ADVANCING AQUACULTURE:

Fish Welfare at Slaughter

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Contents

Personal background

For the past five and half years I have been employed by the Humane Slaughter Association (HSA) as a Technical Officer.

The HSA is the only registered charity to specialise in the welfare of food animals during marketing, transport and slaughter.

As a non-campaigning organisation the HSA works in a practical and rational way to develop welfare standards through technology transfer, education and advice to industry and government.

The HSA uses up-to-date knowledge and practical experience to write best practice guidelines for the industry and regularly advises retailers and others on their codes of practice. My job involves regular liaison with industry and government on animal welfare issues and improvements.

Over the last three years I have been involved in the British aquaculture industry, gaining an understanding of the practical requirements for commercial slaughter systems and providing advice on humane methods of slaughter appropriate to the situation. In addition to the UK work, I have also been involved in assessing alternative slaughter methods used in Norway and New Zealand.

This work has led to production of educational material about the humane killing of fish and various articles for publication and presentations at technical conferences.

Acknowledgments:

I would like to thank the Winston Churchill Memorial Trust for its generous funding of this study tour and its support whilst planning and carrying out this project. In addition thanks are given to the Humane Slaughter Association (HSA) for its support. Without the support of both of these organisations this trip would not have been possible and fish welfare at slaughter may still have been an issue on the back burner in many companies and countries.

I also would like to extend my gratitude to all the people, too numerous to mention, that helped organise the study tour and spend their time detailing current industry practices and the implications of these to fish welfare.

Special thanks are given to those people who went beyond all expectations and spent many hours arranging visits and encouraging the industry to be involved in this project. These people, in particular Melissia Struthers (CAIA), Fred Conte (UC Davis California), Antonio Campos Mendoza (University of Stirling) and Alberto Ramírez (Fundacion Chile), all made a significant contribution to the success of this project and also helped keep me positive (and sane!) throughout the trip.

This study has been invaluable in gaining a sound understanding of slaughter systems and the practical implications of such methods in a wide range of circumstances.

Specific information from this study is confidential, but the knowledge from this work has been used to produce guidance notes on the humane killing of salmon and trout and at the request of various parties best practice guidelines are currently under development.

Introduction

As over 30% of the global seafood harvest is already produced from aquaculture, and predictions made in 2000 forecast that global fish consumption will rise 25% by 2030 (3kg increase per person), it is easy to understand why aquaculture is such a rapidly expanding industry. With such an increase in demand, new sources of cultured fish are required, especially as customers want quality products all year round.

In addition to this there is increasing pressure on wild fish stocks and the cost of catching from the sea is rising. This cost is seen both in environmental and financial terms. The environmental cost of the wild catch is continuously rising as stocks are depleted; the resultant changes in sea life affect the natural balance of the oceans. It is also suggested by the FAO that the actual cost of catching wild fish can be 25% more than the value, a figure which is offset by government subsides.

Although still a relatively new industry in commercial farming terms, aquaculture has already made huge changes since it became a significant commercial venture over 30 years ago. In this time the industry has grown from small individual farms to multi-national companies which are streamlined and increasingly efficient at producing millions of animals annually.

One of the primary aims of aquaculture is to produce a consistent and safe product with full traceability, reliably and, in accordance with customer demands. With this aim it is clear to see how aquaculture can fit the above demands and help resolve the potential lack of supply, not only for food fish, but also improve other industries such as those that rely on fish, ie animal feed and leisure. As the industry progresses, it is essential that it grows responsibly and reacts to consumer requirements in order to develop suitable products that are required.

Although there is over 20 species of fish farmed, salmon and trout are commonly farmed in the UK. For these reasons these species have been the main focus of recent research into humane methods of slaughter and practical improvements. However, as the numbers of fish have increased so has the number of species farmed. New species are continuously being identified for their farming potential as new developments and scientific understanding allows production of many species that were not previously economically viable.

One of the difficulties faced by the aquaculture industry is that recommendations are not necessarily universal or transferable between species or even the countries involved. This makes technology transfer between species very difficult and setting guidelines very complicated, ie what works in one country may not be legal in another or may not even be technically feasible in another. This means that throughout the industry the level of knowledge varies greatly, depending on the length of time that particular species has been farmed.

In response to the growing scientific opinion that fish feel pain and can suffer, careful consideration is now being given to the methods of slaughter employed around the world and in particular in the UK. These methods are also influenced by product quality and the positive relationship this has with humane handling and slaughter.

Whilst the debate about pain perception in fish is ongoing, it is generally accepted that farmed fish should have their welfare protected and be treated humanely whilst kept in aquaculture systems. The consideration of welfare is not only ethically correct, but commercially sound: humane treatment is important to realise potential growth rates and product quality. Although terrestrial animal welfare has been studied for many years, similar studies for aquaculture are still in their infancy. However, over the past few years the aquaculture industry has actively striven to advance this knowledge base; supporting both scientific and practical research which has led to improved technology, knowledge and production procedures.

Fish Welfare

The welfare of an animal can be defined as 'its state as regards its attempts to cope with its environment'. This environment includes physical conditions, social influences, predators, parasites or pathogens interacting with individual animals. Fish maintain a constant internal environment; when this is threatened a range of reactions take place to elicit physiological (production of adrenaline, noradrenaline and cortisol) and physical (increased heart rate, vigorous muscle contractions) changes to reinstate the balance as soon as possible; this is widely known as the stress response. When the response is successful the physiological reactions subside and the internal environment is restored within hours. However, if the challenge is not removed/avoided the response is prolonged and it can be assumed that the welfare of that animal is compromised.

In-depth knowledge of species-specific welfare requirements and relevant signs of the stress response are essential for correct welfare assessment. As a result, welfare is often reviewed using the five freedoms principle which take into account the psychological needs in addition to the physical. These include, freedom from: hunger and thirst; discomfort; pain, injury and disease; fear and distress, and freedom to express normal behaviour.

Whilst some principles for basic requirements and responses are applicable to all species and transferable, there are also important species differences. Every species needs to be considered on an individual basis.

Consideration of the nature of the welfare 'problem', its duration and effect on individual animals must be taken into account during welfare assessments. Fish have the capacity, within limits, to adapt to acute stressors; however, exposure to chronic stressors, or a number of acute stressors simultaneously or for sustained periods, can lead to suppression of the immune system if occurring during production, or can lead to use of energy stores and changes in hormones which will have resultant effects on fish quality.

In 1996 the Farm Animal Welfare Council (FAWC) reviewed farmed fish welfare in the UK and made a number of recommendations, including improvements at slaughter. As a result, government funding was made available in the UK for research into improved slaughter methods. Nine years on, both the salmon and trout industries have commercially viable, humane slaughter systems available to them. This follows considerable research and co-operation within the industry to review the methods available and to develop those most suitable.

As a result, humane methods of slaughter are now employed widely in both the salmon and trout industry in the UK and further afield. These methods include new generation, flow-through percussive stunners and improved electrical systems. The main advantage of both systems is the fact that fish are kept in water right up to the point of slaughter and in both cases rendered immediately insensible with little if any contact with humans whilst conscious. As it is known that handling of fish prior to slaughter can have a detrimental effect on the flesh quality, this also has an impact on the final product.

As the number of species in aquaculture is growing, so is the need for new developments to cater for these novel species.

Another major constraint is the growing conflict between the emerging aquaculture industry and other stakeholders such as traditional fishers, property developers, tourist boards, recreational organisations and the conservation movement.

Achieving the aims

Objectives

This study tour was undertaken to investigate the attitudes of industry, government and research bodies towards farmed fish welfare and to discover international practices for slaughter. Four countries in North and South America were included in the tour: the USA, Canada, Mexico and Chile.

These countries were chosen to represent:

- some of the major salmonid producers
- different levels of economic input into aquaculture
- different species
- scientists working in the field of consciousness and pain perception in fish

The initial aims of the trip were to:

- investigate welfare practices and standards in various countries
- understand the reasons behind the choices made
- meet key scientists working on fish welfare
- help disseminate information on best practice, based on current scientific and practical understanding of welfare

Every country has unique economic, cultural and practical factors which influence attitudes to, and standards of, fish welfare, thereby impacting on national industry practices and products. What is acceptable varies amongst societies and individuals and is constantly changing as new information comes to light.

The initial aim was to develop a sound understanding of the aquaculture industry around the world and gain knowledge of issues that affect the international industry. This was done by visiting research stations and farms in these countries and observing current handling and slaughter procedures. The trip has not only identified current practices but has also given a good indication of the current state of the industry, future ideas, constraints and the potential of each country to develop high welfare standards.

The project proposals also included meeting with scientists with opposing views on the possibilities of fish feeling pain and distress, to learn more about the concept of pain in fish to help form a sound judgement on the extent of pain and distress caused to fish during routine transport/slaughter.

Site visits were a vital part of the project and critical to the success of the trip. These visits allow first hand experience of what really happens and highlights the practical implications of methods used; the financial restrictions; and resultant product quality.

In addition, visits with trade and retail organisations and government departments were proposed to gain an insight into industry goals and realistic standards for now and the future. However, due to the sensitive nature of this topic and the caution of the industry, not as many visits were achieved as were originally proposed.

In North America there is a number of activist groups that use animal welfare as a tool to raise funds for their cause and damage the industry. Likewise, environmental groups have also focused their campaigns on the aquaculture industry. Unfortunately these organisations generally use negative points and out-of-date information to damage the image of the industry. This has meant that the industry has become closed and is very cautious about letting new people on site or entering into discussions about the practices and procedures of the industry.

Previous experience within the Scottish industry has proved very open and co-operative, so it was slightly unexpected to find so much resistance elsewhere. In the UK, the HSA's reputation for practical and realistic improvements to animal welfare at slaughter within other meat producing industries has helped the transition into aquaculture and they have been willing to work with us, but outside of the UK this is not the case.

As this became an increasing problem to the planning of the trip, references were requested from the Scottish industry so that people had a better idea of how I had worked positively and responsibly with the industry in the UK.

However, even with references prior planning still proved very difficult. Many organisations wanted to meet and discuss the project, before allowing site visits. This meant that little prior planning could be made and relatively little organisation done before arriving in the individual countries. This also had a knock-on effect, as it meant meetings needed to be arranged at short notice.

Taking heed of the advice given by the Churchill trust, planning of the trip commenced as soon as I found out my application had been successful in March 2004. This was over six months before the trip was due to start but, as it soon became clear, was absolutely necessary. The study tour took place throughout October and November 2004. During the trip meetings and visits were organised with over 50 people and organisations to discuss fish welfare and its implications at slaughter.

During farm visits the objective was to assess the effectiveness and efficiency of slaughter and handling procedures in terms of fish welfare, as well as discussing the reasons why particular methods are chosen and others disregarded. However, on many visits only visual observations could be made. Unfortunately, due to the nature of the systems and protocols, the physical reflexes which indicate consciousness could not be assessed on-site and the effectiveness of individual systems could not be made.

Farm / processing plant visits were all of a confidential nature, as was much of the other work. For these reasons photography was restricted, if not prohibited, and I am unable in this report to provide specific detail of operations so as not to identify the organisations involved. This also means that a full list of people involved in the project has not been listed within this report despite their considerable help.

Visits to research institutes and government departments went more according to plan, although again fewer meetings took place then first anticipated. A good insight of the current research interests of the respective countries and where they see the future was gained. Regrettably the pain aspect was not discussed in as much detail as was planned.

One of the aims of this trip was to identify the common aquaculture species and their requirements at the point of slaughter. Various methods of slaughter will be discussed later for both the advantages and disadvantages of the systems used and the implications of these on the welfare of the fish.

As aquaculture spans from the first world to the third, the considerations given to choice of method vary vastly on the financial and technological requirements of each system and the ability of each country to cope and integrate the systems. Economics obviously plays a large part in the method of choice and for these reasons the relationship between product quality and method was also explored.

Achieving the aims

As previously mentioned, animal welfare in aquaculture is a relatively new and emerging issue, despite there being laws in place for the protection of other animals for a number of years. The main reason for this is the differing views of whether or not fish are sentient animals and if they have the ability to 'perceive pain'.

As with all species, terrestrial or aquatic, pain is very difficult to define and measure. There is still a lack of consensus about pain perception, but it is agreed that fish should be treated ethically whilst kept in farming systems.

Any method of handling animals will compromise them, the aim of humane systems is to minimise this in both strength and duration.

This report is split into different sections: the countries visited, the species observed, and the methods observed.

The methods are explained first by the general principles of how they are effective and then by the practical and welfare implications associated with them. As a conclusion, areas for improvement have been identified, not only by changing an entire system but also for improving current practices.

Countries

As mentioned, four countries were visited during the trip. Initially Alaska was also included so that a comparison could be made between wild and farmed salmon. In Alaska the farming of salmon is prohibited and all fish caught is wild. However, the study tour plans had to be changed as it soon became apparent from meetings held with buyers in the UK, and industry contacts, that viewing the Alaskan catch would prove very difficult, if not impossible.

Wild fish are caught by individual farmers who each own small boats and the fishing season is short and variable. This meant that the likelihood of getting to see fish being caught was minimal. As it became apparent that my time could be used more efficiently elsewhere, the decision was made to include Chile in the plans and observe the salmon industry there.

Travel

The Winston Churchill Memorial Trust generously funded this trip so that I could travel around North and South America safely.

Planning the actual travel arrangements often proved as much of a challenge as arranging meetings. Fish farms are rarely on the main road and only I could arrive in the Californian desert the day after a rain storm! but these incidents all added to the experience. I managed to make use of practically all modes of transport in the including: planes, trains, ferries, buses and cars. Not to mention the miles I walked, not realising street systems work slightly different outside of the UK and regularly stretched for miles. For anybody embarking on this kind of trip, I would suggest that you can never spend to much time researching time zones and distances between sites - England is a very small country in comparison to the rest of the world! An air miles card may also be beneficial having travelled nearly 25,000 miles, I wish I had got one!

Canada (26 September - 15 October)

The study tour started on the west coast of Canada with a workshop on fish welfare organised by the British Columbia Salmon industry. The trip continued east across the country ending in St George, New Foundland three weeks later. During this time fish farms, processing plants and research stations were visited and practices observed. In addition meetings were held with industry bodies, government officials and research staff.

Whilst in Canada, Atlantic salmon, Pacific salmon, sturgeon, trout, arctic charr and lobster were all observed and discussed with regard to general farming

Canada's aquaculture industry operates on the Atlantic and Pacific coasts and on numerous lakes in between. Even though it is wide spread, there are two major provinces, New Brunswick and British Columbia, which are responsible for about 80% of total production. Although still relatively new aquaculture is now a large-scale commercial industry across the country. Commercial aquaculture production started in the 1970s and has rapidly expanded over the past 30 years to include several salmon species amongst others. In addition, new species are currently being investigated for their potential in aquaculture such, as cod, halibut, haddock and Arctic charr.

In terms of production, Canada produced 123,924 tones in 2000. Comparatively, this is still a relatively small production figure in world standards, but they are the world's fourth producer of salmonids (salmon count for 83% of this total and trout 7 %).

The economic contribution of the aquaculture industry is quite significant: over 5,000 people are involved in the industry (including permanent full-time employment, part-time and seasonal casual jobs). The impact of this on the industry is quite apparent when looking at the amount of opposition the farmers face. For instance, in parts of the east coast aquaculture is still one of the main industries and they seem much less affected by perceived environmental problems or other negative impacts. However, on the west coast tourism plays an important part in the economy and they appear to be in a more difficult position due to the environmental organisation focusing their efforts in these high profile areas.

Canada is a significant salmonid producer and uses a variety of different slaughter methods. These methods range from low-tech methods, such as ice slurry for trout, to some of the most advanced systems currently in operation in the world. During my time in Canada I was allowed enough access to gain a practical insight into salmon and trout farming. In addition to reviewing current research priorities and government attitudes the Canadians are currently faced with big environmental problems and welfare is not the major focal point. However, many companies were running humane systems and they had already seen beneficial quality improvements, making the expenditure worthwhile. Many parts of the salmon industry were being proactive, with some provinces making moves to instigate welfare standards and national organisations introducing standards also.

The main obstacle to implementing humane standards to the entire Canadian industry is the common use of carbon dioxide stunning and ice slurry systems and low tech wellboats. It's acknowledged this will not change quickly, but support should be given to move away from these procedures in a realistic time frame.

Other food animal production industries in Canada have made mention of welfare standards in quality programs and it was felt that this could possibly be the way forward to introduce welfare in a sensible way, without causing too many problems to the industry.

The USA (15 October - 23 October)

My two-week stay in the USA started in Itheca, New York and continued south to West Virginia and Washington DC. The second week was spent in California; starting in Sacramento and ending in the Californian desert.

During these two weeks in the USA I visited fish farms and research institutes, and spoke with government workers and other industry members. Species observed included hybrid striped bass, catfish, tiliapia and trout.

In the USA there is still a large deficit between the amount of fish consumed and the amount produced. However the development of a robust aquaculture industry has the potential to fill this gap. Like Canada, the industry is growing, albeit at a slightly slower rate. Over several years there has been slow but continuous growth in domestic aquaculture production. Catfish production is the largest sector in the US aquaculture industry, concentrated in Mississippi, Alabama, Arkansas and Louisiana. Other major species farmed for food are trout, tilapia, hybrid striped bass.

In the US as a whole, fisheries are far less than 1% of the economic activity, but in many coastal areas, fisheries constitute a major, or even the principal economic base.

The main reason for visiting the US was to meet with a range of scientists to discuss the concept of perception of pain in fish. Over the past couple of years, a number of papers have been published in this area and I wanted to investigate arguments for both sides with these people. Unfortunately, due to conflicting schedules it was not possible to meet up with some of the key scientists involved. However, those that were met provided a valuable insight into this area and if nothing else highlighted the complexity of this concept and that conclusions will not be made in the immediate future.

Busy schedules also resulted in a few of the proposed visits to be cancelled at the last minute. A number of alternatives were arranged and various bodies and farms were visited. A wide range of information from various research and government officials was also provided.

The USA was the most sensitive country to gaining access as there is a very active organisation which campaigns for animal rights. Unfortunately, due to their negative campaigning many producers now have a negative view towards welfare. This means that many producers are not open to the concept of fish welfare, even though there is evidence for significant production improvements. This is also reflected in the government research programmes, funding schemes which focus on post-harvest processes to maintain and improve quality and shelf life – there was little interest in what could be done before harvest.

The US industry is under significant pressure to produce food cheaply and, unlike other countries, it appears there is little pressure from retailer groups to develop fish standards. However, retailer standards are gradually being brought in. As with other countries, fish are the last on the list for these standards and there is no agenda for production of these standards in the immediate future. In spite of this, this issue does have a rising profile and there are now industry moves to develop these humane methods and integrate them into the industry with minimal cost. The main principle that will help this transfer of systems is the significant product quality benefits that can be seen, and in some cases the reduction in production cost.

Although my time in the USA proved difficult in terms of access to farms and cancelled meetings, it did result in an invite to present at the Aquaculture America conference in January 2005. This proved a much more positive visit and meetings were held with various members of the the industry and associated bodies, and discussions were held over potential improvements. The presentation received a positive reception and people were interested in the practical aspects of implementing new systems and the associated benefits. I understand from further communication, that some organisations are seriously considering more humane methods of slaughter and research has now started to develop viable systems.

Mexico (30 October - 6 November)

My week in Mexico was spent with a Mexican family in the state of Michoacan. The week involved work with a research institute that is developing new fisheries with Mexican farmers helping them back into aquaculture. Processing plants and fish farms were all visited during this week. Species included trout, pez blanco and tiliapia.

Over recent years a number of the lakes in Mexico have seen their fish stocks gradually depleted due to years of over-exploitation, poor management and an increased fishing effort of the lakes with little management and, more recently, pollution affecting the stocks. This also means that the future potential for significant growth is minimal.

Most (70%) of what has been reported as "aquaculture" in Mexican fisheries statistics actually comes from inland fisheries of mostly introduced species with few native species being produced.

Inland fisheries catches amounted to 89,513mt in 2001, with 73% of that being tilapia. Other important species are rainbow trout and channel catfish.

In Mexico aquaculture only represents a small contribution to the national economy (0.8% of GDP) and the majority of inland fishermen devote most of their time to agriculture, with fishing being only a part-time activity. This means there is relatively little investment in the industry and methods of low technology are employed.

Mexico's main customer is the United States, 59% of the total exports' volume but 85% of the total value (as frozen shrimp comprises 30% of the exports to that country). Imports into the country come mainly from the US (34%) and Chile (15%).

At the moment there are a number of constraints that affect the progression of the industry. These include social constraints, lack of definition of particular issues like overfishing and lack of legal and practical guidelines to face the problems.

Initially, Mexico was included due to it increasing prominence in the bluefin tuna industry (10% of world production of bluefin). Mexico is now the third largest producer (Spain and Australia are the other two main countries). However, despite contact with various industry bodies, farm visits could not be arranged so alternative species and systems were viewed (tiliapia and trout). Tuna is a high-value product and will greatly benefit from humane slaughter methods, especially for fish being exported, where improved product quality will have a significant impact on the price of fish. This means there is more scope for implementing systems that maybe initially more expensive.

Mexico was also chosen as it is a developing country that exports to a number of countries including the USA.

When looking at new slaughter methods it is important to assess what the requirements are and what options are realistic. As a country with little investment in aquaculture it is pointless introducing systems which are expensive to run, are technologically advanced or dependent on high maintenance unless there are significant benefits. Mexican farmers realise a very small profit from fish and there is currently no real domestic market for high quality products. Without this main incentive, and very low profile of animal welfare, the industry is unlikely to have any incentive to changing systems. Equally, as it is not a main industry, in relatively poor areas there is not the finance for new systems.

The Mexican leg of the study tour highlighted a range of issues and gave an insight into low technology aquaculture and future requirements. One of these could be low technology electric stunners which deal with batches of fish and may provide benefits such as quicker harvests. However, this will only be beneficial if labour is expensive, which is not necessarily the case.

Chile (6 November - 22 November)
The first ten days in Chile were spent in Puerto Montt and Chiloe Island. This area is the main base for many of the aquaculture companies in Chile, including many of the international companies. The last few days were spent in the capital Santiago. During the visit a number of fish farms and processing plants were visited and meetings with industry groups and research bodies were held.

Whilst in Chile, salmon and trout were viewed in a wide range of systems.

Chile occupies an important place in world aquaculture, being amongst the top four countries for salmon production. Aquaculture started developing in the 1980s, mainly based on the culture of salmonids and, at a lesser level, molluscs, clams and seaweeds. There are varying sizes of enterprises which spread from subsistence level to enterprise level achieving industrial sized production.

During 1998, the aquaculture sector reached levels of about 361,4 thousand tones and has huge potential to expand further. Chile undoubtedly has the possibility to maintain, if not improve, their second place as a world producer of salmonids.

As a major salmon producer, Chile exports to a wide range of countries in frozen form. Throughout the trip it was apparent at how much concern this causes the other countries. With cheap labour and the ability to produce large numbers, other markets find it very difficult to compete with the prices of frozen salmon. Equally Chilean farmers are rapidly improving their systems to become more efficient and improve their quality.

One explanation for this is the insurgence of multi-national companies into the industry. These companies bring expertise, technology and finance into the Chilean industry and have helped improve its systems, making the production chain even more efficient and more lately increasing the quality of the fish

significantly. However, systems are not always transferable from one country to another and this expectation can cause internal problems.

The methods of slaughter employed vary greatly as the technology gradually filters into the country and industry. Methods observed included live chilling, carbon dioxide, anaesthetics and percussive stunning (manual and automatic).

In Chile the industry generally uses special companies for the harvest of fish. These can be companies that travel to the farm site and kill on a specially designed harvest boat or specific killing sites. Harvest companies employ their own staff and farms only provide one member of staff to monitor the crowding and removal from water. Specific killing sites require the fish to be transported away from the farm. These sites have holding pens for the fish to be kept in prior to slaughter. This system has the added advantage of specifically trained staff doing one job, so it can be expected they will be competent at the job. It does, however, mean that the control of the harvest procedure is passed from the farm to the harvest company. This potential problem has been targeted by some farms by providing training for the harvest staff.

The methods observed in Chile varied in the financial investment and level of technology. This had obvious impacts on the relative welfare merits of the systems employed.

Farmed fish species

Over 20 species of fish are used in the aquaculture industry. Of these, only a few are widely grown on a commercial basis, ie salmon, trout and tilaipia. A much wider variety of species is developing and is still at experimental stages, with ongoing research discovering breeding cycles, feeding regimes and water quality parameters suitable to farm these fish in a relatively intensive nature.

This section highlights the most commonly farmed species observed during the project.

Salmon

Within the salmon family there are a number of species farmed including:

Atlantic Salmon *(Salmo salar)*

Alternative names: Bay, Black or Silver

The Atlantic salmon is farmed all over the world and was observed in Canada and Chile. Harvest size can vary from 3-10kg depending on the customer requirements and season.

Fish spend the first part of their life in fresh water before being moved to sea water. Fish are grown in cages to the required weight. For harvest, fish can either be killed on site or transported to the processing plant alive. Care needs to be taken to ensure that these fish do not start to mature before harvest. When they do their shape alters and the use of automatic percussive stunning becomes less effective.

A variety of harvest methods for these fish were observed including carbon dioxide, percussive stunning and anaesthetic.

These fish are widely transported, and when done correctly this will have a relatively small impact on their welfare.

Chinook *(Oncorhynchus tshawytscha)*

Other names: Spring, Pacific, Quinnat or King

The chinnock salmon is originally from the Pacific Ocean and is significantly different to the Atlantic in terms of husbandry requirements, as it is a lot more flighty.

Chinook salmon react to interaction with humans by very active movement which could damage the fish externally and also increase the stress hormone production. Although some companies live-haul chinook, it is not common practice as they react badly to the increased handling and reduced stocking densities experienced.

Chinook are farmed in Canada (west coast), in Chile and in New Zealand. Methods of harvest observed included automatic percussive stunning, anaesthetic and carbon dioxide stunning.

Coho *(Oncorhynchus kisutch)*

These are also Pacific fish and are similar to the chinook in terms of reactions and production requirements. These fish are generally harvested around 4–5 kg.

They are native to Canada, the USA (west coast) and Mexico and are caught in Alaska. They have been introduced into Chile and a number of other countries. During the visit methods of harvest observed included carbon

dioxide.

Rainbow trout *(Oncorhynchus mykiss)*
These fish were observed in Mexico, but are also widely farmed in the USA, Canada, and Chile. They are native to Mexico, Canada and the USA, but have been introduced to numerous countries including Chile and the UK.

The slaughter methods observed included ashyxiation and live chill (larger fish of similar size to salmon). Other methods discussed included death in ice slurry, carbon dioxide stunning, electrical stunning and percussive stunning. In Canada and the USA there is also a significant market for live trout. This means that many of the fish are transported and held live in retail outlets ready for sale.

Channel catfish *(Ictalurus punctatus)*
Catfish are farmed in ponds in the south of the USA and Mexico. They are generally sold in frozen form around the country. However, some producers are close enough to markets and will live-haul the fish to gain nearly double the price of frozen fish. Fish are generally sold for slaughter at 1.4kg. The catfish is the most commonly farmed fish in the USA. They are transported live to processing plants where they are immobilised or stunned with electric before being decapitated.

White sturgeon *(Acipenser Transmontanus)*
Sturgeon are one of the oldest living veterbrates with fossil records detailing back more than 150 million years. Historically, the fish has been used for caviar production but more recently people are looking into food production. As the fish are very long lived, the females can take up to 8 years in farmed conditions (15–20 years in the wild) to reach sexual maturity. The fish are sexed at 3–4 years old and the males separated and sold for meat, whilst the females kept on for egg production. These fish can be difficult to kill as they are capable of surviving on relatively low levels of oxygen. They are increasingly farmed in Canada and the USA for food production.

Arctic Charr
This is one of the new species and was observed in a research station. This fish is very different to typical salmonids and provides different challenges to aquaculture. As it is only four or five generations removed from the wild, it cannot be guaranteed to have consistent production factors like growth rates and feed conversion ratios. As the charr prefer higher stocking densities they have the potential to be a very successful aquaculture species with further development.

Tiliapia (*oreochromis niloticus)*

As the world's most widely cultured fish, tiliapia accounts for 20% of the global seafood harvest. Male fish are preferred due to the fast growth potential. Originally hormonal sex reversal was used to produce male-only groups, but this is now being replaced by breeding polices which are just as effective.

Hybrid Striped Bass
Alternative names: Sunshine or Palmetto
The bass family form a large part of aquaculture around the world. The first hybrid was formed in the 1960s with a white bass *(Morone chrysops)* and striped bass *(Morone saxatilis).* Depending on the sex of the parents this produces either the sunshine bass (striped male - white female) or palmetto bass (striped female - white male). Unlike most hybrids these fish can breed. Originally from the Atlantic coast of Canada and the USA, they can now be found along the west coast and in inland populations. They are also widely produced in Europe. These fish are generally harvested at an average weight of 1kg. They are warm water fish with optimum growth occurring at 25-27^{0}C. The method of slaughter for these animals is generally in ice slurry.

Withdrawal of food

Historically food has been withdrawn to save costs, avoid taint in the final product, manipulate flesh composition, or for food hygiene reasons. Science has now shown these problems are not always resolved by feed withdrawal. In some species, such as salmonids, 72 hours is sufficient for complete gut emptying resulting in a safe product with no taint. Food withdrawal purely to save money proves uneconomical as it has no impact on fillet quality and will result in weight loss, especially in warm water species. Food withdrawal raises a number of questions. In the wild, certain species naturally fast for long periods and some people believe this is evidence that food withdrawal is not a welfare concern. However, farmed fish are fed daily and at regular intervals, a procedure that the fish get accustomed to and it is argued that this withdrawal could be detrimental to welfare and may increase aggression. As a result, best practice is to keep withdrawal time to a minimum and never longer than necessary for complete gut emptying.

Crowding

Crowding is an essential procedure to aid the removal of fish from water, but it can cause unnecessary suffering when done incorrectly. It must be correctly managed to minimise the risk of adverse impacts on welfare and quality. Unless carefully controlled, crowding can result in:

- rapid increase in stocking density
- decrease in oxygen levels
- deterioration in overall water quality
- significant increase in risk of abrasion of fish from nets and other fish

To minimise all these risks, monitoring of the pen by experienced staff must be continuous.

Practical observations can help indicate increasing stress levels. The behaviour of fish should remain as normal as possible. When fish are stressed their movements tend to become more vigorous; if this happens, nets should be loosened until the behaviour calms down. The nets should be brought in slowly so that the area is reduced gradually. This reduces the chances of scale loss, eye damage or aggression, as individuals are forced closer to each other. Where possible, the crowd nets should be gathered in such a way that the sides are slack rather than tight and rigid. This makes the nets flexible and will reduce the chance of damage.

Crowding must always be undertaken at an appropriate rate for the subsequent handling operation. Where possible, it should not last longer than two hours. If it takes longer, the process should be reviewed and the way in which the pen is split re-examined. A simple scoring system can be developed by experienced staff to help train others to recognise both acceptable and unacceptable levels of activity, so that procedures can be put in place to resolve problems. Clean and well-maintained nets are essential for humane crowding, as is monitoring oxygen concentration. Water quality can deteriorate rapidly, if not monitored, as carbon dioxide and waste levels increase and oxygen is depleted. If the oxygen levels fall below the critical level for that species, oxygen should be added to alleviate stress. The addition of oxygen to the crowd has another advantage: it attracts fish towards the diffuser. It is important that the correct type of diffuser is chosen to ensure the level is suitable throughout the entire harvest. Water quality can also be maintained by allowing a good water exchange.

Removal from water

Routine husbandry practices and some slaughter methods require removal of fish from the water. When this happens, it will elicit a stress response from the fish as they try to get back into the water. Whilst a brief period out of water often cannot be avoided, they must not be left in air for any longer than necessary, ie 15 seconds for salmon at slaughter. Unless the species can survive out of water, activity levels generally increase after this, along with stress levels and chance of injury due to difficulty in handling. The removal rate must coincide with the speed of the husbandry procedure so that fish are delivered appropriately with a minimal time out of water. The three most common delivery methods are hand nets, pumps and brailles. The use of anaesthetics can also be useful during this process to alleviate stress.

Anaesthetics

In some countries (New Zealand, Australia, Chile and Korea), an anaesthetic agent with the active ingredient iso-eugenol, is licensed for use to sedate fish prior to removal from the water. This anaesthetic (AQUI-S Ltd, New Zealand), which can be used immediately prior to slaughter in the licensed countries, is applied in solution to the water. The fish are introduced into this treated water, where they remain for 30 minutes. Following sedation they are removed from the water and percussively stunned or introduced into carbon dioxide saturated water. This type of harvest is known as 'rested' harvesting. Rested harvests improve flesh quality parameters such as: improved colour, reduced gaping, and a delay in the onset and severity of rigor compared to conventional harvesting methods. This is mainly due to the fish experiencing less exercise and stress. Currently applications are being made for licenses to use iso-eugenol in both Europe and North America, but until these are granted use of the product is not permitted outside of the licensed countries.

Practical implications:

Used correctly prior to removal from water, at the point of crowding, AQUI-S is a very humane method to crowd fish quietly and remove potential injury as the fish are removed from water.

Many companies which are currently in countries without the licence have used an alternative to AQUI-S such as clove oil. This is a natural product but the concentration of the active ingredient can vary greatly so controlled use can be difficult to achieve under commercial conditions.

Some companies visited had used clove oil but mentioned problems with taint.

Where it was observed, it was added to the tank in addition to carbon dioxide following removal from water. This was providing welfare and product quality improvements but not to the full potential if used correctly. The problem was that this fitted into the system and was a cheaper way of using it. The improvements had been recognised and therefore there was no immediate decision to follow the recommended procedures which would require alterations to the systems and slight increase in costs.

Welfare implications:

Positive:

- non-aversive way to reduce movement of fish and induce unconsciousness if used at correct concentration to minimise the stressors they experience
- controlled and repeatable way of inducing unconsciousness. If used correctly, the fish will remain unconscious whilst bleeding occurs

Negative:

- if used at incorrect concentrations it may be aversive
- if not left for long enough, fish may be sedated rather than anaesthetised

Pumps and pipes

A variety of pumps are used for handling fish, so the choice of pump is dependent on each individual situation. Whichever pump is used it should be maintained well to avoid any type of damage to the fish and to be powerful enough to handle the volume.

Pipes connecting the crowd pen to the stunning point should be as short as possible; many well-run systems keep the time fish spend in a pipe below a maximum of two minutes. Any delay can have an adverse effect and increase stress levels. At the end of use, and during any extended breaks, pipes must be flushed through to ensure they are empty. A sponge ball of suitable size can be used to ensure effective flushing of the pipes.

When using pipes, placing the pipe inlet in a shaded area and in the correct orientation for fish to swim towards it against the side will utilise natural behaviour and will help minimise stress.

Practical implications:

Pumps can add costs to production but they are an effective way of delivering fish to the stunning point and are suited to the whole range of slaughter methods. Pumps have to be maintained to prevent injury to the fish. Long pipes can also cause problems especially in warmer countries; if fish are left in the pipes for too long there is a risk of a negative impact on product quality

Welfare implications:

Positive:

- fish are not lifted out of water
- fish are not exposed to the forces of gravity
- less change of abrasion injuries and fish being crushed or suffocated
- fish are delivered at a reliable and controlled rate suitable for all methods of slaughter.

Negative:

- long pipes in hot countries can expose fish to higher temperatures than normal
- long pipes may exhaust the fish if they try and swim against the current
- incorrect set up of pumps may injure fish

Brailling

Braille nets are a quick way of moving large numbers, but this process can seriously compromise welfare when fish are fully conscious. A lining should be used in the braille to keep water within the nets and to provide some protection when fish are removed from the crowd pen; it also minimises the risk of skin and eye damage caused by abrasion from the nets. Overfilling brailles must be avoided at all costs, as this will cause undue pressure on the fish and some may die due to suffocation. The braille must be well-maintained and regularly checked for damage. Where linings are not used, the mesh size must be appropriate for the species/size being brailled; there must be no rough edges on the sides, nor chains which may cause flesh, skin or eye damage. The braille net must be moved slowly and lowered to make contact with the unloading table before the fish are released, otherwise welfare and quality will be compromised.

Time spent training the crane driver to load and unload braille nets correctly is invaluable to minimise welfare concerns and maximise quality.

Practical implications:

Brailles are an effective way of moving large numbers of fish, but their success in not damaging the fish is dependent on the skill of the crane driver. The temptation to overfill, move the nets quickly and unload without touching the table must be avoided.

Welfare implications:
Positive:
- if a lining is used fish are not exposed to the full force of gravity

Negative:
- without a lining, fish may be crushed or suffocated
- fish are at risk of damage from the net, this includes skin damage and eye damage as well as bruising
- the braille can be overfilled
- fish are at risk of injury if the braille is opened above the table and fish allowed to drop
- it provides fish in bulk and is therefore not suitable for many of the humane systems of slaughter
- fish may need to be crowded tighter to allow filling of the braille net

Hand-nets

In many ways, removal of fish by hand-net is very similar to removal by braille. Hand-nets are unlikely to have a lining, so it is imperative the mesh of the net is suitable for the species. Again welfare will benefit immensely from quality staff training, specific to the species.

The use of hand-nets often requires staff to be in the water with the fish, when this happens staff need to know how to minimise any adverse effects this will have, such as decreased water quality, increased activity and possible crushing of fish by operatives. With such procedures staff welfare is also important as this impacts on fish welfare; tired staff or poor working conditions can compromise the ability to work effectively and therefore compromise welfare.

Practical implications:
The use of hand-nets relies heavily on the skill of the operator. Operators need to be trained, and avoid damaging fish when working in the fish ponds.

Welfare implications:
Positive:
- small numbers of fish can be lifted out of a cage/pond

Negative:
- there is a risk of damaging the fish around the operator
- fish are at an increased risk of damage from the net, this includes skin damage and eye damage
- fish are at risk of injury if the hand-net is not emptied carefully
- it provides is a slow way of removing fish and could lead to extended crowding times

Principles of humane slaughter

The key principle of humane killing is to render the animal immediately insensible, a condition which must then persist until it is dead. With red meat animals and poultry the definition of unconsciousness is generally accepted as the point when normal rhythmic breathing stops. Research suggests that this is also true for fish.

At no point should fish be handled in a way that causes unnecessary suffering. In recent years various systems have been developed in an attempt to achieve this. Historically, common methods of slaughter were very basic, ie a manual blow to the head or removing the fish from water. These methods are low cost and were thought to be effective and acceptable. However, as aquaculture has advanced, new systems have been designed and improved and more are under development. This has resulted in a range of options for the more commonly cultured species, which satisfy the requirement for humane slaughter to differing degrees.

Within the UK, producers have embraced the idea of fish welfare and have moved forward, developing methods of slaughter that are more humane, whilst still being able to compete in the competitive market. Following this industry development, many quality assurance schemes now include the requirement for humane slaughter.

Over the past ten years the industry has progressed from traditional methods that have been shown by research to compromise the welfare of fish to modern humane systems.

Around the world, technology is at different stages of implementation and development. Much of this is dependent on the country and the people involved in the industry.

All the methods observed and discussed during the project are listed below.

It is clear from previous experience, and backed-up by the study tour, that what works successfully on one farm will not necessarily be the same for other farms, and likewise for countries. Therefore each of the methods is described in terms of theory, practical implications and the associated welfare advantages and disadvantages for the fish and the practicalities of fitting such systems.

Changing slaughter systems is a long term, often expensive, project. For these reasons recommendations are given at the end to improve methods that are not regarded as humane until decisions can be made about the long term systems.

As previously explained, the stress response in fish is indicative of a compromise in welfare and can potentially damage product quality when it occurs prior to slaughter. It is therefore essential that slaughter methods reduce this stress response whenever possible.

New methods take advantage of modern technology and some are highly sophisticated, but simple systems are also available relatively cheaply. When costing systems it is important to keep in mind the benefits that humane methods may bring; some companies that have converted to more humane systems have seen profits exceed initial investment relatively quickly.

Staff training

A sound understanding of the methods used is essential for operators to perform their job effectively. Husbandry is an extremely important and skillful job; the benefit of training staff to ensure and maintain high standards of welfare cannot be underestimated. All staff involved with live fish, including crane drivers moving braille nets and wellboat crews, should be appropriately trained and have the consequences of poor management explained to them.

Percussive stunning

The objective of percussive stunning is to induce immediate insensibility by administering a severe blow to the skull of the fish which causes irreversible brain damage. It is essential that the blow is applied with correct force, in the correct place to ensure an effective stun that will kill the fish.

The initial effect, when hit correctly is for the fish to become rigid, lose opercular (gill cover) movement. Its mouth opens, and eye reflexes are lost. This period of rigidity can vary in length depending on the force of the blow, but also with age and species.

As stated above, an effective stun is dependent on the blow being administered to the correct part of the skull. To ensure the maximum impact on the brain, the best position is where the brain is closest to the surface of the head and where the skull is at its thinnest. In most fish this is the region behind the nose and above the eyes. The blow does not have to penetrate the head to be effective.

When using percussive methods, fish should be presented to the stunning point carefully and at a rate suitable for the staff carrying out the stunning. If left out of the water for too long, fish will start to flip and become more difficult to handle.

Signs of an effective percussive stun:

- no opercular (gill cover) movement
- no eye movement
- bulging of muscle ring near pectoral fin (Atlantic salmon)

Priest

The priest has been an effective method of stunning fish for many years, but to be humane it relies heavily on the strength, skill and consistency of the slaughter team.

Practical implications:

Used correctly, the priest is a humane method but it is difficult to expect staff to reliably and accurately hit large numbers of fish at a rate required for commercial harvests.

As staff tire they will become less accurate. This not only affects the welfare but can cause meat quality issues that will increase the amount of downgraded flesh.

Staff run the risk of developing conditions such as repetitive strain injury, which can prevent them from further work and may result in litigation.

Welfare implications:

Positive:

- hit correctly, insensibility is caused immediately, which will persist whilst bleeding occurs

Negative:

- immediate insensibility is not always caused due, to: incorrect placement, insufficient power or operator fatigue and or inaccuracy
- second or third blows are often needed
- the longer a fish is held the more it will struggle and it will be increasingly difficult to apply an effective stun
- manual handling and restraint of fish is required whilst fully conscious
- fish need to be removed from water.
- there is a risk of eye damage and bruising whilst conscious

Mechanical systems - manual feed

The 1990s saw the development of automated systems, mechanising the stunning operation and potentially making it a more consistently humane procedure. The operator gently grasps the fish near the middle of the body (not by the tail), guiding it into the opening of the machine to ensure the fish is upright. The fish activates the trigger system, resulting in the piston striking the fish on the head rendering it immediately unconscious.

Practical implications:

The system is more user friendly and does not rely on human skill or strength. Once the operator is competent with the machine it becomes relatively easy to operate, although it may slow down the stunning rate initially.

Fish are still when they reach the bleed point making it easier for the gills to be cut and providing for a cleaner environment for the workers. Less staff may be required at the stunning point, meaning that one member of staff can solely operate the crowd pen. There is an initial cost for the machine, which is not generally prohibitive, but the system will work more effectively and humanely with a pipe delivery system as opposed to the brailling methods.

Not all mature or deformed fish activate the trigger at the right time and therefore do not receive an adequate blow to cause immediate unconsciousness and will need restunning.

Manual handling is still needed, and should fish be left out of water for any period of time they will become more active, this may lead to bruising as they flap but generally makes it harder for the fish to be guided into the machine and they will need to be restrained, potentially causing bruising.

This system has greatly reduced the risk and occurance of repetitive strain injury in staff. Throughput can be increased and less staff used.

***Welfare implications*:**

Positive:

- position and power are far more consistent, ensuring accurate and effective stunning on all fish
- less chance of ineffective stunning
- less risk of eye damage or bruising whilst conscious
- less manual handling as fish are guided rather than physically restrained

Negative:

- fish need to be handled and removed from water
- a small number of mature or deformed fish may not be effectively stunned
- the system is more suited to delivery by pipes then brailles

Mechanical percussive systems - automatic feed

This machine is one of the most recent developments in humane killing equipment and further improves percussive stunners.

These stunners utilise a specially designed table which keeps fish in the water until seconds before being stunned.

Once on the table fish are encouraged, using a raised surface and water currents, to swim to the front of the table and jump over into the delivery channels. The delivery method requires pipes, as brailles would not be effective.

At the bottom of each channel is a stunning machine.These are triggered in the same way as the manual feed machines. Following stunning the bottom drops and the fish falls through to the bleed area.

Practical implications:
The machine can be expensive and time consuming to fit: many companies have had to redesign the table more than once, for it to work effectively. However, once working it has been proven to increase both welfare and flesh quality of the fish in commercial situations.

Correct design of the delivery table is essential and is generally unique for each site. Although staff can be relieved from regularly stunning the fish, it is important that they still remain within the area to monitor the fish coming through and look for fish that have not been hit correctly. Fish also swim to the edge of the table and use the outside stunners more regularly than the inside ones. It can be expected that this can be stressful as they try and free themselves, they will also be out of water at this point

Observations of this machine in operation showed that the majority of fish, including mature fish, received an effective stun first time. Manual back-up stunners are required though.

Welfare implications:
Positive:
- the fish's natural behaviour is utilised
- fish are not handled
- there is minimal time out of water

Negative:
- a small percentage of fish go through in the wrong orientation. Being hit upside down will not produce an effective stun
- as fish swim to the outside channels there can be blockages (very small occurrence).
- some people believe that the fish are more active and therefore will produce higher levels of lactic acid but practical use has shown this not to be the case

General considerations

Operator considerations

The design of the stunning table and of the delivery method to the table/machine is of utmost importance for both fish welfare and the operators' health and safety. Staff should not have to concentrate on keeping their balance, or bend excessively when using the equipment, as this can lead to tiredness and inaccurate stunning, which in turn can lead to a compromise in welfare and product quality.

Failure to stun

If a fish is not properly stunned it must be re-stunned immediately. As described above, manual percussive stunning of fish does not always cause insensibility. Practical observation of this method showed, that whilst an operator can be very effective when just starting the job it is not long (30 minutes) before multiple blows are needed to render the fish insensible.

This not only causes welfare issues but may also cause poor flesh quality through bruising, eye damage and increased production of lactic acid.

Automated mechanical stunning systems are much less likely to ineffectively stun when used correctly and maintained correctly. It is essential that all fish are monitored for stunning efficacy and corrective action taken if a problem arises. If the machine is at fault it should be removed from the harvest immediately until fixed.

If it is just individual fish, ie mature fish, then consideration should be given as to whether or not to use the machine or a priest. If there is doubt that any fish has not been stunned effectively, the priest should be used to repeat the stun.

Carbon dioxide narcosis

Loss of consciousness in fish immersed in carbon dioxide saturated water (pH level 4.5), which is highly aversive, can take 7–8 minutes. Fish will show head shaking and vigorous tail shaking for up to two minutes after immersion in the solution. Movement then subsides and the fish become still after five minutes. This is due to narcosis (loss of control of movement) and exhaustion as opposed to insensibility. Unless fish are kept in a high concentration solution for 7–8 minutes, recovery will begin soon after removal from the solution, ie on the table or in the bin and the fish will be conscious whilst being bled.

Practical implications:

To ensure that all fish are rendered unconscious there needs to be a significant exposure time and the correct concentration. Exposure to the carbon dioxide causes significant and vigorous movement; this makes the area in which staff are working more difficult but will also have repercussions on the quality of the fish and is closely associated with a very quick time to rigor (less than 2 hours in one plant).

Welfare implications:

Positive:

- if they have been exposed for the correct amount of time, at the right concentration, fish may be unconscious as the gills are cut

Negatives:

- loss of consciousness is not immediate
- carbon dioxide is aversive to fish and will elicit the stress response
- it is very difficult to control in commercial conditions and ensure sufficient exposure
- there is a high risk of fish not being unconscious when gills are cut
- concentration of the gas will vary and may not remain at the level sufficient to cause unconsciousness

Live chilling

Live chilling is used around the world for larger fish which are going to be bled. Fish are added to a chill tank which has the water temperature set at around 1°C. This method immobilises fish and reduces the carcass temperature to allow quicker processing. It is not a method of stunning fish and will **not** induce unconsciousness. When fish enter the tank they may show violent movement and escape behaviour. This movement gradually subsides as they become exhausted and or immobile. After about 30–40 minutes they are removed from the water and their gills are cut whilst still fully conscious.

Where chilling is used the rate of chilling should not exceed a drop of 1.5°C at any time. It is essential that the water quality is maintained and that oxygen, carbon dioxide and ammonia levels are measured and controlled, by changing the water throughout the day. Some systems also add carbon dioxide into the system to help speed the process. Carbon dioxide has its own effects on fish which have been discussed in detail above.

Practical implications:

Live chilling machines are bulky and relatively slow. Fish are dewatered prior to entering the tank, and either a pump or a braille method of delivery works for these systems.

Fish are chilled and the core body temperature is brought down relatively quickly, allowing fish to be processed quicker and potentially have a longer shelf life. However, the reaction seen by fish as they enter the system is highly suggestive that the system is aversive.

As an alternative, systems were observed which used chilling for 30 minutes after killing. This has none of the associated welfare disadvantages of live chilling and the factory commented that the fish were still leaving the factory below the recommended temperature set by government for food safety reasons. The fact that the fish had been bled and therefore little circulatory system seemed to have no effect on the time of cooling, but it significantly improved the welfare.

Some systems include carbon dioxide in them to stun the fish. This is an aversive gas for the fish but due to immobilisation they cannot react to this. The advantage of carbon dioxide is that, done correctly, it will cause unconsciousness eventually so fish will not be alive when the gills are cut. However, unconsciousness by carbon dioxide is difficult to induce under commercial conditions.

If fish are put into live chill tanks that actually have the same temperature as the water that the fish have been farmed in, they will acclimatised to this temperature and no matter how long they are in the chill tank there is no immobilisation.

Welfare implications:

Whilst many fish will spend a significant proportion of time at low temperatures, they reach these by slow acclimatisation, around four days, and will show a violent escape behaviour when placed in water with a 10^{o}C difference.

Positive:

- this is not a quick way of inducing consciousness and there are no positive implications for welfare

Negative:

- live chilling does not cause unconsciousness
- sudden exposure to chilled water will cause aversive reactions in fish

Death in ice slurry

Death in ice slurry is one of the most common methods of slaughter around the world and is widely implemented in the trout industry in North America. Fish are passed over a dewaterer and into a slurry mix of ice and water. They are then left in this mix until they die through lack of oxygen. As the fish's metabolic rate slows down in colder temperatures so does the oxygen demand of the fish. This means that the time to death whilst in ice slurry can be considerably longer than asphyxiation. In other warm water species, fish can also suffer temperature shock which may shorten the time to loss of consciousness.

Research into trout has shown that the time for loss of consciousness can vary from two minutes (in air) to nine when put in ice slurry.

Practical implications:

This is a low-tech method of slaughter and relatively cheap. It can reduce the core body temperature helping the processing procedures. However, some scientific work has shown that there is an increased production of lactic acid as the fish show vigorous movements on initial contact with the water.

When fish are placed in ice slurry, it is difficult to use normal behaviour indicators (such as escape behaviour and vigorous swimming) as indicators of welfare, as the ice can have an immobilising effect on the fish. In these circumstances fish will be relatively still, apart from sporadic flips.

Welfare implications:
Positive:
There are no benefits to welfare for this method.

Negative:
- the delay in unconsciousness means this method cannot be described as humane
- in certain circumstances there is a chance that fish are immobile not fully unconscious when they reach the processing plant

Death in air

This method involves removing fish from the water, either by hand-nets or pumps and adding to an empty container. When out of water the gills collapse and are no longer capable of gas exchange. This means that the fish die through lack of oxygen. This is not a method that causes immediate unconsciousness and is not classified as humane.

When fish enter the container there is a severe reaction seen in the fish, the stress response. The fish show vigorous movements as they try and return to water.

Practical implications:
This is a very low tech method and does not require and any set up costs, staff training or maintenance. The vigorous movements seen by the fish last for a long time and can be expected to deplete the energy reserves of the fish may lower quality. Even though the movement is extended (over 15 minutes during observations), research has shown that consciousness is lost before this time.

Welfare implications:
Positive:
There are no positive in terms of welfare.

Negative:
- fish are taken from their natural environment and have no access to water which is expected to be inhumane.
- they will remain conscious for a long period of time

Gill cut without pre-stunning

This method involves removing fish from water and then cutting the gills without any pre-stunning.

On removal from water the fish show escape behaviour and flip their tails. Once the cut into the gills is made, these reactions are dramatically increased and vigorous head shakes and tail flaps are seen for at least 30 seconds. This movement slowly subsides and after several minutes most fish stop moving.

Practical implications:
The method is extremely low-tech, but does rely on a very well trained staff. If gill arches are not cut effectively then the blood loss may be restricted. This will have a negative impact on welfare and flesh quality. This could also be compounded if the fish is handled badly before slaughter. Increased activity causes a build up of lactic acid which will lead to early rigor. Should this rigor start before all blood is drained it will remain in the carcass, increasing the chance of spoilage and reducing the processing options.

As the fish have not been stunned, they will react to the handling and removal from water making it more difficult for the staff to handle the fish. This increases the difficulty of making a good cut and the chances of the operators cutting themselves.

Welfare implications:
Positive:
There are no positive in terms of welfare.

Negative:
- fish will have to be handled and restrained whilst the gills are cut and are fully conscious
- an ineffective cut will not allow fast and profuse bleeding
- there is significant activity exhibited by the fish
- as the gills are cut, this movement increases further

Electrical Stunning

Electrical stunning was not observed during the visit but was discussed on a number of occasions in the USA and Mexico. It is also a human method implemented in the UK.

The general principle of electrical stunning is to pass sufficient current through the brain to cause an epileptic-like fit. This results in immediate unconsciousness and insensibility to pain. If the current flows for long enough the fish will die of anoxia before the brain is able to recover sensibility.

The electric current also causes spasms in the fish muscle which can, under some circumstances, result in haemorrhages and other carcass damage. Stunning conditions therefore have to be carefully designed to ensure that the process causes neither pain, nor carcass damage and that recovery is not possible. These conditions are known to vary widely between different species of fish.

The electric current in a tank of water can pass around the fish as well as through them, therefore it is most useful to define the **electric field** which is required in the water rather than the electric current. The effect of the electricity is related to the frequency. Frequencies close to 50 Hz have a greater effect on both the fish brain and muscle than higher frequencies. However, in trout and salmon a frequency of 50Hz is likely to cause carcass damage. By selecting a higher frequency at a slightly higher electric field strength, immediate insensibility may be achieved without causing haemorrhaging or other carcass downgrading.

Stunning with electricity is known as **electronarcosis**, and killing with electricity is known as **electrocution**. Electronarcosis is a fully reversible procedure, immediately disrupting normal brain function for a short period only. Electrocution leads to complete dysfunction of the brain which prevents the breathing reflex working. Electronarcosis by itself is not suitable for fish that are not bled immediately after stunning. This is because they would recover from the stun before further procedures could be started and they would therefore be fully conscious during processing.

Factors such as species, size, stress levels, temperature, water conductivity and the number of fish in the stun tank may affect the duration of insensibility resulting from a stun.

Signs of an effective electrical stun

- Eye movement stops
- Small muscular twitches
- No opercular movement
- Fish turns upside down

If an electrical field of insufficient voltage, frequency and duration is applied to fish they will not be stunned, but they may become paralysed. Under these circumstances the fish cannot show typical pain responses or escape behaviour. Alternatively, exposure to the correct current but not for long enough to cause permanent insensibility will result in fish starting to recover.

Practical implications:

When using electrical systems it is important that the operator can monitor the machine at all times. It is also important that operators have unrestricted access to the safety stop controls.

Any person stunning and killing fish must know the:

- voltage required for effective stunning
- correct duration of stun
- signs of an effective stun/kill
- signs of an ineffective stun/kill

Welfare implications:

Positive:

- animals are rendered immediately insensible
- fish can be killed in groups or continuously
- fish do not need to be physically handled
- following electrocution, there is no chance of live fish entering the processing plant

Negatives:

- if the parameters are not set correctly fish may receive an electric shock whilst conscious
- if only stunned they will recover consciousness unless bled effectively

Recommendations

The following pages take into account the above implications and give recommendations for each method observed. Although there are recommendations for methods described as inhumane, it is stressed that these methods should be phased out as soon as possible in favour of more humane methods.

When looking at new systems it should be costed appropriately, in terms of quality improvements and cost reductions (water costs, labour costs, time etc.), not just in initial investment. Methods should always be implemented in consultation with staff. The knowledge of staff using the equipment should never be underestimated, but management must also take into account possbile negativity for new ideas due to resistance to change especially if there is concern about loss of jobs.

Methods that render the fish immediately unconscious are stongly recommended. Throughout the study tour it has been repeatedly shown that humane handling and killing of fish is possible, under most scenarios, without compromising the speed or profitability of the system, indeed it can improve both once set up and running effectively.

Humane methods also limit the time out of water for fish, or even completely remove the need for fish to be taken out of water. In addition they also minimise the handling of the fish and the requirement of individual handling by people.

At this point in time the two most humane systems are automated percussive stunning and electrical stunning (and killing). These systems fit the above criteria and as seen on a number of visits are cost effective to implement. Talks with companies who have implemented these humane systems have also revealed:

- extended rigor times, allowing, processing pre-rigor
- improved flesh quality
- decreased amounts of skin and eye damage
- decreased costs of harvest

Humane methods

Priest:

Stunning using a priest should be kept to the emergency killing of fish on an individual basis. Where it is used for commercial harvest the following list can help improve the welfare and reduce the risk of flesh damage. These include:

- increase number of staff to cope with the number of fish
- regular rotation of staff to prevent fatigue and risk of injury
- a delivery system which provides the fish at a suitable rate to allow for effective stunning

Where manual stunning is employed, it is essential for both fish and operator welfare that the operators are given regular breaks and are allowed to work at a reasonable rate. Otherwise accuracy and effectiveness will be compromised leading to adverse fish welfare.

Mechanical percussive stunner - manual feed*:*

Stunning using automatic equipment is a humane way of killing animals effectively. Where it is used, the following list will help the system run humanely, effectively, improve the welfare and reduce the risk of flesh damage. These include:

- the system is used where fish are graded regularly so that the likelihood of mature fish is minimised
- the delivery method is set at a rate suitable to the stunning rate. Fish must never be out of the water for longer than 10 seconds
- machines are regularly rotated and maintained so that they are working at maximum efficacy at all times
- back-up stunners (priests) must be available at the stunning point
- staff are trained in the machines' use and also the back up method
- staff are rotated regularly to maintain concentration. Staff are trained to recognise both effective and ineffective stuns

Mechanical percussive stunner - automatic feed*:*
Like the manual feed stunner, this is a very effective way of stuning large numbers of fish. Although only designed for larger fish now, work is progressing fast for smaller fish (under 1kg). Where it is used, the following list will help the system run humanely and effectively:

- time is taken, and the manufacturers' guidelines and advice are followed, when setting up this system
- when a bank of machines is fitted, they should be rotated so that one machine within the block is not overused
- deformed fish are monitored and stunned manually if required
- staff should be trained to recognise and effective and ineffective stun

Electrical stunning
This is a humane method if the fish are immediately stunned and not immobilised. The stunning machine should always be set up to take amount of the fish passing though it and the water conductivity amongst other things, which are detailed by the manufacturer.

Fish should not be immobilsed by the machine without being stunned. Whilst the electrical current is switched on it is difficult to tell the difference between a fish that is stunned or immobiliised. However, when the current is turned off, a stunned fish will remain stunned for a period of time afterwards. Fish that are immoblised will start to move immediately.

Less humane methods

Death in ice slurry
This is not recommended as it does not induce immediate unconsciousness, especially in cold water fish. It is acknowledged that this is a relatively cheap and low tech method but should be replaced as soon as possible. Where it is used ice slurry will allow fish to be completely submerged in the ice quickly, which can expected to cool fish quicker and help reduce the time till loss of consciousness.

Live chilling
Live chilling does not cause unconsciousness in fish, it immobilises them therefore they do not react to handling or gill cutting.

Where it is used:

- fish should be chilled at a slow rate (1.5^0C has been set by standards written in the UK)
- oxygen levels within the tank should be monitored and kept above 6mg/l
- it should occur after death or at least whilst the fish is unconscious
- it should be followed by a method of stunning before the gills are cut

Gill cut
This method should not be used without prior stunning of some kind. When it is used:

- every cut should ensure that all four gill arches are severed
- fish should not be removed from water for any significant period of time, practical observations show that fish tend to start moving after about 10 seconds
- the delivery method should be suitable for the rate of bleeding.

Carbon dioxide stunning
Well-run systems must use high concentrations of carbon dioxide to induce unconsciouness as quickly as possible and hold fish for a sufficient period to cause permenant insensibility. Where it is used, the system must ensure that:

- a pH level of 5.5 is maintained
- fish are held in this concentration for a period of at least 10 minutes
- the gas concentration is measured and replenished as required

It is essential that staff are capapble of monitoring the gas tanks and can alter the carbon dioxide setting as required.

The Future

As the amount of technology available to the industry is increasing, so is the understanding of how improving slaughter (including crowding practices, transport, de-watering and slaughter methods) can have an overall impact on the final product quality. These improvements will help the industry to produce a more consistent and competitive product.

In the UK the industry has taken on fish welfare in a very positive manner and has embraced change over the past few years. This is partly because they have led the changes, unlike other food producing industries which were forced to change following controversial images being portrayed in the media such as animal welfare problems or food safety issues.

Although there are laws in place to protect farmed food animals, these are rarely enforced on the aquaculture industry and retailer standards are only just including requirements for humane slaughter. By taking the lead, the industry is now in a secure position of being able to comply with standards and regulations as they are applied. This is an example that should be followed around the world and had just been initiated in a couple of the countries visited.

Unfortunately this kind of progress will not follow in some countries due to the lack of individual companies willing or able to invest and move forward, and parts of the industry not wanting to change due to historical or cultural reasons. Progress can also be limited where small changes lead to some quality improvements, and companies don't want to invest further even though the system is not reaching its full potential.

It was mentioned in the introduction that attitudes vary from society to society and are forever changing. This is very true in the aquaculture industry, but as many companies see the benefits of humane treatment of animals it surely must only be a matter of time before others realise they can no longer be left behind as the progressive companies become more efficient and effective in their role.

The large variability of species, and the circumstances in which fish are farmed, makes prescribing specific welfare impossible in practical terms. However, the aim of welfare assessment will always be the same – to provide a suitable environment for the fish to flourish in and to cater for their needs.

How individual companies reach this aim will be dependent on their particular circumstances; it is hoped that this review has highlighted that, whilst there are no definitive answers, there is a whole range of commercially viable options which can improve the welfare of fish at slaughter.

The information gained from this trip is now being used to develop best practice guidelines for fish slaughter, which have been requested by British retailers. These will be written in conjunction with the industry to complement other assurance scheme standards and help the industry further improve with specific requirements for the slaughter and transport of fish.

These guidelines will help retailers maintain the same standards for slaughter when they source fish from abroad. This will ensure that the British consumer can be confident when buying fish from supermarkets, that they are buying a high quality product that has been produced to high standards, regardless of the country of origin.

Conclusions

Over a year ago I started this project with high hopes and aspirations of developing a more practical and commercial understanding of the aquaculture industry, especially at the point of slaughter.

The original objectives of the tour were to investigate the attitudes of industry, government and research bodies towards farmed fish welfare and to discover international practices for slaughter.

Over 50 visits and 25,000 miles later, the experience and knowledge I have gained from this entire project is immense and I believe I have fulfilled the objectives to the best of my ability under the circumstances.

Not only have I improved my knowledge and understanding of the industry, I have developed a wide range of contacts across the world and helped bring the subject of fish welfare to the attention of many. Some of these people were very interested to hear about developments, some were not so keen.

The help I received throughout the trip was very humbling and whilst I have learnt just how long two months is by yourself, I have also found new confidence both personally and professionally.

This comes not only from a great sense of achievement, but also because I now have far more first hand experience. I acknowledge that this is still limited and it is unfortunate that I could not get to see as many killing operations as first planned. However, I believe I have seen versions of most methods now employed in aquaculture. Discussions of these methods with the staff working with them has also helped provide a much more realistic view of the systems.

Speaking with all levels of the industries across these four countries has provided an in-depth knowledge of the future plans for aquaculture and where fish welfare at slaughter fits in around the world.

The position of fish welfare varies greatly, not only between the different countries but also within them.

One common denominator is the fact that commercial benefits will bring about change and it is becoming increasingly accepted that humane treatment of fish will bring about some of these commercial benefits. No amount of processing or packaging will improve a product that is already in poor condition and deteriorating, but a prime product will last longer, despite processing and packaging.

So far there has already been a number of positive outcomes from this project.

Firstly, through contacts developed on this trip, I took part in the first animal welfare session held at the annual conference of the USA's National Aquaculture Association Conference in New Orleans, describing the different methods of slaughter around the world and their implications.

Secondly, production of in-depth guidance notes of the humane killing of salmon and trout has now been completed and will shortly be released to the industry.

I also have written various articles for industry magazines and have been asked to contribute to a forthcoming compendium on aquaculture. The information and experience gained throughout this trip has also led to the submission of two papers which have been accepted by another major conference in Canada.

In addition to this, fish welfare at slaughter now has a rising profile within many companies and across the whole industry.

Without the Churchill Fellowship, this project would have not been possible and none of these publications or presentations would have been given to such a broad range of industry representatives.