million and US$187 million will be lost annually, equivalent to US$1.4 billion over the next 50 years.

Ocean acidification is a serious near-term impact of climate change. There is probably a critical threshold that, once reached, could precipitate a cascading series of events irreversibly altering marine biodiversity, threatening food security, and damaging economies worldwide. North America is a leader in research to document impacts of ocean acidification and identify this threshold; it should also provide political leadership internationally to develop solutions.

Sea-level rise and increasing water temperatures are likely to occur over a more gradual time frame. Nonetheless, aquaculture is strictly regulated and it is generally neither simple nor efficient for existing operations to move to new locations or change the species being farmed. As a result, there is a need to emphasize planning at the national, provincial and state levels to anticipate changes and prepare adaptive strategies in response. In encouraging fashion, the Canadian salmon industry on the Pacific coast has expressed interest in having new locations selected and pre-approved for various climate change scenarios. Regulatory agencies should encourage and facilitate this type of forward planning.

7.1.4 Economics and fish health

Like most economic sectors, Canadian aquaculture has been hit by ongoing global economic downturns. Nevertheless, aquaculture has managed to maintain stability in exports, and demand for Canadian salmon in the United States of America rose in 2008. The demand also supported steady average prices for salmon. As discussed above, the United States catfish industry declined significantly in area farmed and production is down from a peak in 2003. Increased costs for feed and fuel, along with fierce competition from imported fillets, remain challenges exacerbated by the economic downturn.

The outbreak of ISA and consequent abrupt decline in salmon production in Chile, a major salmon supplier to the United States of America, created market opportunities for Canadian aquaculture and contributed to the general rise in the global price of farmed salmon. In 2008, Chile's exports to the United States of America fell by 5 percent from the previous year, whereas Canada's exports increased by 8 percent (Table 13)

Table 13: Volume and value of salmon products exported to the United States of America by Canada and Chile.

	2006	2007	2008	2009
Export volume (tonnes)				
Canada	75 136	70 512	75 594	39 313
Chile	101 016	104 859	102 517	36 249
Export value (US$1 000)				
Canada	421 000	416 000	448 000	232 000
Chile	763 000	811 000	771 000	292 000

Source: USDA ERS, 2009.

The salmon sector was particularly affected by the continuous appreciation of the Canadian currency against the United States dollar. As Canadian aquaculture products are mostly traded in the United States market, a strong Canadian dollar lowers revenue for Canadian exporters. A constructed example will illustrate how much revenue the sector loses in the fluctuation of exchange rate. From January 2008 to December 2008, the Canadian dollar appreciated from US$0.85 to US$1.00. In December, the total Canadian salmon exports were valued at US$37.4 million both in the United States dollar and the Canadian dollar. Had the dollar stayed at the January level, the Canadian exporters could have received another US$5.6 million more.

7.2 Salient issues and success stories

Planning and preparing for external pressures such as natural disasters and climate change are challenges the aquaculture industry will face for the foreseeable future. Coordinated planning to address fish health, economic uncertainties, global warming, sea-level rise, ocean acidification and natural disasters are complicated by the high degree of uncertainty surrounding each issue. For this reason, a reasonable approach is to look at a range of scenarios that may unfold and develop a corresponding range of potential responses.

The Canadian response to the ISA outbreak and resulting biosecurity protocols in the industry is an example of responding to a disaster in a coordinated fashion with demonstrable and continuing success. The industry has not seen subsequent disease outbreaks and the Canadian fish health programme is being used as a model by Chilean farmers as they develop their own health management programme.

While still in the early phases of research, the speed with which the research community ramped up efforts to gain a better understanding ocean acidification and its potential impacts on a wide diversity of organisms has clearly been successful. In the coming years, understanding of the impacts of declining pH on invertebrate growth, reproduction and larval development will be vastly improved. This will enable better-informed predictions of potential population-level impacts on select shell-forming invertebrates and how these may result in trophic-scale shifts and ecosystem impacts.

7.3 The way forward

The increasing interest in coastal and marine spatial planning provides an excellent opportunity for the aquaculture sector to plan future growth in areas that will minimize exposure to externalities that have the potential to affect production. This includes farm locations to protect facilities from severe storm damage, avoid areas prone to harmful algal blooms, and ensure optimal water quality and environmental conditions. Areas with infrastructure threatened by sea-level rise or exposure to severe storms should be avoided.

Perhaps most importantly, the aquaculture sector must join the chorus in pushing for an aggressive research program to evaluate strategies to manipulate ocean pH and for meaningful steps to curb greenhouse gases. Ocean acidification as a result of CO_2 already entrained in the deep ocean and in the atmosphere is likely to continue past a critical threshold wherein shell-forming species will be unable to survive. An intensive research effort should be targeted on identifying means to reverse this trend.

8. THE ROLE OF SHARED INFORMATION: RESEARCH, TRAINING, EXTENSION AND NETWORKING

8.1 Status and trends

The need for scientific research remains critical to enhance the growth and diversity of North American aquaculture. From the early days of development, the DFO has played a lead role in research and technology transfer in Canada, while this responsibility in the United States of America is shared by the USDA and the NOAA. Federal, state and provincial government research facilities are dedicated to research on new species development, selective breeding to improve broodstock performance and seed quality, enhanced growout technologies, health management, and improved husbandry, nutrition and feeds. Federal research provides a sound science and technology base for innovations in the industry, and collaborations with the extensive network of universities and state and provincial researchers, coupled with extension expertise in both countries, expand the reach of this research. Development and commercialization of new technologies in the culture of catfish, salmon, oysters and mussels, and the success of these industries are largely the result of past and ongoing government support through collaborations with industry, academia and extension.

8.1.1 North American aquaculture facilities

The DFO has 12 research facilities and biological stations, with 3 of them dedicated to freshwater research. These facilities, strategically located in different parts of the country, have evolved as the centre of innovation through their collaboration with universities, public and private research institutions, and industry.

In the United States of America, the NOAA and the USDA support research at independent academic institutions and at their own research facilities. The National Sea Grant College Program within the NOAA is a federal and state partnership supporting research, extension and communication to improve management of coastal and marine resources. It comprises a network of 32 university partnerships in coastal and Great Lakes states supporting programmes in aquaculture, fisheries and coastal resources. Through the NMFS, the NOAA also maintains six regional fisheries science centres that engage in aquaculture, fisheries and marine related research located in Alaska, the northwest, Pacific islands, and one each in the southwest, southeast, and northeast of the country.

The USDA maintains a network of five regional aquaculture centres in the northeast, southeast, north-central, west, and the tropical and subtropical regions of the United States of America. These centres support research and extension programming under the guidance of extension, technical, and industry advisory committees. The USDA National Institute of Food and Agriculture (NIFA, formerly CSREES) is a funding partnership with land grant universities throughout the United States of America. The NIFA supports basic and applied research to improve knowledge of the biological, physical and social sciences in support of agriculture, including aquaculture. The wide-ranging NIFA land-grant partnership includes:

- more than 130 colleges of agriculture;
- 59 agricultural experiment stations;
- 57 cooperative extension services;
- 63 schools of forestry;
- Tuskegee University, West Virginia State College, and the other 16 historically black colleges and universities;
- 27 colleges of veterinary medicine;
- 42 schools and colleges of family and consumer sciences;
- 33 Native American land-grant institutions;
- 17 Alaskan native-serving and Hawaiian native-serving institutions;
- more than 160 Hispanic-serving institutions.

The NIFA also provides support for aquaculture development and its funding has increased from less than US$5 million 20 years ago to about US$35 million annually today. The USDA also supports cooperative extension agents that provide aquaculture extension services nationwide, in collaboration with Sea Grant and regional aquaculture centre personnel.

Academic training and research are undertaken by many universities across Canada. Universities that excel in undergraduate and graduate teaching and research include Vancouver Island University in British Columbia, Aquaculture Centre of University of Guelph in Ontario, Université Laval in Quebec, Centre for Coastal Studies and Aquaculture at University of New Brunswick, Nova Scotia Agricultural College, and Centre for Aquaculture and Seafood Development of Memorial University of Newfoundland. There are many community colleges, especially in the coastal provinces, that impart training to cater to the needs of aquaculture technologists.

The United States of America has an extensive array of universities offering undergraduate and advanced degrees in disciplines related to aquaculture. Some of the larger programmes are at the University of Maine, University of Pennsylvania, University of New Hampshire, Virginia Institute of Marine Science, University of Maryland, Auburn University, University of Miami, Texas A&M University, University of Arizona, University of California at Davis, University of Washington, and University of Hawaii.
In its five-year planning (2007–2012), DFO Science has identified sustainability of aquaculture as one of its research priority areas (www.dfo-mpo.gc.ca/science/Publications/fiveyear-quinquennal/index-eng.htm#a4). Partnerships with experts, not only from government departments and universities but also from aboriginal groups, industry and NGOs will be critical in the delivery of the research plan. The partnerships are being maximized through the DFO's centres of expertise. The DFO addresses regional research priorities through its five regional offices.

8.1.2 Canadian aquaculture initiatives

Two research and development programmes run by the DFO are specifically designed to involve industry in research and innovation to promote industry competitiveness and diversification. The first one, Aquaculture Collaborative Research and Development Program (ACRDP), has been in operation since 2001; the second one, Aquaculture Innovation and Market Access Program (AIMAP), began in 2008.

The ACRDP is an industry-driven programme with annual funding of US$4.3 million. For each collaborative research project, the industry partner contributes 30 percent (cash or in-kind) of the funding requested from the ACRDP. Projects are conducted either at DFO research facilities or at industry partner facilities. Funding allocation is determined based on the following three objectives of the programme:

- best performance in fish production;
- optimal fish health;
- industry environmental performance.

National and regional priorities have been established under these broad objectives. By 2007, the programme has approved and funded more than 230 projects across the three priority areas: best performance in fish production (54 percent), environmental performance (30 percent), and optimal fish health (16 percent). To date, research for more than US$53 million has been conducted through the ACRDP. This includes US$24.4 million in ACRDP funds, US$12 million from industry contributions, US$12 million in other DFO funding and US$4.7 million in contributions from other project partners.

The AIMAP began in 2008 and has a budget of US$22.3 million to make available in the next five years. Funding allocation under this programme is determined based on the following four broad objectives:

- sustainable production;
- increased diversification;
- green technology;
- market access.

Specific priorities under each of the objectives have been established based on consultation with provinces, territories and sector stakeholders.

Some provinces also host aquaculture research and development (R&D) committees and commit funding to independent research and development activities that address existing and emerging issues. Research priorities include fish health, environmental interactions, new species development, broodstock improvement, biotechnology, and enhancement of shellfish and finfish production. Industry associations are now also recruiting R&D coordinators in order to improve their representation in local, regional and national research activities. Many federal regional economic development agencies also extend funding to such efforts and thus help in assessing the economic viability of new technologies and challenges involved in their commercialization.

8.1.3 United States of America National Marine Aquaculture Initiative

In the United States of America, the NOAA developed a National Marine Aquaculture Initiative (NMAI) in 1998 as an R&D funding initiative to foster the growth of the aquaculture industry. The NOAA also finalized a ten-year plan for marine aquaculture in 2007 (NOAA, 2007). This plan outlines a strategic approach to achieve the four goals in the plan. This marine aquaculture plan, and a 120-page summary of a 2008 workshop titled Overcoming Technical Barriers to the Sustainable Development of Competitive Marine Aquaculture in the United States of America will serve as guiding documents for federal support of aquaculture in the next decade (Browdy and Hargreaves, 2009). The initial focus of the NMAI on sustainable aquaculture technologies developed in collaboration with academia and industry has evolved to include an ecosystem-based approach. Since 1998, a federal investment of US$15 million has supported key research, technology and policy development. Projects of the NMAI have included research on new species, health and nutrition, BMPs, ecosystems monitoring and management, engineered production systems, and legal and operational frameworks. In addition to NMAI competitive funding, the NOAA has administered US$15–20 million annually through Congressional awards for R&D projects to spur growth in commercial aquaculture.

Shellfish farming has increased significantly in the United States of America in the last decade, and the NMAI, in partnership with an NOAA Sea Grant Initiative in oyster disease research, has contributed to this growth. Selection for disease-resistant, fast-growing shellfish has improved competitiveness in the industry and this sector has provided economic opportunities for fishers displaced by harvest restrictions or declining fish populations.

The NMAI recognizes that new species will be a tool for aquaculture expansion, and cutting-edge research has resulted in a number of new candidate species for commercial aquaculture and stock enhancement. Those species include cobia, Atlantic cod, California yellowtail, black seabass, sablefish, and bait shrimp. Many of these species are candidates for offshore cage culture, and the NMAI has also invested significantly in pilot demonstration projects (mentioned above), such as the offshore net-pen operations in Hawaii, New Hampshire and Puerto Rico.

The NMAI recognizes that policy can be an impediment or catalyst to the industry and has supported policy development to spur growth. Funding from the NMAI helped the west-coast shellfish industry create an environmental policy and codes of practice, and supported a policy analysis for offshore aquaculture that informed development of the National Offshore Aquaculture Act, introduced in the United States Congress in June 2005. While not yet passed, the aquaculture industry is hoping this will provide a supportive federal regulatory structure.

8.1.4 Aquaculture networking

A primary networking organization for aquaculture professionals in North America is the World Aquaculture Society (WAS). The WAS is an international non-profit organization with more than 3 000 members in about 100 countries. Membership is comprised of producers, researchers, agency representatives and, looking to the future, includes a strong student chapter. The primary focus of the WAS is to strengthen and facilitate information sharing and networking on emerging issues internationally. The WAS has a separate United States chapter. Regional associations and research centres also provide effective networking opportunities.

The Aquaculture Association of Canada (AAC) is the most active networking platform for aquaculture professionals in Canada. Established in 1984, the AAC promotes the study of aquaculture and related sciences, gathers and disseminates information relating to aquaculture, and creates public awareness and understanding of aquaculture. It has more than 900 members, including producers, suppliers, students, scientists, educators and government officials. It has also attracted members from the United States of America and 14 other countries.

The National Aquaculture Association (NAA) is a United States-based association dedicated to the establishment of national programmes that further the common interest of producer members. The NAA works with the federal government to create a supportive regulatory and policy arena.

In the United States of America, for most cultured species, there are also producer-based associations that promote networking and information sharing. The National Shellfisheries Association is one of the oldest scientific associations in the United States of America, bringing together producers, researchers, government officials, and students to share information and solve problems facing the shellfish sector. Working to improve management and governance, there is the National Association of State Aquaculture Coordinators, whose members interact and share information in areas of mutual interest.

A different kind of networking for knowledge dissemination is being promoted through the *Canadian Aquaculture R&D Review*. Published in English and French, this biannual review is sponsored by the ACRDP and the British Columbia Innovation Council. It began in 2004 and, at this time, has published three issues featuring a total of 550 reviews of R&D projects undertaken in Canada.

Although limited to the DFO, the Canadian Science Advisory Secretariat (CSAS) provides unique opportunities for DFO scientists to share knowledge with one another. The CSAS is responsible for coordinating the peer review of scientific issues for the DFO. The CSAS works with scientists across the DFO to develop integrated overviews of issues in fish stock dynamics, ocean ecology and the use of living aquatic resources including aquaculture. An important responsibility of the CSAS is to identify emerging issues quickly, and this is carried out in part through advisories related to ecological interactions and aquaculture operations.

In response to growing needs for information, government agencies are partnering with industry to expand the aquaculture information base. The Fish Health Database of the British Columbia Salmon Farmers Association (BCSFA) exemplifies such partnerships. The database is designed to improve access to information on the health of cultured fish stocks in British Columbia. Information from all privately and publicly owned finfish farming and enhancement operations is contributed to the BCSFA database, which is then supplied to the British Columbia Ministry of Agriculture and Land for publishing in a quarterly report. This transparency in aquaculture production and health management is important to communicate to the public and help to counteract negative perceptions.

In a broader hemisphere context, the Aquaculture Network for the Americas (ANA) is an important new organization created to facilitate networking in the Americas that began in 2010 with 21 charter member nations from Latin America and the Caribbean. Supported by FAO, the ANA will act as an intergovernmental body for the sustainable development of aquaculture in the Americas. Many opportunities for productive collaborations will probably develop in the future between the ANA, Canada and the United States of America.

The goal of the ANA is to increase aquaculture production in the region to enhance food security and improve general nutrition through greater availability of affordable safe and sustainable seafood. In doing so, the ANA can contribute to reducing poverty and inequality.

The use of Web technology has helped both government agencies and industry to reach more users in North America and abroad. The DFO, NOAA, and USDA all maintain a dedicated Web page for aquaculture on which users can access updated metadata and relevant links to information sources related to aquaculture science, economics and management. Most of the provincial departments have a similar dedicated page for aquaculture. The five USDA Regional Aquaculture Centers and the 32 Sea Grant Programs have a strong Web presence with links to their research portfolios, archives and publications. The USDA and Sea Grant were instrumental in supporting the development of AquaNIC.org, a comprehensive information site for aquaculture. In Canada, provincial Web sites often post updated data on compliance, fish health, fish escapes, environmental monitoring, and other pertinent topics. Most state agencies that house aquaculture programmes similarly provide Web-based information.

8.1.5 Canadian international conventions and treaties

Internationally, Canada is strengthening cooperation on aquaculture. In 2008, the DFO signed an MOU with the Subsecretaría de Pesca of Chile. Both Canada and Chile share the United States market to sell their salmon products and hence have much in common in the development of sustainable aquaculture. Through the MOU, the two countries agreed, among other things, to promote the exchange of public officers, scientific experts, technicians and researchers, and to cooperate in aquaculture-related research projects of mutual interest. A similar MOU was also signed with the Institute of Marine Research of Norway in 2009.

8.1.6 United States of America international conventions and treaties

The United States of America has a number of international conventions and treaties that usually address both fisheries and aquaculture, as described below.

North Atlantic Salmon Conservation Organization (NASCO), 1982
This treaty was established to work collaboratively for the conservation of wild Atlantic salmon. Among other activities, the NASCO has agreed to adopt the precautionary approach to introductions and transfers including aquaculture impacts and possible use of transgenic salmon.

At the 2009 NASCO meeting, the “focus area report” (FAR) parties agreed to the terms of reference for the third FAR on aquaculture, I&Ts, and transgenics. The United States of America has been pressing Canada for the last few years to improve bilateral cooperation on the management of aquaculture operations, in particular with respect to containment of farmed fish and notification when escapes occur. In bilateral meetings, progress on developing reciprocal notification procedures in the event of escapes has been made. The two parties will continue to liaise on notification issues as well as on aquaculture issues more generally. Canada and the United States of America have also considered whether or not the existing international protocols on I&Ts of salmonids and the associated database of product movement need some reconsideration. The protocols represent agreement to minimize the negative impacts of the I&T of salmonids and require reporting and assessment of such activities.

United States of America–Mexico Fisheries Cooperation Program
The NMFS and the predecessor agency to the Mexican Secretaría de Mexico Ambiente, Recursos Naturales, y Pesca informally agreed in 1983 to meet annually to review the broad range of issues involved in the bilateral fisheries relationship. Working group meetings are held as required on matters such as enforcement, management and aquaculture.

United States of America–Chile Fisheries Cooperation Program
The basic instrument establishing the United States of America–Chile Cooperation Program is an MOU between the NMFS and the Chilean Servicio Nacional de Pesca signed in 1995 and extended in 2004. Recent meetings have included discussions on management, enforcement, recreational fisheries, marine mammals and endangered species, research, environment, aquaculture, and information exchange.

Memorandum of Understanding between the American Institute in Taiwan and the Taipei Economic and Cultural Representative Office in the United States of America
The basic instrument establishing United States of America–Taiwan Province of China cooperation in fisheries and aquaculture is the Memorandum of Understanding between the American Institute in Taiwan (AIT) and the Taipei Economic and Cultural Representative Office (TECRO) in the United States of America Concerning Cooperation in Fisheries and Aquaculture. The MOU was signed by the AIT and the TECRO on 30 July 2002. It expired on 30 July 2007, but was renewed for an additional five years on 21 April 2008. The two parties, through their designated representatives, also agreed to: (i) exchange information on fisheries and aquaculture research and relevant scientific reports and publications; (ii) conduct joint studies and training programmes on fisheries and aquaculture; (iii) promote exchange visits of fisheries and aquaculture personnel; and (iv) strengthen existing cooperation between fisheries enforcement representatives.

Memorandum of Understanding on Cooperation on Fisheries Issues between the National Oceanic and Atmospheric Administration of the United States of America and the Ministry of Fisheries and Coastal Affairs of Norway
The basic instrument establishing United States of America–Norway cooperation in fisheries and aquaculture is the Memorandum of Understanding on Cooperation on Fisheries Issues between the National Oceanic and Atmospheric Administration of the United States of America of America and the Ministry of Fisheries and Coastal Affairs of Norway. The MOU became effective 1 October 2008 and will expire on 30 September 2013.

North Pacific Marine Science Organization (PICES)
The PICES group includes Canada, China, Japan, Republic of Korea, Russian Federation and the United States of America. Member countries work together through WG-24: Working Group on Environmental Interactions of Marine Aquaculture.

International Council for the Exploration of the Sea (ICES)
The ICES coordinates and promotes marine research in the North Atlantic, working with an international community of more than 1 600 marine scientists from 20 member countries: Belgium, Canada, Denmark (including Greenland and Faroe Islands), Estonia, Finland, France, Germany, Iceland, Ireland, Latvia, Lithuania, the Netherlands, Norway, Poland, Portugal, Russian Federation, Spain, Sweden, the United Kingdom, and the United States of America. There are also a number of countries that have affiliate status with the ICES: Australia, Chile, Greece, New Zealand, Peru, and South Africa. Non-governmental organizations with formal observer status include the Worldwide Fund for Nature and Birdlife International. Members of the ICES address interactions between aquaculture and wild stocks, evaluating comparative experiences for Atlantic cod and Atlantic salmon.

Asia-Pacific Economic Cooperation (APEC)
The APEC was established in 1989 to promote open trade and economic cooperation among economies around the Pacific Rim. The APEC Fisheries Working Group (FWG) was formed in 1991. The FWG meets annually and deliberates on a broad range of living marine resource issues and specific project proposals. Decisions are taken by consensus. The FWG includes 21 APEC economies and projects are funded by the broader APEC organization, with individual members supplementing where possible and appropriate. In recent years, the FWG has concentrated project work on: capacity building in the areas of fisheries management and science; fishing capacity reduction; seafood safety; aquaculture; various environmental issues; and development of a network in the Americas for improving aquaculture methodology.

Asia-Pacific Fishery Commission (APFIC)
The APFIC was established under the APFIC agreement as the Indo-Pacific Fisheries Council in 1948 by FAO. The APFIC is an Article XIV FAO regional fishery body established by FAO at the request of its members. The secretariat is provided and supported by FAO. The APFIC acts as a regional consultative forum that works in partnership with other regional organizations and arrangements and members. It provides advice, coordinates activities and acts as an information broker to increase knowledge of fisheries and aquaculture in the Asia-Pacific region to underpin decision-making.

Committee on Fisheries (COFI)
The COFI, a subsidiary body of the FAO Council, was established by the FAO Conference at its Thirteenth Session in 1965. The COFI currently constitutes the only global intergovernmental forum other than the United Nations General Assembly where major international fisheries and aquaculture problems and issues are examined with recommendations addressed periodically on a worldwide basis to governments, regional fishery bodies, NGOs, fishworkers, FAO and the international community. The two main functions of the COFI are: to review the programmes of work of FAO in the field of fisheries and aquaculture and their implementation; and to conduct periodic general reviews of fishery and aquaculture problems of an international character and appraise such problems and their possible solutions with a view to concerted action by nations, FAO, intergovernmental bodies and the civil society. The COFI also reviews specific matters relating to fisheries and aquaculture referred to it by the Council or the Director-General of FAO.

The Joint Project Agreement (JPA) between the NOAA and the Ministry of Food, Agriculture, Forestry and Fisheries of the Republic of Korea for Integrated Coastal and Ocean Resources Management
This JPA is between the NOAA and the Ministry of Land, Transportation, and Marine Affairs and the Ministry for Food, Agriculture, Forestry and Fisheries of the Republic of Korea. The original joint agreement with the Ministry of Marine Affairs and Fisheries was first signed in 2001 for a five-year period and was renewed in 2005 to continue to 2010–11. The overall purpose of the JPA is to pursue marine science and technology cooperation in coastal and ocean resources. The JPA provides a framework for the exchange of scientific data, research and technical training of personnel, and cooperative activities to enhance the integrated coastal and ocean resources management capabilities of both countries.

Organisation for Economic Co-operation and Development (OECD)
The OECD is a Paris-based international organization that provides a forum for consultations on a wide range of economic issues among developed countries. The OECD Committee for Fisheries meets twice annually (in the spring and autumn) and occasionally holds ad-hoc technical meetings. The OECD Committee for Fisheries decided to work on four major areas in the period 2009–2011:

- advancing the aquaculture agenda: policies to ensure a sustainable aquaculture sector;
- economic aspects of climate change in the context of the ecosystem approach to fisheries management;
- fisheries and aquaculture certification;
- the economics of rebuilding fisheries: towards best practice.

United States of America–China Marine and Fisheries Science and Technology Protocol
The United States of America and China signed the Science and Technology Agreement in Washington, DC, on 31 January 1979. Thirty years later, this umbrella agreement contains more than 30 individual protocols for science and technology cooperation between the two countries. Given the critical importance of sustainability of various resources and uses of marine ecosystem including fisheries and aquaculture, both sides agreed to focus future research on ecosystem-based living marine resources management.

8.1.7 Indigenous aquaculture

Indigenous peoples in coastal areas of North America have harvested fish and shellfish for thousands of years. The First Nations of Canada and tribes in the United States of America have increasingly become engaged in aquaculture in the last decade as the expansion of shellfish and salmon farming has demonstrated the economic opportunities afforded rural communities through these endeavours. Many tribes and First Nations are actively engaged in shellfish farming.

In Canada, the Aboriginal Aquaculture Association was formed in 2003 to explore opportunities to expand the involvement of First Nations in the sector, with widespread support among First Nations, industry and all levels of government. The association envisions aquaculture as leading to economic development and self-sufficiency in local communities. With a long history of harvesting fish and shellfish, aquaculture fits well with the historical life style of many First Nations.

A significant partnership between a private commercial venture and the Kitasoo/Xai'xais First Nation in the small coastal town of Klemtu, British Columbia, has been under way for a decade and provides an example of a successful salmon aquaculture joint venture. In 1988, the people of Klemtu invested in salmon aquaculture to try to replace the economic opportunity lost owing to declines in the commercial salmon fishery. This salmon aquaculture business operated for five years before it was forced to close as a result of declining salmon prices and high operating costs. In 1998, the Kitasoo/Xai'xais reached an agreement with a private firm to operate the facility, and the resulting business has achieved considerable success, becoming an economic mainstay for the community. As mentioned above, the farm and processing plant provide revenue and jobs, and the business has reduced unemployment in Klemtu to 40 percent from about 90 percent 10 years ago.

In the Pacific northwest, 20 tribes were formally recognized by the United States of America through treaties signed in 1855, and they have a long history of harvesting the abundant fish and shellfish found in the coastal regions. Today, many of these tribes are actively engaged in shellfish aquaculture to augment traditional harvests. Tribes employ standard shellfish culture techniques, using hatchery seed outplanted to produce Pacific oysters, Manila clams and geoduck clams.

8.2 Salient issues and success stories

In the last decade, two developments in North America have significantly contributed to growth in aquaculture production. The most important has been the transfer of net-pen technology for Atlantic salmon aquaculture to British Columbia and the Atlantic maritime provinces in Canada. The other has been the steady growth of shellfish production, and especially the development of the longline mussel industry in Atlantic Canada.

The current approach in the region to training and information exchange seems to be working well, although additional resources would certainly improve the situation. In the last decade, both Canada and the United States of America have significantly increased federal investments in research and extension.

One challenge that remains is to provide significant opportunities for young people to remain in rural areas and join the workforce. Market development and increased production efficiencies should position the industry to be more competitive and offer employment benefits that would attract more young workers.

8.3 The way forward

The increased availability and accessibility of aquaculture information in the last decade has been phenomenal. New Web-based technologies for virtual meetings will certainly play a role in improving networking in the future, particularly as time becomes more limiting and if travel becomes more expensive. The greatest need on the part of aquaculture professionals is more time to access available information and, therefore, new technologies in automation and real-time monitoring and response will be of significant value.

As more and more coastal and ocean ecosystems come into use for aquaculture production, greater interregional cooperation will become a necessity. Interregional collaboration to manage disease, maintain water quality and protect wild populations and ecosystems will be essential to support sustainable aquaculture development on the scale necessary to supply projected needs. This interregional cooperation and planning should facilitate aquaculture development using an ecosystem-based approach to management. Coastal and marine spatial planning provide an excellent framework for this cooperation and coordination.

9. GOVERNANCE AND MANAGEMENT OF THE SECTOR

9.1 Status and trends

Aquaculture is managed in North America by a combination of federal, provincial, state and local authorities. In the last decade, governments in both Canada and the United States of America have made concerted efforts to improve aquaculture governance and increase financial support for R&D. These have included creation of national policies, strategic plans to support expansion, identification of priority goals and research topics, and efforts to establish national legislation addressing aquaculture. These efforts should improve regulation of the industry, balancing the needs to protect the environment, to sustain fisheries, and to enable a competitive industry to flourish.

9.1.1 Canadian aquaculture strategy

Aquaculture in Canada is a shared federal–provincial–territorial responsibility. The DFO is mandated to develop and implement policies and programmes that create conditions for sustainable aquaculture development. Several other federal departments are also involved in aquaculture governance and ensuring food safety of aquaculture products. The federal, provincial and territorial authorities administer a complex regulatory framework for aquaculture planning and management. Provinces and territories are generally responsible for aquaculture site leasing, licences, and the promotion of aquaculture products. However, these provincial–territorial responsibilities considerably overlap with federal responsibilities. The aquaculture industry establishes its representation in the governing process through its associations and its federation, the CAIA.

In the absence of a federal aquaculture act, three pieces of legislation are used to regulate aquaculture planning. They are the Fisheries Act, the NWPA and the CEAA. The legislation is administered to grant legitimacy to aquaculture operations using open-water resources.

Aquaculture planning also adheres to provincial legislation. All provinces have legislation to regulate aquaculture activities, and some provinces have proclaimed an aquaculture act. In accordance with provincial regulatory requirements, all new and existing operations must prepare a management plan. In some cases, local government bodies also play a role through the application of zoning bylaws.

The management of aquaculture activities also involves a complex regulatory process. The movement of fish is regulated under the National Code on Introductions and Transfers of Aquatic Organisms (2002) to minimize genetic, ecosystem and disease effects. Fish health management on farms complies with the NAAHP and the CSSP, designed to prevent infectious disease or contamination and to maintain competitive market access. The harvest and marketing of aquaculture products are regulated by the Fish Inspection Act (1985) to ensure that the products meet national and international standards of wholesomeness and food safety.

Canada introduced the Federal Aquaculture Development Strategy in 1995. The strategy provides a tool for fostering partnerships and cooperation between the different levels of government and industry, and outlines principles for sustainable aquaculture development (DFO, 1995). In 2000, the federal government launched the five-year Program for Sustainable Aquaculture in support of a strategy to make the regulatory framework more responsive to industry needs and increase science and policy capacity in order to increase sustainability and global competitiveness of the industry. The strategy was followed by the development of the Aquaculture Policy Framework, which outlined a cooperative federal–provincial–territorial framework to create the conditions necessary to enable responsible growth.

Regardless of these initiatives, industry growth did not realize its full potential, partly owing to the prevalence of a complex regulatory arrangement and partly owing to new conditions such as product certification and traceability, imposed by the market. To respond to the changing situations, the federal government launched another five-year Sustainable Aquaculture Program in 2008. The new programme is designed to create the conditions for success of a more innovative sector that is environmentally and socially sustainable, and internationally competitive. The programme is being delivered through distinct pillars to address specific challenges: governance and regulatory reform, regulatory and sustainable production research, innovation, certification and market access.

The governance component will focus on streamlining federal, provincial and territorial regulations and policies pertaining to the environmental aspects of farm-site review. Among other things, this component is developing a Framework for Aquaculture Environmental Management (FAEM). The FAEM will increase federal–provincial/territorial coordination of the environmental regulatory regime with increased predictability, transparency, efficiency, effectiveness and accountability in regulatory management and decision-making, and promotion of shared stewardship with industry and others. The regulatory science component is designed to deliver long-term, ecosystem-based research through the Centre for Integrated Aquaculture Science. The other two components are focused on competitiveness and emerging market requirements. Under the innovation component, the industry is provided grants to explore the scope of commercialization of innovative technologies and management techniques. The certification component is supporting the sector's ability to meet domestic market demands and rigorous international trade and marketing requirements.

Under the new programme, a wide range of consultations have been undertaken to develop five-year strategic action plans for each industry subsector to help the industry reach its full potential. The sector-specific strategic plans will help to establish clear national objectives as well as to address the regional and sectoral needs and challenges separately.

The industry is far more prepared than before to protect the ecosystem and respond to changes. That the Canadian salmon industry was not affected by the outbreak of ISA in other countries demonstrates that the industry has developed and implemented effective biosecurity protocols. However, industry and government need to take more proactive measures to prevent the introduction of disease and invasive species (New Brunswick Aquaculture Summit, 2009). Moreover, the biosecurity infrastructure is often not adequate to meet industry needs, and the expansion of the industry as envisioned under the new programme will require qualitative and quantitative expansions of the biosecurity infrastructure.

The industry associations have voluntarily developed BMPs to improve farm-level efficiency and to address the constant concern regarding food safety. On some aspects of farm operation such as fish escape prevention, adherence to a BMP is enforced under regulation. Industry and government are working together to determine how BMPs can be better used in day-to-day operations to reduce biological and business risks, and enhance competitiveness of aquaculture products.

Canada is the first country to undertake a sustainability reporting initiative. Canada's national statistical agency, Statistics Canada, has been collecting and reporting annual production, value and the value-added account since 1997. In 2007, Statistics Canada and the DFO enhanced collaboration to collect information on social and environmental sustainability indicators. The first sustainability report will come out in 2011. The DFO will follow the sustainability reporting model provided by the Global Reporting Initiative, a network-based organization that has pioneered the development of the world's most widely used sustainability reporting framework. The sustainability report will be produced such that different versions and formats can be targeted at specific audiences. While a general version will be prepared for a broad public audience, particular attention will be paid to the more targeted versions. Targeted audiences may include government agencies, industry, investors, retailers and food service providers, educational institutions, First Nations, and community groups. The content of the targeted versions may vary to meet the needs of the intended audiences. The DFO will refine the sustainability indicators in the coming years through a broad consultation process. A similar sustainability reporting initiative is also under way with impetus from the salmon industry.

9.1.2 United States of America aquaculture strategy

The lead agency for freshwater aquaculture in the United States of America is the USDA, and the lead agencies for marine aquaculture development are the NOAA Fisheries, and the National Sea Grant Program, both of which are administratively housed in the Department of Commerce. In turn, state agencies are charged with upholding federal regulations and permitting such as the Clean Water Act, the EPA's NPDES, and any additional state regulations. The Army Corp of Engineers has permitting responsibilities when aquaculture is undertaken in navigable waters. In general, regulation of aquaculture addresses four main areas of concern: water use, effluent discharges, production, and marketing. State agencies are also authorized to establish a regulatory framework to manage specific activities associated with aquaculture production, such as land and water use, site selection, production and marketing. Similar to the situation in Canada, there are overlapping jurisdictions, and within this regulatory framework, aquaculture in the United States of America has not met expectations.

To improve the regulatory climate and foster growth, national aquaculture policies were adopted by both the NOAA and the Department of Commerce in 1998 and 1999. However, the rate of growth of the United States aquaculture industry projected to 2025 has lagged behind the aggressive targets identified in the policy adopted by the Department of Commerce (DOC, 1999). At that time, some primary targets were to see production increases of ~10 percent/year, reductions in the US$9 billion trade deficit in edible seafood, and increased production value from US$1 billion to US$5 billion. In the ten years after the policy was adopted, the average APR increase was 1.9 percent, the seafood trade deficit rose to US$10 billion, and production value remained about US$1 billion/year.

There are a number of reasons for this relatively slow growth rate, and they include potential environmental impacts associated with aquaculture and resulting public opposition, user conflicts, multiple federal agencies with regulatory authority, economic risks, lack of capital, and foreign competition (Cicin-Sain *et al*., 2001).

In 2004, the United States Commission on Ocean Policy stated that the NOAA should expand marine aquaculture research, including training, extension, and technology transfer, and set priorities for research and technology development. In concert with that direction, the United States President's Ocean Action Plan in 2005 called for submission of legislation to the United States Congress to establish a regulatory structure for offshore aquaculture.

Recognizing the need for further action to accomplish these multiple tasks, and to realize the targets identified in the 1999 policy of the Department of Commerce, the NOAA Fisheries revitalized its Aquaculture Program in 2004 with a National Marine Aquaculture Initiative, recruiting an Aquaculture Program Manager and subsequently filling staff positions in policy, outreach, aquatic animal health and regulatory affairs, and identifying five regional aquaculture coordinators working throughout the country. This NOAA aquaculture team has provided needed momentum to the programme and achieved a number of significant milestones.

In 2007, the NOAA completed and adopted the 10-Year Plan for Marine Aquaculture as an agency-wide policy document. The plan is intended to guide the agency as its works towards establishing marine aquaculture as an integral part of the United States seafood industry and as a viable technology for replenishing important commercial and recreational fisheries. The plan provides specific goals for the NOAA Aquaculture Program and an assessment of the challenges the agency will face. The goals in the 10-Year Plan for Marine Aquaculture are:

- development of a comprehensive regulatory programme for environmentally sustainable marine aquaculture;
- development of commercial aquaculture and replenishment of wild stocks;
- public understanding of marine aquaculture;
- increased collaboration and cooperation with international partners.

Also in 2007, the United States Secretary of Commerce and the NOAA Aquaculture Team hosted a national marine aquaculture summit at which national seafood and aquaculture business leaders, policy experts, government officials, NGOs and researchers discussed the opportunities and challenges for marine aquaculture in the United States of America. Summit participants agreed on the need for national offshore legislation to provide regulatory certainty for those considering investing in federal waters. They also cited complex and uncertain regulations, the lack of a supporting research and development infrastructure, and the lack of economic incentives as three major constraints to expanding marine aquaculture in the United States of America.

Building on this progress, the NOAA announced its intention to pursue a national policy for sustainable marine aquaculture in the United States of America. The NOAA Administrator, Dr. Jane Lubchenco, said: “We will develop a national policy that focuses on the protection of ocean resources and marine ecosystems, addresses the fisheries management issues posed by aquaculture, and allows American aquaculture to proceed in a sustainable way”. The national policy will continue the NOAA’s work in protecting and sustainably using the nation’s coastal and marine resources, while at the same time enabling expansion of a sustainable domestic aquaculture industry.

Along with this policy, a national aquaculture bill submitted to the United States Congress in 2007 would authorize the Secretary of Commerce to establish and implement a regulatory system for offshore aquaculture in the United States Exclusive Economic Zone. Highlights of the bill include:

- a permitting process;
- 20-year permits for offshore aquaculture, renewable in increments up to 20 years and transferable;
- clear environmental requirements and safeguards for the marine environment and wild stocks;
- requirement to conduct an environmental assessment of offshore aquaculture;
- requirements to consult with other federal agencies, states, fisheries management councils, and the public;
- ability for states to “opt out”.

In the last decade, many initiatives have gained traction to improve the overall outlook for aquaculture development. The federal government has taken significant steps to move forward an aquaculture agenda. These include spatial planning that includes aquaculture as an ocean-dependent use, progress in identifying organic certification criteria for aquatic animals, a national aquatic animal health plan, aggregation of aquaculture production statistics, and the national policies and legislation mentioned above. Nonetheless, many challenges remain.

As in Canada’s provinces, state governments in the United States of America play a significant role in land-use decisions and in permitting many of the operational aspects of aquaculture production at the local level. This includes environmental monitoring and land-use planning in nearshore state waters. The NOAA Fisheries Regional Aquaculture Coordinators will be able to engage at the local level with state aquaculture coordinators, agency representatives, industry, Sea Grant, NGOs and the public to harmonize the regulatory process, and foster growth of a sustainable industry that is able to meet the seafood supply challenges of a growing population.

9.2 Salient issues and success stories

The primary need in both Canada and the United States of America is a federal aquaculture act to establish a well-defined programme to foster continued industry growth. The United States of America has such legislation pending, and the industry will benefit greatly from its passage. This will provide a framework and guidelines to open up federal waters to aquaculture production and will encourage the investment that will be required to do so, provided it strikes a balanced between economic viability and environmental protection.

Marine finfish hatchery technology is an area where significant R&D is needed to ensure consistent production capacity is available to stock cages, in particular for yellowfin and bluefin tuna. While progress is being made, existing technology has demonstrated the feasibility of offshore production of a number of species and more have the potential for successful growout. In the Atlantic and Gulf of Mexico, cobia (*Rachycentron canadum*), greater amberjack (*Seriola dumerili*), red snapper (*Lutjanus campechanus*), and red drum (*Sciaenops ocellatus*) have all demonstrated potential (Masser and Bridger, 2007). In the Pacific region, kahala amberjack (*Seriola rivoliana*), Pacific threadfin (*Polydactylus sexfilis*), white seabass (*Atractoscion nobilis)*, hybrid striped bass (*Morone saxatilis x M. chrysops*), and yellowtail (*Seriola lalandi*) are promising species. For example, using cobia and following the model provided by the salmon industry could enable the production of 1 million tonnes/year within the next decade. There is investment capital and an entrepreneurial spirit that can make this happen once there is regulatory certainty in place.

9.3 The way forward

In both Canada and the United States of America, the federal governments have expressed interest in and demonstrated support for expansion of domestic aquaculture production. As discussed, some practices and policies in the past have not achieved desired results, but programmes and policies are being adaptively managed and re-oriented to achieve desired goals and objectives. There have been successes, such as the growth of the Atlantic salmon sector in Canada and the growth of shellfish production in Canada and the United States of America, but there is potential for far more substantial growth. Both nations have national strategic plans and policies to achieve this.

10. IMPLEMENTATION OF THE BANGKOK DECLARATION

Canada and the United States of America have observed growth in the aquaculture sector in the last decade but would like to see a more robust industry with greater production and product diversity. Both governments have created national aquaculture development plans in keeping with guidance provided in the Bangkok Declaration and Strategy adopted in 2000. Efforts to develop the sector's full potential and increase global seafood supplies have been pursued more aggressively in recent years in order to create a regulatory regime supporting industry expansion and accelerate the rate of growth. The industry is being developed in a sustainable fashion in keeping with principles of ecosystem-based management and in accordance with the FAO Code of Conduct for Responsible Fisheries. Industry highlights in light of the relevant strategies outlined in the Bangkok Declaration and Strategy are set out below.

10.1 Investing in people through education and training

Significant investments in post-secondary and technical training have been made in North America. There is a well-educated workforce capable of supporting the industry, although in some sectors of the Canadian industry and in some rural areas the need for more trained employees is a constraint that needs to be addressed. This is being accomplished through the combined efforts of industry and investments in training and technical schools by the provincial and federal governments.

10.2 Investing in research and development

North American governments have increased their investments in aquaculture research in the last decade and will probably continue to do so in the future. There is general recognition that continued success in culture of catfish, salmon and shellfish will require ongoing support to improve performance, and remain competitive. Species diversity is essential to maintaining a strong growth trajectory, and this will require increasing investments in the development of culture and husbandry protocols for promising new species.

10.3 Improving information flow and communication

It is often said in North America that many of the difficulties in aquaculture development stem from the fact that the industry is undertaking a new agricultural endeavour in a modern regulatory environment. While this may be true, the modern information and communication environment has been a tremendous boon to the industry. Information exchange and networking accelerate the rate of problem solving and facilitate industry growth. Rapid technology transfer results from the ability to share information in near real time with a global audience. Continued work by organizations like FAO, the NACA, the WAS, the Canadian Aquaculture Association, governments, industry groups and researchers to compile and consolidate pertinent information fill the communication channels with invaluable content. In the future, Web-based access to real-time information will further accelerate communications. Governments in North America strongly support the enhancement and transparency of information sharing.

10.4 Improving environmental sustainability

Environmental protection and sustainable aquaculture production go hand in hand in North America, and the industry has been a leader in developing environmental codes of practice and good management practices. Canada is a leader in IMTA, and this practice has multiple benefits for the environment and the aquaculture sector. Ongoing, large-scale, commercial pilot demonstrations will provide science-based information to evaluate this practice comprehensively. In the future, it could well be that industry sectors raising primary producers will reap benefits from carbon and nutrient trading.

10.5 Applying innovations in aquaculture

Innovations will drive aquaculture development as new technologies in filtration, water management systems, ocean cage designs, feeds and feeders, animal husbandry, and animal health become widespread and aquaculture production becomes more and more competitive. New species for aquaculture in the last decade have demonstrated how rapidly production can increase through technology transfer and exchange.

10.6 Applying genetics to aquaculture

Genetic selection in agriculture has demonstrated time and time again how dramatically yield can be improved through traditional genetic selection and animal breeding. Selective breeding should be aggressively pursued with new species like cobia, Atlantic cod, yellowtail, halibut and others as they are domesticated. The long-term nature of this research and tremendous payoff dictate that this should be a core investment and commitment made to industry through government investments.

10.7 Applying biotechnology

Biotechnology advances in North America have resulted in the creation of rapidly growing, genetically modified salmon strains with significantly enhanced performance. While these strains are not yet in commercial production, additional research to resolve concerns about their potential interactions in the wild will ultimately see this technology approved for use commercially. The potential for this technology to improve production through enhanced immune response to pathogens, improved utilization of alternative feed ingredients, and enhanced environmental tolerance all have the potential to revolutionize productivity in aquaculture systems. The science is in place to ensure food safety in the use of GMOs and to ensure that the ecosystems are protected.

10.8 Improving food quality and safety

North America has some of the world’s most effective and comprehensive HACCP-based systems to provide the highest levels of seafood quality and safety. Consumers have a great degree of confidence in the nutritional value and safety of the seafood they consume and derive significant health benefits from seafood products.

REFERENCES

2We Associates Consulting Ltd. 2000. *Aquaculture and climate change*. Victoria, Canada.

Agriculture and Agri-Food Canada (AAFC). 2009. Agriculture and Agrifood Canada (available at www.agr.gc.ca).

British Columbia Salmon Farmers Association (BCSFA). 2007. *Economic benefit and public support for aquaculture confirmed*. (available at www.salmonfarmers.org/media_archives_2007.php).

British Columbia Salmon Farmers Association (BCSFA). 2009. BC Salmon Farmers Association (available at www.salmonfarmers.org).

British Columbia Shellfish Growers Association (BCSGA). 2007. *Mussels* (available at www.bcsga.ca/about/industry-encyclopedia/mussels).

British Columbia Shellfish Growers Association (BCSGA). 2008. British Columbia Shellfish Growers Association (available at www.bcsga.ca).

British Columbia, Ministry of Agriculture and Lands. 2009. *Number of farm salmon (pieces) reported escaped into the marine environment, 1987 to 2008* (available at www.agf.gov.bc.ca/fisheries).

British Columbia. 2003. *British Columbia aquaculture employment survey results* (available at www.env.gov.bc.ca/omfd/fishstats/aqua/employ-03.html).

Browdy, C.L. & Hargreaves, J.A., eds. 2009. *Overcoming technical barriers to the sustainable development of competitive marine aquaculture in the United States of America*. NOAA Technical Memo NMFS F/SPO-100. Silver Spring, USA, US Department of Commerce. 114 pp.

Caldeira, K. & Wickett, M.E. 2003. Oceanography: anthropogenic carbon and ocean pH. *Nature,* 425: 365.

Campbell, D., Côté, G., Bergeron, S. & Archambault, E. 2005. *Scan of Canadian strengths in biotechnology*. Prepared for National Research Council Canada. Montreal, Canada, Science-Metrix.

Canadian Food Inspection Agency (CFIA). 2009. *Aquatic animal health* (available at www.inspection.gc.ca/english/anima/aqua/exp/expe.shtml).

Central Intelligence Agency. 2009. *The world factbook* (available at www.cia.gov/library/publications/the-world-factbook/index.html).

Cicin-Sain, B., Bunsick, S., DeVoe, R., Eichenberg, T., Ewart, J., Halvorson, H., Knecht, R. & Rheault, R. 2001. *Development of a policy framework for offshore marine aquaculture in the 3-200 mile U.S. Ocean Zone*. Center for the Study of Marine Policy the Sea Grant Technology Program, National Oceanic and Atmospheric Administration.

Cooley, S.R. & Doney, S.C. 2009. Anticipating ocean acidification's economic consequences for commercial fisheries. *Environ. Res. Lett*., 4.

DeAlteris, J.T., Kilpatrick, B.D. & Rheault, R.B. 2004. A comparative evaluation of the habitat value of shellfish aquaculture gear, submerged aquatic vegetation, and a non-vegetated seabed. *Journal of Shellfish Research*, 23(3): 867–874.

Delgado, C.L., Wada, N., Rosegrant, M., Meijer, S. & Ahmed, M. 2003. *Fish to 2020 – supply and demand in changing global markets*. Washington, DC, International Food Policy Research Institute, and Penang, Malaysia, WorldFish Center.

Department of Commerce (DOC). 1999. *US Department of Commerce Aquaculture Policy* (available at aquaculture.noaa.gov/pdf/18_docaqpolicy.pdf).

FAO. 1995. *Code of Conduct for Responsible Fisheries*. Rome. 41 pp.

FAO. 2009a. *Environmental impact assessment and monitoring in aquaculture*. FAO Fisheries and Aquaculture Technical Paper No. 527. Rome. 57 pp.

FAO. 2009b. *The State of World Fisheries and Aquaculture 2008*. Rome. 176 pp.

FAO FishStat Plus. 2009. Aquaculture production 1950–2007 (available at www.fao.org/fishery/statistics/software/fishstat/en).

FAO FishStat Plus. 2010. Aquaculture production 1950–2008 (available at www.fao.org/fishery/statistics/software/fishstat/en).

Fisheries and Oceans Canada (DFO). 1995. *Federal Aquaculture Development Strategy*. Ottawa.

Fisheries and Oceans Canada (DFO). 2003. *Profile of the blue mussel (*Mytilus edulis*)*. Moncton, Canada. (available at www.glf.dfo-mpo.gc.ca/eng/Economic_Profiles/2003_Mussel).

Fisheries and Oceans Canada (DFO). 2008a. *Reports on plan and priorities*. Ottawa.

Fisheries and Oceans Canada (DFO). 2008b**.** *Overview: qualitative research exploring Canadians' perceptions, attitudes and concerns toward aquaculture* (available at www.dfo-mpo.gc.ca/por-rop/focus-aquaculture-eng.htm).

Fisheries and Oceans Canada (DFO). 2009**.** *Finfish* (available at www.dfo-mpo.gc.ca/aquaculture/finfish-poisson-eng.htm).

GSGislason and Associates Ltd. 2004. *The Canadian farmed salmon industry: benchmark analysis for the US market*. Vancouver, Canada.

Heimstra, L.D. & Davidson, W.S., eds. 2009. Application of genome science to sustainable aquaculture. *Bull. Aquaculture Assoc. Canada*, 107(3).

Interagency Ocean Policy Task Force. 2009. *Interim framework for effective coastal and marine spatial planning* (available at www.whitehouse.gov/sites/default/files/microsites/091209-Interim-CMSP-Framework-Task-Force.pdf).

Langdon, C., Evans, F., Jacobson, D. & Blouin, W. 2003. Yields of cultured Pacific oysters *Crassostrea gigas*, Thunberg improved after one generation of selection. *Aquaculture*, 220: 227–244.

Les Études de MarchéCréatec. 2007. *Perceptions of Canadian aquaculture by U.S. seafood opinion leader*. Montreal, Canada.

Masser, M.P. & Bridger, C.J. 2007. A review of cage aquaculture: North America. *In* M. Halwart, D. Soto & J.R. Arthur, eds. *Cage aquaculture – regional reviews and global overview*, pp. 102–125. FAO Fisheries Technical Paper No. 498. Rome, FAO. 241 pp. (available at: ftp://ftp.fao.org/docrep/fao/010/a1290e/a1290e.pdf).

Mussel Industry Council of North America (MICNA). 2009. Discover mussels (available at www.discovermussels.com/).

Nash, C.E. 2004. Achieving policy objectives to increase the value of the seafood industry in the United States of America: the technical feasibility and associated constraints. *Food Policy*, 29(6): 621–641.

National Aquatic Animal Health Program (NAAHP). 2009. Domestic disease control framework. Information for face-to-face discussions, January-March 2009.

National Oceanic and Atmospheric Administration (NOAA). 2007. *NOAA 10-year plan for marine aquaculture* (available at aquaculture.noaa.gov/pdf/finalnoaa10yrrweb.pdf).

National Oceanic and Atmospheric Administration (NOAA). 2008. *National aquatic animal health plan for the United States* (available at: www.aphis.usda.gov/animal_health/animal_dis_spec/aquaculture/downloads/naahp.pdf).

Natural Resources Canada. 2004. *Climate change impacts and adaptations: a Canadian perspective – fisheries*. Ottawa.

Natural Resources Canada. 2009. Atlas of Canada. 2009. Department of Natural Resources Canada. http://atlas.nrcan.gc.ca/site/english/learningresources/facts/coastline.html

Naylor, R. L., Hardy, R.W., Bureauc, D.P., Chiua, A., Elliott, M., Farrelle, A.P., Forstere, I., Gatlin, D.M., Goldburgh, R.J., Huac, K. & Nichols, P.D. 2009. Feeding aquaculture in an era of finite resources. *PNAS*, 106(36): 15103–15110.
(available at www.pnas.org/content/106/36/15103).

New Brunswick Aquaculture Summit. 2009. *Facilitator's final report*. Fredericton, Canada.

Olin, P.G. 2006. *Regional review on aquaculture development. 7. North America – 2005*. FAO Fisheries Circular No. 1017/7. Rome. FAO. 25 pp. (available at ftp://ftp.fao.org/docrep/fao/009/a0636e/a0636e00.pdf).

Organisation for Economic Co-operation and Development (OECD). 2007. *Education at a glance 2007*. OECD Briefing Note for the United States of America. (available at www.oecd.org/dataoecd/22/51/39317423.pdf).

Population Reference Bureau. *2007 world population data sheet* (available at www.prb.org/pdf07/07WPDS_Eng.pdf).

PricewaterhouseCoopers. 2009. *Profile of the BC farmed salmon industry in 2008* (available at salmonfarmers.khamiahosting.com/sites/default/files/2008_IndustryProfile_PWC.pdf).

Soto, D., Aguilar-Manjarrez, J., Brugère, C., Angel, D., Bailey, C., Black, K., Edwards, P., Costa-Pierce, B., Chopin, T., Deudero, S., Freeman, S., Hambrey, J., Hishamunda, N., Knowler, D., Silvert, W., Marba, N., Mathe, S., Norambuena, R., Simard, F., Tett, P., Troell, M. & Wainberg, A. 2008. Applying an ecosystem-based approach to aquaculture: principles, scales, and some management measures. *In* D. Soto, J. Aguilar-Manjarrez & N. Hishamunda, eds. *Building an ecosystem approach to aquaculture. FAO/Universitat de les Illes Balears Expert Workshop. 7–11 May 2007, Palma de Mallorca, Spain*, pp. 15–35. FAO Fisheries and Aquaculture Proceedings No. 14. Rome, FAO. 221 pp. (available at www.fao.org/docrep/011/i0339e/i0339e00.htm).

Statistics Canada. 2008a. Aquaculture statistics 2007 (available at www.statcan.gc.ca/pub/23-222-x/23-222-x2007000-eng.pdf).

Statistics Canada. 2008b. Food Statistics 2007. Ottawa.

Statistics Canada. 2009a. Income in Canada 2007, Ottawa.

Statistics Canada. 2009b. Bureau of Economic Analysis.

Statistics Canada. 2009c. Aquaculture, production and value, annual (available at cansim2.statcan.gc.ca/cgi-win/cnsmcgi.exe?Lang=E&RootDir=CII/&ResultTemplate=CII/CII___&Array_Pick=1&ArrayId=0030001).

Tim Carey and Associates. 2005. *Introductions and transfers of aquatic animals – a survey of procedures and activities in Canada (2002-2005)*. Ottawa.

Tucker, C., Avery, J., Engle, C. & Goodwin, A. 2004. *Industry profile: pond-raised channel catfish: a review developed for the National Risk Management Feasibility Program for Aquaculture*. Mississippi State University, Agreement No. RMA 01-IE-0831-127. 92 pp.

United States Census Bureau. 2009. U.S. Census Bureau (available at www.census.gov).

United States Department of Agriculture (USDA). 1998. 1998 Census of Aquaculture.

United States Department of Agriculture (USDA). 2005. 2005 Census of Aquaculture.

United States Department of Agriculture (USDA). 2009. *Catfish feed deliveries* (available at usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1592).

United States Department of Agriculture Economic Research Service (USDA ERS). 2006. USDA Economics Research Service (available at www.ers.usda.gov/).

United States Department of Agriculture Economic Research Service (USDA ERS). 2009. Aquaculture data: trade (available at www.ers.usda.gov/Data/Aquaculture/).

United States Department of Agriculture National Agricultural Statistics Service (USDA NASS). 2009. Catfish production (available at usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1016).

United States Department of Commerce (US DOC). 1999. Aquaculture policy (available at www.nmfs.noaa.gov/trade/DOCAQpolicy.htm#).

Van Anrooy, R., Secretan, P.A.D., Lou, Y., Roberts, R. & Upare, M. 2006. *Review of the current state of world aquaculture insurance*. FAO Fisheries Technical Paper No. 493. Rome, FAO. 104 pp. (available at www.fao.org/docrep/009/a0583e/a0583e00.htm).

Wilson, A., Magill, S. & Black, K.D. 2009. Review of environmental impact assessment and monitoring in salmon aquaculture. *In* FAO. *Environmental impact assessment and monitoring in aquaculture*, pp. 455–535. FAO Fisheries and Aquaculture Technical Paper No. 527. Rome, FAO. CD–ROM. 648 pp. (available at www.fao.org/docrep/012/i0970e/i0970e00.htm).

RECOMMENDED FURTHER READING (relevant papers not cited in main document)

Bondad-Reantaso, M.G., Arthur, J.R. & Subasinghe, R.P., eds. 2008. *Understanding and applying risk analysis in aquaculture*. FAO Fisheries and Aquaculture Technical Paper No. 519. Rome, FAO. 304 pp. (available at www.fao.org/docrep/011/a1293e/a1293e00.htm).

De Young, C., Charles, A. & Hjort, A. 2008. *Human dimensions of the ecosystem approach to fisheries: an overview of context, concepts, tools and methods*. FAO Fisheries Technical Paper No. 489. Rome, FAO. 152 pp. (available at www.fao.org/docrep/010/i0163e/i0163e00.htm).

FAO. 2006. *State of world aquaculture 2006*. FAO Fisheries Technical Paper No. 500. Rome. 134 pp. (available at www.fao.org/docrep/009/a0874e/a0874e00.htm).

Halwart, M., Soto, D. & Arthur, J.R., eds. 2007. *Cage aquaculture – regional reviews and global overview*. FAO Fisheries Technical Paper No. 498. Rome, FAO. 241 pp. (available at www.fao.org/docrep/010/a1290e/a1290e00.htm).

Kapetsky, J.M. & Aguilar-Manjarrez, J. 2007. *Geographic information systems, remote sensing and mapping for the development and management of marine aquaculture*. FAO Fisheries Technical Paper No. 458. Rome, FAO. 125 pp. (available at www.fao.org/docrep/009/a0906e/a0906e00.htm).

Lovatelli, A., Phillips, M.J., Arthur, J.R. & Yamamoto, K., eds. 2008. The future of mariculture: a regional approach for responsible development in the Asia-Pacific region. FAO/NACA Regional Workshop, Guangzhou, China, 7–11 March 2006. FAO Fisheries Proceedings No. 11. Rome, FAO. 325 pp. (available at www.fao.org/docrep/011/i0202e/i0202e00.htm).

Olin, P.G. 2000. *Current status of aquaculture in North America* (available at www.fao.org/DOCREP/003/AB412E/ab412e23.htm).

Secretan, P.A.D., Bueno, P.B., van Anrooy, R., Siar, S.V., Olofsson, A., Bondad-Reantaso, M.G. & Funge-Smith, S. 2007. *Guidelines to meet insurance and other risk management needs in developing aquaculture in Asia*. FAO Fisheries Technical Paper No. 496. Rome, FAO. 148 pp. (available at www.fao.org/docrep/010/a1455e/a1455e00.htm).

Technical Drafting Committee. (undated). Bangkok Declaration and Strategy for Aquaculture Development Beyond 2000. *In* R.P. Subasinghe, P. Bueno, M.J. Phillips, C. Hough, C.E. McGladdery & J.R. Arthur, eds. *Aquaculture in the third millennium*, Part V (available at: www.fao.org/docrep/003/AB412E/ab412e28.htm).

ISBN 978-92-5-106836-6 ISSN 2070-6065

9 789251 068366

I2163E/1/04.11