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Humane harvesting and slaughter of farmed fish

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Summary

The overwhelming majority of farmed fish produced throughout the world are killed with little or no consideration for their welfare. Fasting periods can be excessive, transport stressful and killing inhumane. At the time of writing, the salmon industry is the only sector in which consideration of the welfare of the fish at slaughter has resulted in significant improvements throughout most of the industry. There are signs of interest in the use of more humane slaughter methods for some other fish species. This is mostly initiated by the demand for higher standards from European fish retailers. For most species, the humane killing options are limited to percussive stunning and electrical stunning. However, even these methods can have a poor welfare outcome if insufficient consideration is given to the needs of the fish or if the equipment has not been properly designed. The use of food-grade anaesthetics to assist with the harvest has significant potential for improving welfare and their wider use should be investigated further.

Keywords

Aquaculture – Fish – Harvest – Humane killing – Slaughter – Stress – Welfare.

Introduction

More than 40 million tonnes of farmed fish, comprising over 250 species, were produced in 2011 (1). Eighty-five percent of this production took place in Asia, with Africa, Europe and the Americas each contributing a little less than 5% to the total. The industry is growing rapidly and has almost doubled in production during the last ten years. Because of this wide geographical spread, rapid development and the large diversity of species, a comprehensive summary of slaughter practices is not possible. However, the importance of the subject is significant from a welfare perspective, since an estimated 37 to 120 billion farmed fish were killed in 2010 (2), mostly using methods that were developed to optimise convenience, cost and product quality but with little or no consideration for the welfare of the fish. Even now, with a broad scientific consensus that fish are sentient (3) and have the capacity to suffer, there is little evidence of improvement in slaughter methods on the majority of fish farms around the world. Globally, salmon aquaculture is the single general exception to this observation. Descriptions of some of the slaughter methods used for a range of commonly farmed species are to be found in recent publications by the European Food Safety Authority (EFSA) (4, 5, 6, 7, 8, 9, 10) and others (11, 12, 13).

In the past few years, the retail markets in some countries and some national governments have started to demand higher standards of welfare for fish at slaughter. This has resulted in research and development and in some local improvements. Examples include improvements in the methods used to kill eel and catfish in Germany and the Netherlands and trout in the United Kingdom. These pressures, if maintained, will probably result in improved slaughter methods for some species, particularly those grown in or imported into Europe, such as sea bass and bream, tilapia and pangasius. Whether these improvements will become widespread or be restricted to niche markets is not clear.

Protecting the welfare of fish whilst harvesting them is technically challenging. Improvements in fish welfare will be achieved by regularly reviewing every component of a harvest in the light of developments in scientific understanding and technology and adopting state-of-the-art methods wherever available. Since society has a tendency to hold ambivalent attitudes towards fish welfare, and as legislation often does not include detailed provisions for fish, the adoption of new techniques and improvements in harvesting methods will also be determined by perceived changes in the quality of the flesh or operational costs. The development of new methods must therefore also focus on these aspects.

This paper focuses only on farmed fish, but the situation with wild-caught fish is more extreme. The number of wild-caught fish killed each year is at least ten times greater than the number of farmed fish, yet the consideration given to them is less, and the technical problems associated with improved killing methods are greater (14).

The process of harvesting farmed fish usually comprises three stages: a period of food withdrawal to empty the gut; the collection and movement of the fish to the point of slaughter; and the process of stunning and killing. The impact of these processes on the welfare of the fish varies significantly with the species, with the methods used and with the care and attention to detail applied throughout. Owing to the variation in the physiology of different species, it is not possible to identify a slaughter method suitable for all fish (15). Some of the species considered explicitly in this paper are identified in Table I.

Table I
Species of farmed fish and their common names (as used in this paper)
In some cases, the fish are cultured varieties of a specific species; in others, these names can refer to a range of species and hybrids

Commonly used name	Specific identification of main farmed species
Eel	European eel (*Anguilla anguilla*), Japanese eel (*Anguilla japonica*)
Catfish	Various farmed species and hybrids, including Vundu catfish (*Heterobranchus longifilis*) and African catfish (*Clarias gariepinus*)
Trout	Mostly rainbow trout (*Oncorhynchus mykiss*), but also brown or sea trout (*Salmo trutta*)
Salmon	In Europe, mostly Atlantic salmon (*Salmo salar*); elsewhere coho (*Oncorhynchus kisutch*) and Chinook (*Oncorhynchus tshawytscha*)
Bass	European sea bass (*Dicentrarchus labrax*)
Bream	Gilt head bream (*Sparus aurata*)
Tilapia	Various species and hybrids, including Nile tilapia (*Oreochromis niloticus*), blue tilapia (*Oreochromis aureus*) and Mozambique tilapia (*Oreochromis mossambicus*)
Pangasius	Basa catfish (*Pangasius bocourti*)
Halibut	Atlantic halibut (*Hippoglossus hippoglossus*)
Turbot	European turbot (*Scophthalmus maximus*)
Tuna	Atlantic bluefin tuna (*Thunnus thynnus*) and southern blue fin tuna (*Thunnus maccoyii*)
Carp	Common carp (*Cyprinus carpio*)

Fasting

Many farmed fish have their food withdrawn for a period before handling, transport or slaughter. An empty gut during these operations lowers the fishes' metabolic activity and so reduces the rate at which ammonia and carbon dioxide build up in the water during crowding and transport (16). It also prevents faecal contamination during processing, which can shorten the shelf life of the fish (17). The duration of fasting necessary to empty the gut is species- and water-temperature-dependent, but may be expected to be from one to five days.

In commercial practice a range of food withdrawal periods are to be found, often far longer than is needed simply to empty the gut. This is often a matter of tradition and operational convenience. For example, a long period can be used to facilitate a series of partial harvests from a single enclosure. In the past, long periods of fasting were used in salmon aquaculture in the belief that this could be used to improve the flesh quality by reducing oil levels (17). However, the evidence that this process improves the flesh quality of salmon and most other species is weak. An empathetic assessment of the effect of food withdrawal on fish welfare is difficult because fish can adjust their metabolic rate in response to the availability of nutrition (18). However, fish are motivated to eat and excessive periods of fasting are likely to infringe the first of the Five Freedoms of Animal Welfare (freedom from hunger and thirst) (19). The crucial question is whether the duration has been minimised to that needed to empty the gut. López-Luna *et al.* (20) kept rainbow trout in water at about 19°C and fasted them for one, two and three days. The trout appeared to clear their gut within 24 h and further fasting had no significant effect on their body weight or on several other biochemical indicators of stress. However, the leucocyte count for the fish that were fasted for three days was slightly reduced, suggesting that the immune system might be depressed. Robb (21) concludes that no evidence exists for additional benefits from fasting salmon beyond 72 h.

Gathering and transporting to the point of slaughter

Crowding is the first stage in most harvesting operations. For fish grown in nets, this is achieved by slowly lifting part of the net or by inserting a second net into the water. In ponds, raceways and tanks, it is achieved by using a seine net to encircle the fish or by moving partitions or grids. Wall (17) comments that crowding is one of the prime causes of poor welfare during harvest. For many species, the most common problem associated with crowding is shortage of oxygen; however, even when high oxygen levels are maintained, the effects of crowding may be observed in the blood chemistry for days afterwards (22). Different species respond to crowding in different ways. For many fish species, the process needs to be carried out slowly and with great care to avoid a panic reaction which can result in high levels of stress, injury and mortality. However, the behavioural responses of some other species, including turbot and eel, do not appear to be as overt. Brown *et al.* (23) note that, with Atlantic cod, the cage depth needs to be reduced slowly before crowding, to avoid over-inflation of the swim bladder. Guidelines for salmon emphasise the need to crowd progressively, to ensure that the water remains deep and to observe the fish for signs of abnormal behaviour, leaping out of the water, signs of asphyxia or inversion (24).

The period for which fish are held in a crowded condition must be minimised if welfare is to be optimised. Thus, it is important that the organisation of a harvest is efficient and that rapid harvesting methods are used.

Once crowded, fish are moved by pumping or brailing. Pumping is widely used in salmon aquaculture, whereas brailing is more common for sea bass, bream and pangasius and in enterprises with lower levels of capital investment.

Pumping is achieved by placing a large bore tube amongst the crowded fish. The pump sucks up water and fish through this tube, using a centrifugal or vacuum-pumping mechanism. Although fish pass directly through the pumps, they are seldom injured by the moving parts. Under some circumstances, pumping can be achieved using airlift or venturi systems, where the fish are not exposed to any moving parts. Within the tubes there is a risk of injury through collision if poor design or manufacture has resulted in sharp corners or interior projections (5).

Pumping distance varies widely from just a few metres to more than a kilometre. During long pumped transits, hazards can also arise from poor water quality or overcrowding, particularly during stoppages or if the pipe becomes blocked. Single-chamber and, to a lesser extent, double-chamber vacuum pumps result in uneven and turbulent water flow in the pipes. Struggling against this turbulence quickly exhausts the fish. After pumped transit to the slaughter plant, most salmon are too exhausted to swim properly, even when the transit time is as little as 2 to 4 mins (5). At the end of a pumped transfer, the fish should be observed to confirm that they are free of injury and have sufficient energy to maintain their equilibrium (upright orientation) and to swim normally. After pumping, the pipes must be checked to ensure that no fish remain in them.

Brailing uses a large hand net or crane-operated net to gather the fish from the water. Brailing generally requires lower levels of crowding than pumping. This can benefit the fish. However, very high densities of fish occur inside the brail for short periods. Brails can contain anything from a few kilograms of fish in a hand brail to several hundred kilograms in a crane-operated brail. In dry brailing, where water is not held in the brail (Fig. 1), there are particular dangers to the fish through bruising, crushing, puncture and abrasion injuries from contact with other fish, contact with the net and contact through the net with other hard surfaces. Dry brails are frequently used by tradition and for operational convenience; however, they are a significant welfare hazard. In wet brails, water is collected and lifted together with the fish (Fig. 2), so that they are protected from crushing and other untoward effects. Wet brails can be used to collect and move fish short distances with fewer welfare problems. The exit from any brail may be stressful, and may have the potential to cause injury, if the fish fall onto other fish, onto a solid surface or even into water.

It is both difficult and expensive to transport fish without imposing significant stress on them. Thus, it is usually best to slaughter fish at the rearing site. For operational reasons, however, many species, including salmon, pangasius, carp, tilapia, catfish and eel, are commonly transported to a remote point for slaughter.

Considerable investment has been made in the design and development of well boats used for transporting salmon (Fig. 3). Modern vessels are designed to enable water quality to be monitored and controlled, and so that the tanks can be emptied without leaving fish without water at

Fig. 1
A dry brail being used to move sea bass into bins of ice slurry

Fig. 2
A wet brail moving halibut in preparation for size grading

Fig. 3
A well boat collecting salmon from a Scottish farm
The fish pump tube is suspended from the boat's crane

the bottom of the tank. Under some circumstances the fish are cooled during the journey. This may reduce the fishes' need for oxygen and their rate of ammonia production. The Royal Society for the Prevention of Cruelty to Animals has produced Welfare Standards for Farmed Atlantic Salmon (25). These standards recommend that cooling should be no faster than 1.5°C per hour and that the water temperature should not be reduced below 4°C. Recent research by Foss *et al.* (26) indicates that a temperature drop from 16°C to 4°C in one hour or from 16°C to 0°C in 5 h may be acceptable. Wider investigation is needed to support this finding. Following well-boat transport, salmon are frequently allowed to recover (without food) in a lairage for one or more days because immediate slaughter is likely to result in poor quality flesh, due to exhaustion.

Some farmed fish, including eels and pangasius, are routinely transported using road vehicles, sometimes without water. Fish transported in this way are likely to become extremely stressed. Stress factors include not only the lack of water and oxygen but also the pressure of other fish resting on them, rapid temperature changes, vehicle vibration and the physical shock if they are dropped as they enter or leave the transport unit. The fact that many of these fish can survive these conditions is not an indication that it is a stress-free experience. Transport out of water should always be avoided. After transport most pangasius are too exhausted to swim or maintain their equilibrium when returned to the water.

Stunning and killing

Stunning and killing are achieved by a wide range of methods, few of which would be considered acceptable for other vertebrates.

Asphyxiation in air or ice

The majority of farmed fish are killed without prior stunning simply by asphyxiating them in air or in ice slurry. Ice slurry is operationally convenient because it cools and preserves the fish, while killing them with no additional effort or cost. The method is often referred to as stunning by cold shock but, although cheap and convenient, it cannot be considered to be humane (5, 7, 8, 9).

Immersion of sea bass and bream in ice slurry often results in only a brief period of obvious struggling (typically 30 seconds) and so is defended on this basis. However, van de Vis *et al.* (13) have shown that sea bream transferred from water at 23°C to ice slurry take five minutes to lose normal patterns of brain activity. The brain is therefore still active several minutes after the fish has become immobilised (27, 28). Rahmanifarah *et al.* (29) observed that common carp removed from water at 23°C and plunged into ice slurry (0.6°C to 1.8°C) maintained their respiration for 50 minutes and some carp left to asphyxiate in air took almost five hours to cease opercula (gill cover) movements. Roth *et al.* (30) investigated the industrial practice of chilling turbot and showed that, after 90 minutes in chilled seawater at about –1°C, the turbot remained alive and capable of full recovery, even though their internal temperature was below 1°C and their muscles were stiff, resembling rigor. From these and other similar results, we may reasonably conclude that, while a fish's physical reactions may stop or slow relatively quickly after being placed in ice or ice slurry, brain activity indicates the potential for the continuation of consciousness for a substantial period. Therefore, it seems that cold shock may paralyse fish so that they lose sensibility slowly without the ability to display outward indications of suffering.

Bleeding, gutting or beheading

In some species where bleeding is considered necessary, the fish are bled, beheaded or even eviscerated while conscious. Pangasius, tilapia, eel and many flat fish species are examples (7, 9, 30). 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. Van de Vis *et al.* (13) have shown from electroencephalogram (EEG) measurements that some eel brain function continues for up to 13 min following decapitation.

Carbon dioxide

Immersion in water infused with carbon dioxide is a well-established method for killing salmon. However, the slow onset of insensibility and the clear behavioural indications of distress (5) have resulted in it being prohibited in Norway. Trials by Erikson (31) explored the possibility that a low concentration of carbon dioxide might stun or anaesthetise salmon without causing stress. It was nonetheless concluded that any concentration of carbon dioxide that is great enough to have any useful effect on the salmon also results in clear indications of stress. The Norwegian Scientific Committee for Food Safety has concluded that, while there may be some potential for using gases to kill fish humanely, no such methods have yet been found (32).

Percussive stunning

Percussive stunning is widely used in salmon aquaculture. It is likely to result in rapid and prolonged or permanent insensibility if the blow is strong enough and if it is applied at the correct location. When it is performed manually these factors are dependent on the ability, training and state of fatigue of the operator. Automated percussive stunning equipment (Fig. 4) largely overcomes these problems and is probably the most widely used fish stunning method that has been developed, with improved welfare as one of its key objectives.

With automated percussion, the welfare of the fish depends on three main factors:

– the time for which the fish is out of water before stunning

– the position of the fish in the equipment (they must be presented to the machine upright and head first)

– the location and momentum or impact energy of the percussive strike.

When salmon are harvested without prior grading for size, percussive stunning equipment is unlikely to be suitable for the whole range of fish sizes encountered. Some form of intervention is therefore needed to remove very small or very large fish, deformed fish or sexually mature fish before they reach the percussive device.

Fig. 4
A simple automatic percussive stunning unit for salmon

Since the blow must be applied with some precision, the automated percussive stunning of flat fish, where both sinistral and dextral individuals exist, is a challenge. Other species of farmed fish, including catfish, pangasius, carp and tilapia, are very resistant to percussive stunning due to the shape of, and protection afforded by, the skull (33, 34). At present, automated percussion is generally not used for small fish because of the difficulty of designing equipment that operates fast enough to make this approach economically viable.

After percussive stunning, any sign of controlled and coordinated movement should be considered to indicate that the fish was not adequately stunned. Signs include the rhythmic motion of the opercula, the vestibulo-ocular reflex (eye-roll reflex), struggling, swimming activity or efforts to remain upright or regain equilibrium. Occasional spasmodic convulsions can be observed in effectively stunned fish. While Lambooij *et al.* (35) warn that the absence of these signs cannot be considered conclusive evidence of insensibility, they are probably the best indicators available on the farm.

Electrical stunning

Electrical stunning can be achieved both in water (wet stunning) and out of water (dry stunning). It can result in rapid, prolonged insensibility if the correct electrical parameters are used and if they are applied to the fish in a manner that avoids pre-stun shocks. The voltage, current or electrical field needed to achieve both a rapid stun and prolonged insensibility depends upon the species, the orientation of the fish and the conductivity of the water. Using unsuitable parameters compromises welfare (6) and may simply paralyse the animal. The operation of the equipment must be checked for each species. A description of how to identify if the equipment is capable of effectively stunning fish can be found in Lines and Spence (11). Details for various species can be found in a range of publications by Lambooij *et al.* (34, 36, 37), Lines & Kestin (38, 39), Robb *et al.* (40, 41, 42) and Roth *et al.* (43).

Unlike percussive stunning, electrical stunning without suitable post-stun treatment is seldom permanent. The duration of unconsciousness depends on the electrical parameters of the stun, the duration of electrical application and on post-stun treatment. Some species, if stunned for a suitable duration and then placed in still water or ice, will die from hypoxia before they are able to recover consciousness. These include salmon, trout, sea bass and gilt head bream. However, if these fish are returned to moving or agitated water so that a flow of oxygen to the gills is maintained, they may recover. To minimise the risk of recovery during transport, it is therefore better to transport these fish to the processing factory in ice rather than ice slurry. Species which are tolerant of low oxygen levels require a follow-up killing method, such as immediate bleeding, to avoid recovery. Such species include turbot, halibut, eel, tilapia, carp and catfish. It is necessary to sever all of the gill arches on at least one side of the head, immediately after stunning.

Some advantages of wet electrical stunning over percussive stunning are that it can be applied to large numbers of fish simultaneously; the fish do not need to be removed from the water, handled, restrained or orientated until they are insensible; and undersized, oversized or deformed individuals will be effectively stunned without special adjustment of the equipment. This can result in very high standards of welfare at slaughter and in very high throughput rates, making electrical stunning uniquely suitable for small fish with a low individual value. A high throughput of fish is beneficial since it minimises the time for which fish are crowded.

Dry stunning may involve placing fish on a conveyor belt passing under electrified paddles. Higher current densities can be achieved in this way, which may be useful for very resilient species such as flat fish and pangasius. It is important to ensure that the fish are arranged so they do not receive pre-stun shocks. This may occur if they are struggling violently, if their tails make contact with the electrodes before their heads or if fish are lying on top of each other. Various methods have been developed to avoid these situations, the efficacy of which should be checked by direct observation.

Anaesthetics

In Australia, Chile, New Zealand, Korea, Costa Rica and Honduras, the use of an anaesthetic based on isoeugenol is permitted to facilitate harvest (40, 44). However, food safety regulations prevent its use in the European Union and many other countries. While some common fish anaesthetics are known to initiate stress responses (45, 46), it is not known whether this occurs with this product. However, the fact that the fish can lose consciousness with little disturbance means that a high standard of welfare may be possible. Research into the use of food-grade anaesthetics for either sedation or stunning should be encouraged for a range of species.

Other methods

Specific welfare concerns are associated with some species. Tuna have a high individual value and, typically, considerable precautions are taken to guard against stress since this can compromise the value of the product. In some operations, a gun is used to destroy the brain while the fish is in the water. If this is done reliably and accurately, it results in a high standard of welfare at slaughter. In other operations, the tuna are gaffed and hoisted out of the water before killing, a handling process that clearly compromises welfare (10).

Spiking, coring or *iki jime* are terms used to describe a killing method where a tool is driven directly into the skull to physically destroy the brain (10). The fish may be subsequently pithed by passing a wire down the spinal column (47). If a fish has not been rendered unconscious immediately before this intervention, then destruction of the brain must be completed rapidly, to reduce any suffering as a result of the penetrative damage to the tissues of the head. However, fish brains are small so there is a significant risk that the tool may miss the brain (12, 48). This is particularly likely if the fish is struggling. Robb *et al.* (49), working with salmon, found that 50% of the shots analysed were inaccurate. Given these factors and the firm restraint required, typically out of water, spiking may compromise the welfare of fish in multiple ways.

Eels are difficult to kill. Current killing practices include placing them in a salt bath, in an ammonia solution or immobilising them in iced water and eviscerating them while alive (7). Such practices were identified as inhumane more than a decade ago and were banned by law in Germany and will be banned in New Zealand in 2015, but they continue in many other countries. Electrical stunning is now used in Germany and the Netherlands.

In some countries, carp are often sold alive, taken home and stored live before killing in the home. Carp are also commonly killed at the point of sale in supermarkets, small retail outlets or markets. The European Food Safety Authority (6) estimates that as many as 90% of the carp produced may be killed outside commercial processing plants. While the storage and killing of these fish may occasionally be done well, it is probable that most of them will be subjected to inhumane treatment, due to poor environmental conditions, lack of proper facilities and poor killing methods. To reduce struggling, carp are commonly removed from the water for long periods before killing is attempted. Hand-held equipment has been developed to improve the killing method but there is no indication that it is in wide use. The transport and sale of live fish should be avoided wherever possible.

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Le respect du bien-être des poissons lors des prises et des opérations d'abattage

J.A. Lines & J. Spence

Résumé

Dans leur immense majorité, les poissons d'élevage produits dans le monde sont abattus sans aucune considération, ou presque, pour leur bien-être. Ils sont privés de nourriture pendant des périodes excessivement longues, transportés dans des conditions stressantes et mis à mort de manière inhumaine. À l'heure actuelle, la salmoniculture est le seul sous-secteur de la pisciculture où la prise en compte du bien-être des poissons au moment de l'abattage s'est traduite par des améliorations significatives avec des avancées manifestes pratiquement à l'échelle mondiale. Des signes sont perceptibles de l'intérêt suscité par la recherche de méthodes d'abattage moins cruelles pour d'autres espèces de poissons. Cette évolution est due principalement à l'exigence de normes plus élaborées de la part des distributeurs de poissons en Europe. Pour la plupart des espèces, les solutions d'abattage exemptes de cruauté se limitent à l'étourdissement mécanique par percussion crânienne et à l'étourdissement par électrocution. Toutefois, même ces méthodes peuvent se traduire par un résultat médiocre en termes de bien-être si les besoins des poissons ne sont pas suffisamment pris en compte ou si le matériel utilisé est mal conçu. Le recours à des anesthésiants compatibles avec l'usage alimentaire lors des prises présente un fort potentiel d'amélioration du bien-être des poissons ; sa généralisation devrait faire l'objet de recherches approfondies.

Mots-clés

Abattage – Abattage dans des conditions décentes – Aquaculture – Bien-être – Mise à mort – Poisson – Prise – Stress.

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Recolección y sacrificio incruentos de peces de cultivo

J.A. Lines & J. Spence

Resumen

La inmensa mayoría de los peces de cultivo producidos en el mundo son sacrificados sin que se tenga poco o mucho en cuenta su bienestar. Los periodos de ayuno pueden ser excesivos, las operaciones de transporte ansiógenas y los procedimientos de sacrificio cruentos. En el momento de redactar estas líneas, la industria salmonera es la única en la cual el hecho de tener en cuenta el bienestar de los peces al sacrificarlos ha deparado mejoras sustanciales en buena parte del sector a escala mundial. Hay signos de que empieza a surgir interés por el uso de métodos de sacrificio más compasivos en otras especies piscícolas, casi siempre a resultas de la demanda de normas más estrictas por parte de los minoristas de pescado europeos. En la mayoría de las especies, las posibilidades de sacrificio incruento se circunscriben al aturdimiento por percusión o el aturdimiento eléctrico. Sin embargo, incluso estos métodos pueden resultar poco eficaces, desde el punto de vista del bienestar, cuando no se tengan lo bastante en cuenta las necesidades de los peces o cuando el instrumental no esté bien concebido. La utilización de anestesias de uso alimentario para acompañar las labores de recolección podría ser un expediente eficaz para mejorar los niveles de bienestar, por lo que convendría estudiar más a fondo su posible aplicación generalizada.

Palabras clave

Acuicultura – Bienestar – Estrés – Matanza – Peces – Recolección – Sacrificio – Sacrificio incruento.

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