University of Otago

Te Whare Wānanga o Otāgo

SUPER SALMON:

The Industrialisation of Fish Farming and the Drive Towards GM Technologies in Salmon Production

Prepared by:

Carmen McLeod, Janet Grice, Hugh Campbell & Teresa Herleth

CSAFE

Discussion Paper No. 5

July 2006

Centre for the Study of Agriculture, Food and Environment

The authors are from the:
CENTRE FOR THE STUDY OF AGRICULTURE, FOOD AND ENVIRONMENT (CSAFE)

CSAFE DIRECTORS:
Associate Professor Hugh Campbell
Associate Professor Henrik Moller

University of Otago
PO Box 56, Dunedin 9054
New Zealand.
ph. +64 3 479 5220
email: csafe@otago.ac.nz

The Centre for the Study of Agriculture, Food and Environment (CSAFE) is a multidisciplinary research centre established across the Humanities and Science Divisions at the University of Otago. CSAFE has two directors and sixteen researchers and administrators and also works with many researchers and groups outside the University of Otago. CSAFE's mission is to discover and promote effective, practical pathways to sustainable land use, food and fibre production, and wild food harvesting. This mission is pursued through innovative bicultural and trans-disciplinary research of social-ecological systems, and by training students, future researchers, environmental managers and policy managers to the highest international standards. For further information see: www.csafe.otago.ac.nz

PUBLICATIONS

A number of recent publications are available on the CSAFE website. For further information, or to obtain a copy of a publication, please contact CSAFE using the contact details above.

Discussion Papers

Kaye-Blake, B., Campbell, H., Plummer, C., Kitto, L., Polson, C., McKay, W., Fitzgerald, R., and Saunders, C. The GM Food Market: A Current Analysis. CSAFE Discussion Paper No. 4. December (2003).

Plummer, P., Kitto L., Polson C., and Mckay, W. *Co-existence of GM and Non-GM crops: A Review of International Evidence.* CSAFE Discussion Paper No. 3. July (2003).

Manhire, J., Campbell, H. and Fairweather, J. *Pathways Towards Sustainability: Comparing Production Systems Across Four Sectors of New Zealand Agriculture.* CSAFE Discussion Paper No. 2. February (2003).

Campbell, H., Fitzgerald, R., Saunders, C. and Sivak, L. *Strategic Issues for GMOs in Primary Production: Key Economic Drivers and Emerging Issues.* CSAFE Discussion Paper No. 1. October (2000).

Research Reports

Stuart, A. and Campbell, H. *Technology Conflicts in New Zealand Agriculture: Comparing Contemporary and Historical Crises between Publics, Government, Business, and Science.* CSAFE Research Report No. 2. December (2004).

Campbell, H. and Ritchie, M. *The Organic Food Market in New Zealand.* CSAFE Research Report No. 1. June (2002).

Studies in Rural Sustainability

Bourn, D., Newton, B. and Campbell, H. *Strategies for 'Greening' the New Zealand Honey Industry: An Evaluation of the Development of Organic and Other Standards.* Studies in Rural Sustainability Research Report No. 8 (1999).

Fairweather, J., Campbell, H. and Manhire, J. *The 'Greening' of the New Zealand Wine Industry; Movement Towards the Use of Sustainable Management Practices.* Studies in Rural Sustainability Research Report No. 7 (1999).

McKenna, M. and Campbell, H. *Strategies for Greening the New Zealand Pipfruit Industry: The Development of* IFP *and Organic Systems.* Studies in Rural Sustainability Research Report No. 6 (1999).

Coombes, B. and Campbell, H. *Recent Developments in Organic Food Production in New Zealand: Part 4, The Expansion of Organic Food Production in Nelson and Golden Bay.* Studies in Rural Sustainability No. 5, Department of Anthropology, University of Otago. (1998).

Coombes, B., Campbell, H. and Fairweather, J. *Recent Developments in Organic Food Production in New Zealand: Part 3, Exporting of Organic Produce from Gisborne District.* Studies in Rural Sustainability No. 4 (1998).

ACKNOWLEDGMENTS

This research was partially funded by the New Zealand Foundation for Research, Science and Technology – FRST Programme LINX0204 *The Fate of Biotechnology: Why do Some of the Public Reject Novel Scientific Technologies*, and FRST Programme UOCX0221 *Constructive Conversations: Biotechnologies, Dialogue and Informed Decision-Making.* We would also like to thank John Fairweather for editorial comment and Les O'Neill for formatting this discussion paper.

Contents

Executive Summary

- Varieties of the salmonidae family have important cultural connections in many cultures. Salmon was an important food source in traditional hunter-gatherer societies throughout northern Europe and North America. Today, commercial salmon aquaculture is a key export industry for nations such as Norway, the United Kingdom, Canada, and Chile – and to a lesser degree, New Zealand. The historical changes that have seen salmon change from primarily being a hunted to a farmed resource exemplifies the development of an industrialised food system and the industrial relationship that Western consumers have with their food.

- Modern salmon aquaculture systems are 'Fordist' in nature: they require high inputs and production techniques and operate as highly mechanised assembly lines producing standardised products. The ownership of these farms is often under the control of agribusiness corporations (as is the case in New Zealand). There is currently a great deal of controversy about the environmental impacts of intensive salmon aquaculture.

- In the past two decades, laboratory experiments have successfully genetically modified (GM) salmon to grow much faster providing an even more efficient method of producing plentiful, cheaper fish. But this new technology has yet to be approved anywhere for commercial aquaculture production despite predictions in 2000 that GM salmon would soon be commercially available and widely distributed.

- In the wake of these experiments there has been opposition in some countries to the commercialisation of GM salmon and moves to have this fish banned. Those opposing the GM salmon include environmental and consumer groups, but also some commercial salmon farm producers as well.

- A case study from New Zealand illustrates some of the difficulties related to the production of GM salmon for food. The New Zealand King Salmon Company began trials of GM salmon in 1994, but this research was abandoned in 2000 – probably because of negative public opinion about these experiments, but the tightening of government controls cannot be completely disregarded. There is currently no evidence that GM salmon will be commercially developed in this country in the near future.

- This discussion paper argues that there are many complex issues that need to be considered in relation to the intensive farming of salmon in general, and GM salmon, in particular. This paper highlights that animal biotechnology has thus far been dominated by experiments to produce pharmaceutical products, and therefore the production of GM salmon for food presents a radical departure from other animal biotechnologies.

Introduction

> *It cannot but affect our philosophy favorably to be reminded of these shoals of migratory fishes, of salmon, shad, alewives, marsh-bankers, and others, which penetrate up the innumerable rivers of our coast in the spring, even to the interior lakes, their scales gleaming in the sun; and again, of the fry which in still greater numbers wend their way downward to the sea.*
> Henry David Thoreau 1980 {1849}: p. 89

Henry Thoreau wrote in the mid-nineteenth century of the positive impact that salmon and other migratory fish could have on 'our philosophy'. This impact of wild salmon on people's thinking continues to have currency in the contemporary world. Salmon have powerful cultural meanings in many societies, even in countries such as New Zealand where these fish are not a native species. Salmon are often viewed as talismans of nature, representing wild and mysterious cycles outside the orbit of human control. They are fish that are 'good to think with' (Lévi-Strauss 1963: 89) – and, while traditionally imbued with motifs of 'wild', untrammelled nature, salmon have more recently become associated with healthful messages as they deliver omega oils to consumers struggling to cope with the insufficiencies of the Western industrialised diet.

Figure 1: Image of Salmon Jumping. (Source: www.fishingsociety.org/Salmonpics.html).

The realities of industrialised salmon aquaculture and the recent drive towards using genetic modification (GM) technology in salmon production do not fit with the traditional discourses of salmon that evoke 'wholesome images of a salmon jumping against the current of a crystal-clear river' (Ride 2000). There is increasing concern about the impacts of intensive salmon aquaculture – both on the environment and on endangered wild salmon species (see for example National Geographic 2003) and there are growing calls for salmon aquaculture practices to be altered to ensure they are sustainable (Meffe 1992; Montgomery 2003; Eagle *et al.* 2004).

After World War 2, the driving rationale of Western food production was to intensify food production in order to produce more food at cheaper prices. This can be linked to the theoretical concept of food regimes (Friedmann and McMichael 1989), particularly the 'Fordist' and intensive aspects of the second food regime. Proponents of the salmon aquaculture industry argue that utilizing new technologies and systems in salmon farming, including transgenic salmon, will increase production and provide food for more people.

A major study by Melanie Power (2003), based at the W. Maurice Young Centre for Applied Ethics, University of British Columbia, presents an in depth analysis of salmon aquaculture and considers ethical issues that are raised with the possibility of biotechnology being applied to this already controversial industry. Our discussion paper builds on Power's (2003) monograph, and uses New Zealand as a case study to explore some of the issues raised within her research.

1 The Commoditisation and Industrialisation of Salmon

This chapter provides a brief summary of the historical role that salmon has played in a variety of cultures, followed by an outline of salmon farming and the dramatic changes that have occurred over the past few decades with regard to salmon production.

Before looking at the history of salmon, it is useful to clarify the different species that are utilized as food. The *Salmonidae* family includes a variety of different species that fall into two main categories: Atlantic Ocean species and Pacific Ocean species. There is only one species of Atlantic salmon (*Salmo salar*) and this accounts for the majority of salmon available on the world market. More than 99% of the Atlantic salmon products available come from aquaculture production. Conversely, more than 80% of Pacific Salmon species consumed throughout the world come from wild-caught sources. The Pacific Salmon include such species as: Sockeye salmon (Oncorhynchus nerka), Chinook salmon (Oncorhynchus tshawytscha), Pink or Humpback salmon (Oncorhynchus gorbuscha) and Coho salmon (Oncorhynchus kisutch) (Montgomery 2003). The Quinnat salmon, more commonly known as Chinook or King salmon, is the largest salmon in North America.[1] Although fish farming itself has been practiced for centuries, as the following will explain, recent changes to salmon production signal a radical change in the manner in which fish are farmed.

1.1 Fish Farming – General History

China is regarded as the 'ancestral home of aquaculture', but there is also a long history of fish farming throughout the rest of Asia (Little and Edwards 2003: 5). While there is not such a long history of fish farming in Europe, wealthy Roman households often maintained ponds where anadromous[2] fish, such as salmon, could travel to spawn. The fish were then harvested on their return journey to the sea (Montgomery 2000). During medieval times in England, fish farming developed into a large and complex industry but these inland fisheries declined by the end of the 17th century (Aston 1988).

Asia is the 'powerhouse of the aquaculture industry' (Aquaculture Magazine 2002) with over 70% of world aquaculture production taking place in China alone (FAO 2002). During the past few decades there have been enormous changes in the practice and scope of aquaculture. It is currently the world's fastest growing food production sector increasing annually by 10% and currently accounting for approximately 30% of global fish consumption (White *et al.* 2004). While aquaculture, in general, is still dominated by Asia, the key exporters of farmed Atlantic salmon are Norway and Scotland. In the last past ten years, Chile has also become a major exporter of salmon products.

1 New Zealand's salmon farming industry is based around this species.

2 Anadromous fish live mostly in the sea, but travel to fresh water in order to breed (Bonds 1996).

1.2 Brief Cultural History of Salmon

Salmon plays a significant role in the cultural heritage of many societies. Historical evidence of this can be found in Celtic mythologies,[3] and in the histories of Scandinavian and native North American societies (Ride 2000). In Northern Europe, images of salmon feature in cave paintings and as engravings on artefacts dating back to the glacial age (Montgomery 2003: 59).

During the Middle Ages, salmon was plentiful throughout the waterways of northern Europe (Montgomery 2003).[4] This abundant resource was well utilised, as the strict religious edicts of the medieval Christian Church led to an enormous number of fasting days[5] and a corresponding demand for smoked, salted and fresh fish (Braudel 1981).

In the British Isles,[6] salmon was originally a food of the masses. Saint Bede, writing in the 8th century, commented on the plentiful supply of salmon. Three hundred years later, the Domesday Book also mentions that salmon is an abundant resource (Montgomery 2003: 61) and there is evidence that salmon was a common food in all households, poor and rich alike (Spencer 2002). This was still the case in the eighteenth century. A local statute directed at apprentices in Gloucester in 1787 reveals that salmon was an extremely ubiquitous food. The statute instructs that local apprentices should not 'be obliged to dine on salmon off'ner than twice a week' (John Byng 1787, cited in Alcock 1997).

Only a few decades later, however, the availability and price of salmon were changing dramatically. As the demands of the great industrial cities such as London drew food from the countryside, salmon became a food for urbanites – as noted in the Quarterly Review in 1828: '[The] natives of the countries through which salmon-rivers flow [have] become accustomed to see them taken and cased up for the great city, by scores and hundreds, without having it

3 In Celtic mythology salmon was most often associated with knowledge and wisdom (McKillop 2000).

4 However, by the second half of the twentieth century salmon were extinct in Germany, Belgium, the Netherlands and Switzerland. Today in Europe, only Norway, Iceland, Ireland and Scotland still have healthy and flourishing wild salmon populations (Montgomery 2003: 60).

5 Until the reign of Louis XIV in the seventeenth century, there were 166 fast days throughout the year, including Lent (Braudel 1981: 214).

6 For an overview of the cultural history of salmon in the British Isles, see Chapter 5 'Old World Salmon' in David Montgomery's (2003) *King of Fish: the Thousand Year Run of Salmon*.

in their power to purchase a pound for their table' (cited in Montgomery 2003: 73). By the mid-nineteenth century salmon had become a food of the elite:

> In former times, salmon was a staple article of food in this country… So different is the case now that even with persons of comfortable means the salmon is but a rare luxury. It finds its way only to the tables of the well conditioned and affluent (Young 1854, cited in Montgomery 2003: 73).

The increasing demand for salmon and the changes in food preservation and transport technologies during the 1800s created a boom in commercial salmon fishing. This was short-lived in Britain, however, as salmon became increasingly rare. In the river Thames, salmon were completely gone soon after 1821[7] as salmon populations dropped sharply throughout England.

This 'salmon crisis' can be attributed to several causes (Montgomery 2003: 73). Firstly, as a result of the growth of manufacturing industries during the Industrial Revolution, an enormous amount of waste was discharged into rivers and streams. In addition, many rivers were stopped-up in order to supply power to industries. This befouling and blocking of waterways led to the extinction of salmon in many rivers. Secondly, there were changes to laws which had historically helped to reduce overfishing by enforcing closed fishing seasons. After 1828 the salmon season was extended until mid-September when spawning runs were at their peak. A further change allowed fixed nets to be placed across the runs of migrating salmon heading out to sea and this also had a very negative impact on salmon numbers. As the salmon population plummeted, prices rose and with this a corresponding increase in salmon poaching: salmon had become a very lucrative catch. The combination of overfishing, environmental degradation and unsustainable fishing laws led to wild salmon almost becoming extinct in Britain[8] (Montgomery 2003).

Like the British Isles, North America originally had plentiful salmon populations. Before the arrival of Europeans to North America, salmon was a major source of food in the diet of First Nations communities, holding a correspondingly important place in their cultural traditions (Stewart 1977). In the Pacific Northwest, settlement patterns were often organised around the geography of river systems in order to take advantage of the best fishing sites. The low human population and cultural prohibitions against the disturbance of spawning salmon guaranteed that large numbers of fish returned to the rivers and ensured a plentiful and sustainable food resource for the communities living in the area. Many ceremonies involving salmon[9] were practiced to show respect and to ensure the salmon would return year after year. The 'First Salmon' ceremony, for example, was practiced throughout the Pacific Northwest and involved celebrating the first fish that was caught when the salmon returned from the sea to spawn (Montgomery 2003).

The arrival of European settlers had a detrimental effect on salmon populations. In New England, for example, in the late seventeenth century, the population had grown to 50,000 people and the large Atlantic salmon populations in the region's rivers and streams were eaten and also used as fertilizer for the colonists' plough-based agriculture. Salmon was rarely sold at this time, as it was worth less than a penny per pound; however, families did preserve salmon for their own use in salted casks. By the first decades of the eighteenth century, the local supply of salmon had decreased markedly, due mainly to salmon being barred from returning to their spawning grounds by increasing numbers of small dams built on rivers and streams to power mills. By the early nineteenth century, salmon exports had become an important source of revenue for North America and the salmon fisheries expanded exponentially. By the 1850s, however, there were no salmon left to catch. The New England salmon export fishery had been treated as an inexhaustible resource and subsidised by Congress. With river-spanning nets and dams affecting many rivers, 'fish populations crashed throughout the region [and] New England's salmon virtually disappeared in the course of a few decades' (Montgomery 2003: 101). Thoreau, writing in 1849, wrote of the loss of salmon from the Concord River:

> Salmon…were formerly abundant here…they were used as food and as manure, until the dam, and afterward the canal at Billerica, and the factories at Lowell, put an end to their migrations (Thoreau 1980 {1849}: 33).

The dramatic disappearance of the salmon populations from New England has been compared to the contemporary situation in the Pacific Northwest, where wild salmon populations have become endangered (see Cone and Ridlington 1996; Lichatowich 2000; and Montgomery 2003 for historical overviews of this crisis). Salmon holds a crucial place in the identity of many communities who live in this area – both First Nations[10] and non-indigenous cultural groups. The following quotation from John Kitzhaber, Governor of Oregon in the 1990s encapsulates this widely held cultural understanding:

7 The implementation of restoration and pollution control programmes over the past few decades have led to salmon starting to return to the Thames (Montgomery 2003: 85).

8 In Scotland, salmon populations were not so adversely affected as the salmon fisheries were not public fisheries but under tightly controlled private ownership (Montgomery 2003).

9 See the chapter 'Salmon People' in Montgomery 2003, and Stewart's (1997) *Indian Fishing: Early Methods on the Northwest Coast* for more in depth discussion of First Nations' cultural practices relating to salmon.

10 The Pacific Northwest First Nations people are famously associated with the Potlatch, and dried salmon is one of the important gifts included in this ceremony.

> To be in the Northwest is in some visceral way to be connected to the salmon. Whether your family has been here 10,000 years or just 10 days, I believe Northwesterners identify salmon as a symbol of a healthy environment and a symbol of our abundance as a region (Kitzhaber 1997).

The Namgis and Ahousaht – two First Nations communities living in the region of Vancouver Island, British Columbia – utilise their traditional knowledge surrounding salmon as a means to retain some of the fundamental values of their culture even in the face of change. Dorothee Schreiber's (2002) research with these communities found that the traditional cultural meanings associated with wild salmon did not apply to fish from the farmed salmon industry – an industry where many of the local First Nations people are employed. Schreiber argues that, while wild salmon has been crucial to the physical survival of these communities, the salmon farming operations have led to a 'heightened awareness of the value of salmon as a traditional food' (Schreiber 2002: 373) The Namgis and Ahousaht peoples explain that the farmed salmon makes them sick and that it smells, looks and tastes different to the wild salmon that they have traditionally caught. By choosing to only eat wild salmon, Schreiber argues that the First Nations people are utilising salmon as a symbol of cultural resistance by naming farmed salmon as a 'colonialized way of life' and wild salmon as 'emblematic of a First Nations way of life' (Schreiber 2002: 376).

1.3 History of Salmon Farming

Figure 2: Juvenile Alevin Salmon. (Source: Dipper, F. [2001] *Extraordinary Fish.* London: DK Publishing, p. 70).

During the 1830s, research by Scottish biologists into the life cycle of salmon revealed that parr and smolt were juvenile stages of salmon and not different species of fish as previously believed. By the 1880s, eighteen hatcheries were established in Scotland primarily for the purpose of re-stocking the rivers and streams used for sport fishing by the aristocracy (Aquaculture Magazine 2000). By this time, however, new transport and preserving technologies were changing salmon into a sought after food commodity. After the advances of successful canning technologies in the 1860s, and with the development of railways and steamships, which allowed for fast and efficient transport networks, canned salmon was marketed on a global scale. At this juncture, canned salmon was sourced entirely from wild caught salmon populations and it was not until the mid-twentieth century that salmon 'farms' were established. At this time there were many market incentives for an exponential increase in salmon farming (Aarset 1999).

The development of salmon as an intensively 'farmed' food product began during the 1960s and was pioneered in Norway and Scotland. With investment from the large transnational corporate Unilever, Marine Harvest was established in Norway and is now the biggest fish company in the world. Norway was responsible for the revolutionary improvements to production methods in the late 1970s and early 1980s, including conversion from wooden to steel or plastic cages (Aquaculture Magazine 2000). By 1967, Canada and Nova Scotia were domestically rearing salmon (NSSA 2006), and in 1969 Scotland established its first commercial farms of Atlantic salmon near Aberdeen.

Salmon production incorporates a variety of different stages. The process starts in hatcheries where salmon eggs are hatched; the resulting fingerlings are then raised in land-based tanks that are close to, but separate from, the hatcheries. The next stage, where fingerlings have become smolts, is once again in a new location. Smolts are reared in fresh-water cages in rivers, which are then transported to sea-water cages for their final maturing period before entering processing for the global market (Phyne and Mansilla 2003). In 1980, farmed salmon accounted for less than 1% of the world supply of salmon, yet by 1998 farmed salmon surpassed the total of caught salmon (Abbors 2000).[11] In the two decades to 2003, 'commercial aquaculture has expanded at an annual rate of almost 10 percent, compared with a 3 percent growth rate for livestock meat' (Walton 2003: 2). Salmon farming is the fastest growing sector in world aquaculture; aquaculture in turn is the fastest growing food industry in the world (NSSA 2006).

11 In 1988 global salmon farming produced 12,721 tonnes while the figures for 2000 reached over 137,000 tonnes (Friends of the Earth Scotland 2001).

2 Salmon as a Commodity

This chapter will outline some of the qualities of salmon, which have contributed to salmon being such a successful commodity.

From the earliest stages of the Industrial Revolution, the rapid rate of growth of industrial cities (and the low income of the inhabitants), placed pressure on the food supply of industrialising regions. Burnett (1989) and Tannahill (1988) argue that the key aspect that enabled industrialised society to prosper, was the development of global food supply chains premised on durable foods. Initially, foods that were naturally durable – like wheat and dried cod – formed the staples of the new industrialising food system, but the advent of canning and refrigeration technologies opened up a range of different meats as new staples in the global industrial food system.

Initially, salmon was preserved using smoking techniques, but canning technologies 'turned salmon into a commodity' in the late 1860s, and started what has been termed a 'waterborne gold rush' (Montgomery 2003: 121). The 'important quality characteristics of salmon include fat content, fat distribution pattern, body shape, texture, color and appearance. The relative importance of any one characteristic depends, however, on the intended use, regional preferences, consumer attitudes, and methods of preservation' (Morkore *et al.* 2001: 1348). The world salmon commodity export market consists of both wild and farmed salmon and includes fresh, frozen, smoked and prepared/preserved products, with various countries dominating the different commodity aggregates (see Figure 3 below).

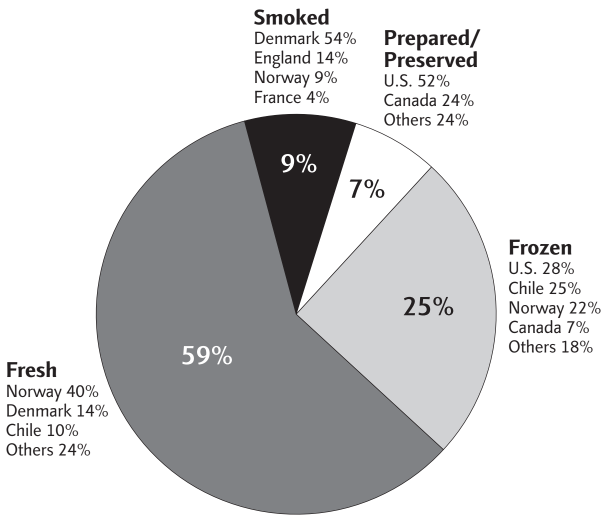

Figure 3: World Salmon Exports and Major Exporting Countries in 1997 – with regard to salmon commodity aggregates (Source: adapted from Abbors 2000: 23).

2.1 The Palatability of Salmon

Salmon is a very palatable food due to the high levels of fat (in the form of Omega-3 oils) that it contains. A recent taste-test of a variety of salmon products highlights the appealing 'mouth-feel' of salmon. A smoked King salmon product, for example, was described as having: 'Nice flavor. Real salmon mouthfeel and texture. Just a hint of oak and sugar – very salmoney' (Fork and Bottle 2006). There is some variation between the different species of salmon with regard to texture and taste. Atlantic salmon is appreciated for its high-fat flesh, and is often described as 'pink and succulent'. Pacific salmon species, such as Chinook (or King salmon), are also high in fat but have a softer texture with colours ranging from off-white to bright red. Coho (or Silver salmon) is high in fat, firm textured and has a pink to red-orange flesh, while sockeye (or red salmon) has a firm deep red flesh and is particularly suitable for canning. Pink (or humpback) salmon and Chum (or dog salmon), are small and delicately flavoured and have the lowest fat levels out of the salmon species (Lefebvre 2005). A study done by Bjorn Roth *et al.* (2005) has also shown that there are seasonal differences in the quality of farmed salmon flesh, with those salmon slaughtered in October having firmer texture, higher fat content and a redder colour.

There is some argument as to which type of salmon American consumers prefer. Some blind taste tests using 'professional groups' found that two-thirds of participants preferred wild sea salmon, while farmed salmon was perceived to have a 'muddier taste' (Knight Ridder Tribune Business News 2004). American chef Sam Gugino argues, however, that most Americans prefer the consistency and higher fat content of farmed Atlantic salmon, partly because they are not used to the stronger flavour of wild Pacific salmon (Gugino 2006).

2.2 Packaging of Salmon

Salmon were dried and smoked by Native American groups in Canada and Alaska. As mentioned above, during the latter half of the nineteenth century, canning of salmon led to the development of a global salmon commodity market. The contemporary salmon commodity market incorporates a variety of different salmon products, including chilled and smoked fillets. Most canned salmon is sourced from the wild, as its flesh is firmer than farmed varieties and therefore more suited to canning (Pittsburgh Post-Gazette 2003). Consumer studies suggest that older buyers mostly purchase canned salmon goods and that newer salmon products, such as smoked salmon 'pouches' are more popular with younger buyers (San Diego Business Journal 2004). It is clear that canned salmon products are decreasing in popularity. In the Alaskan salmon industry for example, in 1976 over 70% of salmon were used by the canning industry – by 1987, however, this percentage had dropped to 30% with an increasing proportion of the salmon catch being used in frozen products (Abbors 2000).

According to USDA Agricultural Trade Report (1996) the impressive increase in total salmon consumption is partially due to the added value products of salmon. Because of growing consumer demand for value added products, suppliers have increased their trade in pre-packed salmon fillets and steaks which are also available ready prepared in a range of sauces and flavours. This has also enlarged the use of these products in the catering sector.

2.3 Salmon as a 'Prestigious' Commodity

> 'Salmon is a trendy food and everyone wants to eat more of it'
> (Marketing Director of 'Chicken of the Sea' in San Diego Business Journal 2004).

As discussed earlier, during the industrial revolution, salmon became an expensive food of the elite. In the United States, initially, salmon only reached the top-of-the range restaurants on the northeast coast of the USA (Abbors 2000). As salmon became such a high valued commodity there were many incentives for intensifying salmon aquaculture (Aarset 1999). This resulted in larger amounts of salmon being farmed and a corresponding drop in the price of even high-value products, such as chilled salmon fillets. Indeed, once a seasonal delicacy and a luxury item, fresh chilled salmon is now commonly available in supermarket chillers and affordable to the average consumer for one or two meals per week (Lindbergh 1999). According to one study carried out in New Jersey, USA, salmon was one of the most available fish in all supermarkets in both upper and lower economic areas (Burger *et al.* 2004).

One large USA salmon company emphasises that salmon should be considered an everyday food by calling themselves 'Chicken of the Sea' (San Diego Business Journal 2004). While salmon is certainly far cheaper and more available than even twenty years ago, many of the salmon products that are currently available are marketed as 'gourmet' products. Smoked, chilled and frozen salmon fillets, in particular, are still associated with a certain amount of prestige and are not viewed as 'everyday' food items – although this could change in the future if the price of these products continues to drop.

2.4 Salmon as a 'Virtuous' Commodity

> Salmon has long been regarded as a prime food delicacy. From its aesthetic features (radiant orange color) to its flavorful taste and delicate texture, salmon allures many a palate and satiates the appetite with its low glycemic blood sugar stabilizing protein content. Equally *virtuous* are salmon's long chained omega-3 fatty acids— EPA and DHA (Wellman 2005, emphasis added).

While the image of salmon as an 'elite' food may no longer be so obviously applied, over the past decade the association of salmon with images of health, means that salmon is predominantly constructed as a 'virtuous' commodity. While the evidence for the nutritional advantages of consuming salmon are not being denied here, what is interesting is that the enormous literature, both popular and academic, that exhorts the benefits of salmon – transcending the marketing hype into a kind of cultural virtuousness in consuming this fish. 'Responsible' consumers will buy salmon to ensure that they 'look after' themselves.

The beneficial attributes of the omega-3 fatty oils found in salmon are well known both amongst the health professional world and the public world of consumers (Burger *et al.* 2004; Conon 2005; San Diego Business Journal 2004). Omega-3 fatty oils reduce 'cholesterol levels and the incidence of heart disease, stroke, and preterm delivery' (Burger *et al.* 2004: 90). This recent awareness and emphasis of the health benefits of salmon (and other oily fish species) is likely to be a major reason for the increased consumption of salmon over the past few years. This emphasis arose out of research during the 1970s[12] into the low incidence of heart disease amongst the Inuit living on their traditional diet of fish and blubber (Otago Daily Times 2006). Eating oily fish like salmon provides high levels of omega-3 fatty acids, which, as outlined above, provide a variety of health benefits. Salmon is also recognised as a substitute for beef and pork since the problems of BSE and other food health issues (Abbors 2000; L.A. Times 2002). In addition, salmon has been identified as a good source of vitamin A (Penton Media Sep 2005) and recent research suggests that fish oils can aid in reducing complications associated with diabetes (Otago Daily Times 2006).

The health benefits of consuming salmon are not debated, but the 'virtuousness' of salmon has been threatened by research that has linked farmed salmon to PCB contamination (Hites *et al.* 2004). Rembold (2004) responded to this research by outlining the health benefits of salmon, contending that the consumption of farmed salmon should be presented in a positive light. While he agrees that toxic contamination of farmed salmon should be investigated and reduced, Rembold argues that even eating farmed salmon that is contaminated is more beneficial for individuals with coronary artery disease than not eating the salmon. Conan (2005) examines various studies which have looked at the risks of cancer-causing PCB contamination in salmon and concludes: 'the likelihood of getting cancer from PCBs is much lower than the risk of heart disease from avoiding salmon – including the farm-raised type' (Conan 2005).

Although there are an increasing number of articles outlining potentially negative health aspects from consuming

12 See for example, Dyerberg and Bang's (1979) 'Haemostatic function and platelet polyunsaturated fatty acids in Eskimos'. *Lancet* 2:p.433–435.

farmed salmon (see for example Forristal 2000; Bell and Paone 2002; Conan 2005), it is clear that salmon continues to be perceived positively by most consumers as a 'virtuous' food that endows health. It does appear, however, that if farmed salmon continues to be linked to health risks that this 'virtuousness' may become less associated with farmed salmon, and more with salmon sourced from the wild. This is certainly the marketing emphasis from companies selling wild Alaskan salmon:

> In contrast to farmed salmon, sockeye salmon derived from the pristine waters of Alaska grows unadulterated by antibiotics, pesticides, growth hormones, synthetic coloring agents and genetically modified organisms (GMOs) (Wellman 2005).

Future research will be directed towards exploring this kind of tension around the risks, benefits, and cultural positioning of farmed versus wild salmon in New Zealand. As well as the preservative qualities, palatability, and 'virtuousness' of salmon, a further aspect that has contributed to the successful commoditisation of salmon relates to economic issues.

2.5 Economic Attributes Encouraging Commoditisation

In recent times, research funding for commercial ventures involving salmon, and other commodities sourced from aquatic environments, has grown enormously and this funding now exceeds that for traditional agricultural meat farming. As Abbors (2000) explains, salmon – and fish in general – are particularly suited to intensive aquaculture production systems:

> Fish are for many reasons suitable for intensive farming. For one thing, they grow rapidly, and they may be reared in relatively dense populations… The most important reason, however, is that fish are the most efficient utilisers of protein on earth. On an average, 70% of the protein taken in by fish goes to increase their weight and muscle mass (Abbors 2000: 18).

There are two primary reasons why aquatic animals attract more research than terrestrial domesticated animals. First, fish produce an abundance of eggs that are easily manipulated and bred selectively for size and other favourable characteristics.[13] Second, as mentioned above, commodities from fish farming continue to service a growing market especially compared to other meat industries (Aerni 2004). Aquaculture production costs have decreased over the past decade, in particular, and this can be attributed to the following:

- The development of fish feed with better digestibility and absorption.
- The development of new fish vaccines, which have led to better health and lower death rates of the fish.
- Better farming stocks, improved development of breeds and development of applied veterinary research.
- New farming technologies have led to rationalisation and automation of production that has lowered payroll costs.
- 'Off-shore' technologies have led to larger and more efficient production units (Abbors 2000: 19).

Salmon farming has also been seen by some governments as a means to help address unemployment problems. The governments of Norway (Power 2003) and Chile (Phyne and Mansilla 2003) for example – two of the leading salmon producers in the world today – supported the establishment of salmon farming industries as a means of improving employment rates, particularly for communities in rural and isolated areas (Power 2003; Aerni 2004). Although Josh Eagle *et al.* (2003) argue that this employment and profitability was only truly established within certain politically favourable sectors.

The commercialisation and intensification of fish farming is seen by some people as a means to solve the declining natural stock of wild fish resources, a means of overcoming the 'ecological and economic constraints of capital-intensive marine capture fisheries' (Aerni 2004: 329). 'Most scientific opinion is agreed that fish farming is the most logical and practical solution to meet the rapidly growing global demand for fish and to reduce pressure on capture fisheries' (African Business 2005). As wild fisheries decline and are no longer able to provide the quantities of fish demanded by consumers, intensive aquaculture systems will increasingly become the main source of fish in the industralised world, as is already the case for frozen and chilled salmon fillets (Goldburg and Naylor 2005).

Proponents of salmon aquaculture also argue that fish farming is a more reliable and predictable business to operate than depending on wild salmon capture fisheries. This is because farmed salmon have a superior 'feed conversion rate' than wild fish and, additionally, the chances of wild fish actually reaching suitable size and being caught are far less reliable when compared to the control and predictability of aquaculture (Aquaculture Magazine 2000). Hence, salmon farming is able to capture all the key efficiencies of labour, inputs, predictability and scale characteristic of industrial production processes.

This chapter has outlined some of the favourable attributes, which have helped to make salmon such a successful product. Initially, during the late 1800s, this success was mainly as a canned product using wild salmon, but since the 1970s and the enormous growth in salmon farming ventures there has been an explosion of different salmon commodities – including perishable chilled and frozen

13 The abundance and easy manipulation of fish eggs also makes them amenable to biotechnology processes (Lim 2002).

products – available on supermarket shelves throughout the world. Technological developments have allowed for the intensive and cheap production of salmon, which has led to an escalation of competition between salmon companies. The reduction of production costs has become a priority for salmon farmers, initiating further research into technological development and pushing prices down even more. Salmon is now available and affordable to millions of consumers across the world,[14] mainly because of the large-scale, intensive and cost-effective salmon farming system. The wholesale price of salmon has decreased from $US6 to $US2 a pound in the last ten years (Van Aken 2000). Once a seasonal delicacy marketed primarily to elite restaurants in the United States, salmon has become as cheap and available as chicken and is marketed as a healthful and 'virtuous' food product. As will be discussed in the next chapter, however, there are some negative aspects to salmon farming which need to be considered.

---

14 The biggest consumers of salmon in 1996 were Japan, USA, and the EU (with France making up 40% of this market). German consumption of salmon is only about 1kg per person per year, in contrast to the Japanese where annual consumption is about 4kg per person (Abbors 2000).

3 Salmon Farming on the 'Technological Treadmill'?

3.1 'Tides of Flesh'[15] – Contemporary Salmon Farming

The intensive 'Fordist' aquaculture systems that produce farmed salmon have been described as 'feedlots of the sea' (L.A. Times 2002). In common with other types of intensive animal food production, salmon farming has to manage issues of disease and stress that result from raising livestock and fish in crowded conditions that differ markedly from wild habitats. The following description highlights the similarities between salmon farming and other forms of intensive animal production:

> If you bought a salmon fillet in the supermarket recently or ordered one in a restaurant, chances are it was born in a plastic tray here, or in a place just like it. Instead of streaking through the ocean or leaping up rocky streams, it spent three years like a marine couch potato, circling lazily in pens, fattening up on pellets of salmon chow. It was vaccinated as a small fry to survive the diseases that race through these oceanic feedlots, acres of net-covered pens tethered offshore. It was likely dosed with antibiotics to ward off infection or fed pesticides to shed a beard of bloodsucking sea lice. For the rich, pink hue, the fish was given a steady diet of synthetic pigment. Without it, the flesh of these caged salmon would be an unappetizing, pale grey (L.A. Times 2002).

It is not so much the natural biology and physiology of salmon that allows for the success in the commoditisation of salmon and this intensive form of animal husbandry, but rather technological developments in vaccinations, antibiotics and pesticides. With these new improvements, 'farms typically put 50,000 to 90,000 fish in a pen 100 feet by 100 feet' (approximately 30 metres by 30 metres) (L.A. Times 2002). Without the inputs listed above, parasites, pathogens

15 Taken from Harriet Friedmann's (2000) essay, where she refers to William Cronon's (1991) book, *Nature's Metropololis*. The full quote reads: 'Plants and animals have been turned into homogenous rivers of grain and tides of flesh, more closely resembling the money that enlivens their movement from field to table, than their wild ancestors' (Friedmann 2000: 481).

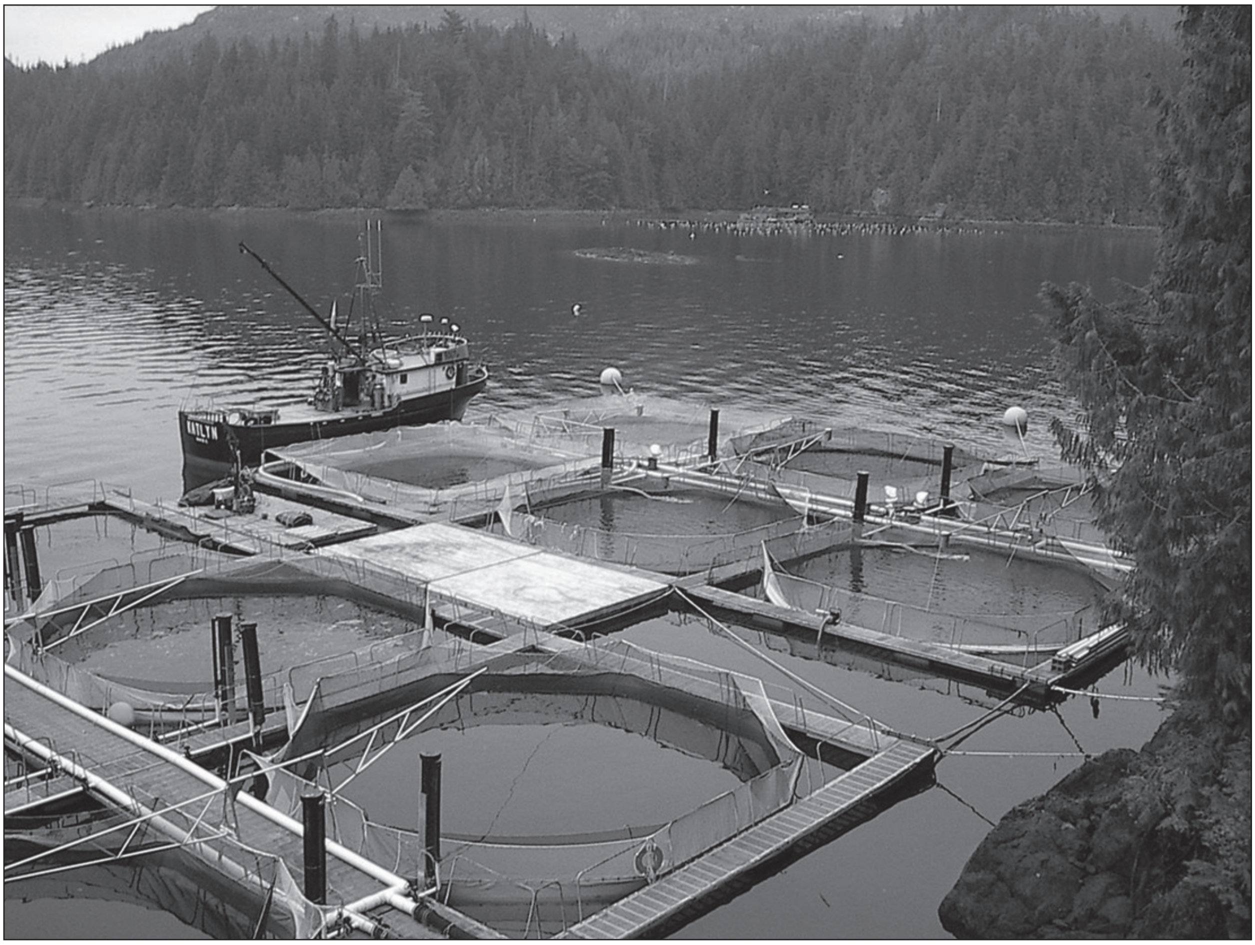

Figure 4: Salmon Farm in British Columbia (Source: www.dfo-mpo.gc.ca/aquaculture/photos_e.htm).

and other diseases would make caged salmon farming far too risk-prone and thus uneconomic. Waste levels have been reduced by installing video cameras showing when salmon stop eating and indicating when workers can stop feeding (L.A. Times 2002; Aerni 2004). Technology and better risk management has played a role in reducing the number of salmon mortalities relating to weather (Abbors 2000). This greater control over timing, consistency and quantity within the farming sector has allowed for a more predictable flow of salmon production worldwide (Eagle *et al.* 2003). Technological innovation to prevent, or at least reduce, escape and cross breeding of farmed salmon with wild salmon involves improved containment, reduced mesh size, and sterilisation (Aerni 2004).

A greater understanding of biology and breeding has led to improvements in food conversion rates, although, as will be discussed further below, much research is still being conducted to find a substitute for fish meal and oil (Power 2003). Furthermore control over genetic make up has allowed for regular sized and shaped farm salmon, which lowers processing costs and also allows for an increased mechanisation of the process (Eagle *et al.* 2003 and Hein 2005). Unfortunately, while intensive salmon aquaculture has grown to be an enormously successful commercial industry, serious problems have arisen from this intensive growth.

3.2 Problems with the Intensification of Salmon Farming

Fish farming 'is one of the most intensive forms of animal husbandry' (Ride 2000). Considerable knowledge about habitats and life cycles, is required to ensure a successful salmon farming operation, involving research and development of technically specialised conditions (PREMnote 2005; Aerni 2004). 'Salmon farming requires natural resources, intermediary inputs that can be imported and situation-specific knowledge. The hatcheries need to be established in uncontaminated water and favourable climatic conditions. In the second stage of cultivation, the critical ingredients are the quality of tanks, feeding equipment and food' (PREMnote 2005).

There are many problematic issues challenging the success of salmon farming. In particular, the very intensive, monocultural nature of salmon farming raises some fundamental questions about the sustainability of this type of farming. With tens of thousands of salmon in an enclosed pen for months at a time, disease and parasites are offered an optimal environment, posing a huge threat to the health of farmed and wild salmon. Consequently there is a high use of pesticides and antibiotics whose effects are not only potentially dangerous for the salmon but also to humans (L.A. Times 2002). There are also cases of salmon farmers using illegal toxic chemicals to manage such risks (Friends of the Earth Scotland 2002). In addition, salmon farms produce masses of waste, for example, the volume of waste excreted from a fish farm in Scotland was found to be the equivalent to the waste of 8 million people. This waste smothers the sea floor attracting bacteria that consume oxygen. This can result in a reduction in levels of oxygen as well as diseases that affect other aquatic species (Aerni 2004; L.A. Times 2002). Some evidence suggests that this waste produces toxic algal blooms (Friends of the Earth Scotland 2002).

There are also significant concerns relating to farmed salmon (including eggs) escaping into the natural environment competing with wild fish species for food and also possibly endangering wild salmon populations and genetic variation (Aerni 2004). One of the main concerns about selectively bred, non-GM salmon, is the lack of genetic diversity in the farmed fish, and the impact that will have when they breed with wild species. Also of concern is the impact of farmed Atlantic salmon escaping into the waters of the Pacific North-West and competing with the native Pacific salmon species which are, in many places, endangered (Reichhardt 2000; L.A. Times 2002).

Another major concern about intensive salmon aquaculture relates to the enormous amount of low-value fish that must be caught in order to produce feed required for carnivorous species like salmon. It is estimated that feed costs equate to between 35% to 60% of the total production costs for farmed salmon (Power 2003). It is widely accepted that the use of animal protein to produce animal protein is not sustainable. According to research from Stanford's Centre for Environmental Science and Policy, it takes up to 2.4 pounds (approximately 1.1 kilograms) of fish to produce a single pound (approximately 400 grams) of farmed salmon. 'Farming salmon and other carnivorous marine fish represents a net loss of fish protein, as about two to five times more wild-caught fish are used in feeds than are harvested from aquaculture' (Goldburg and Naylor 2005). This feed consists of fish oil and fish meal, made up of sardines, anchovies, mackerel, herrings and other small fish (Weiss 2002). As a result, fish farming is not substituting for the wild capture fisheries, and may in fact be impacting negatively on wild fish populations. As fish farming becomes more prevalent there will be an inevitable increase in competition for small fish. These fish are an important part of the ocean food chain, and if they become depleted this will impact upon the wild predatory fish that prey on them (Goldburg and Naylor 2005).

A further concern about the exploitation of smaller fish species for fish feed relates to negative repercussions on communities who rely on these fish for food:

> Currently 85 per cent of internationally traded seafood products come from developing countries. It is here that smaller-scale fishers – who provide the primary source of protein for over one billion people – will feel the effects of overfishing and pollution from fish farms most acutely (Ride 2000).

Both Netto (2003) and Kurian (2003) argue that the aquaculture boom has adversely affected the poor, especially in Southeast Asia and Indonesia. The low-value fish traditionally eaten by the poor are being exploited for aquaculture fish-feed which in turn goes to feed value-added fish products only available to more affluent consumers in wealthier countries. With dwindling supplies of wild fish the prices rise above that affordable to the poor who lose their food security (Kurian 2003).

A great deal of research is investigating alternatives to the high-protein fish feed that is based on smaller fish species.[16] Some research proposes soybean meal as a possible alternative but this has a number of problems associated with its use (RSPB 2004). There has also been research into the use of rendered animal products sourced from terrestrial livestock as a replacement to fish meal for salmon (Tye 1997).

There have been suggestions that farming genetically modified (GM) salmon could provide a solution to feed problems. Biotechnology could be a means to improve the quality and quantity of farmed fish – also a means of making fish, in particular salmon, disease resistant and with enhanced growth rates (Aerni 2004). Power (2003) suggests:

> Transgenic fish with enhanced growth rates grow regardless of seasons, and reach market size more quickly than their non-transgenic counterparts, thereby reducing an individual fish's demand for feed (Power 2003: 23).

Another possibility is to genetically manipulate carnivorous salmon so that they are able to survive on plant-based feed, rather than fishmeal, although this is an extremely complex proposition and has far-reaching implications with regard to the metabolism of salmon (Jystad 2001). While some potential benefits from GM salmon have been raised, as the following chapter will outline, there are many complex issues to consider in relation to this.

16 For an in-depth discussion on issues relating to marine sourced fish feed see Tuominen & Esmark (2003).

4 Genetically Modified Salmon

4.1 Genetic Modification of Animals

Genetic modification (GM) has emerged as a major technology since the early 1970s. As a technology, genetic modification can be described as the alteration of the genetic information of an organism as a result of human action aimed either at adding new genetic material or at deleting or rearranging existing genes within the organism (Ho 1998). GM has been used in developing several crops such as canola, cotton, soy and corn to be pesticide and insect-resistant. These crops have been grown commercially since the 1990s. Research has also been conducted into the production of GM animals.

Several projects have been undertaken in the cloning of animals. The original cloned sheep 'Dolly' was not genetically modified but other clones have been. 'Polly' – produced by the same team as 'Dolly' – received foetal cells modified with a human gene. Other transgenic sheep have been developed to produce proteins in their milk to treat the symptoms of cystic fibrosis and for the use of patients with clotting disorders (Lim 2004). Additional work has been done to develop animals for xenotransplantation, i.e. animal to human organ transplants (Lim 2004). This work is primarily occurring using pigs. In the short term, it is more likely that implantation in humans of single cells and tissues will occur rather than whole organ transplantation (Committee on Defining Science-Based Concerns Associated with Products of Animal Biotechnology 2002).

Recombinant bovine somatotropin (rBST), or recombinant bovine growth hormone, was developed in the 1990s to increase milk production. It was approved for use in the US in 1993 but was banned in Europe and Canada. According to its developer, Monsanto:

> The use of supplemental bST [Bovine somatotropin] by dairy farmers, both large and small, generally increases milk production by 10 to 15 percent using the same number of cows. The use of supplemental bST also results in the use of less water, less land, less soil loss and less fuel associated with grain production and dairy operations. Other environmental benefits include less methane gases, less manure, and reductions of other waste. These benefits help dairy farm profitability while protecting our environment (Monsanto 2006).

rBST was the subject of a number of concerns regarding human safety. Concerns have also been raised about the need to increase productivity and the subsequent affects on small farmers. The use of rBST to sustain milk production of cows for up to 600 days following calving has resulted in a shortage of replacement heifers for producers as cows are now restricted to only one calf per milking life (National Research Council 2002).

The above examples of genetic modification have resulted in animals that are not to be consumed by humans. Pigs have been developed with enhanced growth but they have not been released commercially (Norton 1998). Fish species have several advantages over mammals when conducting genetic manipulation. Female fish produce large numbers of eggs – usually large and transparent. Fertilization occurs externally and once gene transfer has occurred it is not necessary to implant the eggs as in mammalian manipulation. Further, the cost of maintenance of eggs within a fish hatchery is relatively inexpensive (Lim 2004). Research has been conducted on a number of fish species including Atlantic salmon, rainbow trout, tilapia, grass carp, goldfish and catfish. Fish are being altered to allow faster growth, improve disease resistance, increase cold tolerance and to produce pharmaceutical products (Walton 2003). The purpose of these GM fish is not for pharmaceutical production but as food.

GM Salmon

Salmon has been genetically modified to:

- Develop genetically superior broodstocks;
- Improve growth rates;
- Improve feed conversion efficiencies;
- Improve disease resistance;
- Improve cold resistance;
- Improve tolerance to low oxygen levels;
- Improve ability to digest alternative diets (Power 2003).

The primary reasons for genetic modification are to enhance growth and improve feed efficiencies. This has the potential to improve economic returns from fish farming (Power 2003). Aqua Bounty Farms (purchased in 1996 by A/F Protein Canada Inc.) have produced a transgenic Atlantic salmon – AquAdvantage salmon – that has been shown to grow to mature size in two years instead of the three years required by non-transgenic salmon (see Figure 5).

The AquAdvantage salmon contains two novel genes – a growth hormone gene from Chinook salmon and a promoter sequence from ocean pout. The promoter sequence activates the growth hormone so that it promotes year-round growth. While fish grow faster, they do not grow larger than non-transgenic salmon. Faster growth is important:

> To salmon farmers, faster growth means marketing fish sooner …, thereby reducing the risk of disease … and reducing feed requirements …. By extension this means increased overall production due to expedited (and therefore more) production cycles … lower costs through fewer fish losses; and reduced feed imports (Power 2003:16-17).

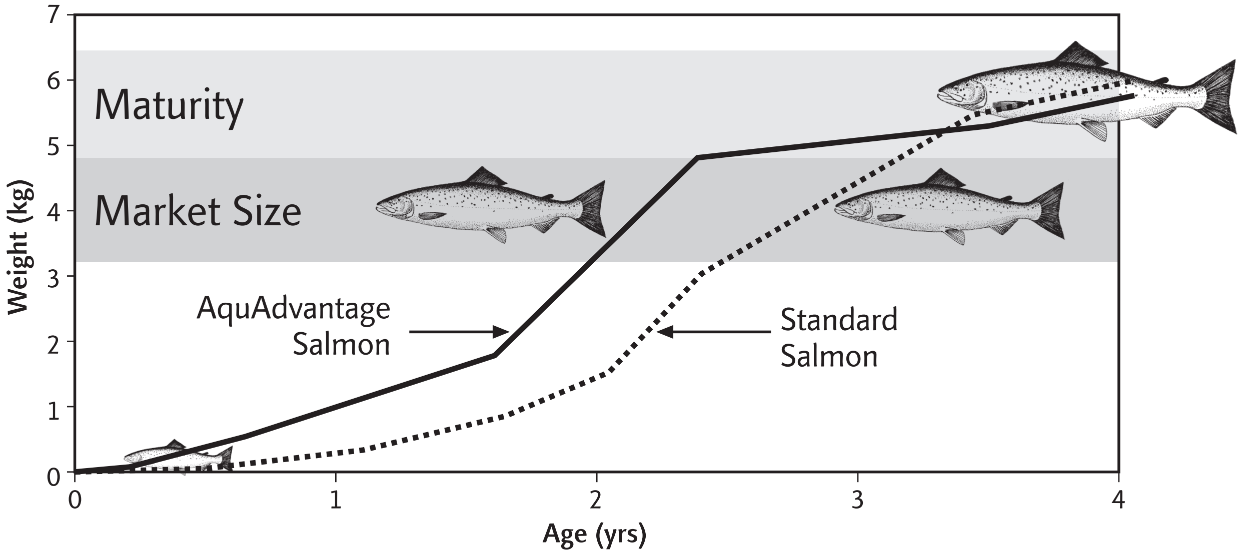

Figure 5. Comparison of Growth – GM and non-GM Salmon (Source: adapted from: http://www.aquabounty.com).

4.2 Concerns and Reasons for Opposition to GM Salmon

As genetic engineering has developed over the past decades, one of the most problematic applications of this technology has been in connection with animal biotechnology (Rollin 1995).

Animals experimented upon in laboratory settings are carefully confined and, assuming the stringent regulations associated with keeping these animals are followed, there is little risk of these animals escaping. Animals reared in agricultural settings, however, raise significant risks as they cannot be as closely contained, generally requiring enough space and time to reach an optimum size that will garner maximum profit for the producer. The numbers of animals reared is also significantly more than the small number of experimental species in laboratories. Fish are particularly problematic when reared in pens in the sea due to the frequent evidence of escape into the wild.

A study by Chern and Rickertsen (2002) compared consumer attitudes towards GM foods in Norway and the USA. As Chern and Rickertsen (2002: 96) observe, 'there is substantial resistance to GM crops in Europe', and therefore it is not surprising that their study found that, in general, people living in the USA view GM foods more favourably than Norwegian consumers. This research also found, however, that opinions in the USA were variable and this was clear with regard to questions about salmon. Chern and Rickertsen (2002) found that 'American consumers are willing to pay substantial amounts of premium to avoid GM-fed or GM salmon' (Chern and Rickertsen 2002: 106). This study found that health concerns appeared to be the main explanation for negative attitudes towards GM food and some of these concerns will be outlined in the following section.

Health Concerns

While there is no certainty what, if any, health risks GM salmon might pose for humans, it is known that the health of genetically modified salmon themselves could be compromised (Greenpeace 2003). There is also some concern that some genes transferred via genetic engineering will maintain their allergenic properties and thus potentially pose a threat to allergic individuals through their presence in food not usually associated with those allergies (Power 2003; CFFS 2001). However, current research in GM salmon is using fish-to-fish genetic transfer and the possibility of novel allergen introduction is small. It is known that pollutants accumulate in fat tissue and because farmed (transgenic) salmon have higher fat levels than wild salmon there are greater risks of poisoning (L.A. Times 2002). Farmed salmon are also fed antibiotics, pesticides and dyes because of the intense monocultural environment they are cultivated in and these conditions would not change for GM salmon and thus they too would be fed such chemicals. Consumers are concerned with health issues relating to GM foods, in general, and because of the lack of research and information of potential health risks with consuming genetically modified animals, in particular, the public continue to be sceptical and unsympathetic towards GM foods such as salmon (Power 2003; Chen and Chern 2004).

Economic Concerns

While some firms and market segments will benefit from GM salmon there are many others that will not and are thus unwilling to support any use of GM salmon (Walton 2003). Some large fishing firms such as Nutreco oppose transgenic fish because they are already under attack by NGOs for their salmon farming practices in Chile and GM salmon would only increase these issues thus impinging on their profitability. Retailers are generally unwilling to buy transgenic salmon as many consumer surveys suggest that buyers (outside of the USA in particular) do not appreciate GM foods and therefore it is likely there would only be a small market, if any, for such salmon (Aerni 2004). Many insurance companies are refusing to cover genetically modified foods as too little is known about the potential risks of these new technologies and products (Salon News 2000).

Cultural and Spiritual Concerns

Many indigenous peoples oppose the genetic engineering of animals as they see this technology as threatening traditional cultural associations with those animals and the environment that they live in (Power 2003). Two studies by the Agribusiness and Economic Unit at Lincoln University consider the cultural and spiritual dimensions of public attitudes towards biotechnology (Coyle *et al.* 2003; Roberts and Fairweather 2004). Roberts and Fairweather's (2004) research focuses on Maori living in the South Island of New Zealand and participants in their study expressed a desire for new technologies to be both spiritually and physically safe. This research also found that Maori participants who emphasised their Maori culture were more strongly opposed to genetic engineering (Roberts and Fairweather 2004). At this time, no studies have focussed on Maori attitudes or beliefs about GM salmon specifically, and this is an area where future research needs to be carried out.

Environmental Concerns

As outlined above in Section 3.2, the escape of non-GM farmed salmon has already been raised as a concern by environmentalists due to the effect that these selectively bred stock can have on wild populations. Escapes from salmon farms are common occurrences, and sometimes on a very large scale – for example, 170,000 one-year-old salmon escaped from a fish farm in Maine in 2000 (Labriola 2002). If GM salmon were able to escape and 'release their added growth-hormone genes into wild populations' the results would be unpredictable (Reichhardt 2000). The main concern raised thus far with regard to GM salmon relates to enhanced body size. In many fish species, including salmon, larger fish have a higher chance of mating. Although there is the possibility of making the farmed salmon sterile, this does not necessarily eliminate the problem, as although functionally sterile, the farmed fish are still likely to demonstrate spawning behaviour with fertile wild salmon. This could have serious consequences if wild fertile male salmon are rejected in favour of non-fertile farmed salmon, leading to what some environmentalists see as possible extinctions of some salmon species. This has been termed the 'Trojan gene effect' (Reichhardt 2000; van Aken 2000). The counter argument is that non-fertile farmed salmon will not be able to reproduce and therefore if there are any escapes into the wild the wild gene pool will not be adversely affected (Lim 2002).

There is concern from some researchers about the risk of GM fish escaping and that the US regulatory system will not be able to adequately assess potential risks:

> Patented, genetically engineered salmon are proposed for deployment in commercial aquaculture. If released accidentally into ecosystems, these novel organisms would have uncertain effects on ecological processes. Proponents suggest that ecosystems are fundamentally balanced and resilient and therefore that risks are negligible because of transgenic fishes' reduced ecological fitness. Opponents maintain that ecosystems are characterized by instability and contingency rather than equilibrium and that a small number of ecologically fit organisms may change the state of an ecosystem if conditions are favourable. Current U.S. federal regulations hamper public discussion about potential risks, limit the role of agencies with the greatest expertise in fisheries and ecological sciences, and make precautionary action difficult without proof of harm (Kelso 2004: 509).

The following section considers regulatory issues with regard to GM salmon in more detail.

4.3 Regulation of GM Salmon

> The governance of aquaculture is complex and multilayered. Depending on jurisdiction, these layers may include international, transnational, provincial/state and regional regulation (Power 2003: 34).

According to CorpWatch (2000) GM technologies and products are so new that there are no internationally recognized systems for assessing their safety. In the USA federal policy has regulated biotechnology under existing statutes (Walton 2003) and A/F Protein is waiting approval to put GM salmon on the market (Power 2003).

Several regions around the world currently ban all GM products, including GM salmon. In Scotland, for example, GM salmon is currently banned and will remain in place as long as the public are opposed to GM foods. Australia has not applied GM technologies to its aquaculture industry. Canada does not support the use of transgenic salmon farming. British Columbia, Washington State and the International Salmon Growers Association have rejected the possibility of introducing transgenic salmon in their regions (Power 2003) and 172 regions in Europe have declared themselves GE-free (Organic Consumers Association 2006).

In New Zealand, regulation of genetically modified organisms is controlled by the Hazardous Substances and New Organisms Act (HSNO). Under the Act, the Environmental Risk Management Authority (ERMA) controls the development, importation, field testing or release of genetically modified organisms. The maintenance of food safety and the labelling of foods is the responsibility of the New Zealand Food Safety Authority.

Regulations are problematic because there are many different institutions and factors affecting and influencing regulations and policies on GM salmon. The public also has a lot of influence, yet because many institutions influence public opinion, the whole GM salmon issue will possibly be shaped by whichever group has the greatest resources available, or influence upon, public opinion (Midden *et al.* 2002; Bauer and Bonfadelli 2002). Aerni (2003) also argues 'the consumer market rather than regulations will determine the ultimate fate of transgenic fish' (Aerni 2004: 327).

4.4 Responses to GM Salmon – Public and Corporate

Various groups and organisations have expressed concern about genetically modified salmon. This includes environmental groups such as Greenpeace, but also some fish producers and traditional fish farmers (Mindfully.org 2000). For example, the Scottish Quality Salmon organization has also taken a strong and public opposition to the use of genetically modified salmon. They are concerned about negative public opinion towards GM foods and are therefore disinclined to use or promote the use of genetic modification in salmon aquaculture (Scottish Quality Salmon 2002). In Scotland, the salmon industry has voted against transgenic salmon (Salon 2000). Tony Blair's chief science advisor Sir Robert May has expressed his preference for non-GM organic fish farming (Salon 2000).

In the United States in April 2002, the Senate Natural Resources Committee approved a bill by Senator Byron Sher that would make importing, transporting, possessing or releasing transgenic fish illegal in California (San Francisco Chronicle 2002). Washington Fish and Wildlife Commission have banned GM fish from marine net pens. A joint legislative resolution introduced by assemblyman Joe Nation urges the FDA to place a moratorium on transgenic fish alongside denying Aqua Bounty's application for commercial release (San Francisco Chronicle 2002). Maryland bans the introduction of GM fish in State waters (Walton 2003). Oregon has laws prohibiting the release of transgenic fish. Alaska might ban GM fish outright (San Francisco Chronicle 2002). Christopher Poupard the director of the Salmon and Trout Association and the program officer for the Institute for Fisheries Resources expressed concern about genetically modified fish breeding with wild fish and disrupting the natural and complex reproduction process (Mindfully.org 2000; San Francisco Chronicle 2002). The president of the Canadian Aquaculture Industry Alliance said that the farms they represent are against genetic modification (Animal Biotechnology BBC 2004). According to the Centre for Food Safety, 468 businesses in the US have pledged not to buy or sell GM fish (Animal Biotechnology BBC 2004). While the members of Marine Aquaculture Association have not formally opposed GM fish, they have also not expressed interest in using GMO products (MOFGA 2002).

Of all the groups opposing transgenic salmon the Center for Food Safety (CFFS) has initiated the leading response to A/F Protein's requests for a transgenic salmon to be approved by the FDA for sale on the public market (CFFS 2001). This United States consumer group filed a petition against A/F Protein's GM-Fish. Greenpeace, and over sixty other fisheries protection, conservation and consumer groups signed the petition (Binas Online News 2001). Petitioners include: Atlantic Salmon Federation, Genetically Engineered Food Coalition, Half Moon Bay Fisherman's Marketing Association, Institute for Agricultural and Trade Policy, Institute for Fisheries Resources, Organic Trade Association, National Environmental Law Centre, several commercial fishermen, Sweet Lisa Seafood, and many others (CFFS 2001). This Citizen Petition, which is still before the United States Food and Drug Administration, seeks a moratorium on the domestic marketing and importation of transgenic fish. They are demanding:

> A moratorium on the domestic marketing, importation and exportation of transgenic fish, including but not limited to all transgenic fish, transgenic fish eggs, and food products containing any ingredients or material derived from transgenic fish, until the FDA establishes a comprehensive regulatory framework under the mandate of the Federal Food Drug and Cosmetic Act ('FFDCA') to evaluate and fully address the human health and environmental impacts caused by the commercialization of transgenic fish (CFFS 2001:2).

4.5 GM Salmon – the Solution to World Hunger?

Some theorists (see for example Coull 1993; White *et al.* 2004) have described this industrialising of aquaculture as the 'Blue Revolution', which in common with the agricultural 'Green Revolution' has not successfully delivered cheap food to those communities who really need it. Coull (1993) argues that, like the Green Revolution in agriculture, any advantages from these developments in the Third World situation have been 'patchy and partial' and mainly benefit those people who are already economically secure. The fish that are being produced through these new technologies are also, in general, species aimed at high-value markets and therefore not affordable to poorer people. In addition, like other Green Revolution foods, salmon and other intensive aquaculture production systems, appear to be caught on the 'technological treadmill', where priority is given to producing higher and higher yields without taking into account the long-term environmental, social and economic consequences:

> Largely controlled by multinational corporations, industrialized farming of carnivorous fish such as salmon requires the intensive use of resources and exports problems to the surrounding environment, often resulting in environmental impacts and social conflicts (White *et al.* 2003: 4).

Well-known ocean environmentalist, Jean-Michel Cousteau (2000) has expressed his opposition to GM salmon. In his article 'GE Fish: A Threat Disguised as a Solution to World Hunger,' he disagrees that engineering new strains of fish, such as salmon, will be an effective response to world hunger. Cousteau sides with other critics of the Green Revolution, and argues that there is no global shortage of food, but rather a 'shortage of equity, accountability and ethics.' He sees the genetic manipulation of salmon as a means to increase profit, rather than to increase food for the hungry:

> In this market, when nearly a billion people can't afford the basics, why is there such a rush to engineer new fish? Not to ease world hunger. No, simply because there is money to be made by selling to wealthy consumers in industrial nations (Jean-Michel Cousteau 2000).

As this previous discussion has outlined, there are currently serious concerns about the commericalisation of transgenic salmon as a food. The following section briefly examines the possibility of utilising GM salmon to produce pharmaceuticals.

4.6 Biopharming and Salmon

> *Biopharming*, is a sub-sector of the biotechnology industry that involves the process of genetically engineering plants so that they can produce certain types of proteins. The proteins can then be harvested and used to produce pharmaceuticals (Wikipedia 2006).

Current biopharming activities primarily involve plants, however, research in biopharming is also being conducted with animals. Cattle, sheep, goats, pigs, chickens and rabbits have been genetically modified to produce proteins. Transgenics is useful in this area as it has:

- the ability to produce large amounts of protein with a higher expression level and volume output than traditional culture systems;
- the ability to express novel proteins, particularly in milk; and
- the potential for significant cost per unit production reduction (Lim 2004 p.150).

As yet, no such research is being undertaken using salmon. However, a US project is looking at producing a drug to assist in blood clotting that uses tilapia as the production mechanism (Walton 2003).

Nutraceuticals/Functional Foods

Nutraceuticals or Functional Foods are those foods that are seen to have a positive health benefit in addition to their traditional nutritional role. Thus, salmon, with its high values of Omega-3 oils can be considered a nutraceutical. The genetic modification of salmon to increase its oil content is a possible future scenario. No projects are currently under way in this area.

5 New Zealand Case Study

5.1 Salmon in New Zealand

Salmon are not native to New Zealand. At present, only Chinook salmon (or King salmon) is farmed on a significant scale in New Zealand (NZSFA 2005). The first attempt at establishing salmon in New Zealand waters was as early as the 1870s but was unsuccessful. Early in the twentieth century 'chinook were successfully introduced, via a hatchery on the Hakataramea River, between 1901 and 1907. This was done by the Marine Department in the hope of starting a commercial canning industry although this never developed' (SeaFic 2000). It was only during the 1970s when any real success of salmon rearing became evident (McDowall 1994). Initially ocean ranching was attempted in Golden Bay but this was not successful. The first sea-cage salmon farms were established in 1983 in Stewart Island's Big Glory Bay by BP New Zealand Ltd. This was soon followed by the development of farms in the Marlborough Sounds (NZSFA 2000).

In 2004, the market revenue for King salmon was estimated at NZ$81 million, with NZ$36 million being exported. King salmon production accounts for 28% of the total aquaculture market revenue (NZAC 2005). Salmon is exported primarily to Japan as well as Australia and other Pacific Rim countries. Salmon is exported in gilled and gutted or headed and gutted form, but the local market includes value added products such as steaks, fillets, smoked or kebabs (NZSFA 2005).

Treaty of Waitangi Issues

In 1987, The New Zealand Government set up a Quota Management System and assigned property rights to individuals and companies in the seafood industry. Following challenges by Maori to this system, after an interim settlement in 1989, the Treaty of Waitangi Fisheries Commission was set up in 1992 to hold Maori assets. Under the agreement reached at this time any further claims Maori have on fresh-water and sea-water fisheries were extinguished. In September 2004, the Maori Fisheries Act was passed in Parliament and the Fisheries Commission dissolved. In its place Te Ohu Kai Moana Trustee Limited and Aotearoa Fisheries Limited established (Te Ohu Kaimoana 2006).

Aquaculture is governed by the Aquaculture Reform Bill 2004. In accordance with the 1992 Fisheries Settlement, Maori are entitled to 20% of marine farming space in any region. In effect, this accounts for 20% of all space allocated since 21 September, 1992 and 20% of all marine farming space created in the future (Ministry for Environment 2005).

5.2 The New Zealand King Salmon Company

The New Zealand King Salmon (NZKS) company, based in the Marlborough Sounds, is one of the largest global producers of farmed King salmon, processing approximately 5000 tonnes of salmon per year (NZKS 2006). They have three hatcheries and four operational salmon farms. According to their web page, NZKS produce 70% of all of New Zealand farmed salmon and 40% of the world production of King salmon. The company promises that their salmon are fed with ingredients that are traceable and that have been 'obtained only from safe and sustainable sources with guaranteed ingredients, which are BSE and GM free' (NZKS 2006). They also guarantee that the fish feed they use has been supplemented with essential vitamins and minerals and that no antibiotics, growth stimulants, drugs or toxic substances are added. NZKS is fortunate not to have the serious disease and pest problems that affect Northern Hemisphere salmon farms due to New Zealand's isolation. NZKS also slaughter the fish using a natural anaesthetic developed in New Zealand, which has been favourably reported on by the British Humane Slaughter Association (NZKS 2006).

Figure 6: New Zealand King Salmon Transgenic Chinook Salmon – 'The top 3 fish are transgenics: 11 months old with an average weight of 850g, while the bottom fish is a non-transgenic sibling of the same age, weighing 280g'. (Source: www.oceans-atlas.com).

In 1994, NZKS first applied for, and received, approval to experiment and research genetically modified salmon at Kaituna near Blenheim. At the time, the NZKS' GM salmon trials were reported on local television news programmes and in newspaper items. The approval was granted through the Environmental Minister, Simon Upton. No formal controls were put in place but the company was required to act under a voluntary regime in regard to the containment of eggs and fish (Weaver and Motion 2002). In July 1998 the Hazardous Substances and New Organisms Act (HSNO) came into effect and the NZKS research operation was assessed by the Environmental Risk Management Authority (ERMA) to ascertain whether it conformed to the HSNO Act (The Press 1999a).

In 1999 the Green co-leader Jeanette Fitzsimons obtained a leaked copy of a report written by the Public Relations firm Communications Trumps (based in Wellington) who were acting as advisors to NZKS. Communications Trumps advised NZKS to keep issues such as deformities[17] in their GM salmon trials carefully hidden from the public (The Independent 2000). The Green Party used the leaked document to challenge the government in the 1999 election. Jeanette Fitzsimons stated: 'With genetic engineering we are at the same stage as we were last century when releasing rabbits and possums around New Zealand. As is the case now, government agencies hoped the result would be beneficial, but didn't really know' (cited in Pollack 2003). Further opposition came from other environmentalists within New Zealand (Genet 2000). Local residents in Marlborough and Nelson also organised protests against NZKS (The Press 1999b).

The resultant debate in the local New Zealand media quickly gained international attention, becoming the focus of much discussion and articles on the Internet. With words such as 'Frankenfish' (Drudge 2000; San Francisco Chronicle 2002; MOFGA 2002) and 'Frankensalmon' (Salon News 2000) being applied to GM salmon, clearly these trials hit a nerve with many people around the world.

In 2000 NZKS closed their salmon trials and all modified salmon were killed and disposed of (The Press 2000). The chief executive of NZKS, Paul Steere denied that the company's GM salmon trials were suspended due to political, ethical or scientific resistance (Genetics 2000). There are several possibilities that could have been factored into this decision. Firstly, the stricter controls imposed by ERMA in order for NZKS to conform with the HSNO Act – such as improving containment with smaller wire mesh screens, appropriate disposal and contingency plans in case of floods, accidental release or deliberate removal of transgenic material – may have been deemed uneconomic (The Press 2000). Although denied by Paul Steere, it is also likely that the public concerns with regards to GM salmon were taken into consideration – particularly because the negative publicity jeopardised the image of NZKS, putting their non-GM salmon products at risk. To date there is no indication that NZKS will continue with the GM salmon trials, although the company still has the modified eggs frozen and securely stored for later research (Genetics 2000). The promotional material on the NZKS website emphasises that their salmon farms are very 'natural', and that the salmon-rearing programme is GM free – suggesting that the company has no plans to carry out any further GM trials in the immediate future at least.

17 These deformities are a result of inserting a growth hormone gene into salmon. Specifically, 'in transgenic salmon the growth rate seems to be correlated with skull and jaw deformities. Overproduction of cartilage in the skull and jaw has been found in transgenic salmon with a strongly enhanced hormone production' (COGEM 2001:17–18).

5.3 Public Opinion on GM Salmon and other GM Foods in New Zealand

A number of research projects have been conducted in New Zealand to determine the general public's attitudes to GM foods. The New Zealand Department of Scientific and Industrial Research (DSIR) commissioned research on public attitudes to GM (Couchman and Fink-Jensen 1990). This was a comprehensive project involving both qualitative and quantitative methods. Results showed that most people were aware of genetic engineering although few were able to explain what it exactly meant. Genetic manipulation of plants was considered to be the area that would provide most benefit while the manipulation of human genes was seen to have the least benefit. There were some concerns about eating food products containing genetically modified organisms. These related to unknown effects or side effects. Attitudes to genetic engineering were found to vary according to age, educational qualification, occupation, knowledge of genetic engineering and interest in science and technology. Concern was highest among those with a greater interest in science and technology, those with a greater knowledge of genetic engineering, those in professional occupations, those with higher education qualifications and those aged between 45–54 years (Couchman and Fink-Jensen 1990).

The Eurobarometer survey was conducted in New Zealand in 1997 (Muggleston 1998). Results suggested that New Zealand respondents had positive attitudes towards specific applications of genetic engineering and had a high background knowledge and understanding of biotechnology. Genetic engineering of plants to resist pests received the support of 2 out of 3 respondents. About 1 in 4 respondents considered that current regulation could protect the public from risks. Universities or research institutes were trusted most by people to tell the truth about biotechnology (Muggleston 1998). It is important to note that both these important studies predated the rise in media coverage of public opposition to GM that took place between 1998–2000.

The Foundation of Research Science and Technology (FRST) initiated a research project in 1998 in an attempt to measure and understand the underlying reasons for acceptance of genetic engineering (Gamble 2000). The study focussed on transgenic plants and plant-based products. Women were more likely to have negative attitudes towards genetically engineered foods than men. Acceptance of a particular food product was dependent on whether it offered a positive benefit to consumers. Risks, such as environmental hazards and threats to human health, were indicated by respondents to be of concern. Participants who considered that they were knowledgeable about biotechnology and those who expressed concerns about the environment were more likely to perceive risks than benefits associated with the technology (Gamble *et al.* 2000).

Cook *et al.* (2000) (cited in Campbell *et al.* 2000) completed a review of studies of New Zealand attitudes to GM food production. They found that knowledge of GM had increased over time and that acceptance of the technology was higher than in other areas of the world until 1998 when it started to diminish. Concerns over the technology included food safety issues, environmental effects and its 'unnatural-ness' (Campbell *et al.* 2000)

In another similar study conducted by Lincoln University, Hunt *et al.* (2003) have also identified New Zealanders concerns over risk associated with GM. A dominant theme throughout the results was that no biotechnology was perceived as being risk free and it was recognised that it would be the public who suffer any adverse consequences. Participants requested more information about what GM was, how it worked, the reasons and purposes for it, who benefits from it, who pays for what, and more details about current research.

Further research has shown the genetic modification of plants to be more acceptable than modification of animals and humans. Different applications of biotechnology appear to be received quite differently, with, for example, medical uses generally more accepted than agricultural uses (Cook *et al.* 2004). Research suggests that most of New Zealanders' concerns with regard to biotechnology are related to food safety issues, environmental effects and the 'unnaturalness' of genetic engineering. Acceptance or rejection of new biotechnologies is also influenced by attitudes towards nature and spirituality. Coyle *et al.* (2003) argue that: 'The clean green representation of a pure New Zealand embodied national identity, and was cited to both support and refute new [biotechnology] innovations' (Coyle *et al.* 2003: 85). Cook *et al.* (2004) found that the concepts of nature and spiritual beliefs that participants in their research held, were unlikely to be easily altered:

> The new dimension introduced in this research is the modelling of factors we have associated with worldviews. The worldview model has shown that factors such as spiritual beliefs and beliefs about the character of nature are linked to a general disposition towards biotechnology. Such factors cannot be immediately regarded as beliefs that can be changed through the provision of new information. Whereas there is potential to change views about the likelihood and consequences of an event, such as a perceived risk to public health, there is little potential to similarly alter a person's beliefs or their conception of nature… It can now be plainly understood that dispositions towards biotechnology are resilient and relatively unresponsive to new information about the immediate concerns and consequences of biotechnology (Cook *et al.* 2004: 70–71).

The 2004 *Hands Across the Water* research project had a different focus. Its intent was to develop dialogue between various stakeholders in the biotechnology debate. This study found a number of similarities between opponent and proponent groups. Each were 'calling for the issue to be 'broken down' and for greater recognition for the risks of different forms of the technology, and its end use' (Cronin and Jackson 2004: 133). Participants asked for assessment to be carried out on the basis of the proposed modification and the character of the risk raised, rather than by single application. In addition, Cronin and Jackson (2004) expressed the fear that due to the current framing of the debate as 'entrenched' this may result in opportunities for understanding between both sides of the debate being lost.

Some research has been conducted into specifically Maori attitudes to biotechnology (Roberts and Fairweather 2004). In addition to concerns such as lack of knowledge and information regarding the technology, distrust of science and scientists, uncertainty over long term effects, and concerns for animals – which they have in common with the public as a whole – participants in the 2004 South Island study expressed concerns related to the negative effects on *whakapapa* (genealogy), *wairua* (spirit) and *mauri* (life principle). They considered that Maori – and the general public – should have more involvement in the decision-making processes. As well, they wanted development of culturally appropriate risk assessment guidelines and frameworks (Roberts and Fairweather 2004).

NZ public acceptance of GM salmon is, therefore, open to debate. Will the current lack of acceptance of GM animals by the general public be equally applied to fish? The lack of acceptance of GM food in general is also of concern. Until now, however, GM food has been restricted to processed foods. It is not known how consumers will react to a fresh GM food. Research into biotechnology applications within aquaculture in New Zealand still continues. According to Statistics New Zealand (2006), there were a total of 21 organisations conducting research into aquaculture applications of biotechnology in New Zealand in 2005. While biotechnology research groups listed a number of constraints affecting biotechnology research and development and commercialisation, public perceptions were not given a great deal of priority (Statistics New Zealand 2006). In the US, there has been continued debate over the acceptability of GM salmon. The request to licence it for human consumption has been before the FDA for six years and scientists are concerned that it is still not clear what regulators want (Pew Initiative 2005). As mentioned earlier, there has been considerable opposition towards GM salmon throughout the world. Further research is required to determine the potential risks, benefits, barriers and acceptability of GM salmon as a commercial product in New Zealand.

Conclusion

Salmon can be described as a 'cultural touchstone' for many societies (Power 2003: i) and as Thoreau's quotation reveals at the start of this discussion paper, thinking about salmon raises powerful questions and issues. Historically, salmon held an important place in the cultural and economic lifeways of many First Nations societies through the Pacific Northwest, and continues to do so for many of those communities today. For many other diverse communities around the world, salmon symbolises wild and mysterious natural processes that are universally appreciated and valued.

This symbolism continues to be an important feature of the marketing of salmon on the global commodity market – whether those salmon commodities come from wild or farmed sources. The intensive farming of salmon introduces a number of concerns broadly relating to health, economics, cultural beliefs and environmental issues.

The introduction of GM salmon adds to the concerns outlined above. Genetic engineering is widely understood in the popular media to be an 'unnatural' process and therefore the association with this procedure and the very 'natural' processes associated with salmon possibly appear particularly disjunctive to many people. As an article from the New Internationalist argued: 'modifying the genes of salmon is the final step in making them completely *unnatural*' (Ride 2000, emphasis in the original).

Further to this, GM salmon highlight the many complex issues that need to be considered in relation to applying animal biotechnology for the primary purpose of producing food. While GM plants are widely consumed, particularly in the USA, thus far biotechnology experiments with animals have been primarily aimed at producing pharmaceutical products.

Dorothee Schreiber's (2002) study of two North American First Nation's resistance to farmed salmon replacing wild salmon in their diet raises some pertinent issues with regard to the topics raised here. While the Namgis and Ahousaht peoples resist farmed salmon because of its association with colonial oppression, GM salmon could be seen as an emblem of the industrialised food system and resistance to it a way of culturally affirming more traditional fish foodways. However, perhaps GM salmon may one day be seen as a way to produce fish more efficiently and with less harm to the environment. The issues relating to GM salmon are important and reveal much about the complex issues relating to contemporary agrifood production.

This discussion paper gives the background to current salmon farming techniques and some of the issues that the industry is facing. The introduction of genetic technology to the industry is a concern to many. The case study from New Zealand outlined here, presents some particularly interesting issues and further research is needed to understand the perspectives of the various stakeholders who were involved. It is planned, in the near future, to conduct interviews and focus groups with stakeholders and the general public in order to determine their perceptions of GM salmon. It is essential that Maori perceptions of salmon, salmon farming and the genetic modification of salmon be included in this process. Work is currently being done to develop suitable research methods to establish these. Results of these research activities will be published when available.

Appendix: Timeline Outlining the Development of GM Salmon

1980s

- Fish researcher in Newfoundland discovered that flounder could survive in frozen water due to a specific adaptation found in polar fishes. These fish have a gene which produces an anti-freeze protein.

- Experiments with salmon followed with the attempt to splice this gene into salmon so that they would grow in freezing waters. These experiments failed as this genetic transfer failed to stop salmon from freezing.

- At the time of these experiments there was an accidental discovery that splicing a part of the 'anti-freeze' gene into a salmon's growth-hormone gene results in much quicker development (5–6 times faster in early months) leading to a salmon that grows twice as fast overall.

- The scientists involved in this research started a company in Waltham, Massachusetts 'A/F Protein Canada Inc' (A/F stands for anti-freeze) (Lim 2002: 96).

'The experimental hatchery [Aqua Bounty Farms], purchased in 1996 by A/F Protein Canada Inc., is continuing to expand on earlier work in molecular genetics begun at Memorial University by investigators Drs. Fletcher and Hew'. Dr. Fletcher' – research scientist and President of A/F Protein Canada Inc. describes how the initial work began in 1982 with the intent of producing salmon that could tolerate sub zero sea temperatures. 'We were studying the antifreeze proteins of several marine species and thought if we could incorporate the antifreeze gene into salmon it might prevent ice formation in their tissues.' From this invaluable basic work evolved the concept of using the antifreeze gene promoter to activate growth hormone transgene (derived from Chinook salmon) resulting in growth hormone production by the liver of the fish. After several years of experimenting with various gene delivery methods, techniques to inject the genes through the micropyle of the egg have become somewhat routine at Aqua Bounty' (http://www.aquabounty.com/peidof.htm)

1996

- Aqua Bounty Farms (an experimental hatchery/research facility located in Fortune, Prince Edward Island, Canada) were purchased by A/F Protein (http://www.aquabounty.com/peidof.htm)

2001

- A/F Protein has 10–20 thousand 'supersalmon' in 136 tanks in three locations in Canadian Maritime Provinces. Developed with the goal of producing eggs for commercial aquaculture in Canada, New Zealand, Chile and U.S. (Lim 2002: 96).

2005

- A/F Protein Inc mission statement: 'The company's mission is to develop the use of antifreeze proteins for the control of cold-induced damage in medical, food and cosmetic products and to develop fish with improved growth rates and other economically desirable traits through the use of gene constructs, many based on promoters. A/F Protein Inc is the world's only commercial producer of antifreeze proteins purified from natural sources for sale to the research and development community. The regulatory sequences controlling expression of AFPs in fish have been used by the company to re-engineer the fish growth hormone gene, resulting in the development of transgenic AquAdvantage™ Salmon and other species which grow at an initial rate of 400%–600% faster than standard fish, offering significant economic advantage in commercial aquaculture.'

References

Aarset, B. (1999) 'Aquacultural development, institution building and research and development policy: Norwegian salmon and Arctic char farming as cases.' Aquaculture Economics and Management. 3(2): 177–191.

Abbors, T. (2000) *The Structure and Development of the World Salmon Market*. Fisheries Unit Publications by the Fisheries and Game Management 46/2000 Volume 8. Helinski: The Department of Fisheries and Game at the Ministry of Agriculture and Forestry in Finland. Available at: www.mmm.fi/julkaisut/Kokojulk/krojulkaisusarja/Lohijulkaisu%2046-.pdf

Aerni, P. (2004) 'Risk, regulation and innovation: The case of aquaculture and transgenic fish. *Aquatic Science*. Vol 66: 327–341.

African Business (2005) 'Aquaculture a Sustainable Solution'. Issue 314 (Nov): p. 30.

Alcock, J. P. (1997) ' 'God Sends Meat, but the Devil sends Cooks': or 'A Solitary Pleasure': the travels of the Hon. John Byng through England and Wales in the late XVIIIth century, in Harlan Walker (ed.) *Food on the Move: Proceedings of the Oxford Symposium on Food and Cookery 1996*. Devon: Prospect Books.

Animal Biotechnology (2004) Genetically Engineered Animals: Push to have GM Salmon Approved. BBC News: www.animalbiotechnology.org

Aquaculture Magazine (2000) 'Scottish Salmon Farming: Past and Present.' Mar/Apr Vol. 26, No. 2.

Aquaculture Magazine (2002) 'World Aquaculture Outlook 2002.' Available at: www.aquaculturemag.com/siteenglish/printed/buyers/web-worldoutlook.pdf Accessed 20 June 2006.

Aston, M. (1988) *Medieval Fish, Fisheries and Fishponds in England*. Oxford: BAR.

Bauer, M. W. and Bonfadelli. H. (2002) 'Controversy, media coverage and public Knowledge', in M. W. Bauer and G. Gaskell (eds), in M. W. Bauer and G. Gaskell (eds), *Biotechnology – the Making of Global Controversy*. Cambridge: Cambridge University Press: 149–175.

Bell, W. and Paone, S. (2002) 'Human Health Risks Associated with Salmon Farming.' Paper presented to the *Federal Standing Committee on Fisheries and Oceans* on behalf of Friends of Clayoquot Sound, 7 May.

Binas (2001). Moritorium on GM Fish Damanded in USA. Available at: www.binas.unido.org Accessed 20 Feburary 2006.

Bonds, C. E. (1996) *Biology of Fishes 2nd ed.* Philadelphia: W. B. Saunders.

Braudel, F. (1981) *Capitalism and Material Life, 1499-1800*. New York: Harper and Row.

Burger, J., Stern, A. H., Dixon, C., Jeitner, C., Shukla, S., Burke, S. and Gochfeld, M. (2004) Fish availability in supermarkets and fishmarkets in New Jersey. *Science of the Total Environment*: Vol. 333: 89–97.

Burnett, J. (1989) *Plenty and Want A Social History of Food in England from 1815 to the Present Day* (3rd ed). Routledge: London.

Campbell, H., Fitzgerald, R., Saunders, C. and Sivak, L. (2000) *Strategic Issues for GMO's in Primary Production: Key Economic Drivers and Emerging issues*. CSAFE Discussion Paper No.1. University of Otago, New Zealand.

CFFS – Centre for Food Safety (2001) *Citizen Petition Before the United Sates Food and Drug Administration.* Available at: www.centerforfoodsafety.org/pubs/PetitionFDA5.9.2001.pdf. Accessed 24 October 2005.

Chen, Hsin-Yi and Chern, Wen S. (2004) 'Willingness to Pay for GM foods: Results from a Public survey in the USA', in Robert E. Evenson and Vittorio Santaniello (eds), *Consumer Acceptance of Genetically Modified Foods*. Oxon, Cambridge. CABI Publishing: 117–129.

Chern, Wen S. and Rickertsen, Kyrre. (2004) 'A Comparative Analysis of Consumer Acceptance of GM foods in Norway and the USA', in Robert E. Evenson and Vittorio Santaniello (eds), *Consumer Acceptance of Genetically Modified Foods*. Oxon, Cambridge. CABI Publishing: 95–109.

COGEM (2001) *Transgenic Salmon a safe product? Environmental risks associated with the production of transgenic salmon*. Available at: http://www.cogem.net/pdfdb/advies/CGM031124-01uk.pdf Accessed 26 June 2006.

Committee on Defining Science-Based Concerns Associated with Products of Animal Biotechnology (2002) *Animal Biotechnology: Science-Based Concerns.* Washington: The National Academies Press.

Conan, Kerri (2005) 'Salmon: to eat or not to eat? Should you cross farm-raised salmon off your shopping list? We take a closer look.' *Health.* April 1, Vol. 19(3): Available at: www.bll.epnet.com Accessed 16 December 2005.

Cone, J. and Ridlington, Sandy (eds.) (1996) *The Northwest Salmon Crisis: A Documentary History*. Corvallis: Oregon State University Press.

Cook, A. J., Fairweather, J. R., Satterfield, T. and Hunt, L. M. (2004) *New Zealand Public Acceptance of Biotechnology*. Agribusiness and Economics Research Unit, Research Report No. 269. Canterbury: Lincoln University.

Corpwatch (2000) 'Scotland: Consumer Advocates Throw Down Gauntlet on GE Foods.' 29 February. www.corpwatch.org Accessed February 2006.

Couchman, P.K. and Fink-Jensen, K. (1990) *Public Attitudes to Genetic Engineering in New Zealand,* DSIR, Christchurch.

Coull, J. R. (1993) 'Will a Blue Revolution Follow the Green Revolution? The Modern Upsurge of Aquaculture.' *Area* 25(4): 350–357.

Cousteau, J-M. (2000) 'GE Fish: A Threat Disguised as a Solution to World Hunger'. Environmental News Network, July 20. Available at: http://www.organicconsumers.org/ge/gefish.cfm Accessed 24 August 2005.

Coyle, F. J., Maslin, C., Fairweather, J. R., and Hunt, L. M. (2003) *Public Understandings of Biotechnology in New Zealand: Nature, Clean Green Image and Spirituality*. Agribusiness and Economics Research Unit, Research Report No. 265. Canterbury: Lincoln University.

Cronin, K. and Jackson, L. (2004) *Hands Across the Water: Developing Dialogue Between Stakeholders in the New Zealand Biotechnology Debate.* A project for the Ministry of Research, Science and Technology (MORST) 'Dialogue' Programme. Wellington: Victoria University.

Cutting, C. (1962) 'Historical Aspects of Fish', in G. Borgstrom (ed.) *Fish as Food, Vol.2.* New York: Academic Press.

Drudge, M. (2000) 'New Zealand Company Stops Breeding 'Franken-Fish'. Dudgereport 26 February. Available at: http://www.drudgereport.com/matt.htm Accessed 26 July 2005.

Dyerberg, J. and Bang, H. O. (1979) 'Haemostatic function and platelet polyunsaturated fatty acids in Eskimos'. *Lancet* 2: 433–435.

Eagle, J., Naylor, R., and Smith, W. (2004) 'Why Farm Salmon Outcompete Fishery Salmon'. *Marine Policy* Vol. 28: 259–270.

Food and Agriculture Organization of the United Nations (2002) *The State of World Fisheries and Aquaculture.* Rome: FAO. Available at: www.fao.org/docrep/003/x8002e/x8002e00.htm Accessed 26 October 2006.

Fork and Bottle (2006) 'Wild Smoked Salmon Tasting'. http://forkandbottle.com/tastings/food/smsalmon/salmon0105.htm Accessed 24 June 2006.

Forristal, L. J. (2000) 'Is Something Fishy Going On?' *World and I.* May. Available at: http://www.worldandi.com/public/2000/may/fishy.html Accessed 14 June 2006.

Friedmann, H. and McMichael, P. (1989) 'Agriculture and the State System'. *Sociologia Ruralis*. Vol. 24(2): 93–117.

Friedmann, H. (2000) 'What on Earth is the Modern World-System? Food Getting and Territory in the Modern Era and Beyond. *Journal of World-Food Systems Research*. Vol. 1(2), Summer/Fall: 480–515.

Friends of the Earth Scotland – FoE (2001) *The One that Got Away: Marine Salmon Farming in Scotland*. Summary available at: www.foe-scotland.org.uk Accessed 24 August 2005.

Gamble, J. (2000) *Public Perceptions of Genetic Modification*. Available at: www.hortresearch.co.nz/ Accessed 4 July 2006.

Gamble, J., Muggleston, S. and Hedderley, D. (2000) How the Public Views Genetic Engineering – Preliminary Summary of Results. Available at http://www.hortresearch.co.nz/.

Genet (2000) 'Commercialization of path-Breaking transgenetic salmon faces Stumbling Blocks' in, Eric M. Hallerman *ISB News Report*: April 3: USA, Available at: www.gene.ch Accessed 10 February 2006.

Genetics (2000) 'GE- very fishy.' Thursday March 2nd. Available at: genetics@gn.apc.org Accessed 20 February 2006.

Goldburg, R. and Naylor, R. (2005) Future Seascapes, Fishing, and Fish Farming. *Frontiers in Ecology and the Environment*: Vol. 3 (1): 21–28.

Gugino, S. (2006) 'Wild Salmon: In the Pink. *Wine Spectator*. Available at: http://www.samcooks.com/flavor/salmon.htm Accessed 2 June 2006.

Greenpeace (2003) 'Genetically Engineered Salmon: Q & A.' Available at: http://www.greenpeace.org/raw/content/usa/press/reports/genetically-engineered-salmon Accessed 5 October 2005.

Hein, Treena (2005) 'Down the Farm.' *Food in Canada*. Nov/Dec Vol. 65 (9):p. 49.

Hites, R. A., Foran, J. A., Carpenter, D. O., Coreen Hamilton, M., Knuth, B., and Schwager, S. J. (2004) 'Global Assessment of Organic Contaminants in Farmed salmon.' *Science*: Jan 9,Vol.303 5655: p.226–229.

Ho, M.-W. (1998) *Genetic Engineering Dream or Nightmare? The Brave New World of Bad Science and Big Business*. Bath: Gateway Books.

Hunt, L. M., Fairweather, J. R., and Coyle, F. J. (2003) *Public Understandings of Biotechnology in New Zealand: Factors Affecting Acceptability Rankings of Five Selected Biotechnologies*. Research Report No.266. Lincoln University Canterbury Christchurch New Zealand.

The Independent (2000) 'Frankenfish Fracas goes to Auckland District Court.' Wednesday, 31 May, p.3.

Jystad, P. T. (2001) *Fishmeal and Oil or Vegetable Alternatives: Will High Volume Production Spoil Premium Fish Products?* IntraFish.com Industry Report. Available at: http://www.wwf.no/pdf/fishmeal_and_fishoil.pdf Accessed 24 June 2006.

Kelso, D. D. T. (2004) Genetically Engineered Salmon, Ecological Risk, and Environmental Policy. *Bulletin of Marine Science*, 74(3): 509–528.

Kitzhaber, John (1997) Governor of Oregon, before the City Club of Portland on October 3, 1997. Quoted from Oregon Public Broadcasting recording of program. Available at: http://oregonstate.edu/instruct/anth481/sal/salsym.html Accessed 24 June 2006.

Knight Ridder Tribune Business News (2004) 'Head of Chefs' Activist Group Not Surprised at Salmon Health Warnings'. January 23: pg.1. Available at: http://proquest.umi.com/pqdweb?index=1&did=528957861&SrchMode=1&sid=4&Fmt=3&Vinst=PROD&Vtype=PQD&RQT=309&Vname=PQD&TS=1137546400&clientId=18927 Accessed 3 February 2006.

Kurian, John (2003) Expert moots curbs on fishery exports, in Financial Times Information Limited – Asia Africa Intelligence Wire: Mar 13. p.1. Available at: www.proquest.umi.com Accessed 15 February 2006.

Labriola, T. (2002) 'Transgenic Fish: Saviour or Sabateur?' *Vermont Journal of Environmental Law.* Available at: http://www.vje.org/editorials/pdf/2002S/labriola.pdf-Supplemental Result Accessed 30 August 2005.

Lefebvre, J. (2005) 'Slammin' Salmon.' *Food Management.* Available at: http://www.food-management.com/article/9393 Accessed 3 February 2006.

Levi-Strauss, C. (1963) *Totemism*. Translated from the French by Rodney Needham. Boston: Beacon Books.

Lichatowich, Jim. (2000) *Salmon Without Rivers: A History of the Pacific Salmon Crisis*. Washington, D.C.: Island Press.

Lim, Hwa A. (2002) *Genetically Yours: Bioinforming, Biopharming, Biofarming*. Singapore: World Scientific.

Lindbergh, J. (1999) 'Salmon Farming in Chile: Do the Benefits Exceed the Costs?' *Aquaculture Magazine* 25(2) Mar/Apr.

Little, D. C. and Edwards, P. (2003) *Integrated Livestock-Fish Farming Systems.* Rome: Food and Agriculture Organization of the United Nations. Available on: ftp://ftp.fao.org/docrep/fao/006/Y5098E/Y5098E00.pdf Accessed 10 February 2006.

Los Angeles Times (2002) 'Fish Farms Become Feedlots of the Sea,' Kenneth R. Weiss. Dec 9th. Available at: www.mercola.com Accessed 10 February 2006.

McDowall, R. M (1994) *Gamekeepers for the Nation: The Story of New Zealand's Acclimatisation societies, 1861–1990.* Christchurch: Canterbury University Press.

McKillop, J. (2000) 'Salmon' in, *A Dictionary of Celtic Mythology*. Oxford: Oxford University Press.

Meffe, G. K. (Sep 1992) 'Techno-Arrogance and Halfway Technologies: Salmon Hatcheries on the Pacific Coast of North America'. *Conservation Biology*: Vol. 6 (3): 350–354.

Midden, C., Boy, D., Einsiedel, E., Fjaestad, B., Liakopoulos, M., Miller, J. D., Ohman, S. and Wagner, W. (2002) 'The Structure of Public Perceptions,' in M. W. Bauer and G. Gaskell (eds), *Biotechnology – the Making of Global Controversy*. Cambridge: Cambridge University Press: 203–223.

Mindfully.org (2000) 'Giant GM salmon on the way.' 11 April. Available at: http://www.mindfully.org/GE/Giant-GM-Salmon.htm Accessed 24 August 2005.

Ministry for Environment (2005) *Aquaculture Reform: An Overview*. Available at http://www.mfe.govt.nz/publications/rma/aquaculture-info-overview-jan05/aquaculture-overview-jan05.pdf

MOFGA – Maine Organic Farmers and Gardeners Association (2002) 'Genetically Engineered Salmon Debate: Frankenfish and the FDA', by Sharon S. Tisher. February, 15th. Available at: http://www.mofga.org Accessed 10 February 2006.

Monsanto (2006) 'About Posilac.' http://www.monsantodairy.com/about/index.html Accessed 11 June 2006.

Montgomery, D. R. (2003) *King of Fish: The Thousand-Year Run of Salmon*. Cambridge, MA: Westview Press.

Morkore, T., Vallet, T. J., Cardinal, M., Gomez-Guillen, M. C., Montero, P., Torrissen, O. J., Nortvedt, R., Sigurgisladottir, S. and Thomasen, M. S. (2001) 'Fat Content and Fillet Shape of Atlantic Salmon: Relevance for Processing Yield and Quality of Raw and Smoked Products.' *Journal of Food Science*, Vol. 66, No. 9: 1348–1353.

Muggleston, S. (1998) 'Talking about Gene Technology: a New Zealand Perspective.' *Australasian Biotechnology* 8(3): 160–163.

National Geographic (2003) 'Everybody Loves Atlantic Salmon… Here's the Catch.' July.

Netto, A. (2003) 'Development: Rising Prices, Scarcity of Fish to Affect Poor', in *Global Information Network*: New York. Available at: http://www.proquest.umi.com Accessed 10 February 2006.

NZKS – New Zealand King Salmon (2006) http://www.kingsalmon.co.nz Accessed Feb 2006.

North Atlantic Salmon Conservation Organisation (NASCO) (2001) 'GM Salmon Release Rejected by NASCO' http://binas.unido.org/binas/show.php?id=331&type=html&table=news_sources&dir=news Accessed 5 September 2005.

Norton, J. (1998) Throwing up concerns about novel foods' in Hindmarsh, R., Lawrence, G. and Norton, J. (eds) *Altered Genes - Reconstructing Nature: The Debate*, Allen & Unwin, St Leonards: 173–185.

NSSA – Nova Scotia Salmon Association (2006) 'News & Issues: Aquaculture.' Available at: http://www.novascotiasalmon.ns.ca Accessed 5 September 2005.

NZAC (2005) *Aquaculture Sector Strategy – Discussion Paper*. Available at: http://www.salmon.org.nz/Aquaculture_Sector_Strategy_Executive_Summary.pdf Accessed 26 June 2006.

NZSFA – New Zealand Salmon Farmers Association (2005) 'Salmon Aquaculture in New Zealand.' Available at: http://www.salmon.org.nz/aboutsalmon.shtml Accessed 24 August 2005.

Organic Consumers Association (2006) 'EU Steadfast in Rejecting Genetically Engineered Food, Despite WTO Pressure'. http://organicconsumers.org/ge/ruling060208.cfm Accessed 17 July 2006.

Otago Daily Times (2006) 'More Evidence on the Good Oil.' Wednesday, 28 June.

Pittsburgh Post-Gazette (2003) 'Salmon Wars: Wild vs. Farm Factions Face Off'. April 3. Available at: http://www.post-gazette.com/food/20030403salmonmainp4.asp Accessed 24 June 2006.

Penton Media (Sept 2005) 'Salmon' by Joanna Lefebvre in, *Food Management*: Vol. 40, Iss. 10: Pg 84–85

Pew Initiative on Food and Biotechnology (2005) *A Future for Animal Biotechnology, Washington: Pew Initiative on Food and Biotechnology*. Available at: http://pewagbiotech.org/events/1205/proceedings.pdf Accessed 26 June 2006.

Phyne, John and Mansilla, Jorge. (2003) 'Forging Linkages in the Commodity chain: The Case of the Chilean Salmon Farming Industry, 1987–2001'. *Sociologia Ruralis*. Vol 43, No 2:

Pollak, D. (2003) *Clean Green and Genetically Modified? GMOs and the Future of New Zealand*, Available at: http://www.fulbright.org.nz/voices/axford/docs/pollakd.pdf Accessed 26 June 2006.

Power, Melanie D. (2003) 'Lots of fish in the sea: Salmon aquaculture, genomics and ethics.' Electronic Working Papers Series. W. Maurice Young Centre for Applied Ethics. University of British Columbia. Available at: http://www.ethics.ubc.ca Accessed 26 October 2005.

PREMnote (2005) Technology and Growth Series: Chiliean Salmon Exports, in *The World Bank PREMnotes Economic Policy*. No 103 October.

The Press (1999a) 'Queer Fish.' Saturday, 10 April, Edition 2: p.10.

The Press (1999b) 'Salmon Farm Picketed.' Thursday, 8 April, Edition 2: p.7.

The Press (2000) 'Mutant Fish Dead and Buried, Says Firm.' Saturday, 27 February. Available at: http://www.commondreams.org/headlines/022700-02.htm Accessed 24 October 2005.

Reichhardt, Tony. (2000) 'Will Souped up Salmon Sink or Swim?' *Nature*. Vol. 406, July 6th.Available at: www.nature.com Accessed 26 October 2005.

Rembold, C. M. (2004) 'The health benefits of eating Salmon.' *Science*: July 23,Vol. 305 i5683: p. 475.

Ride, A. (2000) 'Fishy Business: The seas are running out of fish but the supermarkets are not. What's the catch?' *New Internationalist.* Issue 325, July. Available at: www.newint.org Accessed 5 September 2005.

Roberts, Mere and Fairweather, J. R. (2004) *South Island Maori Perceptions of Biotechnology*. Agribusiness and Economics Research Unit, Research Report No. 268. Canterbury: Lincoln University.

Rollin, B. E. (1995) *The Frankenstein Syndrome: Ethical and Social Issues in the Genetic Engineering of Animals.* Cambridge: Cambridge University Press.

Roth, B., Johansen, S., Suontama, J. Kiessling, A., Lekens, O., Guldberg, B., and Handeland, S. (2005) 'Seasonal variation in flesh quality comparison between large and small Atlantic salmon transferred into seawater as 0= or 1= smolts'. *Aquaculture*. Vol. 250 (3-4): 830–840.

RSPB - Royal Society for the Protection of Birds (2004) 'Alternative Supplies of Fish Meal and Oil'. Available at: http://www.rspb.org.uk/policy/marine/fisheries/sustainable/alternatives.asp Accessed 19 January 2006.

Salon News (2000) 'Stalking the Wild Frankensalmon', by Bruce Shapiro. May 5th. Available at: http://www.salon.com Accessed 16 October 2006.

San Diego Business Journal (2004) 'San Diego Canneries Hope to Lure Salmon Eaters'. October. Vol. 25 (40): p.5. Available at: www.proquest.umi.com/pqdweb?index=19&did=709135361&SrchMode=1&sic=13 Accessed 16 December 2005.

San Francisco Chronicle (2002) '"Frankenfish" Spawn Controversy: Debate over Genetically Altered Salmon, by Jane Kay'. Monday April 26th. Available at: http://www.commondreams.org Accessed 26 October 2005.

Scottish Quality Salmon (2002) 'Scottish Quality Salmon's GM Free Status.' Available at: http://www.scottishsalmon.co.uk/media/positionstatement/ps030902.html Accessed 24 August 2005.

Seattle Times (2004) 'Research fuels fear of gene-altered fish, by Sandi Doughton'. Tue June 8th. http://www.seattletimes.nwsource.com Accessed 10 February 2006.

Schreiber, Dorothee. (2002) 'Our Wealth Sits on the table: Food, Resistance, and Salmon Farming in Two First Nations Communities.' *The American Indian Quarterly*: 26: (3): 360–377.

Spencer, C. (2002) *British Food: An Extraordinary Thousand Years of History.* London: Grub Street.

Statistics New Zealand (2006) *Biotechnology in New Zealand 2005* Statistics New Zealand, Wellington.

Stewart, H. (1977) *Indian Fishing : Early Methods on the Northwest Coast*. Seattle: University of Washington Press.

Tannahill, R. (1988) *Food in History.* Penguin Books: London.

Te Ohu Kaimoana (2006) 'Maori Fisheries Act 2004: Background.' Available at http://teohu.maori.nz/mfa/background.htm

Thoreau, H. D. (1980{1849}) *A Week on the Concord and Merrimack Rivers*. Edited by Carl Hovde and Textual Center Staff, William L. Howarth, & Elizabeth Witherell. Princeton: Princeton University Press.

Tuominen, Taija-Riita and Esmark, Maren (2003) *Food for Thought: the Use of Marine Resources in Fish Feed.* WWF-Norway. Available at: http://assets.panda.org/downloads/foodforthoug.pdf Accessed 24 June 2006.

Tye, J. (1997) 'An Alternative to Fish Meal.' *Aquatalk* Vol. 2(1) Winter: 1-2. Available at: http://www.ingvar.is/Alternative/Aquatalk2.pdf Accessed 24 August 2005.

USDA Agricultural Trade Report (1996) *U.K: Salmon – Updated Production, Supply and Distribution Report*. Available at: http://proquest.umi.com/pqdweb?did=206130271&sid=2&Fmt=3&clientId=18927&RQT=309&VName=PQD Accessed 24 November 2006.

Van Aken, J. (2000) 'Genetically Engineered Fish: Swimming Against the Tide of Reason.' *Greenpeace International*, January 2000. Available at: http://archive.greenpeace.org/geneng/reports/bio/bio016.htm Accessed 24 August 2005

Walton, Isaac. (2003) *Future Fish: Issues in Science and Regulation of Transgenic Fish.* Washington: Pew Initiative on Food and Biotechnology. Available at: http://www.pewagbiotech.org/research/fish/ Accessed 26 October 2005.

Weaver, C. K. and Motion, J. (2002) 'Sabotage and Subterfuge: public relations, democracy and genetic engineering in New Zealand.' *Media, Culture & Society* Vol. 24: 325–343.

Wellman, T. (2005) 'Alaskan Salmon: Nature's Ideal Health Food'. *Total Health Magazine*. Available at: http://totalhealthmagazine.com/cgi-bin/thm?XwsSrvID=XTothm01,[a=01[b=30[c=01[d=atotgmhl[e=00068423[f=xxxxxxxx[g=270-67008 Accessed 24 June 2006.

White, K. O'Neill, B. and Tzankova, Z. (2004) *At a Crossroads: Will Aquaculture Fulfill the Promise of the Blue Revolution?* Seaweb Aquaculture Clearinghouse. Available at: http://www.seaweb.org/resources/sac/pdf/At_Crossroads.pdf Accessed 24 August 2005.