Farmed fish welfare during slaughter

Report

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Contents

1 Executive summary

As global aquaculture grows, and exceeds the production output of fisheries, ensuring the welfare of fishes at slaughter is paramount. In the European Union (EU), legislation protects fishes at slaughter based on a general principle of avoiding suffering. However, the European Commission have stated that a thorough assessment of farmed fish slaughter will be conducted, with a view to introducing more specific rules to the slaughter regulation to protect fishes.

According to the World Organisation for Animal Health (OIE) and the European Food Safety Authority (EFSA), percussive stunning and electrical stunning systems are best able to provide a humane slaughter for many of the key species farmed in the EU. Spiking or coring, and shooting underwater, can also be humane methods for some species. Important research into the theory behind these systems, and also their deployment, has been conducted to safeguard fish welfare. However further work is needed to minimise the risks to welfare associated with each of the methods.

The main farmed species in the EU are: Atlantic salmon, rainbow trout, common carp, European sea bass, gilthead sea bream, turbot, North African catfish, European eel, and Atlantic Bluefin tuna (ordered by greatest tonnage). Humane stunning systems exist or can be developed for all of these, but progress towards this goal varies for each species. The OIE and EFSA's Scientific Opinions (2009) on the key fish species, provide a useful point of reference (see the key documents in Appendix A), but further developments have been made since their publication.

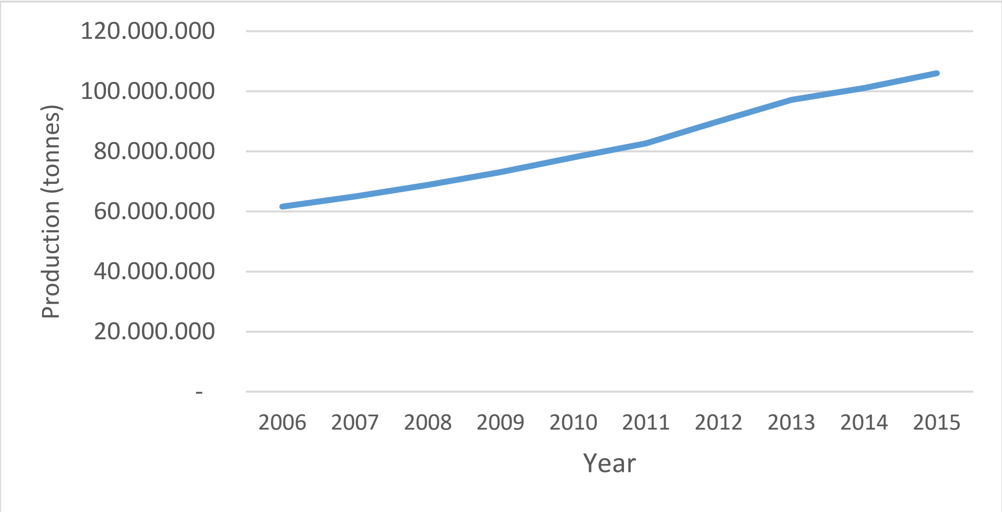
Moving forward, a clear, well-integrated strategy for developing humane methods of stunning and killing fish is needed. Systems must tested thoroughly (for each species that they are used) to ensure that stunning render fishes instantly unconscious until death. This testing process should 1) establish stunning parameters in theory, 2) develop equipment to deliver an effective stun, 3) implement the stunning system, and 4) verify of effective stunning in-situ. When developing systems that advance fish welfare, we must also take social, practical and economic issues into account.

There is much research and development still to be done. However the progress made in recent years, and the rapidly increasing availability of commercial systems creates a positive outlook for farmed fish welfare at slaughter in the EU.

2 Aquaculture in the European Union

Globally, aquaculture production has increased rapidly over the past decade, while EU production has remained at around 1.3 million tonnes annually with some variation (FAOSTAT, 2015; figure 1). Production is generally reported by weight of fish, however it is important to recognise the number of individuals involved in discussions of animal welfare. An estimated 439-1,602 million fishes were produced and killed in the EU in 2010[1]. The United Kingdom is the largest producer in terms of production tonnage (figure 2), however Greece produces the greatest number of individual fishes (figure 3; for a full list see appendix B). The main fish species, in terms of production weight, farmed in the EU are shown in figure 4 (for a full list see appendix C).

(a)



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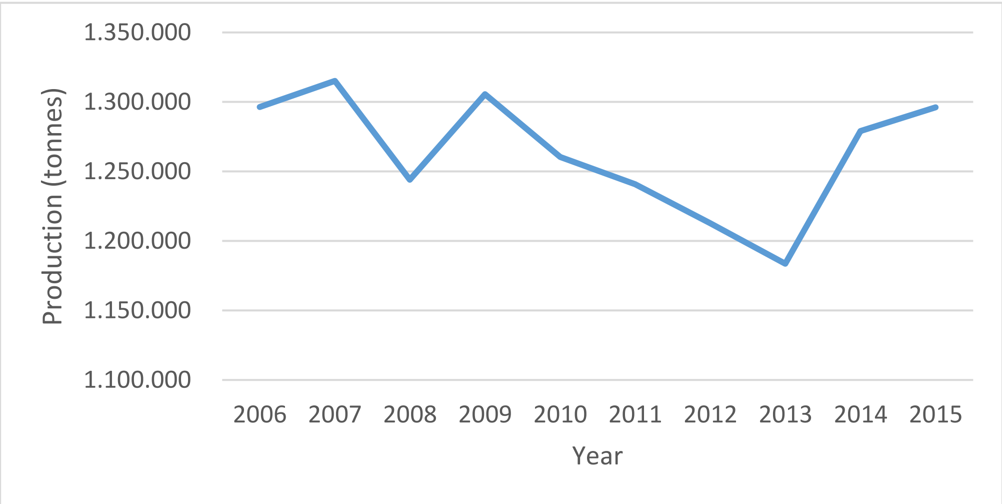


Figure 1. Total aquaculture production globally (a) and in the European Union (b), from 2006 to 2015. N.B. This includes all aquaculture, not just fish species.

[1] Estimates of fish numbers throughout this report are calculated based on data from FAOSTAT (annual tonnages of farmed fish production) and fish weights from www.fishcount.org.uk. As most fish are killed at a range of weights, an upper and lower weight is used to calculate a range of estimated fish numbers.

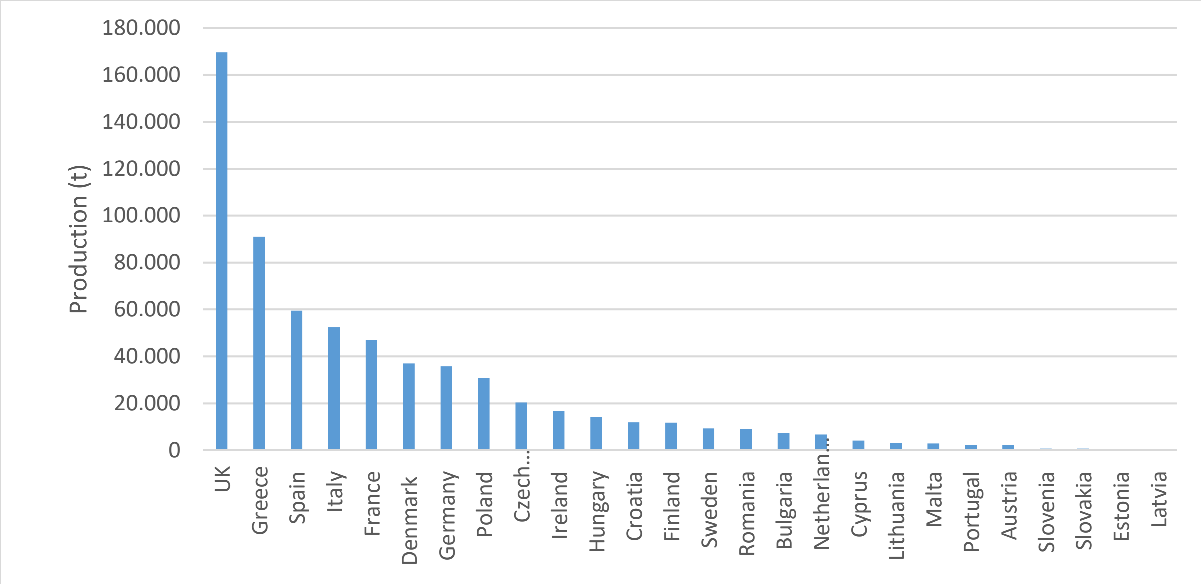
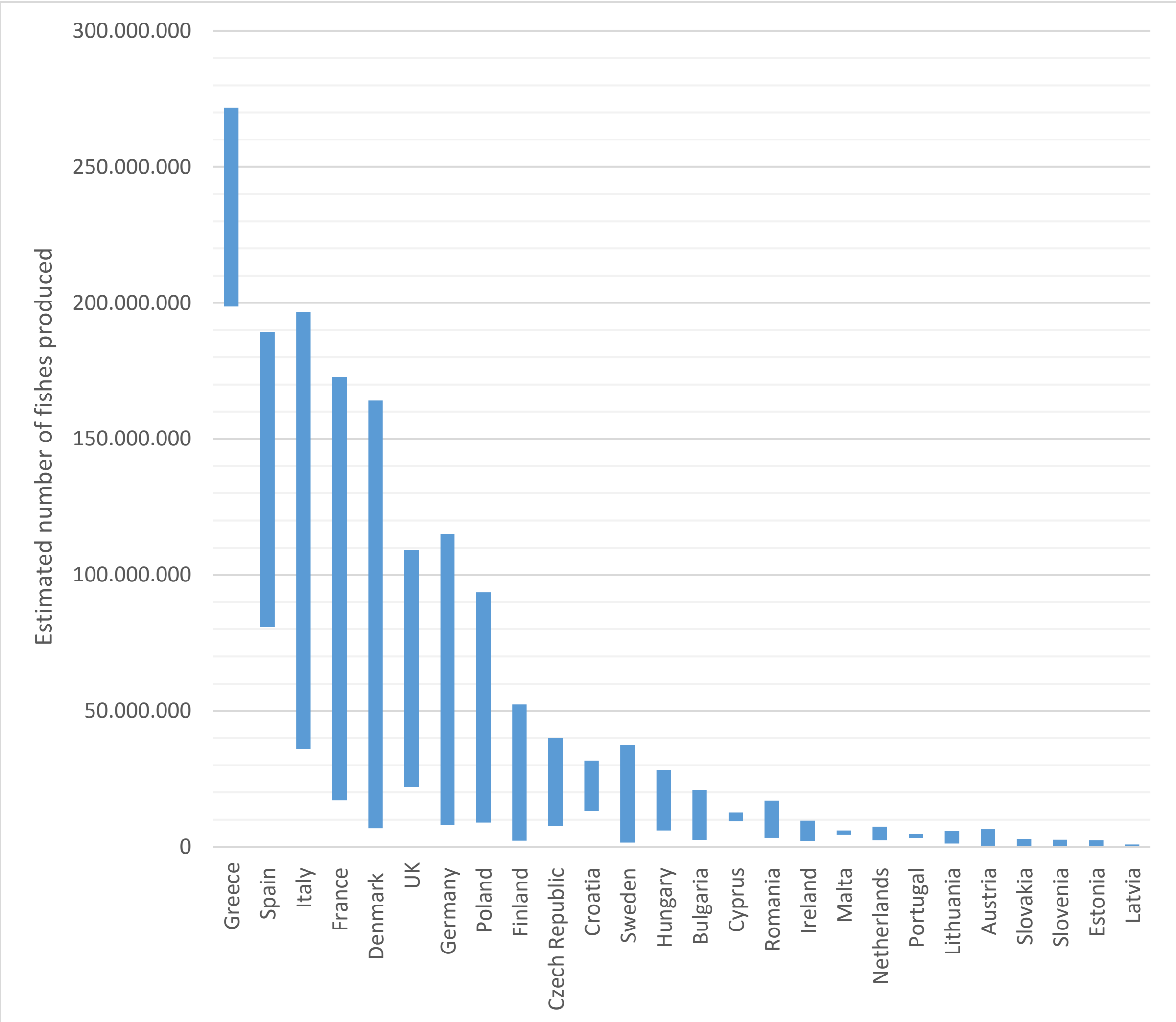


Figure 2. Total production of farmed fishes (tonnes) by EU member states during 2010. (FAOSTAT).

Figure 3. Estimated number (range shown as floating bar) of farmed fishes produced by EU member states during 2010, based on data from FAOSTAT and adjusted according to estimated weights, by www.fishcount.org.uk



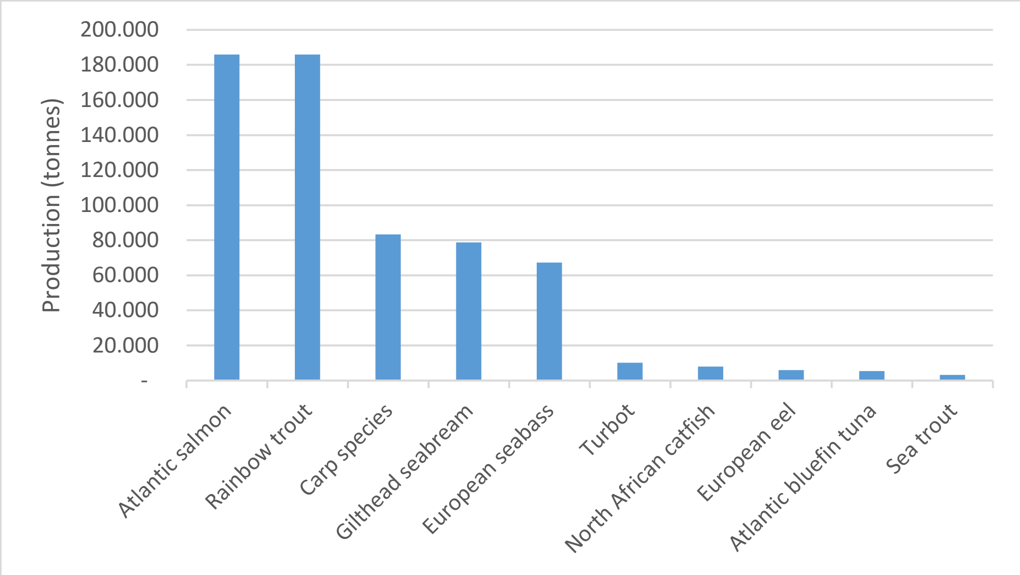


Figure 4. The ten most farmed fish species in the EU during 2015, in order of greatest tonnage. N.B. carp species consist of common carp, bighead carp, silver carp and grass carp.

3 Legislation relating to slaughter of farmed fishes in the EU

Fishes are recognised as sentient beings by law, as included in The Treaty on the Functioning of the European Union (2012). Article 13 states that "[i]n formulating and implementing the Union's…agriculture, fisheries…policies, the Union and the Member States shall, since animals are sentient beings, pay full regard to the welfare requirements of animals…".

There is legislation in place to regulate the slaughter of animals in the European Union. Yet, while Council Regulation 1099/2009 (on the protection of animals at the time of killing) includes specific requirements for the slaughter of terrestrial species farmed for food, fishes are excluded from much of the recommendations (European Union, 2009). As explained therein, this is due to differences in physiology and slaughter context, and less developed understanding of the stunning process for fish. However, it is stated explicitly that the key principle remains applicable to fish, which states that

> "Animals shall be spared any avoidable pain, distress or suffering during their killing and related operations" (Article 3(1)).

Accordingly, there is a legal requirement for member states to take action to avoid, or at least minimise, the suffering of fishes at slaughter. They should therefore, wherever possible, be slaughtered using humane methods. The European Food Safety Authority (2004) state that:

> “Since the intention of humane slaughter regulations is to avoid as much as possible anxiety, pain, distress or suffering at slaughter, stunning and stun / killing methods should ideally fulfil the following criteria:
>
> • induce immediate (e.g. <1sec) and unequivocal loss of consciousness and sensibility;
>
> Or,
>
> • when loss of consciousness is not immediate, the induction of unconsciousness should be non-aversive and should not cause anxiety, pain, distress, or suffering in conscious animals.”

However the predominant methods of fish slaughter practised in the EU for many species do not meet these requirements. According to EFSA (2004) "many existing commercial killing methods expose fish to substantial suffering over a prolonged period of time".

Council Regulation 1099/2009 also indicated the European Commission’s aims to progress understanding of fish welfare at slaughter, stating that “[n]o later than 8 December 2014, the Commission shall submit to the European Parliament and to the Council a report on the possibility of introducing certain requirements regarding the protection of fish at the time of killing taking into account animal welfare aspects as well as the socioeconomic and environmental impacts. This report shall, if appropriate, be accompanied by legislative proposals with a view to amending this Regulation, by including specific rules regarding the protection of fish at the time of killing” (Article 27). As of September 2017, this report is currently long overdue.

The enforcement of the key principle in Regulation 1099/2009 (be spared any avoidable pain, distress or suffering) is the responsibility of EU member states. The World Organisation for Animal Health (OIE) have recommendations on ‘Welfare Aspects of Stunning and Killing of Fish for Human Consumption’ (OIE, 2010). As members of the OIE, all 28 EU countries should use these as guidance until the Regulation can be amended by the Commission to include specific rules on farmed fish slaughter.

In the Aquatic Animal Health Code, the OIE propose that handling, stunning and killing equipment should be “tested on a regular basis to ensure that performance is adequate”, and stress the importance of effective stunning, which “should be verified by the absence of consciousness” and “should not take place if killing is likely to be delayed such that the fish will recover or partially recover consciousness”(OIE, 2010). Article 7.3.7. states that the following stunning/killing methods can enable humane slaughter: percussive, spiking or coring, free bullet, and electrical stunning followed by kill method such as gill cutting.

The OIE also list inhumane methods that are known to be used commercially but “result in poor fish welfare”:

> "The following methods are known to be used for killing fish: chilling with ice in holding water, carbon dioxide (CO_2) in holding water; chilling with ice and CO_2 in holding water; salt or ammonia baths; asphyxiation by removal from water; exsanguination without stunning […] these methods should not be used if it is feasible to use the methods described in points 2 and 3 of this article [those listed above], as appropriate to the fish species".

In addition to ineffective stunning and inhumane slaughter methods, the practice of processing live (unstunned) fishes is a serious welfare concern. For example a salt bath followed by evisceration, a common method for killing farmed eels, results in the majority of eels being alive and still conscious when evisceration commences (Morzel & Van De Vis, 2003). "Welfare oriented research" into stunning and killing, among other key issues, is identified an important research need by EFSA (2009h).

4 Systems with potential to deliver humane slaughter

Further detail on the main systems (those suggested by both OIE (2010) and EFSA (2009a-g)) that have potential for humane slaughter of farmed fishes, are described below:

4.1 Percussive stunning

Method:

The principle of percussive stunning is that the head is struck with an object (manually or by specially designed machine) with a force sufficient enough to stun or kill instantaneously due to haemorrhaging in the brain (Roth, Slinde, & Robb, 2007). This may be followed by a separate killing method, such as gill cutting.

Risks to welfare:

- Asphyxia can occur in hand held manually fed percussive systems(EFSA, 2009b).
- Mis-stuns can occur in automated percussive stunning systems, due to size variation between fishes (EFSA, 2009b).
- Paralysis without loss of consciousness can occur EFSA (2009b).
- Injuries that can occur due to percussive stunning include eye dislocation (proptosis), eye bursting or rupture, and haemorrhaging (Roth et al., 2007). If occurring as result of a mis-stun, fishes could experience severe pain and distress with these injuries.

Important considerations:

Percussive machines should not be used if fishes are likely to be injured, not stunned or not rapidly killed because of their size or orientation in the machine. Size adjustment of percussive machines should be done by skilled personnel. Percussive systems should have a separate air supply or alternatively have security valves to block the system if the pressure is reduced below a certain threshold EFSA (2009b). Combined electrical and percussive systems are being developed to reduce the risk of mis-stuns.

4.2 Spiking or coring

Method:

A tool is driven directly into the skull of the fish to physically destroy the brain (EFSA, 2009c). A wire may then be passed down the spinal column (‘pithing’) (Lines & Spence, 2014). Has the potential to cause near instant unconsciousness, if performed correctly and accurately.

Risks to welfare:

- The tool may miss the brain (Poli, Parisi, Scappini, & Zampacavallo, 2005), especially if the fish is struggling. Firm restraint is therefore needed, which is a risk to welfare in itself (Robb, Wotton, McKinstry, Sørensen, & Kestin, 2000).
- Typically performed out of water.

Important considerations:

Destruction of the brain must be completed rapidly, to reduce suffering due to penetrative damage to the tissues of the head (Lines & Spence, 2014).

4.3 Free bullet

Method:

Shooting using a free bullet may be used for killing large fishes (such as tuna). The fishes may either be crowded in a net and shot in the head from the surface, or individual fishes may be killed by shooting in the head from under the water (commonly called lupara). Fishes are then quickly bled out (by gill cut or severing of lateral blood vessels) to preserve flesh quality (Benetti, Partridge, & Buentello, 2015).

Risks to welfare:

- Shooting from the surface involves crowding (for approx. 15 minutes) and is less accurate than the underwater method, with 7-10% requiring a second shot (EFSA, 2009h).

4.4 Electrical stunning followed, if necessary, by a separate killing method

Method:

In electrical stunning systems, an electric current is delivered to fishes via two electrodes. They may be dry (fishes are removed from holding water and passed over electrified surface), semi-dry (the water-filled buffer in front or the fishes are sprayed with water between the buffer and the stunner) or stuns may be delivered in water (while fishes are pumped through a tube).

Electrical stunning works by stimulation of the higher nerve centres in order to “cause their dysfunction, either by induction of epileptiform activity or by complete cessation of function” (Robb, O’Callaghan, Lines, & Kestin, 2002). In rainbow trout, there is a tonic phase immediately after a sufficient electrical current is applied, during which the fish typically becomes rigid with some muscular twitches, and shows disrupted brain activity that is indicative of unconsciousness (Robb et al., 2002). Following the tonic phase, opercular movements resume and brain activity indicates a return to consciousness. The duration of the tonic phase is largely affected by the current magnitude, duration and frequency; longer durations (or death) can be achieved by increasing the magnitude of the current, increasing the duration of the applied current and/or decreasing the frequency of the current (Robb et al., 2002).

Risks to fish welfare:

- Insufficient electrical current, voltage or duration can lead to unsuccessful stunning.
- Unsuccessful electrical stunning can lead to ‘immobilisation’, whereby the body is motionless and unresponsive in reflex tests but brain activity shows that the fish remains conscious and sensible to pain (e.g. Retter, 2014). Therefore, behavioural indicators are not always reliable when assessing stun efficacy.

In dry stunning systems: pre-stun shocks can be caused, for example, by fishes entering the machine tail first or because spasms cause them to lose contact with the electrodes.

Important considerations:

Electrical stunning can be used to humanely slaughter fishes but effective electrical parameters must be identified, which will be specific to the fish species, weight, size, number of fish, water conductivity, etc. The electric current must cause fishes to become unconscious and insensible to pain immediately (stunning the fish), and the stun duration must be longer than the time to death by the subsequent killing method.

All stunning systems should have an appropriate backup system to enable an immediate correction from a mis-stun.

5 Slaughter of the main farmed fish species in the EU

For the main farmed fish species in the EU (figure 4; Appendix C), some information on production amount and number of individual fishes are provided below. Methods of stunning and slaughter are also reported for each, and commercial availability of stunning systems is summarised in Appendix D.

5.1 Atlantic salmon (Salmo salar)

The vast majority of Atlantic salmon production in the EU takes place in the United Kingdom (figure 5). In 2015, over 185 thousand tonnes of Atlantic salmon were produced, which equates to approx. 21 – 51 million individual fishes. In response to an enquiry by EFSA regarding slaughter methods, the United Kingdom reported that percussive stunning, followed by exsanguination, was the main killing method used for salmon intended for human consumption (EFSA, 2009d). Furthermore, at any given time 70-80% of Scottish salmon farms adhere to the RSPCA Assured scheme (Rodgers, 2017). The RSPCA standards (2015) state that "an efficiently applied percussive blow is the only permitted killing method at present." This must consist of a sufficient blow, followed by bleeding within 10 seconds.

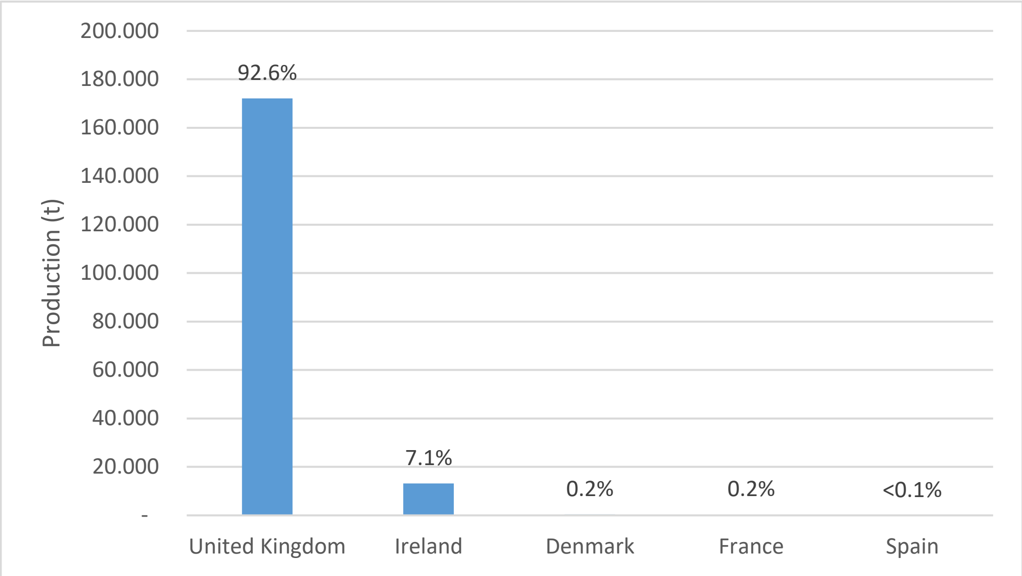


Figure 5. Atlantic salmon production in EU member states during 2015.

According to EFSA (2009d), both percussive and electrical stunning can reliably cause unconsciousness in the vast majority of salmon. For percussive stunning, Lambooij et al. (2010) describe that where "sufficient force is used the fish will be rendered unconscious and insensible and eventually die of cerebral haemorrhage". The study, using Atlantic salmon with a live weight of 1.5kg, showed that pressures below 8.1 bars were unsuccessful in causing unconsciousness in fishes. However, percussive stunning with 8.1 to 10 bars caused unconsciousness and was therefore useful as part of a humane slaughter system (Lambooij et al.,2010).

Electrical methods are capable of delivering an effective stun to salmon, causing unconsciousness within one second (e.g. Robb & Roth, 2003). Roth, Moeller, & Slinde (2004) recommend "for stunning alone, sinusoidal AC frequencies of 50–80 Hz at 25–50 V/m for 10s or at 50 V/m for 3–10 s are recommended. However, to minimize the proportion of Atlantic salmon injured by electrical stunning, sinusoidal AC frequencies of 500–1,000 Hz at 50 V/m for 10 s should be used." Another study, by Lambooij et al. (2010), found that "a combined AC and DC supply for dry electrical head to body stunning in minimum 0.5 s can be recommended using currents of 668 mArms and≈107 Vrms, where all fish were stunned unconscious. Upon exsanguinations the fish did not die unconsciously post a 5 s stun duration and methods to prolong the unconscious conditions until death ensues should be sought or alternatively become percussive stunned, as commercially practiced." Therefore, stunning must be applied for longer (than the minimum needed to cause unconsciousness) in order to prolong unconsciousness until death occurs (EFSA, 2009d).

Electrical stunning systems are now commercially available for Atlantic salmon and may be used instead of, or prior to, percussive stunning (Mejdell et al., 2009, cited in EFSA, 2009d). A combined approach, whereby fishes are first stunned with electricity (short duration) then percussively stunned, may allow for more accurate percussive stunning as the fishes will be motionless. This could result in high welfare standards without compromising carcass quality (Mejdell et al., 2009, cited in EFSA, 2009d).

5.2 Rainbow trout (Oncorhynchus mykiss)

Over 185 thousand tonnes of rainbow trout were produced by 25 countries in the EU in 2015, with France, Denmark and Italy being the top producers (FAOSTAT, 2015; figure 6). This equates to somewhere between 37 and 929 million trout.

Trout are stunned and killed by a range of methods: "percussive stunning, electrical stunning, carbon dioxide, asphyxia and asphyxia in ice slurry. All followed by evisceration (portion sized trout) or exsanguination and evisceration (large trout). In addition, several combinations of these methods may be used." (EFSA, 2009b). According to EFSA (2009b), humane slaughter of rainbow trout can be achieve by percussive and electrical stunning methods.

Previously in the UK, most rainbow trout were killed by inhumane methods: immersion in ice slurry, asphyxiation in air or by immersion in a water bath saturated with carbon dioxide gas (Robb, O'Callaghan, et al., 2002). This was due to the small slaughter size common in the UK (350-400g) making individual stun/killing uneconomical (Robb, O'Callaghan, et al., 2002). However, after research funded by Department for Environment, Food & Rural Affairs (DEFRA), suitable electrical stunning methods have since been identified and developed commercially for small trout.

Currently in the UK, around 80% of trout production in the UK is represented by the British Trout Association, and these farms now use electric stunning (Lines, n.d.). Additionally, some UK farms are certified by the RSPCA Assured scheme, and thus must humanely stun/kill trout using: an effectively applied percussive blow, electronarcosis (electric current to stun) followed by bleeding, or electrocution (electric current to kill); dry stunning methods are prohibited (RSPCA, 2014).

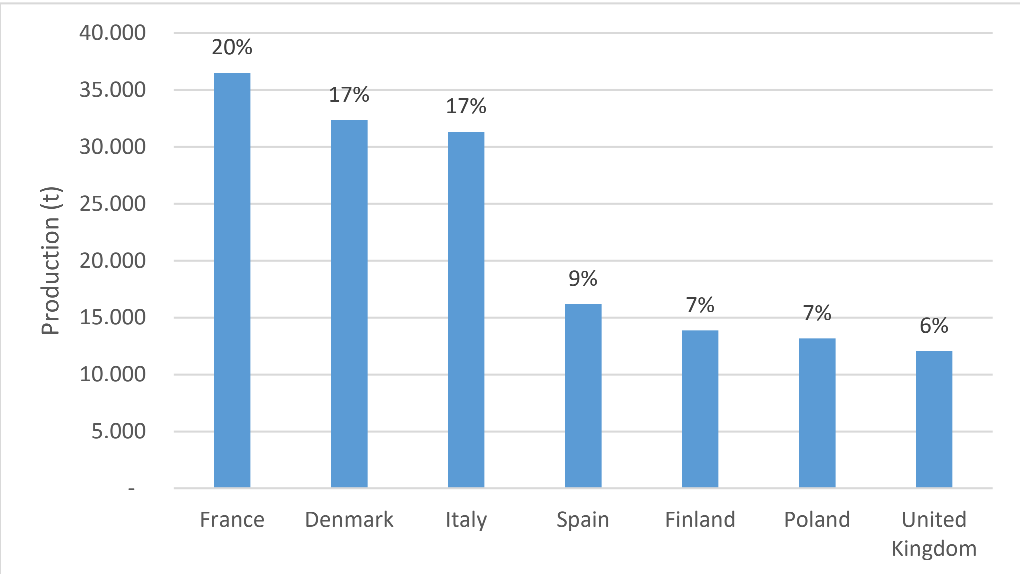


Figure 6. Production (tonnes) of EU countries with more than 10t annual rainbow trout production during 2015 and percentage contribution to total EU production.

If the fish were to be stunned in a water bath, a current density of at least 8.3 A m-2 at 50 Hz had to be passed for at least 5 s to stun all fish and for at least 30 s to kill all fish. Finally, using current densities between 10.2 and 10.8 A m-2 for a duration of 5 s, a waveform frequency of 2000 Hz or less was required to stun the fish. By using combinations of the three parameters it is possible to stun or stun/kill portion sized rainbow trout".

Jeff Lines (n.d.) recommends that "60 second exposure to a 1000Hz sinusoidal electric field of 2.5 v/cm rms results stuns portion size rainbow trout beyond recovery without causing carcass damage. A small increase in the field strength may be required in areas of very low conductivity water. A demonstration humane trout harvester has been built and shown to work effectively, producing high quality carcasses, a safe working environment and to fit into current harvest practice. It has been tested on farms during commercial harvests and in back to back comparisons with traditional techniques. It produces the same low level of haemorrhaging as the traditional slaughter method, a longer pre-rigor period during which the fish can be processed and lower levels of slime and surface damage on the fish".

Larger trout are generally stunned by percussive systems in the UK (Farm Animal Welfare Council, 2014). Percussive stunning of trout can be effective in causing immediate unconsciousness, when applied correctly (Kestin, Wotton, & Adams, 1995; Robb, Wotton, McKinstry, Sørensen, & Kestin, 2000).

5.3 Common carp (Cyprinus carpio)

Over 71 thousand tonnes of common carp were produced by 17 countries in the EU in 2015, with the Czech Republic, Poland and Hungary being the main producers (FAOSTAT, 2015; figure 7). This equates to somewhere between 28 and 142 million carp.

In 2009, EFSA (2009c) estimated that the majority of carp in the EU were sold alive to retailers or direct to the consumer, with less than 15% slaughtered in commercial processing plants. Carp that are taken home by members of the public may be kept alive for a few days in make-shift tanks (e.g. bath tubs (Lambooij, Pilarczyk, Bialowas, van den Boogaart, & van de Vis, 2007)) before being killed. For carp that are slaughtered in the home, there is little data on the methods used (EFSA, 2009c). Slaughter methods are likely to include death by asphyxia, percussive stun/killing with varying effectiveness. There may be a risk that with inexpert stunning, fishes may be processed while still conscious. Carp are also often killed by the retailer at the point of sale, usually by a manual percussive blow, followed by immediate gill arch cutting (alternatively, they cut off the spinal cord and blood vessels by decapitation). In either case, carp may be subject to prolonged suffering before slaughter due to insufficient handling practices and storing facilities.

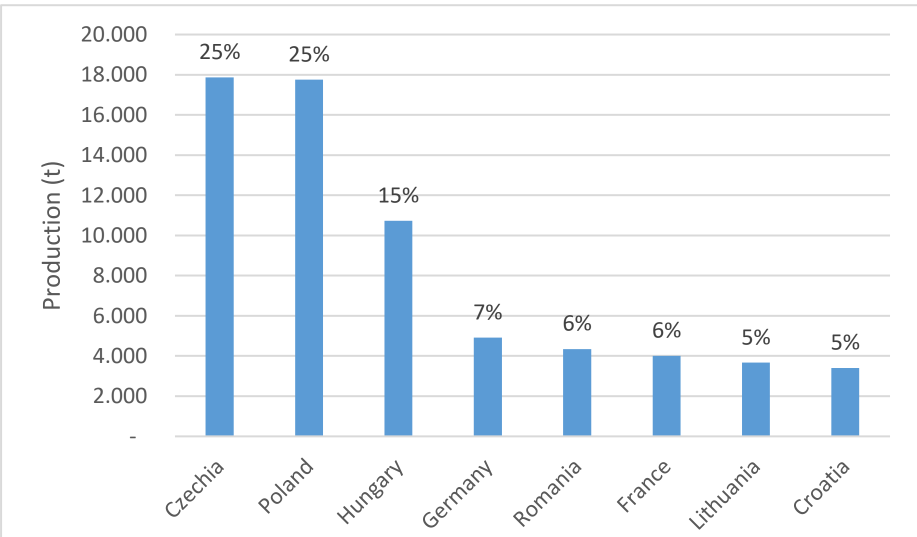


Figure 7. Production (tonnes) of top eight EU countries producing common carp during 2015 and percentage contribution to total EU production.

The Czech Republic Act on the protection of animals against cruelty (The Czech National Council, 1992, last amended in 2017) requires that animals must be stunned prior to bleeding. It states that "fish in industrial processing may be stunned by a device using 230 V alternating electrical current, CO_2 gas or other gas or gas mixture approved according to a special legal regulation". Additionally, "[i]n case of industrial processing of fish, the competent veterinary authority may grant a derogation from … [para 1; requiring stunning before bleeding], in so far as the technology facilitates the processing of fish immediately after its slaughter". It should be noted that the OIE (2014) approve effective electrical stunning as a humane method, but do not recommend CO_2 gas since this causes poor welfare. According to the Czech Fish Farmers Association (pers. comms. October 2017), commercial plants use electrical stunning followed by decapitation.

The Czech Fish Farmers Association also state that "the method of manual carp killing is generally accepted, widely known to public (either killing at home or at selling stands) and is based on the legislation background (paragraph 5i Act No. 246/1992 Coll., on the protection of animals against cruelty (Welfare Act)). It involves manual percussive stunning, followed by immediate gill arches cutting (or alternatively cut off the spinal cord and blood vessels by decapitation). This is certainly impossible to control in the homes, however, welfare of fish being killed at the selling stands is widely controlled under the law by State veterinary authority".

In Germany, carp may be electrically 'stunned' in commercial plants but this is usually insufficient and a percussive blow is also required to stun before slaughter (Feneis Bernhard, pers.comm, July 2017). Some research has been conducted into electrical stunning parameters for carp (Daskalova, Pavlov, Kyuchukova, & Daskalov, 2016; Lambooij et al., 2007).

Lambooij et al. (2007) studied percussive and electrical stunning of common carp, and concluded that fishes are "effectively stunned by head-only electrical application with 0.24 ± 0.03 A (~160 V, 50 Hz, a.c.). An effective stun is also obtained when the water is electrified with a current of 0.14 ± 0.03 A/dm2 (~115 V, 50 Hz, a.c.; electrode distance 16 cm) for 1.2 s at a water conductivity of 200 mS". However in this study they did find that fishes subject to head-only electrical stunning responded to pain stimuli as early as 30 seconds after stunning, showed fin movements at around 48 seconds, and returned to normal swimming behaviour at around 2 minutes. Similarly, fishes subject to whole-body electrical stunning (in fresh water) responded to pain stimuli as early as 30 seconds. This is unlikely to be long enough to allow bleeding and death before conscious recovery. In the same study they found that "the application of an electrical current of 0.73 A/dm2 (~411V, 50Hz, a.c.; electrode distance 16 cm) for 5 s to individual carp in fresh water at a conductivity of 330 mSin combination with chilling in ice water, [was] an effective procedure for slaughter in practice". Further work is needed to find parameters that provide a suitable stun for a long enough duration, and the subsequent development of a commercial system.

On mechanical percussive stunning, Lambooij et al. (2007) concluded that "since not all carp were unconscious after percussion stunning, it is judged that this method can be used, but there is no certainty for instantaneous loss of consciousness and sensibility." They advise that the blow performed in the traditional way, manually with a priest, is inaccurate and insufficient in many cases. In practise, several blows are often necessary.

Therefore currently, an electrical stun followed by a percussive blow and then bleeding may be the most humane method for slaughter of carp. It seems that the further development of electrical stunning systems for carp is the most promising avenue for humane stunning of these species. Ace Aquatec is currently building an in-water stunner for stunning of carp on farm (pers.comm. September 2017).

It is essential that animals killed in stores or on stalls are stunned effectively and humanely. The development of small, humane stunning systems for use by trained staff in store would help improve the welfare of fish slaughtered at point of sale. In the longer run, a move towards humane commercial processing is the best option.

In the Czech Republic, the State Veterinary Administration states that random checks on the seasonal selling of live fish (5% at least) are carried out (State Veterinary Administration of the Czech Republic, 2010). Over the 2016 Christmas season, official veterinarians of the State Veterinary Administration performed checks on one third of the registered carp selling stands (State Veterinary Administration, 2017). In Poland, a series of workshops have been delivered to train those who sell carp, including farmers and supermarket staff, about aspects of fish welfare including humane killing (Anna Pyc of the Polish Trout Breeders Association, pers.comms. October 2017). These examples of good practice should be adopted more widely.

5.4 European sea bass (Dicentrarchus labrax) and gilt-head sea bream (Sparus aurata)2

During 2015, the EU produced over 69 thousand tonnes of European sea bass, consisting of approx. 138-172 million individual fishes. Over 82 thousand tonnes of gilt-head sea bream were also produced, which equates to between 206 and 275 million fish. For both species, over half were produced by Greece, with Spain being the second major producer, responsible for over a quarter of the EU total (FAOSTAT, 2015; figures 8 & 9).

Currently, sea bass and bream are killed under commercial conditions by asphyxia in air; live chilling on ice; and live chilling in ice slurry. EFSA (2009f) assessed these methods and determined that they "included a prolonged period of consciousness (several minutes) during which indications of poor welfare were apparent (physiological and behavioural responses)." Likewise, the OIE advise that these methods should not be used if it is feasible to use alternatives such as percussive or electrical stunning (OIE, 2010).

Immediate loss of consciousness from electrical stunning has been demonstrated in laboratory tests with sea bass, both in seawater (whole body application) and in air (head-only stunning) (Lambooij et al., 2008). An additional killing method may also be required. In 2009, the Animal Health and Welfare panel (EFSA) recommended the "urgent development of commercial stunning methods to induce immediate (or rapid) unconsciousness in seabass and seabream".

[2] Due to similarities in size and production method, European sea bass and gilt-head sea bream are commonly grouped together in discussions of welfare and slaughter methods (e.g. EFSA, 2009f), hence they are also combined here. In general, parameters for electric stunning in water are similar for both species (Jeff Lines, pers.comm., October 2015).

It is possible to electrically-stun sea bass then kill by chilling in ice water slurry, which also serves to preserve flesh quality. EEG recordings by Lambooij et al. (2008) show that, when stunned correctly and for a long enough duration, sea bass can be stunned until death by chilling in ice slurry. In this study, researchers conclude that “the application of an electrical cur-rent of 3.3 Arms/dm2 (sinusoidal 50Hz or pulsed square wave AC, 133Hz, 43% duty cycle) for 1s to individual sea bass head-to-tail is effective to induce a general epileptiform insult (unconscious and insensible). A combination of electrical stunning for 10 s combined with chilling in seawater with flake ice resulted in death of the stunned fishes. Analysis of the flesh quality showed that it seemed to be acceptable.”

Prototypes have recently been developed (Ace Aquatec) and at least one is now in use commercially (Optimar). The system designed by Optimar involves pumping fishes onto a boat via continuous flow pump. From here they pass through a dewater unit and into the stunner. They then pass into iced water. Electrical parameters for the stun are: combination 120V DC and 25V AC, frequency 100Hz. The stun time is 10s to prevent recovery of consciousness. The system is in use by a producer in Turkey, at the request of buyers based within the EU. The buyers are happy with the quality which has in fact improved (partly due to pumping systems replacing brailling).

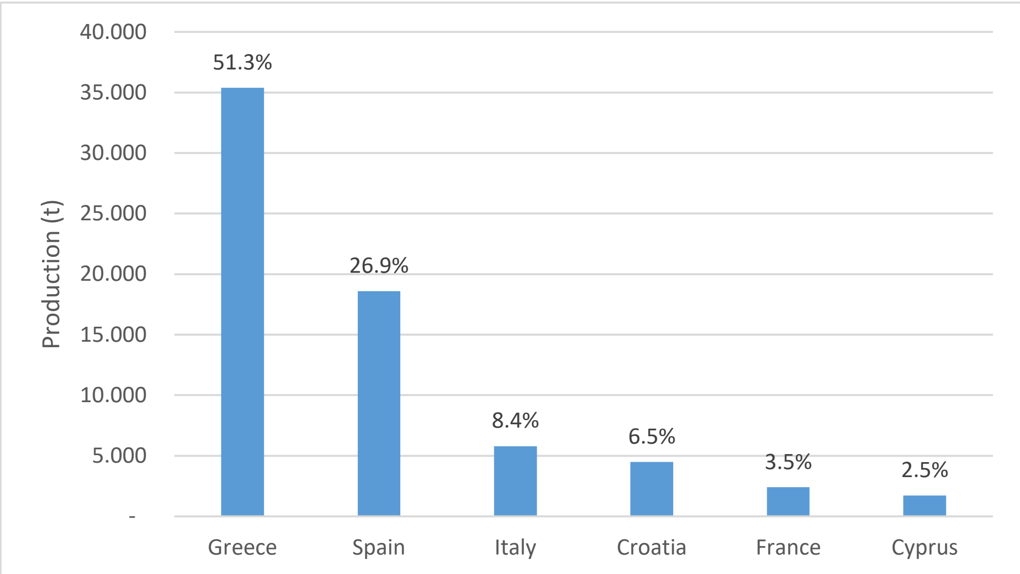
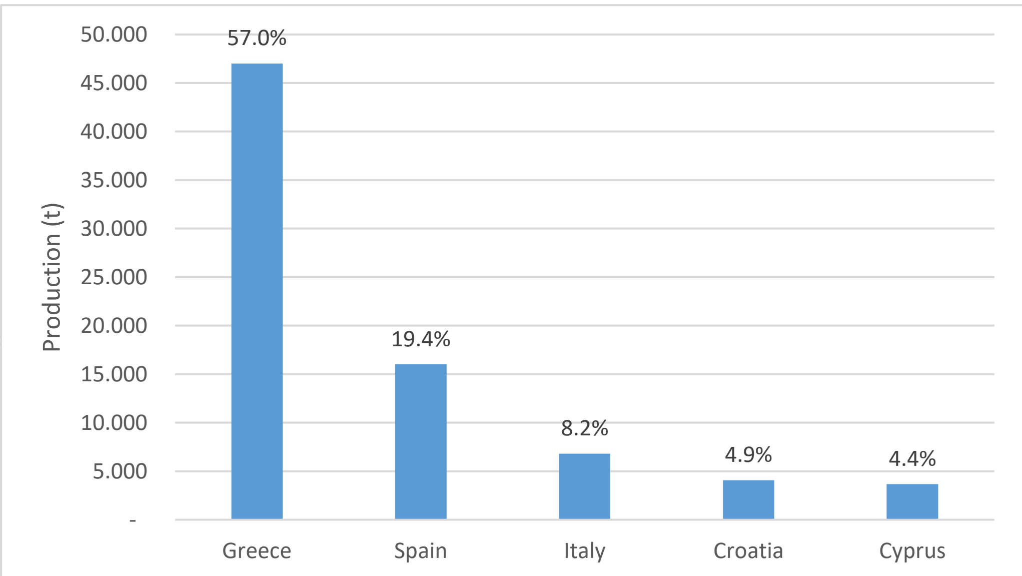


Figure 8. Production (tonnes) of top six EU countries producing European sea bass during 2015 and percentage contribution to total EU production.

Figure 9. Production (tonnes) of top five EU countries producing gilt-head sea bream during 2015 and percentage contribution to total EU production.



5.5 Turbot (Scophthalmus maximus)

Over 10 thousand tonnes of turbot were farmed in the EU in 2015, with Spain being the predominant producer (~73% of production), followed by Portugal (~23%) with the remainder from France, the Netherlands, Romania and Croatia (FAOSTAT, 2015; figure 10). Therefore, between 5 and 14 million turbot (approx.) were farmed according to estimated weights.

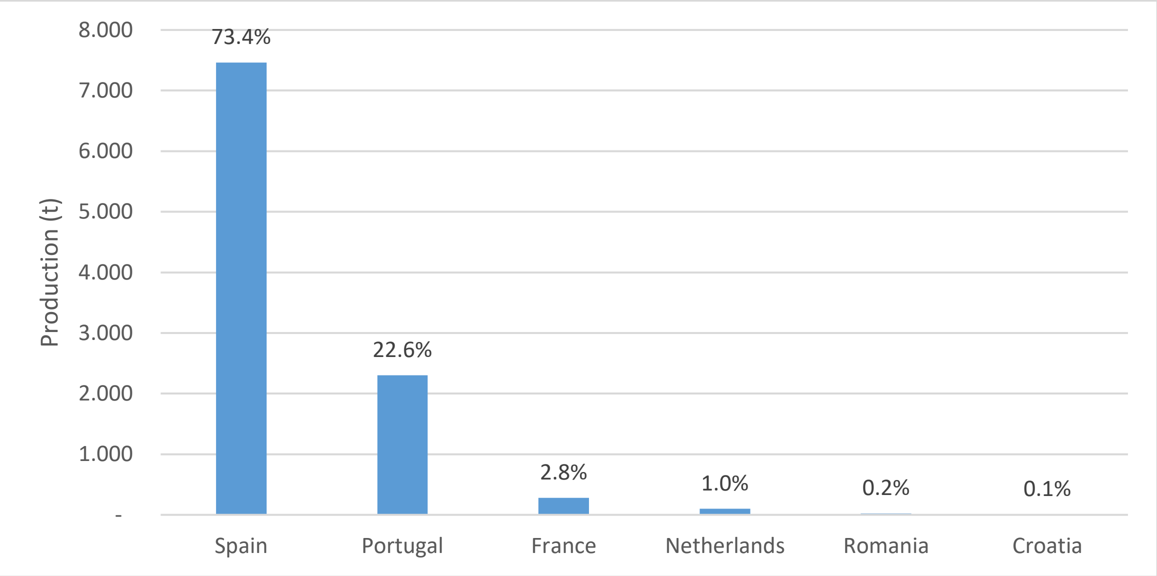


Figure 10. Production (tonnes) of turbot in the EU during 2015 and percentage contribution of each country to total EU production.

EFSA reported in 2009 that turbot were not stunned prior to slaughter under commercial farming conditions (EFSA, 2009g). Instead, they were typically killed by exsanguination and asphyxia on ice, which involves very prolonged periods of consciousness, stress, and results in poor welfare (EFSA, 2009g). Indeed, flatfish are particularly robust – they are less sensitive to oxygen deprivation than salmonids (Morzel, Sohier, & Van De Vis, 2003) and turbot can survive out of water for several days (EFSA, 2004). In 2009, EFSA (2009g) considered the development of commercially viable alternatives (such as electrical stunning followed by chilling or percussive methods) "a matter of urgency".

Electrical stunning tests in turbot using EEG recordings showed that a 5 sec stun followed by chilling in ice water slurry for at least 15 minutes is sufficient to prevent recovery following stunning (StunFishFirst 2005, cited in EFSA, 2009g). A recent study by Daskalova et al. (2016) supports that electrical methods (followed by immersion in ice water) are suitable for turbot, with confirmation from EEG results. Ace Aquatec report that their universal in-water stunning system can be used and adapted for turbot and Optimar sell equipment for semi-dry electric stunning. As with all such systems, thorough testing is required to confirm that stunning is effective in practice.

Percussive stunning is another viable option for turbot and is commonly used to stun/kill other flatfish species such as halibut. Morzel, Sohier, & Van De Vis (2003) report an immediate loss of consciousness using an air gun (8 bars of pressure), and conclude that percussive stunning appears to be a suitably humane method for the slaughter of portion-sized farmed turbot. However due to variable positioning of the eyes in this species, it must be applied manually which may be less suitable in commercial conditions. However, EFSA (2009g) believe that "percussive equipment capable of stunning and killing turbot without causing these potential problems could be developed, according to the expert opinion".

5.6 North African catfish (Clarias gariepinus)

The Netherlands and Hungary are the two primary producers of North African catfish in the EU, together accounting for over 70% of the total (FAOSTAT; figure 11). Over 7.9 thousand tonnes of North African catfish were slaughtered in 2015, which equates to somewhere in the region of 5 to 16 million fishes.

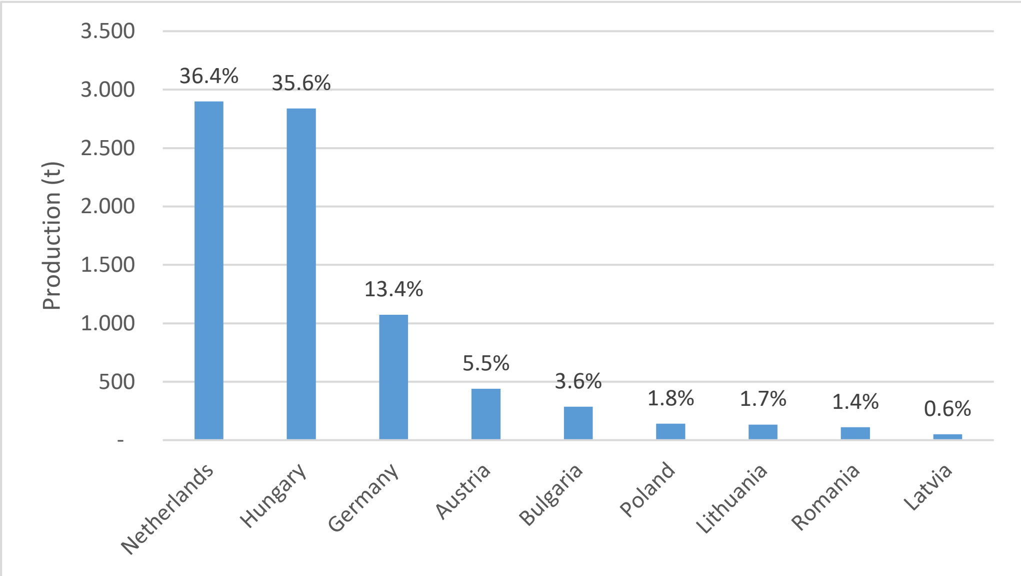


Figure 11. Production (tonnes) of North African catfish in the EU during 2015 and percentage contribution of each country to total EU production.

In 2010 study by Sattari et al. live chilling (before decapitation and evisceration) is reported to be the typical pre-slaughter procedure used for farmed fishes in the Netherlands. However, this method has been described as resulting in poor welfare for fishes by EFSA, and indeed in African catfish, has been shown to be a slow method, taking between 5 and 20 minutes to the onset of unconsciousness, and also inducing muscle cramps and tachycardia (Lambooij et al., 2006; Lambooij, Kloosterboer, Gerritzen, & van de Vis, 2006).

The skull morphology of African catfish may present difficulties for stunning (Van De Vis et al., 2003). However, a study by Lambooij et al. (2006b) demonstrated that electro-stunning (average current of 1.60±0.11 A/dm2 (50 Hz, sinusoidal, a.c.) at a conductivity of 876 µS of the water) of African catfish inside a water tank can be effective in inducing unconsciousness within 1s. Following this stun with decapitation resulted in minimal brain activity until death. Furthermore, Sattari et al. (2010) dry-stunned North African catfish for 9.1±0.4 s using a measured current of 0.91±0.18 A (150 V, AC+DC) followed by decapitation. They found a lack of behavioural response, in 9/10 fishes, to noxious stimuli and therefore suggest that this may be useful method for slaughter of these fishes industrially.

Optimar have developed a system that can be used to stun catfish commercially (Optimar, pers.comms., September 2017).

5.7 European eel (Anguilla anguilla)

Almost 40% of EU European eel production takes place in the Netherlands, with Denmark and Germany being the next significant producers (FAOSTAT, 2015; figure 12).

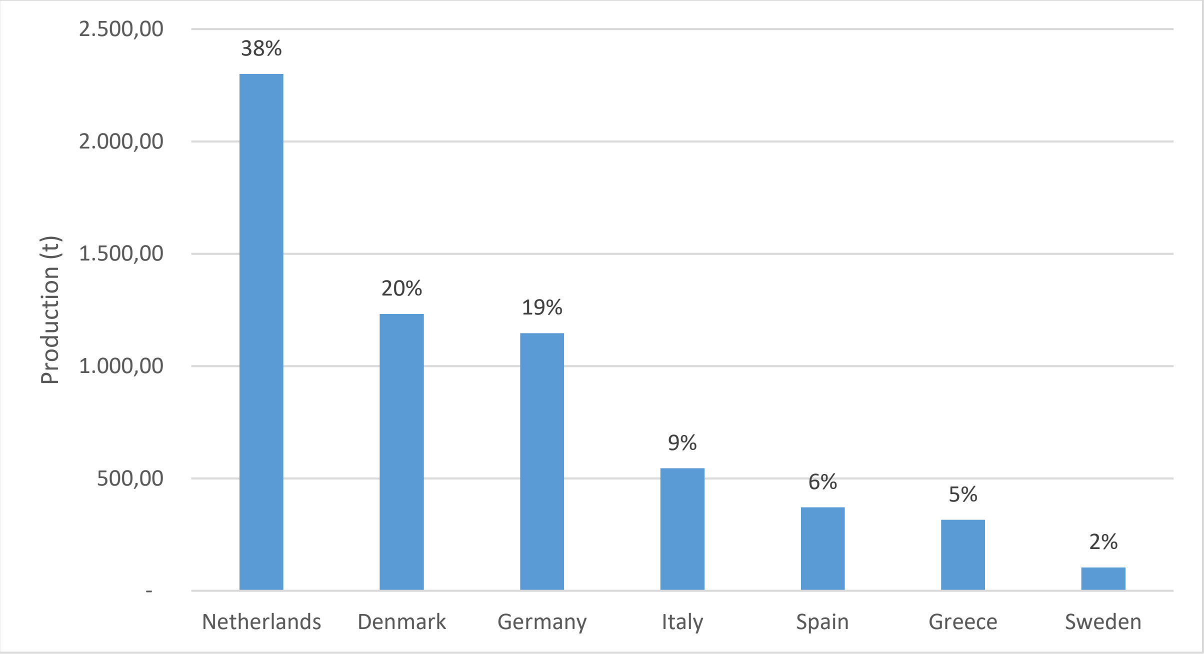


Figure 12. Production (tonnes) of top seven EU countries producing European eel during 2015 and percentage contribution to total EU production.

Eels are very robust, being able to survive out of water for several days (EFSA, 2004), and are therefore difficult to kill (Lines & Spence, 2014). EU slaughter practices for eels include: salt bath, desliming and evisceration; ammonia, washing and evisceration; and immobilization by exposure to ice (and salt), washing and evisceration(EFSA, 2009e). These methods have been identified as inhumane (EFSA, 2009e) and were banned by law in Germany (Bundesqesetzblatt, 1993, cited in Lines & Spence, 2014) and will be banned in New Zealand in 2015, but they continue in many other countries (Lines & Spence, 2014).

According to EFSA (2009e), "electrical stunning immediately followed by a killing method is the preferred practically available method. Electrical stunning methods, as currently practised, however, should be improved. Evidence indicates that commercial electrical stunning systems do not guarantee an immediate loss of consciousness for a sufficiently long period for all eels. On-going research indicates that a higher voltage and current in combination with a killing method shows the potential to overcome these deficiencies”.

(Van De Vis et al., 2003) suggest that electrical stunning of eels can be humane, causing unconsciousness instantaneously and until death; a 10-20kg batch of eels in fresh water can be humanely slaughtered using 0.64 A dm-2 for 1 s, followed by 0.17 A dm-2 combined with nitrogen flushing for 5 min.

Electrical stunning is now used in the Netherlands and Germany (Lines & Spence, 2014). Optimar have developed a system that can be used to stun eels commercially (Frode Kjølås, pers.comms., September 2017).

5.8 Atlantic Bluefin tuna (Thunnus thynnus)

The EU produced around 5.4 thousand tonnes of Atlantic Bluefin tuna in 2015, over half of which was farmed in Malta (FAOSTAT; figure 13).

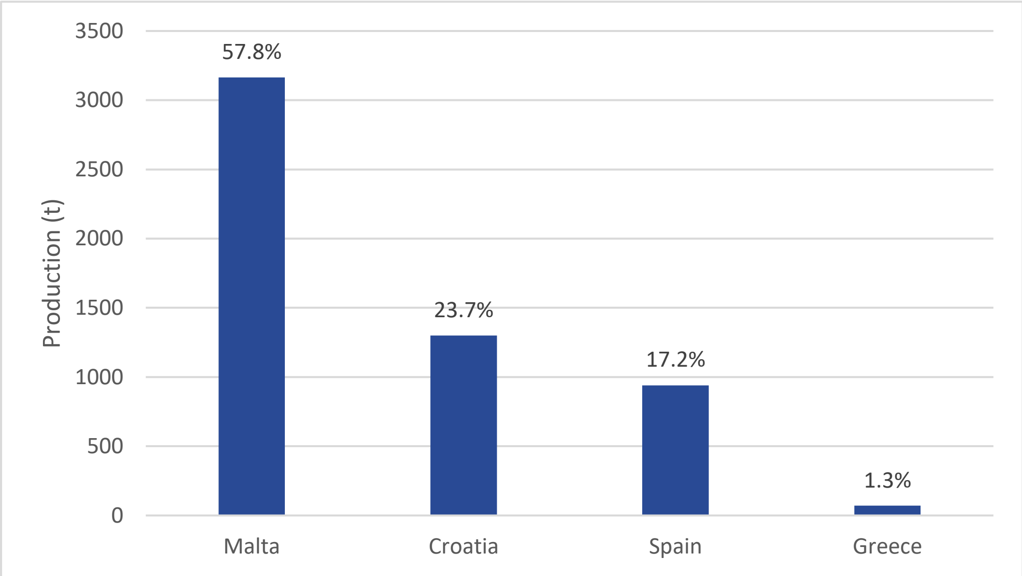


Figure 13. Production (tonnes) of Atlantic Bluefin tuna in the EU during 2015 and percentage contribution of each country to total EU production.

Tuna have extremely high lactate dehydrogense activity (Guppy & Hochachka, 1978), which means stressed fishes can accumulate extremely high lactate levels during slaughter, at detriment to flesh quality (Benetti, Partridge, & Buentello, 2015). Therefore there is strong motivation to minimise stress before slaughter and ensure death is fast, in addition to safeguarding fishes’ welfare.

The three methods currently practised in the EU are: underwater shooting (70-80% of large tuna), shooting from the surface (20-30 % of large tuna), and coring or spiking (100% of small tuna) (EFSA, 2009h). Welfare is believed to be good with underwater shooting because a single shot is usually sufficient to cause immediate death then the tuna are bled out (Benetti, Partridge, & Buentello, 2015). This is the most accurate shooting method and requires only 1-4% of fishes to be shot more than once (EFSA, 2009h). Shooting from the surface is more stressful for tuna than the underwater method as it involves crowding (for approx.. 15 minutes) and is less accurate, with 7-10% requiring a second shot (EFSA, 2009h). However it allows a faster processing speed.

Smaller tuna are typically spiked underwater, however this method can lead to poor welfare as "hoisting or gaffing the tuna before coring or spiking […] involves severe pain and distress"(EFSA, 2009h).

Electrical stunning systems are being developed as an alternative method for stunning/killing Atlantic Bluefin tuna, which may be beneficial for both welfare and processing speed. Ace Aquatec are developing an electrical stunning system for use in Atlantic Bluefin tuna in Australia.

6 A strategy for optimising fish welfare at slaughter while ensuring social and economic sustainability

Humane methods of stunning and killing fish are needed urgently for all species. At the same time, a holistic approach is needed to ensure the practicality and economic sustainability of the system and allow other social factors to be addressed. Research efforts should also aim to include the practicalities of new systems.

6.1 Developing humane slaughter systems

1. **ESTABLISH STUNNING PARAMETERS IN THEORY**:

Parameters required for effective stunning of each species must be established. For example with electrical and percussive stunning, loss of consciousness should be induced immediately without recovery. In most cases this must be followed by a killing method. Onset of unconsciousness, and maintenance of this, should be determined using multiple methods including EEG and ECG recordings. EEG measures should be used to test whether effective stunning can be verified in the field using behavioural observations, as the latter are not always reliable. The stunning parameters must be sufficient to ensure that fishes do not recover consciousness before death occurs; tests should determine the time until death by each method. Information on the variability, or consistency, based on size, age, etc., should be reported. The results should be published in peer-reviewed journals for wide dissemination.

2. **DEVELOP EQUIPMENT TO DELIVER AN EFFECTIVE STUN**:

Prototypes, and subsequently commercial stunners, should then be developed and tested. Although it is often not possible to test for unconsciousness on farm (e.g. EEG cannot be measured in this setting), it is essential to verify that the stunning parameters (established in step 1) are delivered reliably in practice, and that there are no overt signs of fishes recovering consciousness before death occurs.

a. For electrical stunning this includes ensuring adequate: voltage, amperage, waveform of the electrical current, duration of exposure to the electricity, etc. whether in water or after dewatering. The method of transferring the fishes into the stunner should be assessed and the maximal time interval between fishes leaving the stunner and the application of a killing method should be measured.
b. For percussive stunning these specifications include whether fishes enter the equipment head first and whether the air pressure that drives the bolt for percussion is sufficiently high and accurately performed.

3. **IMPLEMENTATION OF THE STUNNING SYSTEM**:

To be effective, this should include:

a. Staff training
b. Mechanisms for ensuring staff competence
c. Standard operating procedures for use of stunning equipment
d. Guidelines for the whole process, including pre-slaughter fasting and handling, to optimise welfare.

4. **VERIFICATION OF EFFECTIVE STUNNING IN-SITU**:

Various measures could be taken to ensure that systems are working reliably and effective stunning is maintained over time including:

a. Systems for ensuring that stunners which are marketed meet the requirements of EU legislation and humane stunning
b. Protocols for performing checks that can be done in-situ for indicators of consciousness/unconsciousness, e.g. behavioural indicators identified in step 1
c. Collection of data (ideally automatic recording) from stunning machines, for example the electric field delivered to each batch of fish
d. Third party certification schemes
e. Appropriate enforcement mechanisms, e.g. surveillance systems, inspections.

Welfare at slaughter cannot be separated from the welfare requirements which lead up to it. This includes requirements for minimising pre-slaughter and transport fasting times, handling and transport. Handling systems may need to be adjusted to fit in with systems of effective stunning.

6.2 Ensuring economic and social sustainability

There are several issues to address while developing humane stunning systems.

HUMAN SAFETY:

Systems should be designed to ensure human safety, and standard operating procedures for safe operation and good practice should be provided. This should ensure that:

a. Equipment, systems and working environments are safe for producers and staff. For example, manufacturers of electric stunning equipment must confirm that their stunning machines are electrically safe, also taking into account weather conditions. Records should also be kept of any accidents, and health and safety should be continually evaluated.
b. Food safety is maintained. For example, if stunning systems reduce the throughput of fishes, there is a risk of fish mortality and a delay in cooling the fish. Keeping fishes for longer in crowded conditions with potentially poor water quality raises fish welfare issues in itself. Solutions include the adoption of systems which maintain a high throughput and/or reducing the level of crowding and the number of fishes collected at a time.

PHYSICAL PRACTICALITY:

Systems should be designed with physical practicality in mind. This is particularly important for smaller producers, who may, for example be more restricted by equipment size because of smaller boats for fish species that are typically slaughtered at the production site.

ECONOMIC SUSTAINABILITY:

a. Product quality should be maintained as far as possible; designers of stunning equipment should check for the effect on quality whilst ensuring that welfare requirements for the fishes are met. Reducing stress is commonly beneficial to both welfare and fish quality. Alternative methods of delivering the fish to the stunner, for example pumping rather than brailing, may improve the product quality and should be tested.
b. The authorities should provide assistance where necessary in the development and purchasing of suitable equipment and the provision of training, especially to meet the needs of smaller producers.
c. We should work to ensure a level playing field both within and outside the EU, i.e. the food industry must be encouraged to develop the same requirements for humane slaughter of fish imported from outside the EU. For example, one UK retailer applies their welfare standards across their global food supply chains3.

[3] https://www.tescoplc.com/assets/files/cms/Welfare_standards_for_farmed_fish_082015.pdf

7 Conclusions

Various inhumane slaughter methods have been widely used for farmed fishes. However in recent years, there has been good progress in developing humane stunning and slaughter systems. Such systems are consistent with the recommendations of the EFSA and the guidelines of the OIE.

Generally, there is a move towards automatic systems for stunning fish percussively and electrically (either semi-dry or in-water systems). Commercial systems are already available, and/or in use, for stunning Atlantic salmon, trout, European sea bass, gilt-head sea bream, eels, turbot, North African catfish, halibut, tilapia, arctic char and yellowtail kingfish (these are summarised in Appendix D). It is the view of the main stunning system manufacturers of both semi-dry and in-water electric stunning equipment that stunners can be developed to humanely stun any species (Optimar and Ace Aquatec, pers comm., 2017). It was proposed that, as stunning systems had been successfully developed for 'difficult to stun' species (due to robustness) such as eels and catfish, there is potential to adapt systems to stun any farmed fish species. Indeed systems are currently being built for in-water stunning of carp, tuna, pangasius and prawns (Ace Aquatec, pers. comm., September 2017).

It is important to remember that evidence that a system delivers an effective stun for one fish species, is not evidence that it can be used humanely for another. It is vital that each system is tested thoroughly, for each species for which it is used, to ensure that stunning is effective (in rendering fishes unconscious until death) and the slaughter process is humane. This testing process should 1) establish stunning parameters in theory, 2) develop equipment to deliver an effective stun, 3) implement the stunning system, and 4) verify of effective stunning in-situ. When developing systems that advance fish welfare, we must also take social, practical and economic issues into account.

Knowledge on handling and slaughtering fish humanely, and best practice for verifying these processes, should be shared among stakeholders to ensure the humane and sustainable development of aquaculture.

There is much research and development still to be done. However the progress made in recent years, and the rapidly increasing availability of commercial systems creates a positive outlook for farmed fish welfare at slaughter in the EU.

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9 Appendices

9.1 Appendix A. Links to key documents with recommendations on humane slaughter of fish

World Organisation for Animal Health (OIE) standards on:

- Welfare during stunning and killing of farmed fish, in Chapter 7.3 of the OIE Aquatic Animal Health Code. http://www.oie.int/index.php?id=171&L=0&htmfile=chapitre_welfare_stunning_killing.htm
- Welfare during killing for disease control purposes in Chapter 7.4 of the Code http://www.oie.int/index.php?id=171&L=0&htmfile=chapitre_killing_farm_fish.htm

The Commission's key advice comes from **EFSA's Animal Health and Welfare Panel**. EFSA's advice on farmed fish welfare, published around 2009, is to be found at links at https://www.efsa.europa.eu/en/topics/topic/fish-welfare. This includes EFSA's general approach to fish welfare and to the concept of sentience in fish (https://www.efsa.europa.eu/en/efsajournal/pub/954), research needs (https://www.efsa.europa.eu/en/efsajournal/pub/1145) and papers on species-specific welfare aspects of the main systems of stunning and killing for some of the key species:

- Atlantic salmon - http://onlinelibrary.wiley.com/doi/10.2903/j.efsa.2009.1011/epdf
- Rainbow trout - http://onlinelibrary.wiley.com/doi/10.2903/j.efsa.2009.1012/epdf
- European sea bass and gilt-head sea bream - http://onlinelibrary.wiley.com/doi/10.2903/j.efsa.2009.1010/epdf
- Carp - http://onlinelibrary.wiley.com/doi/10.2903/j.efsa.2009.1013/epdf
- European eel - http://onlinelibrary.wiley.com/doi/10.2903/j.efsa.2009.1014/epdf
- Atlantic Bluefin tuna - http://www.efsa.europa.eu/en/efsajournal/pub/1073
- Turbot - http://onlinelibrary.wiley.com/doi/10.2903/j.efsa.2009.1073/epdf

The UK's **Farm Animal Welfare Committee (FAWC)** has also published an opinion on the welfare of farmed fish at the time of killing, which includes recommendations for Atlantic salmon, rainbow trout, tilapia and halibut:
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/319331/Opinion_on_the_welfare_of_farmed_fish_at_the_time_of_killing.pdf.

RSPCA Assured standards for Atlantic salmon and rainbow trout farming can be found at https://science.rspca.org.uk/sciencegroup/farmanimals/standards.
Specifically for salmon at https://science.rspca.org.uk/sciencegroup/farmanimals/standards/salmon
And trout at https://science.rspca.org.uk/sciencegroup/farmanimals/standards/trout

The Spanish standardisation organisation (AENOR) has produced guidelines for farmed fish slaughter, including standards for European sea bass, gilt-head sea bream, turbot, meagre, trout, sturgeon and sole.:
http://apromar.es/sites/default/files/2016-AENOR%20Guia%20practicas%20correctas%20sacrificio%20piscicultura.pdf

9.2 Appendix B. Farmed fish production in EU member states in 2010.

Ordered by higher estimated numbers. As no data on number of fishes is reported by FAOSTAT, estimates are calculated based on annual tonnage from FAOSTAT and fish weights from www.fishcount.org.uk. As most fish are killed at a range of weights, an upper and lower weight is used to calculate a range of estimated fish numbers.

Country	Production (t)	Estimated lower no. farmed fishes slaughtered	Estimated higher no. farmed fishes slaughtered
Greece	90,975	198,578,038	271,749,820
Italy	52,452	35,940,441	196,558,351
Spain	59,483	80,807,854	189,227,467
France	46,990	17,074,854	172,740,409
Denmark	37,007	6,891,000	164,050,476
Germany	35,709	8,044,025	115,058,273
United Kingdom	169,571	22,199,804	109,305,367
Poland	30,751	8,979,600	93,577,048
Finland	11,772	2,196,800	52,304,762
Czech Republic	20,420	7,777,467	40,156,667
Sweden	9,261	1,571,800	37,423,810
Croatia	11,930	13,169,867	31,774,381
Hungary	14,245	6,092,533	28,209,905
Bulgaria	7,212	2,462,650	21,047,333
Romania	8,981	3,308,587	16,988,648
Cyprus	4,115	9,427,300	12,680,238
Ireland	16,857	2,080,926	9,591,250
Netherlands	6,760	2,393,333	7,395,238
Austria	2,167	387,133	6,490,000
Malta	2,916	4,591,500	6,105,000
Lithuania	3,191	1,200,400	5,961,600
Portugal	2,236	3,165,850	4,931,821
Slovakia	687	163,333	2,870,667
Slovenia	700	243,050	2,615,762
Estonia	572	113,260	2,400,229
Latvia	548	177,960	906,352
EU totals	**647,514**	**439,039,367**	**1,602,120,872**

9.3 Appendix C. Production of farmed fish species (weight and estimated numbers) in the EU during 2010

Ordered by estimated number of individuals. As no data on number of fishes is reported by FAOSTAT, estimates are calculated based on annual tonnage from FAOSTAT and fish weights from www.fishcount.org.uk. As most fish are killed at a range of weights, an upper and lower weight is used to calculate a range of estimated fish numbers.

FAO Species Category	Production (t)	Estimated numbers lower (millions)	Estimated numbers upper (millions)
Rainbow trout	195,338.40	39.07	930.18
Atlantic salmon	171,215.20	20.30	47.38
Gilt-head seabream	89,996.20	224.99	299.99
Common carp	67,780.60	27.11	135.56
European seabass	56,633.40	113.27	141.58
Turbot	8,548.70	4.27	12.21
European eel	6,819.40	6.43	21.36
Freshwater fishes nei	6,574.40	6.20	20.60
North African catfish	5,307.60	3.54	10.62
Sea trout	4,501.60	4.24	14.10
Silver carp	3,402.00	2.27	11.34
Atlantic bluefin tuna	3,150.00	2.97	9.87
Bighead carp	3,060.50	2.04	6.12
Meagre	2,388.00	2.25	7.48
Chars nei	2,177.00	2.05	6.82
Grass carp(White amur)	2,026.90	0.81	4.05
Roach	1,900.30	1.79	5.95
Marine fishes nei	1,844.20	1.74	5.78
Trouts nei	1,758.80	1.66	5.51
Sturgeons nei	1,464.80	1.38	4.59
Wels(=Som)catfish	1,279.80	1.21	4.01
Tench	1,192.20	1.12	3.74
Goldfish	1,153.00	1.09	3.61
Cyprinids nei	1,007.50	0.95	3.16
Brook trout	848.40	0.80	2.66
Flathead grey mullet	758.50	0.51	1.52
European whitefish	749.00	0.71	2.35
Torpedo-shaped catfishes nei	650.00	0.61	2.04
Northern pike	469.60	0.44	1.47
Pike-perch	383.70	0.36	1.20
Danube sturgeon(=Osetr)	333.20	0.31	1.04

FAO Species Category	Production (t)	Estimated numbers lower (millions)	Estimated numbers upper (millions)
Arctic char	236.70	0.22	0.74
Nile tilapia	235.00	0.29	0.94
Senegalese sole	223.70	0.21	0.70
Mullets nei	221.50	0.21	0.69
Blackspot(=red) seabream	214.20	0.20	0.67
Striped bass, hybrid	204.50	0.25	0.25
Black bullhead	199.90	0.19	0.63
Salmonoids nei	176.00	0.17	0.55
Atlantic halibut	139.00	0.03	0.05
Shi drum	130.60	0.12	0.41
Common sole	116.00	0.11	0.36
Beluga	115.10	0.11	0.36
Channel catfish	108.00	0.16	0.32
Catfishes nei	89.00	0.08	0.28
White seabream	87.20	0.08	0.27
Largemouth black bass	81.00	0.12	0.12
Siberian sturgeon	71.70	0.07	0.22
European perch	51.20	0.05	0.16
Common pandora	50.00	0.05	0.16
Finfishes nei	45.00	0.04	0.14
Freshwater bream	39.80	0.04	0.12
Porgies, seabreams nei	29.00	0.03	0.09
Mississippi paddlefish	24.20	0.02	0.08
Adriatic sturgeon	21.10	0.02	0.07
Soles nei	20.00	0.02	0.06
Sharpsnout seabream	19.10	0.02	0.06
Japanese seabream	14.00	0.01	0.04
Tilapias nei	13.00	0.02	0.05
Common two-banded seabream	11.80	0.01	0.04
Rudd	11.60	0.01	0.04
Barramundi(=Giant seaperch)	8.20	0.00	0.03
Huchen	7.00	0.01	0.02
Roaches nei	6.50	0.01	0.02
Marbled spinefoot	4.80	0.00	0.02
Bleak	3.40	0.00	0.01
Chub	2.60	0.00	0.01
Greater amberjack	2.10	0.00	0.01
Asp	1.00	0.00	0.00

FAO Species Category	Production (t)	Estimated numbers lower (millions)	Estimated numbers upper (millions)
Big-scale sand smelt	1.00	0.00	0.00
Grayling	1.00	0.00	0.00
Whitefishes nei	1.00	0.00	0.00
Atlantic cod	0.70	0.00	0.00
Crucian carp	0.50	0.00	0.00
Sargo breams nei	0.50	0.00	0.00
Barbel	0.40	0.00	0.00
Sterlet sturgeon	0.40	0.00	0.00
Danube bleak	0.10	0.00	0.00
Totals	**647,753.00**	**479.47**	**1,736.69**

9.4 Appendix D. Availability of commercial stunning systems for farmed fish with the potential to be humane

This table is not exhaustive and it is expected that further development of species will be quite rapid. As stated in the text, it is essential that various stages of verification and testing are carried out to ensure effective stunning. We do not at present have full details as to which levels of testing and verification have been carried out for each of these. N.B. Optimar has taken over Stansas.

Species	Percussive stunning	Electric stunning in water	Electric stunning after dewatering	Other/Notes
Atlantic salmon	*Commercially available* BAADER 101 automated Swim-In System can achieve throughputs ranging from 50 fish/min with 1-2 operators (Baader, 2012) BAADER 101 Manual Feed System can achieve throughputs ranging from 30 fish/min with 1 operator, up to 240 fish/min with 8 operators (Baader, 2012)	*Commercially available* Humane Stunner Universal (Ace Aquatec, 2014) N.B. sometimes used in addition (prior to) percussive stunning.	*Commercially available* Stansas #01 (Stansas, n.d.)	OIE state salmon can be spiked or cored.
Rainbow trout	*Commercially available* BAADER 101 automated Swim-In System can achieve throughputs ranging from 50 fish/min with 1-2 operators (Baader, 2012). BAADER 101 Manual Feed System can achieve throughputs ranging from 30 fish/min with 1 operator, up	*Commercially available* Humane Stunner Universal (Ace Aquatec, 2014) N.B. sometimes used in addition (prior to) percussive stunning.	*Commercially available* Stansas #01 (Stansas, n.d.)	

Species	Percussive stunning	Electric stunning in water	Electric stunning after dewatering	Other/Notes
	to 240 fish/min with 8 operators (Baader, 2012).			
Carp species (Common, Grass, Silver, Bighead)	*Manual method used*	*Under development* Ace Aquatec are currently building a system for on-farm stunning of carp (pers.comm, September 2017).		Electrical stunning likely to be used in combination with percussive methods.
European sea bass & gilt-head sea bream	*Small and highly active fishes, so unlikely to be practical.*	*Commercially available* Humane Stunner Universal (Ace Aquatec, 2014)	*Commercially available* Optimar system	
Turbot			*Commercially available* Stansas #01 (Stansas, n.d.)	
North African Catfish			Commercially available Stansas #01 (Stansas, n.d.)	
European eel			*Commercially available* Stansas #01 (Stansas, n.d.)	
Tuna		*Under development* by Ace Aquatec (for use in Australia).		Shot with underwater gun, with rifle in air or spiked (EFSA)
Halibut		*Commercially available*	*Under development*	

Species	Percussive stunning	Electric stunning in water	Electric stunning after dewatering	Other/Notes
		Humane Stunner Universal (Ace Aquatec, 2014)	Stansus claim to have a stunner available.	
Tilapia		*Commercially available* Ace Aquatec		
Arctic char	*Commercially available* BAADER 101 automated Swim-In System can achieve throughputs ranging from 50 fish/min with 1-2 operators (Baader, 2012). BAADER 101 Manual Feed System can achieve throughputs ranging from 30 fish/min with 1 operator, up to 240 fish/min with 8 operators (Baader, 2012).	*Commercially available* Humane Stunner Universal (Ace Aquatec, 2014)		
Yellowtail Kingfish		*Commercially available* Ace Aquatec	Criteria for developing a stunner available. (Hans van der Vis, pers.comms)	

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