Humane Slaughter Association

Humane Harvesting of Fish

This is the downloadable version of the online guide. As such, some of the features may be missing, including video footage and web links. Visit the online version at www.hsa.org.uk

Introduction

Every year millions of fish are reared for food. The slaughter of these fish should be carried out in a way that causes no unnecessary pain or suffering. In recent years various systems have been developed in an attempt to achieve this. The key principle of humane killing is to render the fish immediately unconscious and insensible to pain, a condition that must persist until they are dead.

Historically, one of the most common methods for stunning or killing fish was to use a priest (a truncheon-like instrument). In 1999 automated stunning systems for administering the stun were introduced and first used in the industry. Although the majority of fish are killed by the initial sharp blow to the head, either by a priest or automated mechanical methods, there is a small chance that some may be ineffectively stunned. Therefore, when using these systems, it is imperative that staff can recognise effective stunning and know how and when to re-stun if necessary.

Whilst it may appear that percussive stunning is a straightforward procedure, great care must be taken in the operation, as both operator error and/or equipment failure will severely compromise animal welfare (and affect product quality).

Methods for commercially stunning and killing fish by electricity in the UK were initially developed in the late 1990s. Electrical methods can be divided into two types: stunning only (electronarcosis), where the stun is quickly followed by a method of killing; and stun/kill (electrocution), where fish are rendered permanently insensible by an electrical current, so there is no need, for welfare reasons, to follow up with any other procedure.

These guidance notes explain the theory, practice and use of the different methods of stunning and slaughter currently used in the industry. They provide essential technical information for everybody involved in the handling and slaughter of salmon and trout, including the slaughter teams, supervisors, veterinary surgeons and maintenance engineers. They provide operators with background information to help them carry out their job safely and competently and explain how pre-slaughter handling can affect carcase quality.

The Humane Slaughter Association (HSA) is aware that research into humane slaughter of farmed fish is still ongoing and there are some fundamental technical issues that remain to be resolved for some species. This booklet represents current industry best practice. It will be regularly reviewed and updated to incorporate new developments and information.

The guide also outlines a number of methods used in some parts of the industry that the HSA cannot recommend due to welfare concerns. The HSA actively encourages producers to move towards using modern humane practices as soon as possible.

Please do not read further if you feel you may be negatively affected by the content.

Important Points About This Website

This guide is intended to provide guidance to operators in the humane harvesting of fish. However, anyone aiming to undertake stunning and slaughter procedures should also seek practical training with an experienced operator. In some countries, training and certification may be required by law.

In order to safeguard the welfare of the animals to be killed, it is necessary for the guide to be both thorough and illustrated. As such, some people may find some of the descriptions and graphics upsetting. Please do not read further if you feel you may be negatively affected by the content.

Stunning and slaughter equipment is potentially lethal. You are advised to read the safety section of these notes with particular care. If you are in any doubt as to any aspect of the safe operation of equipment you should consult the manufacturer. In no circumstances can the Humane Slaughter Association accept any liability for the way in which equipment is used, or for any loss, damage, death or injury caused thereby, since this depends on circumstances wholly outside of the HSA's control.

The HSA aims to provide up-to-date and accurate information. If you have suggestions for improving any of the material included in this guide please let us know at info@hsa.org.uk or using the contact details provided.

Hardcopy versions of this guidance are also available to purchase from the printed publications section of this website for £7 including postage.

Pre-Slaughter Handling

Most fish demonstrate an emergency response when threatened. This may follow a sudden disturbance from a net, a noise or other unexpected activity, or when they are removed from water. The response usually involves increases in stress levels which will have an adverse effect on the welfare of the fish and also the flesh quality. It is therefore essential that, regardless of the slaughter method employed, fish must always be prepared, handled and delivered to the stunning point in a humane way.

Withdrawal of food prior to slaughter

The withdrawal of food for a number of days before slaughter is believed by some producers to have beneficial effects on the final product in terms of food hygiene and flesh quality. Current research suggests that 72 hours maximum is sufficient for complete emptying of the gut whilst minimising adverse welfare implications. This period should not be exceeded.

Where cleaner fish, such as wrasse, are used, these should be removed before food is withdrawn in order to avoid predation.

Crowding

Crowding is the term given to the process in which the area available to the fish is reduced, usually in order to facilitate the removal of fish from the pond or cage. Net 'crowd pens' are typically used for the process. Crowding can cause suffering and stress for the fish but, with correct management and careful handling, it is possible to keep stressors to a minimum.

Unless crowding is carefully controlled, fish will be exposed to a decrease in oxygen levels, a rapid rise in stocking density, an increase in light intensity and abrasion from the net or other fish. For these reasons there must always be at least one member of the slaughter team monitoring the crowd pen. It is important that this person, who is solely responsible for the welfare of the fish, can recognise problems and knows what action to take to resolve them.

Where possible, a crowd pen should be set up so that fish can swim against the tide towards the inlet pipe and preferably into a shaded area. Taking advantage of the natural behaviour of the fish in this way will encourage movement with minimal stress.

Managing a crowd pen

Crowding should always be done in a gradual manner. It is not acceptable to pull nets tight, leave them and return to pull them in tighter. If any signs of escape behaviour are seen and movements become more vigorous, the nets should be loosened until the behaviour of the fish calms down. However, this can still cause problems, regardless of how quickly the nets are loosened and the fish return to more normal activity: the stress experienced will have an effect on the eventual flesh quality. There are two main concepts behind the shape of a crowd pen: either narrow and deep (the preferred option) or wide and shallow. Overhead covering nets can be used on either to reduce light levels and to protect against aerial predators.

Deep nets

Deep, narrow nets can provide a more relaxed environment for the fish. Due to the smaller surface area, the light intensity is similar to that found in the fish’s normal environment. As the net is not kept taut, fish have more freedom for movement without damaging themselves. See Figure 1 for an illustration of a deep net.

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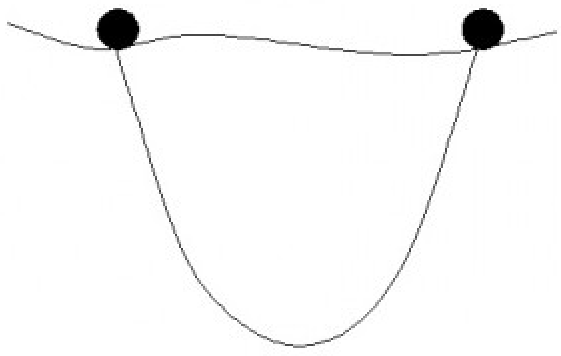

Figure 1: Deep net

Shallow nets

Large surface areas in the crowd pen expose fish to brighter light levels than normal, which can result in higher activity levels. This, combined with the taut net sides, can increase the amount of carcase damage. Even slight movements of a tight, shallow net can have a significant negative impact on fish, as a large number are in close contact with the net. This means it is especially important for the type of net shown in Figure 2 to be brought in very slowly and gently, rather than suddenly.

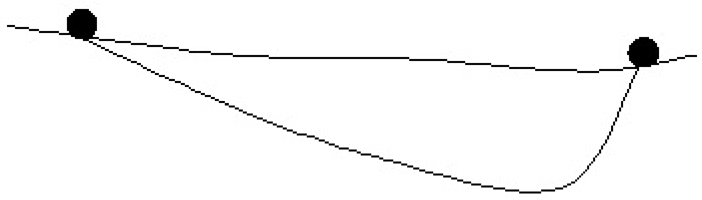

Figure 2: Shallow net

Raceways

As with crowd pens, the area in which fish are held in a raceway must be decreased gradually with no sudden or rapid movements which may cause excitement to the fish. Rapidly decreasing the area available to the fish forces them closer together and may increase stress levels.

Water quality

The water quality in a crowd pen can deteriorate in a short time. It is essential that clean and well-maintained nets are used for crowding and that the oxygen level is monitored. If the oxygen level falls below the critical level of 6mg/l then oxygen should be added to the water to alleviate stress. The addition of oxygen to the crowd pen has two advantages: it replenishes the oxygen content and attracts fish towards the diffuser. When correctly positioned it can help to move fish, passively, towards the exit. Careful consideration should be given to the type of diffuser chosen to release the oxygen, in order to ensure the oxygen level is suitable throughout the entire harvest.

Monitoring a crowd pen

Fish must always be crowded at an appropriate rate for the subsequent stunning operation. Where possible, fish should not be kept crowded for more than two hours. If the system requires longer than this, the process should be reviewed and the way in which the pen is split re-examined. Figure 3 shows how calm the water should be during crowding. Figure 4 shows a crowd pen that has been brought in too quickly, causing the fish to swim and burrow. A simple scoring system can be used to help train staff to recognise acceptable levels.

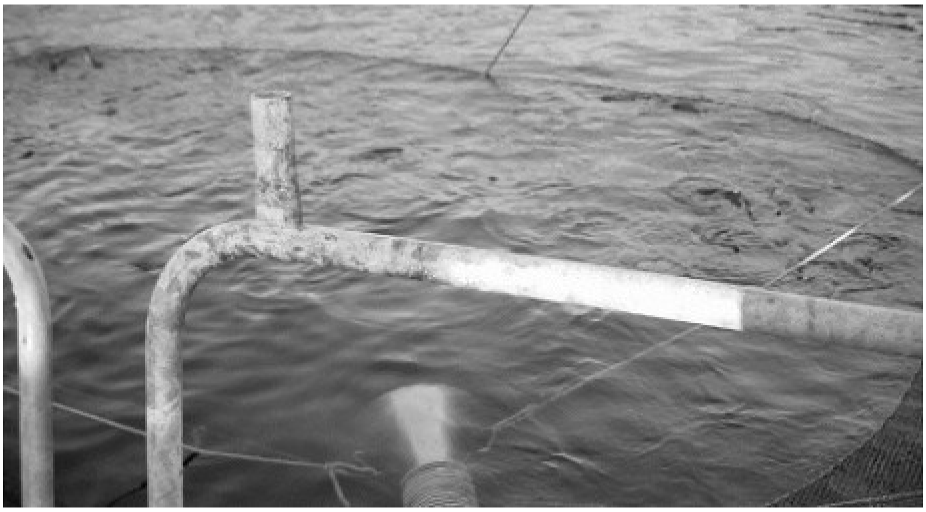

Figure 3: Good crowd rate (note the water is calm)

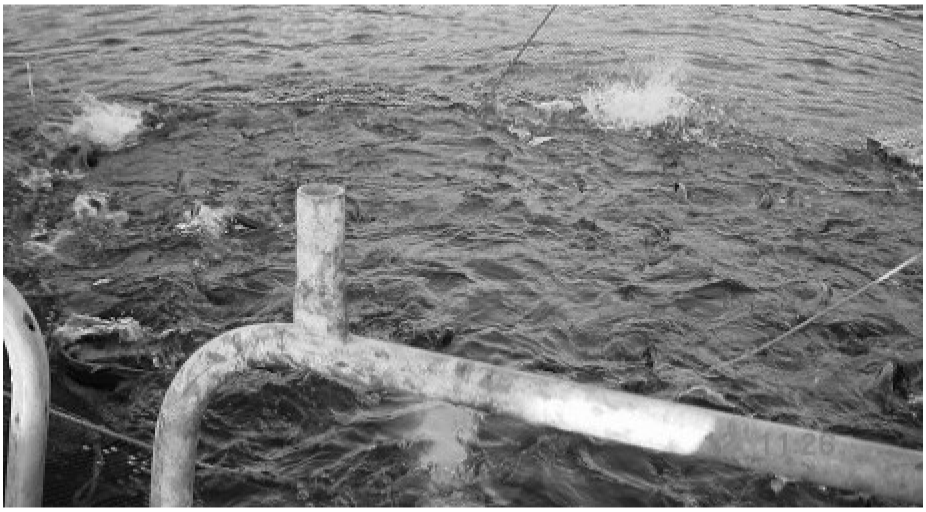

Figure 4: Fish have been crowded too quickly (note the splashing of the water surface)

Monitoring a Crowd Pen

The shown in Table 1 provide a simple scoring system for various behaviours that can be used in training all members of staff so they can assess the crowd behaviour objectively.

It is important to keep the stocking density as low as possible during crowding, whilst ensuring a sufficient number of fish reach the stunning table at the required rate.

Crowding should be carried out slowly and gently and always under the control of a trained operator with sole responsibility for the crowd pen.

Table 1 Behavioural categories of fish during crowding

Level	Crowd Behaviour
1	No vigorous activity, occasional fins breaking the surface of the water.
2	Fins and part of the fish above the water over the whole surface of the crowd.
3	Fins and part of the fish above the water over the whole surface of the crowd. Some burrowing, gasping and vigorous activity in parts of the crowd.
4	The whole surface of the crowd vigorously burrowing, gasping and splashing.
5	The whole surface of the crowd boiling with violent splashing.

At all times you should be aiming for Level 1.

Levels 3, 4 and 5 are unacceptable and the crowding procedure should be reviewed and altered as appropriate.

Removal from Water

The majority of methods for stunning and killing involve removing fish from the water alive and conscious. Stress is inevitable once they are out of their natural environment. Whilst a brief period out of water is often difficult to avoid, fish must not be left in air prior to slaughter for more than 15 seconds. Beyond 15 seconds they will display more pronounced aversive behaviour and become more difficult to handle.

Regardless of the method of stunning and killing, the method for delivering fish to the stunning point should be suitable to provide fish at a similar rate to the stun rate so that they are not exposed to air for longer than necessary. The three most common delivery methods are hand nets, pumps and braille nets. Hand nets are only suitable for small numbers of fish.

To reduce the amount of time fish are exposed to air, they should be removed from water, or dewatered, as close to the stunning point as possible. The dewatering process should be designed to move fish gently and promptly to the stunner in the correct orientation. Out of water, fish are more susceptible to injury and therefore equipment needs to be designed to reduce impact points and the possibility of bruising.

Live fish must not be out of water for longer than 15 seconds

Rested harvest/anaesthetics

In some countries an aquatic anaesthetic, with the active ingredient iso-eugenol, is used to sedate fish prior to their removal from the water. This anaesthetic, which can be used immediately prior to slaughter, is applied in solution to the water. The fish are then introduced into the anaesthetic solution, where they remain for 30 minutes. Once fully sedated, they are removed from the water and then percussively stunned. Alternatively, they remain in the water and are introduced into carbon dioxide saturated water.

This type of harvest is known as 'rested' harvesting. 'Rested' harvests can have the added advantage of improved flesh colour, firmness and appearance, reduced gaping and a delay in the onset and severity of rigor when compared to conventional harvesting methods. These advantages result from the lower levels of stress experienced by the fish. Anaesthetic concentration, exposure time, water temperature and fish size and weight are factors that need to be carefully considered when using this method. Currently this method is not available in the EU as there are no anaesthetic products licensed for use.

Pumps

Pumps used to move fish from the crowd pen should be well maintained to avoid damage to the fish. The pump determines the speed and rate at which fish are delivered to the stun point, therefore careful consideration is needed when deciding which pump is most suitable.

Air lift pump

The air lift pump works by bubbling air up into the pipe, lifting the fish and the water with it. The system needs to be set-up in deep water to generate the correct pressure. Fish are supplied in a continuous flow to the stunning point. The efficiency and effectiveness of this pump is dependent on precise set-up and operation and it is therefore important that all manufacturer's instructions are followed.

Venturi pump

Jets of water cause a rapid flow of fish through the pipe. These pumps are capable of delivering fish in a continuous flow down long pipes. Unlike air pumps they can be used in relatively shallow water and are easier to run, although they tend to be more expensive to buy.

Vacuum pump

These supply fish in batches and are not suitable for pumping fish long distances (over 30 metres). When using these pumps it is difficult to monitor the fish as they cannot be seen.

Dual action pumps

These also work using a vacuum system but involve two pumps working in tandem, resulting in a continuous supply of fish to the stunning point.

Pipes

Pipes are often used to transport fish from the crowd pen to the stunning point. They should always be as short as possible. The time fish spend in the pipe should be kept to a minimum, and never be more than two minutes. Any delay can have an adverse effect on the fish and increase stress levels. At the end of each harvest, and during any breaks, the pipes must be flushed through to ensure there are no fish left in the pipes. A sponge ball of suitable size can be used to ensure effective flushing of the pipes.

Brailling

Braille nets must always be used with a lining inside the net. This lining helps keep water within the net and provides some protection to the fish during removal from the crowd pen; it also minimises damage caused by abrasion of the fish against the nets. Brailles should never be overfilled as this will cause excessive pressure on the fish, causing damage or death. The braille must be well maintained and regularly checked for damage. The mesh size must be appropriate for the fish being brailled and there must be no rough edges on the sides or chains which may damage the fish as they are dragged through the crowd pen. The braille must be moved slowly and lowered to make contact with the unloading table before the fish are released, otherwise fish may be injured on exit. See Figure 5 for a diagram of potential welfare risks associated with the use of braille nets.

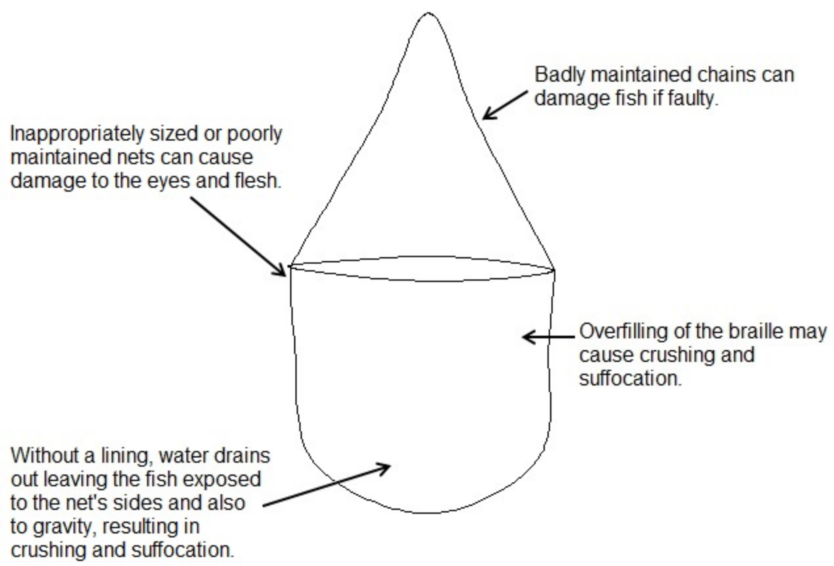

Figure 5: Braille net risk areas

Wellboats

Whilst the use of wellboats can have welfare advantages, their use can also compromise the welfare of fish if the conditions within the wellboat are not carefully controlled. Wherever possible, wellboats should be operated on an open-valve system. In cases where the boat has to travel with the valves closed, such as when the fish are being chilled or the boat is in close proximity to other fish farms, then the carbon dioxide level should be closely monitored. During this time, carbon dioxide strippers must be used to help maintain satisfactory water quality.

The extra handling required when using wellboats can be stressful. Suitable pumps, capable of delivering fish into the boat safely and quickly, should be used (see 'Removal From Water'). Crowding should not be started until the wellboat's arrival time is confirmed.

Water quality must be regularly monitored during the transport of live fish. The following table (Table 2) identifies the acceptable limits for fish during transport.

Table 2: Humane parameters for wellboat transport of fish[1]

Parameter	**Acceptable Level**
Carbon dioxide	Must be kept as low as possible[2]
Oxygen	Not below 6mg/l
Ammonia	Not above 0.0125mg/l
Rate of chilling	Not quicker than 1.5°C/hour
Temperature range of well water	Within 4-16°C
pH	Within pH6.5-pH8.0

[1]Adapted from Standards for Farmed Atlantic Salmon, RSPCA 2004

[2]At present the Council of Europe recommends 20mg/l maximum for carbon dioxide levels in cages. However, in wellboats levels can rise to over double this. Currently there is little research or practical evidence to suggest this level has an adverse effect on the fish during transport. Until new information is published the HSA recommends that levels are kept to a minimum at all times.

It is essential that trained and experienced staff monitor fish behaviour, in addition to the water quality parameters, throughout the journey to ensure that a high level of welfare is maintained. Before fish are pumped into the wellboat, there must be sufficient water in the well to prevent injury to the first fish to enter.

Boat operators should be fully trained and know:

- How to load the boat safely;
- How to monitor the fish during the journey – by visual monitoring of behaviour and by gas levels;
- How to crowd the fish off the boat;
- The potential welfare issues (Figure 6);
- The capacity of the boat, which is dependent on the size of the fish.

There should always be contingency plans in place in case the boat cannot be unloaded for any reason or becomes stuck within a closed-valve area.

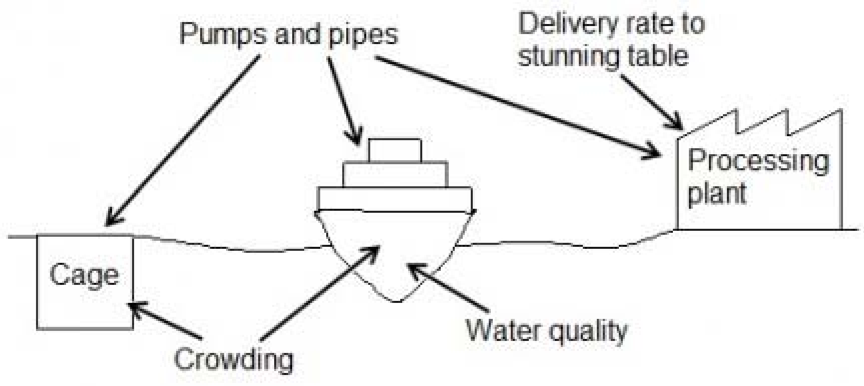

Figure 6: Potential stressors when using a wellboat

Percussive Stunning

The objective of percussive stunning is to induce immediate insensibility by administering a severe blow to the skull of the fish. The fish must then remain unconscious until death. The term 'percussive' describes the principle of striking the skull with a solid instrument, i.e. the forcible striking of one solid body against another.

Physiological effects of percussive stunning

When a fast, heavy blow is correctly applied to the skull it produces a rapid acceleration of the head, causing the brain to collide against the inside of the skull. This causes disruption of normal electrical activity resulting from a sudden, massive increase in intra-cranial pressure followed by an equally sudden drop in pressure. The consequent damage to the nerves and blood vessels causes brain dysfunction and/or destruction and impaired blood circulation. The duration of insensibility depends on the severity of damage to the nervous tissue and the degree to which the blood supply is reduced.

The initial effect on fish is immediate insensibility, accompanied by what is known as 'tonic' activity: the fish becomes rigid, loses opercular movement, its mouth opens, eye reflexes are lost and a ring of muscle near the pectoral fin contracts and bulges for a short period of time. This period of rigidity can vary in length depending on the force of the blow, as well as the age and species of fish. When a fish is hit with sufficient force and in the correct position the stun is normally irreversible. However, if insufficient force is used, or the position is not ideal, it may recover to some degree. If there is any uncertainty as to whether a fish is effectively stunned, it should be re-stunned immediately.

An effective stun can be defined as one which renders the fish immediately unconscious and insensible to pain. This condition should last until death.

Basic physics

When a severe blow is rapidly administered to a fish's skull there is a transfer of energy from the percussive instrument to the head and from there directly to its brain, resulting in immediate unconsciousness.

Effective percussive stunning is achieved by delivering the maximum amount of energy to the correct part of the fish's brain, in the shortest possible time.

Practical use

When using percussive methods, fish should be presented at such a rate that they are only on the table for a maximum of a few seconds prior to being stunned. This is more important for tables which do not hold water, as this will minimise the duration of stress experienced by the fish and will make them easier to handle. When left on the table for too long, fish will start to flip and become more difficult to place in the stunner correctly.

Fish should not be kept out of water for longer than 15 seconds before stunning. Where procedures result in longer periods than this, the rate of delivery needs to be slowed down to a rate appropriate to the stunning process. In some percussive stunning systems fish are electrically stunned before removal from the water so that they are unconscious, and easier to handle, during the process leading to percussive stunning.

Contingency plans should be made for occasions when there is an equipment failure or other unexpected occurrence which could result in fish being left out of water or in the stunning machine. Manual percussion and gill cutting may be a suitable back up in these instances.

It is essential that all equipment is maintained and repaired as necessary to ensure that all fish are humanely stunned. Failure to maintain equipment will reduce its efficacy.

Percussive Equipment

For many years the priest (Figure 7) has been used as an effective way of stunning fish, but in order to be humane it relies heavily on the strength, skill and consistency of the slaughter team. The subsequent development of automated systems in the 1990s mechanised the stunning operation, introducing greater consistency. Research, showing that sufficient percussive force alone causes insensibility and indeed death in the majority of fish, has led to the development of individual stunners (Figure 8) and flow-through machines (Figure 9) which deliver a non-penetrative blow to the fish.

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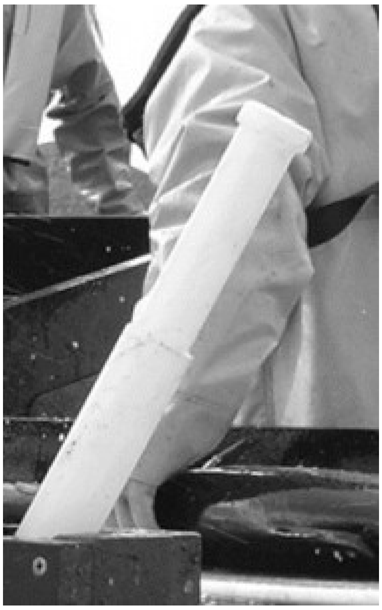

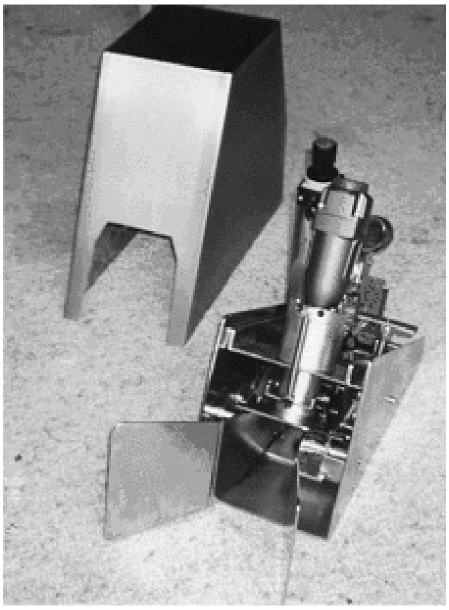

Figure 7: Priest

Figure 8: MT4 stunner

Figure 9: SI5 stunning machines

Manual percussive stunning

The priest still remains a humane option for slaughter when used appropriately. However, due to the pressures associated with a commercial harvest, it is very difficult to maintain enough accuracy to ensure 100% effective stunning with the first blow of the priest. Therefore it is advised that for commercial harvesting this method of stunning is used only as a back-up, for casualty fish or very small numbers.

Automated percussive stunning

The most commonly used automated stunning machines are powered by compressed air with an air pressure range of 90-120 p.s.i. (6-8 bar). 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.

More recent models avoid the need for the operator to handle the fish as the design of the table encourages fish to swim into the entry channels. These tables need to be set up carefully and adjusted for the site's individual circumstances. They should always be used in line with manufacturer's guidelines. Incorrect set-up will not encourage the fish to flow through and intervention will be required.

A percussive stun may also be delivered by a handheld captive-bolt device designed for poultry. This will ensure sufficient impact energy is delivered to each fish, but may cause unacceptable carcase damage in some species.

To enable back-up stunning it is imperative that all staff stunning and bleeding have quick access to a priest and that all staff are properly trained and competent in its use.

Limitations of automated machines

The automatic systems currently available have been developed for large salmonids such as salmon and trout (over 1kg). They are not suitable for fish with a significantly different body shape to these fish. Problems can arise when the machines are used for deformed or mature fish as they do not always activate the trigger at the correct time, resulting in incorrect positioning of the blow.

Effective Percussive Stunning

Amongst other things, 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 thinnest. In salmon and trout this found directly above and slightly behind the eyes (Figure 10). The blow does not have to penetrate the head to be effective.

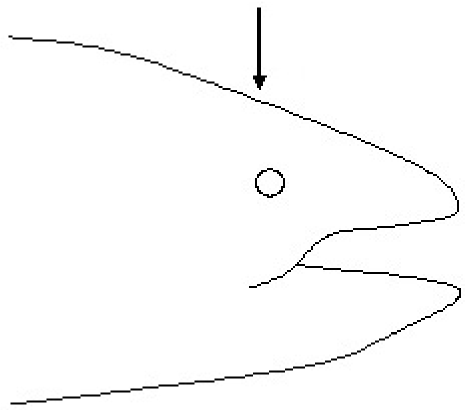

Figure 10: Position for effective percussive stunning of salmon and trout

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Signs of an effective percussive stun:

- No opercular movement;
- No eye movement;
- Bulging of muscle ring near pectoral fin.

Failure to stun

If a fish is not properly stunned it must be re-stunned immediately and bled without delay. When using a priest there is a risk that the blow may not be positioned correctly. If positioned too far back, not only will this fail to produce an effective stun but it can also damage the flesh. If hit too far forward it may not produce an effective stun.

Mature and deformed fish can present problems when using automated mechanical stunning systems as they may not correctly activate the trigger. When these fish are found at the stunning point, consideration should be given as to whether to use the machine or a priest. If the machine is used, fish should be double checked for an effective stun. If there is any doubt that a fish has not been stunned effectively, the priest should be used to repeat the stun.

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 operator's health and safety. Operators should not have to concentrate on keeping their balance, or to bend excessively when using the equipment, as this can lead to operator tiredness and inaccurate stunning, leading to poor welfare and damage to the fish.

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.

Humane slaughter using percussive stunning is dependent on:

- The use of an appropriately trained, competent slaughter team;
- Selection of suitable equipment/staff capable of producing an effective stun;
- Correct setting of the equipment;
- Correct delivery of the blow;
- Recognition of an effective/ineffective stun;
- Back-up stunning equipment being immediately to hand;
- Operator's knowledge and competence in the use of back-up equipment;
- Regular maintenance and cleaning of equipment, i.e. daily.

Electrical Stunning

The general principle of electric 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 (typically 30 seconds for trout) the fish will die of anoxia before the brain is able to recover sensibility.

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The electric current also causes spasms in the fish muscle which can, under some circumstances, result in haemorrhages and other carcase damage. Stunning conditions therefore need to be carefully designed to ensure that the process causes neither pain nor carcase damage and that recovery before death is not possible. These conditions are known to vary widely between different species of fish. This section explains some basic electrical principles and how they apply to electrical stunning and killing of fish.

- An electric stun must cause unconsciousness within one second of application and the unconsciousness must last long enough to ensure that the animal does not regain consciousness before dying.

There are electrical stunning systems which stun fish whilst they remain in water and others which stun fish out of water using electrodes which make direct contact with the fish ('dry' or 'semi-dry' systems). Both methods have pros and cons. Stunning fish in water reduces the stress of exposure to air and light and reduces the likelihood of mechanical damage to the skin. However, 'dry' or 'semi-dry' stunning systems have a more consistent effect on the fish and can result in less electrical carcase damage.

In some instances, electrical stunning is used prior to application of a percussive stun. This renders fish unconscious for the duration of the handling process prior to percussive stunning.

Current, voltage and conductivity

The flow of electricity through an object is known as the current and is measured in amps (A). the current is related to the number of electrons that pass in one second. Current can be either direct current (DC), as from a battery, which flows only in one direction; or it can be an alternating current (AC), from the mains supply or a generator, where the direction of the current flow changes many times per second. The driving force or pressure causing the flow of current is known as the voltage and is measured in volts (V).

The conductivity of a material is a measure of how easily an electrical current can pass through it. Conductivity is measured in micro-siemens (µS/cm). River water typically has a conductivity in the range 50-700µS/cm, while sea water may have a conductivity of up to 50,000µS/cm.

Frequency

The frequency of a current is how many alternating cycles of current occur per second. This is measured in cycles per second, or Hertz (Hz). Mains electricity has a frequency of 50Hz (i.e. 50 cycles per second). The frequency of the current determines the effect it has on fish.

Stun parameter selection

When fish are electrically stunned whilst they remain in water, electric current 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. If the water tank holding the fish is rectangular in shape and the electrodes cover two opposite walls of the tank then the electric field in a tank can be calculated as the difference in voltage between the electrodes divided by the distance between them. This is specified in units of volts per centimetre. The strength of the electric field required to stun fish is affected to some extent by the conductivity of the water. Trout in river water typically require 3V/cm whereas Halibut in seawater can be effectively stunned using 1V/cm.

As already mentioned, the effect of electricity on the fish is influenced by the frequency. Frequencies close to 50Hz have a greater effect on both the fish brain and muscle than higher frequencies, resulting in an effective stun. However in trout and salmon, due to the effect on muscle, a frequency of 50Hz is likely to cause unacceptable carcase damage. A higher frequency, at a slightly higher electric field strength, can still achieve immediate insensibility whilst also minimising carcase damage. A frequency of 1000Hz has been found to be suitable for trout. Higher frequencies above 1000Hz should not be used since the fish may not be rendered immediately unconscious and insensible to pain.

Effects of Electricity

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. This means that fish die through lack of oxygen whilst still in an unconscious state. This section of the guide describes what happens to fish during electrocution, detailing the parameters required to ensure that each stun is immediate and effective. Electronarcosis by itself is not suitable for fish that are not percussively stunned or bled immediately after stunning. This is because they would recover from the stun and be fully conscious during processing.

Electrocution

The purpose of electrocution is to kill by causing immediate insensibility and loss of consciousness and preventing the respiratory system working effectively. When held in an appropriate electric field for sufficient time the brain is severely damaged and the breathing reflex is abolished. Fish therefore die due to lack of oxygen.

When a fish is electrocuted, it becomes rigid with slight body tremors, then gradually relaxes and shows no further movement. In practice, fish are killed by electrocution using equipment which exposes the fish to an electric field that causes an immediate stun and which then, through extended exposure, results in permanent and fatal brain damage. Following electrocution, some fish will show strong sporadic muscular spasms in which the mouth gapes and gills flare whilst they are unconscious. Following each spasm the fish relaxes. These spasms normally cease within five minutes. They are uncontrolled irregular movements which should not be confused with regular movements indicative of a return to consciousness.

In order to stun and kill fish with electricity, sufficient current at a suitable frequency must pass through the brain for sufficient time. 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. These factors therefore need to be carefully considered when selecting equipment parameters.

Signs of an effective stun:

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

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Animals should be regularly monitored during operation of the stunning machine. **All** fish should be effectively stunned on exit from the stunner and remain so until death. Signs of recovery should be looked for when fish are on the bleed table. Regular monitoring allows problems to be identified and responded to quickly.

Inappropriate stunning

If an electrical field of inappropriate voltage, frequency, current or duration is applied to fish they may not be effectively stunned and may instead be paralysed whilst still conscious. Under these circumstances the fish cannot show typical pain responses or escape behaviour. Alternatively, exposure to a sufficient current, but for insufficient time, will result in a stun with only a limited period of insensibility and a high risk of recovery before death.

Stunning equipment must display the stun parameters being applied to the fish in a way that is clearly visible to the operator. The equipment should be designed to provide a visible or audible warning if the correct parameters are not being delivered.

Corrosion can build up quickly on the electrodes of the stunner, especially in saltwater systems. This can impact on the amount of current delivered to the fish and result in an ineffective stun. Regular cleaning and maintenance of electrodes is essential.

It is essential that all equipment is maintained and repaired as necessary and in line with manufacturer's guidelines to ensure that all fish are humanely stunned. Failure to maintain equipment will reduce its efficacy.

Two-stage Electrical Stunning/Killing

Rapid and permanent insensibility can be initiated in trout, without causing significant carcase damage, by using a two-stage electrical stun. Following an initial stun, in an electric field of 2.5V/cm at 1000Hz, fish are held within an electric field of 0.5-1.0V/cm with a frequency of 50Hz for 30-60 seconds to produce permanent insensibility (for water conductivity of 500µS/cm). This significantly reduces the power requirements of the machine in comparison with single-stage machines, lowering the capital cost of the equipment and enabling a wider range of mechanical configurations to be used.

To achieve humane stunning with a two-stage method it is necessary to ensure that:

- Insensibility is established rapidly;
- An irrecoverable stun is achieved using a low-voltage maintenance stun.

Fish stunned for a brief period of time can quickly regain full consciousness. It is therefore important that fish are moved into the low-voltage maintenance stun electric field within a few seconds.

The introduction of a pause between the two stages can reduce the effectiveness of the stun, but is necessary in continuous flow systems to prevent interference between the two electric fields.

Conductivity

The figures mentioned above are for water conductivities of 500µS/cm. When water of different conductivity is used, electric fields need to be adjusted to ensure that every fish is humanely stunned and killed.

The conductivity of water differs greatly across the country and can have a significant effect on the required field strength. An irrecoverable stun can be achieved for freshwater fish under the conditions detailed in Table 3.

Table 3: Lowest tested electrical field strengths found to produce a permanent stun when using a frequency of 1000Hz AC

Water conductivity (µS/cm)	**50**	**100**	**160**	**300**	**500**	**1000**
60 second exposure (V/cm)	5	5	5	2.5	2.5	2.5
30 second exposure (V/cm)	6.3	5	5	5	5	2.5

Careful observation of the fish and their reactions must be made during the initial setup and regularly throughout the operation to ensure humane stunning.

Operator considerations

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.

Contingency plans should be made for occasions when there is an equipment failure or other unexpected occurrence which could result in fish being left out of water or in the stunning machine. Manual percussion and gill cutting may be a suitable back up in these instances.

Signs of Recovery

Whichever method of stunning/killing is used, it is important that staff are able to recognise the signs of an effective and ineffective stun as shown in Table 4. These signs vary depending on the species. It is essential when deciding on a method to check that it is reliable and effective for that species. A number of tests can be performed on salmon and trout to check whether they are conscious or unconscious. These are outlined in the following table.

Table 4 Indicators of a successful stun

Reflex	Conscious	Unconscious
Eye roll	Eyes remain on the same plane as the fish is rotated.	Eyes do not move as fish is rotated.
Breathing	Regular movement of the operculum.	No/random movement of the operculum.
Swimming	Fish constantly swimming.	No movement or attempt to swim.
Equilibrium	Fish will right itself when knocked.	Fish will remain upside down.
Prick*	Fish may move away from the stimulus.	Fish will not move away from the stimulus.
Electric current*	Fish may move away from the stimulus.	Fish will not swim away from the stimulus.

*These tests do not always provide conclusive results: some fish may not show a reaction to these stimuli when fully conscious.

The most reliable and effective signs of recovery for salmon and trout are the return of the eye roll reflex (Figure 11) and the breathing reflex. Rhythmic movement of the operculum should be looked for, but take into account that apparently random and irregular movements can be, but are not usually, a sign of recovery.

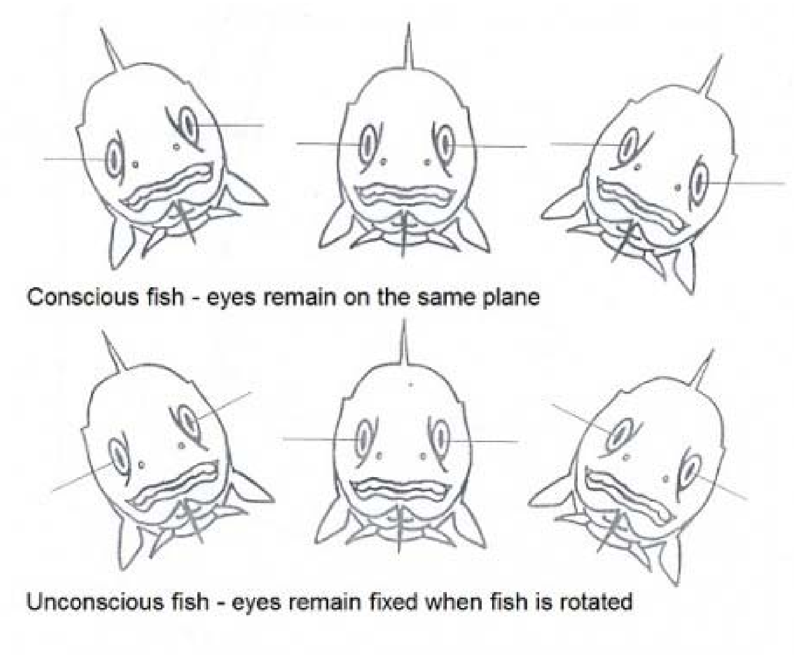

Figure 11: Signs of recovery in fish - the eye roll reflex[1]

[1] Adapted from 'Protocol for assessing brain function in fish and the effectiveness of methods to stun and kill them'. SC Kestin, JW van de Vis, DHF Robb. *The Veterinary Record, March 9 2002*.

Unacceptable Methods

Recent work on the perception of pain in fish has shown that they have mechanisms for pain perception like those in other vertebrates, including mammals and birds. They should therefore be afforded the same welfare considerations as any other animals kept for food. Therefore the HSA does not recommend the use of any of the following methods: death in ice slurry; live chilling; gill cut without stunning; or carbon dioxide narcosis. If these methods are currently used as standard practice, they should be replaced as soon as possible with a more humane method.

Death in ice slurry

This process involves fish passing over a de-waterer and into ice slurry. The fish are left until they die through lack of oxygen. In some cases, loss of consciousness can take over nine minutes. When fish are placed in ice slurry it is difficult to use normal reactions (such as escape behaviour or 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. The long period for the onset of unconsciousness with this method could result in fish being bled and eviscerated whilst still conscious, but immobile. If fish are not left for long enough in the ice slurry, or are not bled out effectively, they are likely to recover and regain muscle movement and brain function as they warm up.

Live chilling

This method immobilises fish and reduces the carcase temperature to allow quicker processing. Fish are introduced to temperatures of 2-6°C, where they may show violent movement and escape behaviour. This movement gradually subsides as they become exhausted and/or immobile. After about 30 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.

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.

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 approximately 5 minutes. This is due to 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, i.e. on the table or in the bin.

High concentrations of carbon dioxide must be used to maintain a pH level of 4.5 for a period of at least ten minutes, to cause unconsciousness in every fish before the gills are cut. If removed before then, or if the pH is altered, signs of recovery may be seen, especially when the gills are cut. It is essential when using this method that the gas concentration is measured and replenished as required.

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Flesh Quality

Although this guide is focussed on fish welfare, post-mortem flesh quality can give a valuable insight into pre-slaughter treatment of the fish. Many flesh quality issues can be greatly reduced by improving pre-slaughter handling. The following section details some common flesh quality problems that can be indicative of welfare problems.

Early rigor

If fish are stressed during crowding they will deplete their energy reserves prior to slaughter and rigor will occur much sooner than when the fish have been crowded carefully. With early rigor the flesh can be difficult to process, reducing both the yield and flesh quality and resulting in a shorter shelf-life. A delayed rigor allows processing to take place before rigor occurs and avoids these associated problems. However, early rigor can also occur when the health status of fish is low, so the reasons for early rigor need to be considered carefully.

Gaping

Increased stress and activity immediately prior to slaughter results in increased lactic acid levels in the muscle tissue. This causes the breakdown of connective tissue between the muscle fibres, resulting in gaping of the flesh. Not only does this make it difficult to cut the flesh, reducing the yield, but it also reduces the appeal of the product to the consumer.

Bruising

This can be seen with percussive stunning, particularly when a priest is used. When slaughter teams become tired the degree of accuracy can deteriorate, resulting in blows behind the head and on the neck, which can cause bruising.

The way in which the fish are delivered to the stun point can also cause bruising: if fish fall or are dropped from the dewaterer or braille, or if poorly maintained and operated pumps and pipes are used.

Haemorrhages

Haemorrhages are caused by blood leaking from blood vessels into the flesh. They are typically seen in the tail region if a fish has been lifted or held tightly by its tail prior to slaughter. Haemorrhages downgrade the fillet and result in a shorter shelf-life.

Haemorrhages can also be caused by poorly-positioned manual percussive stunning and by electrical stunning if the correct parameters have not been used.

Scale loss

When fish are crowded, their environment changes significantly. In a well-run crowd this change is minimal and will have little effect on the fish. However, if the crowd is brought in too quickly, the net pulled too tightly, or the fish are left crowded for too long, they may struggle and damage themselves against the nets and other fish as they try to escape. This can result in a loss of scales as well as other damage. Scale loss can also happen during other procedures, such as grading, but by

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examining the fish it should be easy to determine when the damage occurred, i.e. whether the damage is recent or not.

Eye damage

Eye damage occurs during percussive stunning when the blow is position incorrectly and either hits the eye directly or close enough for the eye to rupture. Eyes can also be affected by poorly maintained nets.

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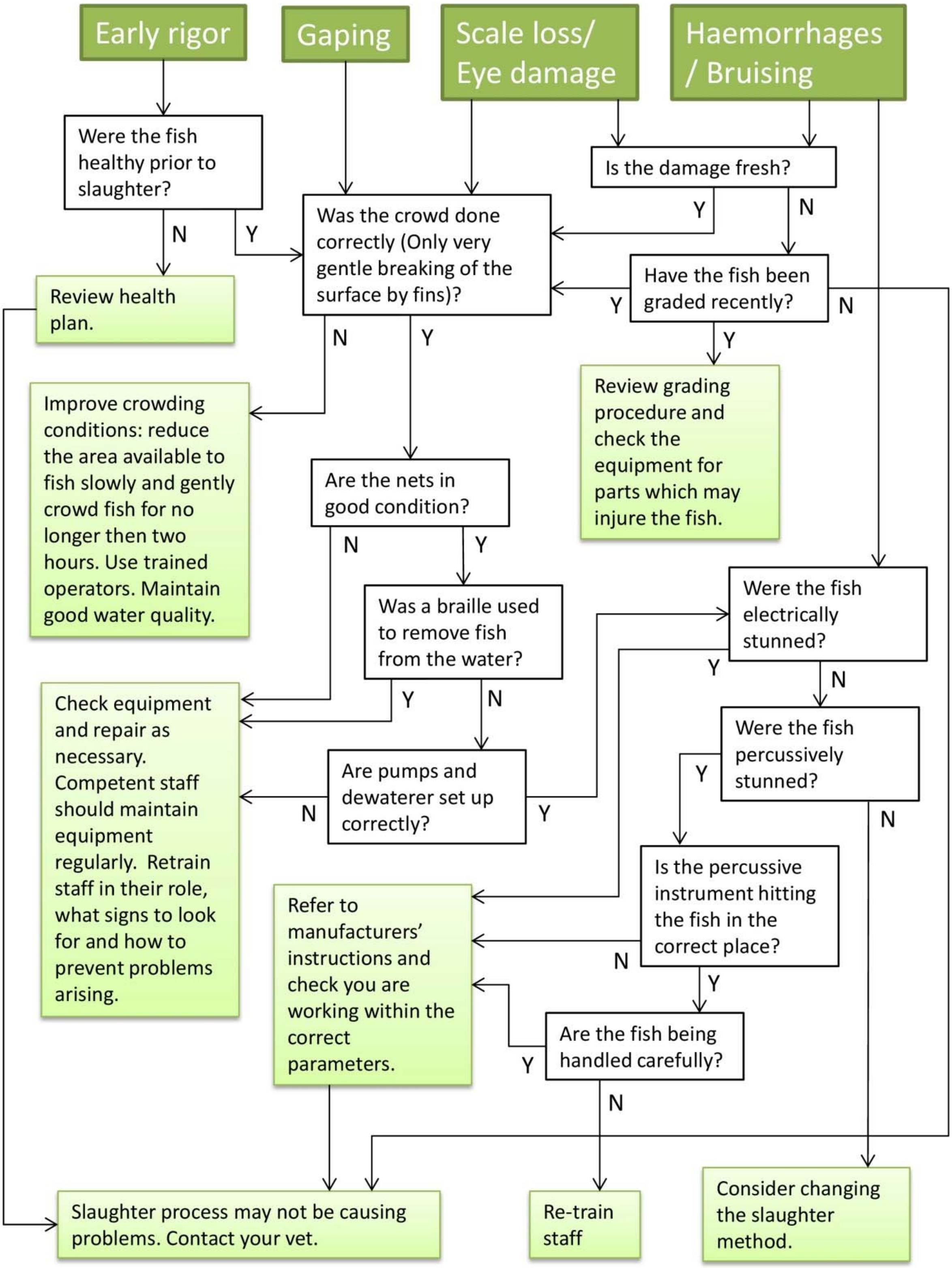
Troubleshooting the Harvest



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