Institution: University of Bristol		
Unit of Assessment: 6) Agriculture, Food and Veterinary Sciences		
Title of case study: Improved welfare at slaughter of commercially farmed fish worldwide		
Period when the underpinning research was undertaken: 2000 - 2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
Steve Kestin	Senior Research Fellow	1990 – 2005
Steve Wotton	Senior Research Fellow	1991 – 2017
Justin McKinstry	Technician	1991 – present
Dave Robb	Research Associate	1997 – 2001
Toby Knowles	Professor	1990 – present
Jeff Lines	Honorary Senior Research Fellow	2010 – present
Period when the claimed impact occurred: 1st August 2013 - 2020		
Is this case study continued from a case study submitted in 2014? No		

1. Summary of the impact

As a result of University of Bristol (UoB) research, billions of farmed fish annually worldwide have improved welfare at slaughter. UoB was the first to identify and measure welfare problems with slaughter by asphyxiation in air or on ice, or gill cutting and bleed-out while still conscious; they proceeded to develop proven humane stunning techniques. Their collaborative research with industry has pioneered commercial stunning equipment now used worldwide for salmon and trout and enabled humane mass slaughter with improved productivity and fish quality. Concurrently, the research has led to significant changes in policy worldwide, including the World Organisation for Animal Health (OIE) guidelines, RSPCA welfare standards, the Soil Association's and Naturland's international organic standards. Affecting a wide range of fish species, these policies all follow UoB's research by recommending stunning before slaughter.

2. Underpinning research

Pioneering research at the University of Bristol (UoB) has led the way in evaluating the welfare of farmed salmon and trout at the time of slaughter. Studies support the view that fish are sentient animals that can feel pain. It has been shown, for instance, that given the choice, fish will access analgesics to alleviate pain. To be considered humane, a killing method must render the fish immediately unconscious, unaware of any pain, and that this condition should persist until death.

Research by the UoB group in the early 2000s, led by Dr Kestin, was the first to establish that there was a welfare problem with the then prevalent methods of fish slaughter [1]. By monitoring the electrical activity of fish brains, they established that fish take a long time to die with the commercial methods of handling and slaughter used at the time. These included leaving fish to die a slow, painful death in air or in ice slurry, or gill cutting without stunning, which results in fish remaining conscious whilst slowly dying from blood loss [2].

The UoB team developed protocols for assessing welfare of fish at the time of slaughter [3], focussing on indicators of consciousness, such as respiration, eyes responding to light, checking whether the eyes move with movement of fish (conscious fish maintain their eyes horizontal when the body is turned, termed 'righting mechanism') and twitching in response to pinching. In experimental work, electroencephalograms provided the gold standard against which to benchmark these methods of assessing consciousness, which are easier to use in a commercial situation. Using these welfare protocols, the researchers found percussive or electrical stunning to be the principal humane methods of slaughter. Electrical stunning also has the potential to reduce handling of conscious fish. From a welfare perspective, electrocution (which may both

stun and kill a fish instantaneously) is ideal, but there are potential commercial disadvantages in that it can affect flesh quality by causing, for example, blood spots and broken bones.

Thus, the body of work not only compared different methods of welfare assessment, handling and slaughter, but also investigated the consequences for the whole fish, its flesh quality and shelf life to ensure acceptability to the aquaculture industry. It was necessary to determine which electrical parameters of the equipment used to electrically stun fish would be effective in terms of fish welfare but without commercial downsides. Systematic experimental studies determined that the duration of stun application, plus the frequency and magnitude of the current, were important for how long trout remained stunned and whether or not they were humanely killed [4]. Further work on salmon [5] led to a better understanding of the electrical parameters needed to produce unconsciousness (animals that lose consciousness quickly are unaware of subsequent procedures used to kill them and do not feel pain: hence this is deemed humane). Follow-on research on electrical stunning specifically investigated flesh quality, including new species, such as turbot [6] and sea bass [7]. LINK-funded research [iii] by UoB and Silsoe Livestock Systems Ltd with industrial partners The Co-operative Group (CWS) Ltd, Waitrose Ltd, Ace Aquatec, Kames Fish Farming Ltd, Shetland Halibut Co. Ltd, together with the Humane Slaughter Association and funding from Defra, moved from stunning in fresh water to electrical stunning in sea water of farmed halibut, extending both species and water type.

This body of research, along with research conducted in development with a commercial partner, laid the foundation for practical, welfare-friendly methods of killing the billions of fish (more than all other food animals) farmed globally.

3. References to the research

1. **Robb DHF, Kestin SC.** (2002). Methods used to kill fish: Field observations and literature reviewed. *Animal Welfare,* 11(3), 269-282. https://www.ingentaconnect.com/content/ufaw/aw/2002/00000011/00000003/art00001
2. **Robb DHF, Wotton SB, McKinstry JL**, Sorensen NK, **Kestin SC.** (2000). Commercial slaughter methods used on Atlantic salmon: determination of the onset of brain failure by electroencephalography. *Veterinary Record,* 147(11), 298-303. doi:10.1136/vr.147.11.298
3. **Kestin SC,** van de Vis JW, **Robb DHF.** (2002). Protocol for assessing brain function in fish and the effectiveness of methods used to stun and kill them. *Veterinary Record,* 150(10), 302-307. doi:10.1136/vr.150.10.302
4. **Robb DHF**, O'Callaghan M, **Lines JA, Kestin SC.** (2002). Electrical stunning of rainbow trout (*Oncorhynchus mykiss*): factors that affect stun duration. *Aquaculture,* 205(3-4), 359-371. doi:10.1016/s0044-8486(01)00677-9
5. **Robb DHF**, Roth B. (2003). Brain activity of Atlantic salmon (*Salmo salar*) following electrical stunning using various field strengths and pulse durations. *Aquaculture,* 216, 363-369. doi:10.1016/S0044-8486(02)00494-5
6. **Knowles TG, Brown SN, Warriss PD, Lines J,** Tinarwo A, Sendon M. (2008). Effect of electrical stunning at slaughter on the quality of farmed turbot (*Psetta maxima*). *Aquaculture Research,* 39, 1731-1738. doi:10.1111/j.1365-2109.2008.02049.x
7. **Knowles TG, Brown SN, Warriss PD, Lines J, Tinarwo A,** Bravo A, Carvalho H, Gonçalves A. (2007). Effect of electrical stunning at slaughter on the carcass, flesh and eating quality of farmed sea bass (*Dicentrarchus labrax*). *Aquaculture Research*, 38 (16)*,* 1732 - 1741. doi:10.1111/j.1365-2109.2007.01846.x

Grant Funding

i. **Kestin SC.** Optimisation of harvest procedures of farmed fish with respect to quality and welfare. EU programme FAIR-CT97-3127, 1997-2000, EUR273,000

ii. **Knowles TG.** StunFishFirst - Development of prototype equipment for humane slaughter of farmed fish in industry. EU – CRAFT (Coop-CT-2004-512991), 2005-2006, EUR755,894

iii. **Lines J.** Humane electric stunning of farmed sea-fish (Link Collaborative Research). Defra, 2005-2006, GBP121,072

4. Details of the impact

Production of the six top species groups of farmed fish was estimated at 48.5 million tonnes in 2018 (Food and Agriculture Organisation (FAO))[1], representing many billions of individuals. These species are grouped as: carps and barbels; tilapias; catfish; salmons, trouts and smelts; freshwater fishes; and marine perch-like species, which include sea bass and sea bream. Total global production of farmed Atlantic salmon alone, the focus of initial UoB research, is estimated to comprise 200,000,000 fish (2.5 million tonnes in 2018, (FAO)).

Research at UoB (2000 – 2020) alerted animal welfare charities, government agencies and fish producers to problems with existing slaughter practices within aquaculture fish production. Moreover, the work [4-7] identified practicable solutions to achieving an instantaneous loss of consciousness via electrical stunning which represents a more humane method of slaughter than those previously used. Thanks to the evidence base provided by this work, electrical stunners are now used around the world on salmon, trout, turbot and sea bass [2-7]. The use of stunners on pangasius (catfish), sea bream, yellowtail, carp and barramundi is currently under investigation by UoB with industrial partners in an Humane Slaughter Association project (see below), thus the work has successfully reached species from five of the six top groups of farmed fish, and beyond. Thanks to the specification of the new humane methods of stunning at slaughter by international standards, awareness of the methods is global, even if they are not always implemented (e.g. where farms are too small in scale for the equipment to be practical). Further, the UoB research team has collaborated with a commercial partner, Ace Aquatec, to develop stunning equipment. This, in turn, has opened up new markets and increased staff (recently doubling in number) and sales from European, Australian and South American regional offices for Ace Aquatec [I].

Impacts on national and international policy: food and animal welfare standards

To reassure consumers, most food derived from animals, including fish, complies with standards that ensure high standards of hygiene and animal health and welfare. The UK is the EU's biggest producer of farmed salmon, the focus of earlier UoB research [2,5], and is responsible for 163 thousand tonnes of salmon each year (~15 million fish), 90% by volume of total EU production and 8% of the global market. Over 70% of UK salmon producers adopt RSPCA Assured welfare standards, which require certificate holders to ensure good welfare practices at slaughter. These practices reflect the UoB team's research; Kestin of the UoB group contributed to the RSPCA's guidelines on fish welfare at slaughter for farmed Atlantic salmon, which were updated in 2018 [A] and are still informed by UoB work. The UoB team further influenced retailer standards, opening up the use of electrical stunning to more species investigated by UoB, including trout [4] and sea bass [7]. For example, Waitrose, the retailer with the greatest market share of fish in the UK (1.9 million fish/year), requires that "*All our farmed salmon, sea farmed rainbow trout, rainbow trout, brown trout, sea bass, sea bream and halibut are stunned prior to slaughter*." [Bi]. Both Waitrose and the Co-op were partners in Link-funded research [iii] which extended the range of species that could be effectively and practicably stunned, given the widely differing responses between species to stunning, and also investigated stunning in sea water (Waitrose was also a partner in [ii]). The Co-op standards also require that fish are stunned before slaughter [Bii].

The Farm Animal Welfare Committee (FAWC), the expert committee to Defra and the Devolved Administrations in Scotland and Wales, and which informs UK legislation and practice, produced a report in 2014, 'Opinion on the Welfare of Farmed Fish at the Time of Killing' [C]. The report is based predominantly on UoB's research: 13 of its 20 references come from their work. The 2018 Humane Slaughter Association (HSA, the UK charity concerned exclusively with promoting humane treatment of all food animals worldwide) report 'Humane Slaughter of

[1] http://www.fao.org/3/ca9383en/ca9383en.pdf

Farmed Finfish around the world' [D] acknowledges the leading work at UoB, "*Two common methods of stunning fish, currently considered to be the most humane and globally acceptable for food safety, are electrical and percussive stunning. Both methods are already in-use in the rainbow trout and Atlantic salmon industries, respectively, and the stunning parameters are based on scientific recommendations (e.g. Robb et al, 2002b* [4]*)*". The report notes how methodologies for welfare assessment, humane stunning and stun-kill are continually being refined and extended to include other fish species [D].

UoB research continues to inform EU practice and is widely cited (seven references) in a 2017 review [E] funded by the European Commission. This report also notes that "*The OIE and EFSA's Scientific Opinions (2009) on the key fish species, provide a useful point of reference*" (Executive Summary). The EFSA 2009 report on salmon cites nine UoB papers whilst its trout report seven key papers from UoB research (including [1-6]). Other international food standards that insist on humane slaughter (stunning before kill) include the Global Aquaculture Alliance's Best Aquaculture Practices (GAABAP, 2017) [Fii], which base their stunning and killing on a review citing seven papers from UoB research (including [1,3,5]), and the Soil Association's Aquaculture standards [Fiii], which are underpinned by the UoB-informed FAWC guidelines [C]. A 2009 report published by the Research Institute of Organic Agriculture (FiBL), 'Stunning and slaughter methods for edible fish', cites 13 UoB papers and forms an important part of the evidence base used by Naturland's Standards for Organic Aquaculture (latest version 2020) [Fv]; Naturland is a major international association for organic agriculture.

An increasing number of worldwide standards are adopting guidelines for stunning before slaughter, not only of salmonids (salmon and trout), but also of other farmed fish species. The scientific evidence base for these policy changes includes the pioneering studies by UoB. For example, the World Organisation for Animal Health (OIE) publishes an Aquatic Animal Health Code for its 181 member countries, which states: "*farmed fish should be stunned before killing, and the stunning method should ensure immediate and irreversible loss of consciousness"* and recommends electrical stunning for "*carp, eel, salmonids*" (OIE, 2019) [G]. A review undertaken for the OIE by Lines (of UoB) and Spence (2014) [H] provided the evidence base for the Aquatic Animal Health Code and cites 11 references from the UoB team, including [1-6]. A 2017 assessment of uptake of OIE guidelines, produced for the European Commission by the IBF Consortium (cited in the HSA report [D]), estimated that "*best practices are mostly achieved, with a few exceptions*" for Atlantic salmon produced in the European Economic Area.

Economic impacts: industry collaboration and commercialisation of fish stunning equipment

Having developed validated methods for measuring fish welfare at slaughter and defined the principal factors to achieve effective stun with fish in the laboratory, the next step for the UoB group was to upscale the stunning method for commercial settings. Robust and effective stunning equipment was needed to cope with large numbers and rapid processing of fish (line speed in major UK farmed salmon processing factories may be 4,000 per hour, with fish weighing 10-12kg each). This was achieved through Kestin, Knowles and Lines' research collaboration from 2001 with Ace Aquatec Ltd (AA), producers of aquaculture and marine technologies. Kestin introduced AA to the concept of electrical stunning at an industry meeting and, together, UoB and AA went on to develop and test the first prototype in-line electrical stun systems for the humane commercial killing of farmed salmon and trout [I].

Development work between AA and UoB is ongoing, both in-house and via externally funded research, including GBP721,580 awarded in 2019 by the charity the Humane Slaughter Association to implement in-water electrical stunning in aquaculture of Nile tilapia, Pangasius (catfish), gilthead sea bream, yellowtail and possibly carp [I].

As a result of contributions from UoB, AA is now an award-winning and major provider of humane fish slaughter equipment; in 2019, its Humane Stunner Universal (HSU) technology won a Queen's award to industry for Enterprise Innovation, while in 2017 it was awarded the Innovation Award at Aqua Nor, the world's largest aquaculture industry fair. HSU is now in use

on farms around the world, including in Chile, New Zealand, Japan, Germany, Greece, USA and Canada [Ii]. Before UoB involvement, AA's core business was seal deterrents for salmon farms. The company has experienced significant growth as a result of introducing the humane slaughter equipment into its product line. AA's CEO sums up the considerable commercial impacts of the stunning equipment as including: "*new regional offices in Chile, Norway, and Australia; investment … this year totalling over £4m; doubling of staff from 10 to 20 employees in six months; addition of new species to our stunning capabilities, including bream, tilapia, and prawns … The company has grown from a family run business in 2008 with a handful of deterrents sold each year, to an international business with recurring rental revenue of £2m, with an aim to double each year*." [Ii]. AA has increased its net assets from GBP299,904 in 2015 to GBP3,545,347 in December 2019 [Iii], with sales of its humane slaughter equipment making a major contribution. AA also report that the electrical stunning equipment brings sustainability benefits, having "*reduced waste going to landfill and provided an income to farmers/suppliers where otherwise there was an expense for removal and destruction. These products are now supplying high end restaurants and pet food where before the use of anaesthetic required them to go to landfill*." [Ii].

5. Sources to corroborate the impact

[A] RSPCA (2018). RSPCA welfare standards for Farmed Atlantic Salmon
See: Part B of Appendix 1

[B] i) Waitrose (2020). Animal welfare (accessed 29/04/2020)
ii) Co-op (2020) Email correspondence - Fish Sustainability Manager

[C] FAWC (2014). Opinion on the welfare of farmed fish at the time of killing

[D] Humane Slaughter Association (2018). Humane slaughter of finfish farmed around the world

[E] Aquaculture Advisory Council (2017). Farmed fish welfare during slaughter

[F] Multi-national standards:
i) GAABAP (2020). Email correspondence – Country Coordinator
ii) GAABAP (2017). Aquaculture Facility Certification
iii) Soil Association (2020). Soil Association Standards Aquaculture Version 18.4 *(see p34)*
iv) Naturland (2020). Email correspondence - Aquaculture & Fishery Department
v) Naturland (2020). Naturland Standards Organic Aquaculture

[G] i) OIE. (2019). Aquatic Animal Health Code: Chapter 7.3 Welfare Aspects of Stunning and Killing of Farmed Fish for Human Consumption
ii) Cefas (2020) Email correspondence – Epidemiologist, Aquatic Pests and Pathogens

[H] Lines & Spence (2014). Humane harvesting and slaughter of farmed fish. *Rev. sci. tech. Off. int. Epiz.,* 33 (1), 255-264. https://doc.oie.int/dyn/portal/index.seam?page=alo&aloId=31762

[I] i) Ace Aquatec (2020). Supporting statement – CEO
ii) Companies House (2021). Ace Aquatec Limited – Unaudited abridged accounts for the year ended 31 December 2019