Improving the welfare of farmed pangasius at slaughter

COMPASSION in world farming Food Business

Compassion in World Farming's recommendations

All animals killed for food should be slaughtered humanely. This means that they must be effectively stunned, rendered instantaneously insensible, and remain unconsciousness until death supervenes.

For *Pangasius bocourti* and *Pangasius hypophthalmus*:

- The use of a single method (i.e. electrocution) that both stuns (instantly) and kills is recommended above other methods where possible, however, given the species' capacity to withstand long periods of hypoxia an electrical stun followed by decapitation, spiking/coring or gill cut* is currently the most humane method for pangasius.
- Percussive stunning followed by decapitation or gill cutting is acceptable[1] provided that the stun is effective and lasts until death supervenes (i.e. the fish do not regain consciousness).
- Repeated ineffective percussive stunning and leaving pangasius to asphyxiate in air are unacceptable killing methods and must be phased out.

[i] There is currently urgent need for research in this area to ensure that the electric stun lasts longer than bleed out time

Introduction

Fish are sentient beings capable of feeling pain and suffering[2]. As such, they are entitled under animal welfare law to a humane slaughter that minimises suffering and renders them unconscious as quickly as possible, a state that must extend until death. The guidelines of the World Organisation for Animal Health (OIE) on the stunning and killing of farmed fish[3] provide information on humane methods of slaughter outside the EU, however, many producers are using slaughter methods considered inhumane by the OIE. Subsequently, food companies are increasingly incorporating fish welfare into their corporate social responsibility policies and practices. This document provides information on the humane slaughter of pangasius (*Pangasius bocourti* and *Pangasius hypophthalmus*) including:

- an overview of the welfare issues associated with pre-slaughter fasting and handling,
- an overview of the main methods of slaughter in use commercially,
- recommendations for corporate animal welfare policies and practices,
- methods to assess welfare at slaughter.

Information on *Pangasius bocourti* and *Pangasius hypophthalmus* are combined in one document as these are often farmed and slaughtered using the same methods although *P. bocourti* are less commonly farmed as they grow more slowly and are more expensive to produce[3]. However, these are different species with different behavioural and physiological responses to stress[4], therefore specific information on each species is given where available.

Pangasius pond farm in Vietnam

Pre-slaughter procedures

Humane slaughter of fish can only be fully achieved by minimising stress and injury during the pre-slaughter phase as well as during the killing procedure itself. Crowding, and moving of fish from home/holding pens to the place where they will be slaughtered can be very stressful and can take several hours.

Fasting

Farmed pangasius are fasted before slaughter in order to reduce the metabolic rate (and therefore lower the oxygen demand) and the physical activity of the fish before handling and live transport. It also serves to empty the digestive system prior to killing, which reduces water fouling (undigested feed, faeces and microorganisms) during transport, and aids hygienic processing. Fish should never be fasted for presumed flesh quality benefits.

Gut emptying times of fish are dependent on water temperature (with gut emptying taking longer at lower temperatures). There is relatively little research evidence measuring how long pangasius should be fasted for gut emptying and good welfare but considering the warmer temperatures these fish are farmed at, it should be no longer than 48 hours. Whilst fish in the wild may not feed for long periods, farmed fish receive feed at regular intervals therefore periods without food are likely to negatively impact welfare.

It is usual for a whole pond or cage of pangasius to be harvested at the same time. The harvest process must be managed so that withdrawal of food prior to slaughter does not exceed 48 hours and all fasted fish must be slaughtered within this timeframe.

Crowding

To begin the slaughter process, pangasius are harvested from a variety of rearing environments; ponds (on land), nets (along riverbanks) and cages (in rivers). Harvesting is carried out by crowding the fish and then netting or pumping them onto transport vessels. Where fish are reared in cages, the netting is raised by hand to crowd the fish before they are removed from the water. Net pens are harvested by seine netting (a vertically hung net) on spring low tides[5,6]. Pangasius species kept in ponds are harvested following partial tidal gravity drainage and pumping[5]. In general, the entire pond or cage is harvested at the same time due to the large volume requirements of processing plants[5,6]. Pumping fish has a higher welfare potential but is dependent on careful design and operation to move the fish as gently and efficiently as possible. Dry Braille nets should not be used as they involve removing fish from the water and subject them to physical trauma due to pressure from other fish in the net and abrasion on the surface of the net.

Hazards for welfare during this phase include high stocking densities during crowding, long periods of crowding, and exposure to air. Pangasius species[5] have the ability to switch to air-breathing when water conditions become very poor and will survive in water with dissolved oxygen as low as 0.05 to 0.10 mg/l, however, despite surviving these conditions they may still undergo considerable stress and suffering[7]. Welfare may be further impacted by poor water exchange (especially in pond systems), low oxygen levels, and fish waste accumulation (e.g. toxic ammonia) in the water. Fish that are last to be caught and slaughtered will experience repeated attempts at catching and more prolonged periods of crowding and significant stress.

Severity and duration of crowding should be minimised as much as possible, and crowding should never occur for longer than 2 hours.

Moving Fish

Moving fish causes stress, so should be limited as much as possible. Ideally, pangasius should be slaughtered as close to the rearing area as possible so that they can be moved directly from the rearing pond, net or cage to the slaughtering facility. Currently this is not the case and there is a need to transport fish long distances by road or boat to a processing plant for slaughter which currently causes serious welfare issues[6]. Road transport containers can contain very little, or no, water, and pangasius are typically too exhausted to swim or maintain their equilibrium on reaching the slaughter unit[6]. Live transport in well boats is normally carried out without additional aeration[5] resulting in fish spending as long as 10 hours in oxygen depleted water[8].

Both road and boat transport methods currently result in high mortality rates. Estimates of 2-8% mortality (by weight) during transport of pangasius have been given although this varies according to mode of production. Fish from the closed ponds are considered to produce the lowest quality fish and up to 10% of fish may die during transport[8]. Given the fishes' ability to survive poor conditions there is clearly an urgent need for improvement in both methods of transport not only to prevent unnecessary mortality and suffering but to provide optimal conditions for transport.

The common method for transferring fish from the well boat to the factory is in baskets without water where damage can occur from the pressure of other fish and contact with hard surfaces. Transfer can take up to 20 minutes before the fish is killed[8]. Transferring or moving any fish without water causes stress and injury and should always be avoided. This method of transfer urgently needs addressing.

Slaughter methods that can be humane for pangasius

Currently, the vast majority of pangasius are killed inhumanely, without stunning, by exsanguination (bleeding) whilst still conscious, by decapitation or gill cutting[6,9] (see Text box 1), or are left to asphyxiate in air (see Text box 2). These methods are aversive, causing suffering for extended periods (minutes to hours) before consciousness is lost. An alternative method of electrical stunning before decapitation or gill cut can provide a humane death when performed correctly.

1. Electrical stunning

Electrical stunning is currently only used on a small number of pangasius commercially although it has the potential to be part of a humane slaughter system for these species[10,11]. When performed correctly, it can cause instant insensibility[12,13], however, consciousness will usually be recovered after a period of time, and so in order for it to meet requirements of humane slaughter, electrical stunning must be followed by another method to kill[14]. Electrical stunning of pangasius species is a relatively new method and further verification of machines and careful on-farm management and verification of stun effectiveness is needed. Research is urgently needed to thoroughly validate this method for pangasius, to ensure the stun lasts until death.

There are variations on the systems used to electrically stun fish (described below), but more generally, there are important factors to be aware of:

- The specific electrical parameters used are critical in ensuring that electrical stunning is effective. When the electrical current or voltage is too low, or the application duration too short, there may be ineffective stunning. This can be painful and cause injuries to conscious fish[13]. Alternatively, it can mean fish regain consciousness during some stage of the killing or processing procedures, during which they may experience significant pain and suffering. When the electrical current or voltage is too high it can result in carcass damage such as haemorrhages, blood spotting, and spinal fractures[15,16].

- Ineffective electrical stunning can go unnoticed as it can lead to physical immobilisation only, whereby the body is motionless and unresponsive in reflex tests but the fish remains conscious (as shown by brain activity measures) and sensible to pain[17]. To prevent this, it is important that the parameters used in electrical stunning systems are based on recommendations from research that has validated parameters using measurements of brain activity (via electroencephalograph (EEG) measurements) and not just based on behaviour signs.

  Dry stunning is thought to reduce the amount of carcass damage and injuries sustained by the fish[18] when compared to in-water stunning. However, in-water stunning is preferable in terms of fish welfare as fish need not be restrained, handled, or removed from the water (all being stressors) before they are stunned[16,19].

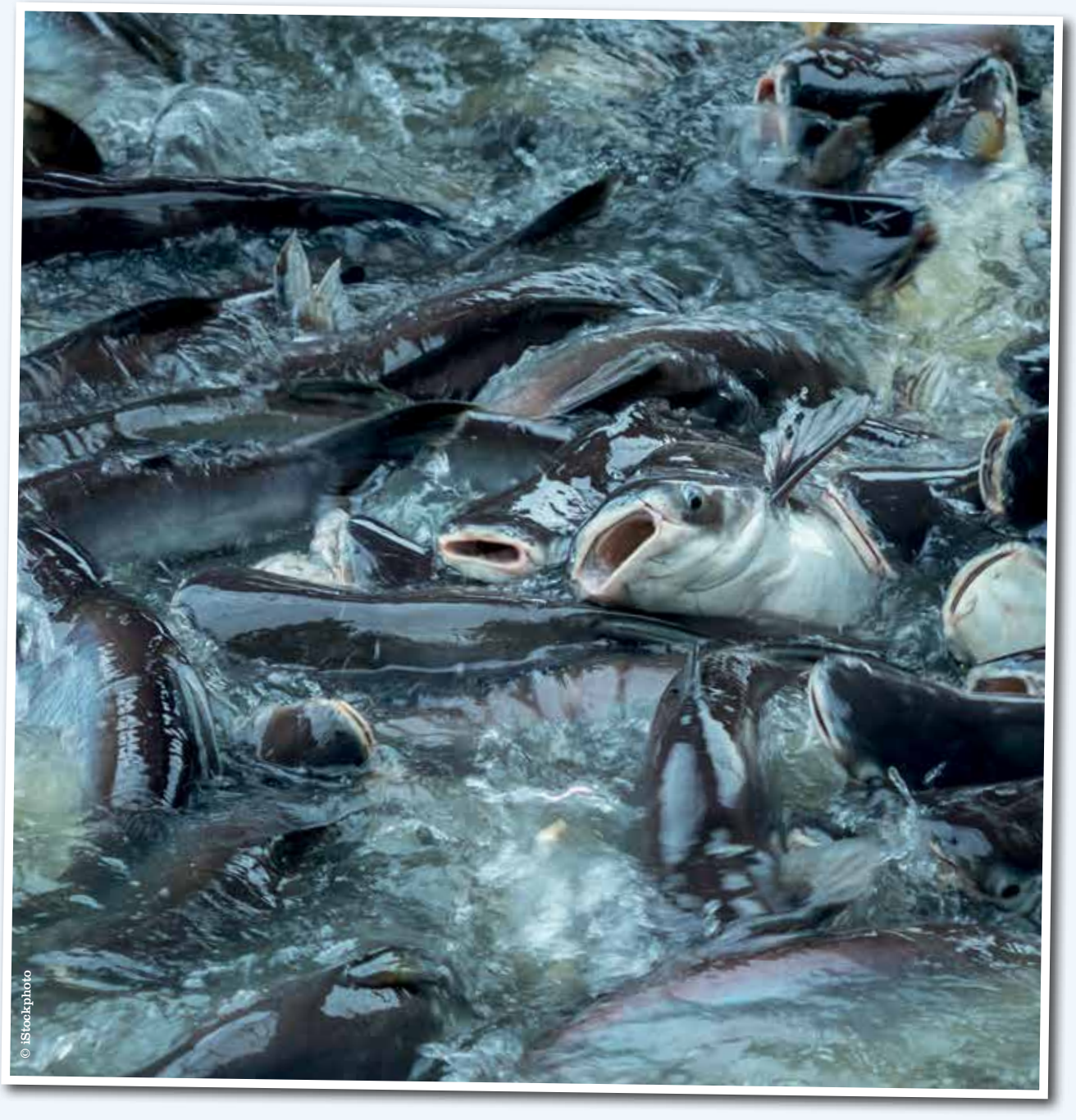
a. In-water electrical stunning: Fish are exposed to an electric current in water, either within a water tank (batch system) or while pumped through a pipe (continuous flow system) which allows for faster processing. For in-water electric stunning, the voltage gradient in the water or electric field strength (measured as volts per metre) is the important parameter to consider rather than the total current.

The electrical current passes not only through the fish but also through the water surrounding it so the current is dependent on the electrical conductivity of the water and on the amount of water around the fish.

It is difficult to provide general recommendations on the best electrical parameters to use in electrical stunning systems as so much depends on the individual set up of the system, the size and number of fish being slaughtered, as well as water conductivity, and other factors.

b. Dry electrical stunning: Fish are removed from water and passed over a conveyor belt which acts as one of the electrodes, with a chain of plate electrodes (steel flaps) hanging above acting as the other to complete the circuit. In some systems fish are sprayed with water between removing them from water and stunning, and this is referred to as semi-dry stunning.

It is crucial that the fish enter dry stunning machines correctly – entering head-first and without excessive struggling. Incorrect orientation of fish brings a significant risk of pre-stun shocks and ineffective stunning, meaning that the process is inhumane because fish may feel the electricity for a few seconds before the electrodes reach the head. With correct orientation, dry electrical stunning can be humane, providing the follow-up killing method is suitable.



Text box 1

Exsanguination (bleeding) without stunning – an unacceptable method of slaughter

Currently pangasius are exsanguinated (bled) whilst still conscious by decapitation or gill cutting[6,9]. Decapitation without prior stunning is not considered an ideal killing method for any species of animal because the brain continues to function for an appreciable time and it is unclear whether animals remain sensible during that period[6]. Van de Vis *et al.*[20] have shown from electroencephalogram (EEG) measurements that some eel brain function continues for up to 13 min following decapitation. Any method of exsanguination without stunning results in "poor fish welfare"[21] and should not be used if either mechanical or electrical stunning is available.

Text box 2

Exposure to air – an unacceptable slaughter method

Some pangasius are killed by removal from water, however this is a very stressful killing method, with an extremely prolonged period to unconsciousness and death. Behavioural studies show fish typically make violent attempts to escape and cortisol and meat quality studies indicate high physiological stress responses[22,23]. The time to loss of consciousness and death is species dependent and there is currently little data specifically relating specifically to pangasius but given both species can withstand significant hypoxia, time to death is likely to be in excess of one hour[22,24]. Use of this method means that there is a long period of prolonged suffering before death and may be processed while still alive.

Text box 3

Selling at wet markets – unacceptable place of slaughter

Pangasius are sold at wet markets (live animal markets). The fish sold at these markets are kept in crowded conditions for long periods. During this time, the water quality degrades, exposing the fish to low quality environmental conditions. When a fish is selected by a buyer; it is handled out of water, often roughly potentially causing injuries. This causes extreme stress for the fish. It is then often exsanguinated without prior stunning (see Text box 1) or left to asphyxiate without prior stunning (see Text box 2). This practice causes long periods of stress, pain, and suffering. Pangasius should be humanely slaughtered and should not be sold at wet markets.

Selling of live fish at a wet market

Recommendations for corporate policies on humane slaughter of pangasius

1. All animals killed for food should be slaughtered humanely. This means that they must be stunned, rendered instantly insensible, and they should not regain consciousness before dying. For pangasius, the use of exsanguination/bleeding without pre-stunning is unacceptable and should be phased out. Effective electrical stunning before decapitation, gill cutting or spiking/coring is instead recommended, as this can enable humane slaughter and there are commercial systems available. Percussive stunning followed by a separate kill method where necessary, may also be acceptable, providing that fish become immediately (<1s) unconscious after stunning and repeated percussion is not required. However current percussive systems are unlikely to be commercially viable due to the shape and protection given by the skull making it hard for effective, efficient and humane percussion in this species. This may change in the future and we will update accordingly.

2. The killing of animals by bleeding without the use of pre-slaughter stunning is not considered a humane method of slaughter. Corporate animal welfare policies should stipulate that all fish products in the supply chain come from fish that have been subject to pre-slaughter stunning.

3. Fish removed from the production line (i.e. sick or injured fish, or those that do not fit market criteria) must be killed humanely.

4. All systems for killing animals should be effectively managed and monitored. This includes:

   - The development and use of Standard Operating Procedures (SOPs) for all live animal operations.
   - Effective training of all staff involved in live animal operations.
   - Designating a member of staff responsible for animal welfare in the slaughterhouse, an "Animal Welfare Officer", whose role it is to monitor operations to ensure SOPs are followed and to require remedial action be taken if non-compliance or other issues are found.
   - Use of CCTV in all live animal handling areas, with effective monitoring of the footage.
   - Effective measurement and proactive management of welfare outcomes at slaughter.

5. Pre-slaughter fasting periods should be no longer than is required for fish welfare benefits (i.e. to reduce oxygen requirements and waste accumulation in the water) and should not exceed 48 hours for each fish. Procedures should be in place to ensure that this maximum time is adhered to for every fish in the pen. For example, where multiple harvests/days are required to slaughter all fish in a pen, the fish should be segregated so that fasting times can be adhered to. Records of the dates and duration of fasting should be kept.

6. Crowding time and intensity should be minimised.

- Narrow, deep nets should be used as they are more welfare-friendly than wide shallow nets for crowding fish.
- Crowding should be carefully monitored and managed so that the crowd remains calm, with very few fish showing signs of distress, such as leaping or thrashing. If this occurs it is a sign that the fish are too crowded.
- The fish should not be crowded for longer than 2 hours and repeated crowding should be avoided.
- Oxygen levels in the water should be monitored throughout the crowding process and producers must ensure that oxygen saturation stays above 2.5 mg/l. If fish show behavioural signs of stress, frequently air-breathe, or oxygen levels fall below 2.5 mg/l then fish should be given more space by releasing the nets. Additional oxygen can be supplied to the water. Keeping nets clean also help as fouled nets can reduce the water flow.

7. Movement of fish to the point of slaughter should be carefully managed to minimise stress.

- Only healthy fish should be transported so a health check should be done before transporting fish.
- If hand-nets are used (e.g. to remove sick fish from the cage), they should be used to remove small numbers of fish only. Nets should have a smooth surface and should be used carefully, with fish being out of water for a maximum of 15 seconds.
- Braille nets should not be used to move fish out of water. Instead, pumping systems should be used to move fish in-water, and these must be carefully designed and managed to ensure gentle movement of fish through pipes. The following points are important:

- An even flow of fish should be achieved, rather than a pump which delivers fish in bursts.

- Fish must move through the pipes at a suitable speed - fish should not be able to swim against the pumping current as this risks injury and exhaustion of fish and keeps them inside the pipe for longer than necessary. However, if the pumping current is too strong the fish may be at risk of injury either inside the pump or on exit.

- Pipes should be dimensioned to accommodate the size of the fish and the number of fish being pumped, and should have a smooth surface on the inside, including at the point of any joins between pipes.

- Pipes should be as short and straight as possible.

- All fish should be cleared from the pipes/ pumps before any break/stop in pumping, and fish should not spend any longer in the pipes than necessary. Oxygen is quickly depleted inside the pipes and fish will die quickly if stuck in the pipes.

- If injuries occur (e.g. fin damage, skin damage, wounds on the snout, bruising etc.) inside the pipe, measures must be taken to investigate and correct any flaws in the system.

8. If fish are dewatered before slaughter this should be well designed so that fish are moved with the least impact and risk of injury. The time that fish are exposed to air should be kept to a minimum; 15 seconds should be the maximum.

9. If well boats are used to transport fish, the water conditions should be monitored and controlled, ensuring that oxygen levels do not fall too low, and the ammonia and other waste products are not accumulating to damaging levels.

10. Electrical stunning systems:

- Compromises to the welfare of the fish should not be made for the sake of product quality. Electrical parameters should be chosen that result in an effective stun which lasts until death and that minimises the risk of electro-immobilisation (fish being paralysed but still conscious). The parameters should be appropriate for the size and number of fish being slaughtered, equipment set-up and water conductivity.

- In dry and semi-dry systems, all fish must enter the machine head-first. Operators should be present to orient fish manually and check that every fish is correctly aligned.

- In dry and semi-dry systems, the time out of water should be kept to a minimum (the Humane Slaughter Association recommend a maximum of 15 seconds from dewatering to stunning)[25] to minimise stress and prevent aversive movements which may affect their smooth entry into the electric stunner.

- A kill method (immersion in ice slurry, decapitation, percussive blow or spiking) must be performed as soon as possible following stunning and must prevent recovery of consciousness before death occurs.

- For in-water systems it is important to clean and maintain electrodes daily as corrosion can build up quickly, especially in saltwater systems, which can affect the amount of current delivered to the fish and result in an ineffective stun.

11. All fish must be observed post-stun by a trained operator. If any fish show signs of recovery, such as opercular movement or eye roll, or in the case of stunner equipment failure, a contingency plan must be in place to immediately stun and kill the fish, e.g. with manual percussion and gill cutting, or spiking.

Welfare outcomes at slaughter

In order to proactively monitor and improve animal welfare at slaughter it is necessary to start by identifying appropriate measures of welfare. Whilst it is important (and in many cases mandatory) to record non-animal-based measures, such as electrical stunning parameter data, it is also important to look at the animal. Welfare outcomes are animal-based measures which give a more direct insight into the animal's experience than can be achieved by measuring 'inputs' such as husbandry resources. They are influenced by several factors and corrective action may require investigating a range of potential solutions.

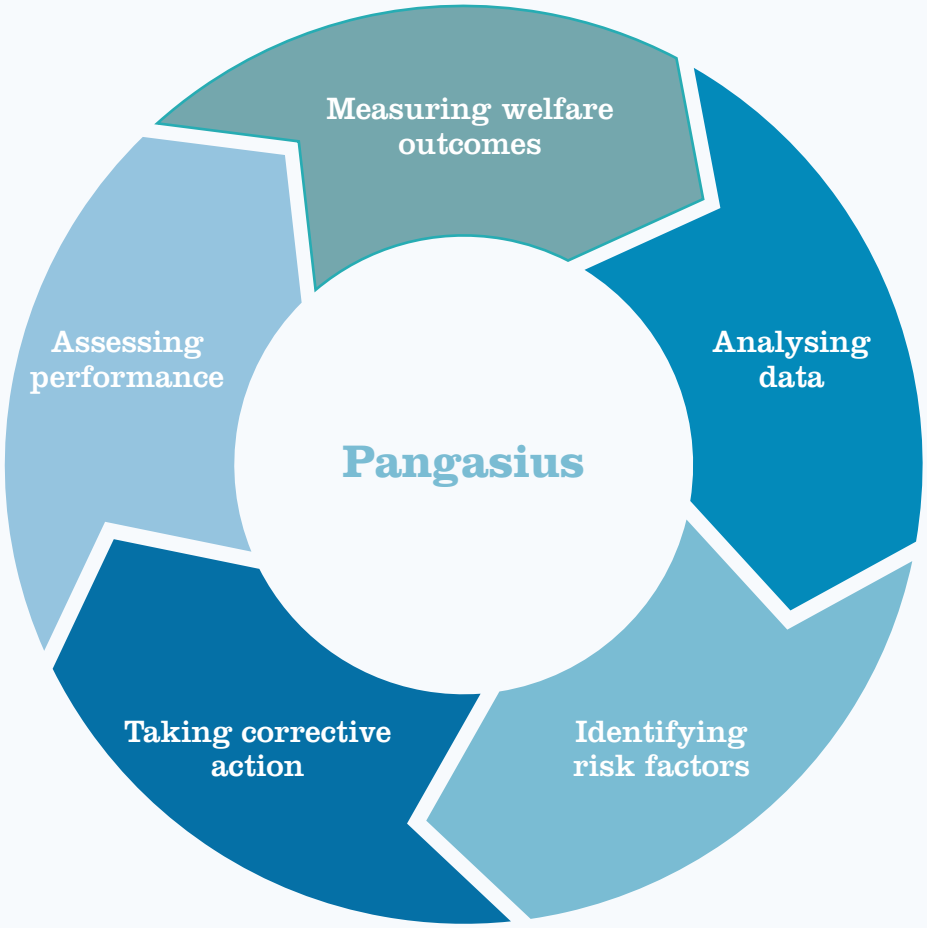
Corporate policies on animal welfare should stipulate that welfare outcome measures are used at slaughter. Recommended welfare outcome measures for pangasius in slaughterhouses are tabled overleaf.

Welcome Outcome	Detail
Activity during crowding	**WHAT:** A qualitative assessment of the activity of fish during crowding. **WHY:** The activity of the fish during crowding, as seen at the surface of the water, is an indicator of the stress experienced during this time. **HOW:** This measure should be continuously recorded. Their activity can be scored on a 5 point scale, described here: https://www.hsa.org.uk/downloads/publications/harvestingfishdownload-updated-with-2016-logo.pdf **TARGET:** 100% of the crowding procedures to be scored 1.
Indicators of consciousness	**WHAT:** An assessment of consciousness performed during the time interval between stunning and death. **WHY:** For slaughter to be considered humane, fish must be effectively stunned (rendered unconscious) so that they do not experience pain or stress during the process. **HOW:** This measure should be continuously recorded. Assess indicators of consciousness post electrical stun (see later table for a full list of potential indicators that can be used) and record the number and percentage of fish that show signs of recovering consciousness. Also record the action taken when fish showing signs of consciousness are detected. **TARGET:** 0% of fish to show signs of returning to consciousness[26]. *If signs of consciousness are seen, fish must be immediately re-stunned or stunned with an alternative, back-up method.*
Pre-stun shocks	**WHAT:** Fish may receive electric shocks upon entry to a dry electrical stunner, which are not sufficient to cause unconsciousness but which cause pain. These can be caused, for example, when a fish is moving vigorously and makes contact with one but not both of the electrodes, or due to tail-first entry to the stunner. **WHY:** The fish are still conscious and therefore these pre-stun shocks cause pain. Pre-stun shocks indicate that the stunning machine is poorly designed and/or operated. **HOW:** This measure should be continuously recorded. The incidence of fish entering the stunner head-first and calm (not thrashing) can be recorded. **TARGET:** 100% of fish to enter the stunner head-first and without thrashing movements.
Post-mortem flesh quality	**WHAT:** Time to rigor mortis and gaping of the muscle tissue. **WHY:** Post-mortem flesh quality can give a valuable insight into pre-slaughter treatment of the fish. When fish are stressed before (i.e. when crowded) and during slaughter they can become very active and use up their energy reserves, causing an increase in lactic acid. This has a negative impact on flesh quality, i.e. time to rigor decreases (decreasing yield and shelf life) and flesh gaping increases (reducing yield and making it less appealing to consumers). **HOW:** Record time to rigor and gaping from a sample of carcasses.

Welcome Outcome	Detail
Post-mortem haemorrhages	**WHAT:** Haemorrhages on the flesh of the fish. **WHY:** Physical damage post-mortem can give a valuable insight into pre-slaughter treatment of the fish. Haemorrhages are areas of flesh that have been damaged causing blood to leak into the area. Haemorrhages can occur if fish fall or are dropped from the dewaterer or braille, or if poorly maintained and operated pumps and pipes are used. They are also typically seen in the tail region if a fish has been lifted or held tightly by its tail prior to slaughter. Haemorrhages can also be caused by poorly-positioned manual percussive stunning and by electrical stunning if the correct parameters have not been used. **HOW**: Record incidence of haemorrhages from a sample of carcasses.
Post-mortem eye damage	**WHAT:** Eye damage. **WHY:** Physical damage post-mortem can give a valuable insight into pre-slaughter treatment of the fish. Eye damage occurs during percussive stunning when the blow is positioned incorrectly and either hits the eye directly or close enough for the eye to rupture. Eyes can also be affected by poorly maintained nets. **HOW:** Record incidence of scale damage from a sample of carcasses.
Post-mortem snout damage	**WHAT:** Snout damage such as bleeding and/sore areas. **WHY:** Physical damage post-mortem can give a valuable insight into pre-slaughter treatment of the fish. Snout damage occurs when pre-slaughter crowding is not well managed and fish are swimming into the nets and each other. **HOW:** Record incidence and level of snout damage from a sample of carcasses.
Peri-mortem skin and fin discolouration	**WHAT:** Red discolouration of the mouth, fin and belly areas. **WHY:** Acute stress is seen to result in immediate discolouration of the mouth, fin and belly areas. These changes are often seen prior to slaughter due to stressful handling, crowding and transportation procedures. **HOW:** Record incidence and measure the percentage of fish displaying red belly or mouth at each stage of the pre-slaughter and slaughter process.

Welfare outcome measures

Welfare outcome measures should be used as part of a proactive programme of measurement and continuous improvement, including target setting. A programme should involve a continuous cycle of:



Regular monitoring of welfare outcomes enables swift detection of problems, implementation of corrective action and continuous improvement to be achieved. Some measures should be continuously recorded (as indicated in the table above). For the other measures, it is recommended that they are recorded on a representative sample of a minimum of 50 fish per harvest. Target setting should be used for all measures, to drive improvement.

Indicators of conciousness

It is difficult to reliably determine unconsciousness of fish (and therefore that stunning is effective) at the slaughterhouse (EEG are required and this can only be measured in the lab) but it is important to ensure that there are no signs of consciousness after stunning. If any of the following signs of consciousness are observed, then stunning is likely to have been ineffective. If in any doubt as to whether a fish is unconscious, do not hesitate to repeat the stun or use an alternative, back-up method.

Signs of an ineffective stun	Comment	Stunning methods applicable to
Breathing	Regular opercular movements indicate the fish is likely to be conscious	All
Eye roll	The vestibulo-ocular reflex (VOR), known as "eye roll", refers to the movement of the eyes in the head as the fish moves. In a conscious fish, the eye rotates dorso-ventrally when the fish is rocked from side to side	All
Coordinated behaviour	Coordinated behaviour such as swimming or attempts to escape is a sign that fish is conscious	All
Behavioural response to tail pinch	Behavioural response such as movement away from the stimulus indicates the fish is likely to be conscious	All
Ability to achieve equilibrium	If a fish is able to achieve equilibrium after being inverted in water, then it is likely to be conscious	All

Disclaimer

We will incorporate new scientific information regarding humane slaughter for fish into subsequent versions of these resources. Some of this research may alter our understanding of current established practice. Last update: November 2018

Ferreira, N. D. A., de Araújo, R. V., & Campos, E. C. (2018). Good practices in pre-slaughter and slaughter of fish. PUBVET, 12(7), 1-14.

REFERENCES AND FURTHER READING

[1] EFSA. Welfare of Farmed Fish: Common Practices during Transport and at Slaughter. 2017.

[2] Chandroo KP, Duncan IJH, Moccia RD. Can fish suffer?: Perspectives on sentience, pain, fear and stress. Appl Anim Behav Sci. 2004;86(3-4):225-250. doi:10.1016/j.applanim.2004.02.004

[3] Edwards P, Allan G. Feeds and feeding for inland aquaculture in Mekong region countries. 2004.

[4] EFSA. Scientific Opinion of the Panel on Animal Health and Welfare on a request from the European Commission on welfare aspect of the main systems of stunning and killing of farmed eel (*Anguilla anguilla*). EFSA J. 2009;1014:1-42. doi:10.2903/j.efsa.2009.1013

[5] FAO. *Pangasius Hypophthalmus* - Fisheries and Aquaculture Department. Fisheries and Aquaculture Fact Sheets. Rome; 2013.

[6] Lines J, Spence J. Humane harvesting and slaughter of farmed fish. Rev sci tech Off int Epiz. 2014;1(33):255-264.

[7] Lefevre S, Huong DTT, Wang T, Phuong NT, Bayley M. Hypoxia tolerance and partitioning of bimodal respiration in the striped catfish (*Pangasianodon hypophthalmus*). Comp Biochem Physiol - A Mol Integr Physiol. 2011;158(2):207-214. doi:10.1016/j.cbpa.2010.10.029

[8] Sørensen NK. Slaughtering Processes for Farmed Pangasius in Vietnam Consultancy Surveying Slaughter Processes and By-Products Handling in the Vietnamese Industry. Tromsø; 2005. https://nofima.brage.unit.no/nofima-xmlui/bitstream/handle/11250/2576750/Rapport%2B12-2005%2BPangasius.pdf?sequence=1&isAllowed=y. Accessed February 14, 2020.

[9] Lines JA, Spence J. Safeguarding the welfare of farmed fish at harvest. Fish Physiol Biochem. 2011;38(1):153-162. doi:10.1007/s10695-011-9561-5

[10] King-Nobles H, Billington T, Kirsch J-J, Dang T. Welfare Scoping Report: Vietnam; 2020. https://www.fishwelfareinitiative.org/vietnam-scoping-report.

[11] Boyland N, Brooke P. Farmed Fish Welfare during Slaughter. 2017. https://www.aac-europe.org/images/Slaughter_report__AAC_report.pdf.

[12] Lambooij B, Gerritzen MA, Reimert H, Burggraaf D, André G, Van De Vis H. Evaluation of electrical stunning of sea bass (*Dicentrarchus labrax*) in seawater and killing by chilling: Welfare aspects, product quality and possibilities for implementation. Aquac Res. 2008;39(1):50-58. doi:10.1111/j.1365-2109.2007.01860.x

[13] Van De Vis H, Kestin S, Robb D, *et al*. Is humane slaughter of fish possible for industry? Aquac Res. 2003;34(3):211-220.

[14] IBF, VetEffecT, Wageningen University, (SANTE) RC for the ECDH and FS. Welfare of farmed fish: Common practices during transport and at slaughter. 2017.

[15] Kestin SC, van deVis JW, Robb DHF. Protocol for assessing brain function in fish and the effectiveness of methods used to stun and kill them. Vet Rec. 2002;150(10):302-307. doi:10.1136/vr.150.10.302

[16] Lines JA, Robb DH, Kestin SC, Crook SC, Benson T. Electric stunning: A humane slaughter method for trout. Aquac Eng. 2003;28(3-4):141-154. doi:10.1016/S0144-8609(03)00021-9

[17] Zampacavallo G, Parisi G, Mecatti M, Lupi P, Giorgi G, Poli BM. Evaluation of different methods of stunning/killing sea bass (*Dicentrarchus labrax*) by tissue stress/quality indicators. J Food Sci Technol. 2015;52(5):2585-2597. doi:10.1007/s13197-014-1324-8

[18] van de Vis H, Abbink W, Lambooij B, Bracke M. Stunning and Killing of Farmed Fish: How to Put It into Practice? Vol 3. Elsevier Ltd.; 2014. doi:10.1016/B978-0-12-384731-7.00199-9

[19] Robb DHF, O'Callaghan M, Lines JA, Kestin SC. Electrical stunning of rainbow trout (*Oncorhynchus mykiss*): Factors that affect stun duration. Aquaculture. 2002;205(3-4):359-371. doi:10.1016/S0044-8486(01)00677-9

[20] van de Vis H, Kestin S, Robb D, et al. Is humane slaughter of fish possible for industry? Aquac Res. 2003;34(3):211-220. doi:10.1046/j.1365-2109.2003.00804.x

[21] OIE, ed. Welfare Aspects of Stunning Fish and Killing of Farmed Fish for Human Consumption. In: Aquatic Animal Health Code. 2015. https://www.oie.int/fileadmin/Home/eng/Health_standards/aahc/2010/en_chapitre_welfare_stunning_killing.htm. Accessed February 26, 2020.

[22] Poli BM, Parisi G, Scappini F, Zampacavallo G. Fish welfare and quality as affected by pre-slaughter and slaughter management. Aquac Int. 2005;13(1-2):29-49. doi:10.1007/s10499-004-9035-1

[23] Ashley PJ. Fish welfare: Current issues in aquaculture. Appl Anim Behav Sci. 2007;104(3-4):199-235. doi:10.1016/j.applanim.2006.09.001

[24] Bergqvist J, Gunnarsson S. Finfish Aquaculture: Animal Welfare, the Environment, and Ethical Implications. J Agric Environ Ethics. 2013;26(1):75-99. doi:10.1007/s10806-011-9346-y

[25] Humane Slaughter Association. Humane Harvesting of Fish. 2014.

[26] HSA. Humane Harvesting of Fish. 2016.