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TITLE: **ECONOMIC EVALUATION OF
HUMANE SLAUGHTER METHODS
FOR FARMED FISH IN ITALY**

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slaughter methods for farmed fish in Italy'
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SUMMARY

Consumers are increasingly concerned with ensuring that the fish they purchase are produced to high welfare standards. In Italy, there are many opportunities to improve the welfare of fish. In this report, we show how producers can improve fish welfare by stunning fish humanely before slaughter. For rainbow trout, this could involve electrical stunning or percussive stunning, while for European sea bass and gilthead sea bream, this would involve electrical stunning. Our economic analysis shows that stunning before slaughter would only represent a small additional production cost (3% for trout; 1.2% for sea bass and sea bream). Even if these additional costs were passed along to consumers, we expect retail price increases to be minimal when compared to the willingness to pay more for higher welfare standards expressed by the consumers. We conclude with details about manufacturers of equipment.

INTRODUCTION

There is increasing support for improving fish welfare in aquaculture. The scientific understanding of fish sentience and welfare has advanced in recent years, and consumers are increasingly choosing to shop for ethical food products [1]. Given this, improving the welfare of fish is crucial for not only the fish themselves, but also the future profitability of farmers and retailers.

One frequent source of intense, unnecessary suffering is the slaughter practice. Here, we analyse the question of whether implementing humane stunning and slaughter methods in aquaculture in Italy is financially feasible for farmers. We focus on the three most commonly farmed finfish species in Italy: rainbow trout (here, 'trout'), European sea bass ('sea bass'), and gilthead sea bream ('sea bream') [2]. We identify the best slaughter methods for improving welfare for these three fish species in Italy. Then, we perform an economic analysis to calculate the effect of these methods on the cost of production, concluding with details of some manufacturers and suppliers of equipment.

AQUACULTURE IN ITALY

In 2020, aquaculture enterprises in Italy produced a total of 33,200 tonnes (t) of trout, 4,700t of sea bass, and 6,200t of sea bream [3]. There are several hundred enterprises for farming each of trout, sea bass, and sea bream throughout Italy [4,5]. Most of these enterprises are small, with 62% of all aquaculture enterprises having fewer than five employees [6].

Rainbow trout are farmed inland, usually in intensive, flow-through systems like raceways or concrete tanks. A minority are farmed in floating cages in freshwater lakes [2]. Meanwhile, the majority (ca. 78%*) of sea bass and sea bream are farmed in floating sea cages [2,7]. Beyond this, some are farmed in

land-based systems (ca. 16%*), and a small minority are farmed in wetlands (ca. 6%*) [8].

Imports are particularly important for sea bass and sea bream. In 2020, Italy imported 2,200t of trout, 34,900t of sea bass, and 36,400t of sea bream. On top of this, exports may be of significant importance for all three species: in 2020, Italy exported 10,600t of trout, 4,700t of sea bass, and 6,800t of sea bream, though it is unclear what proportion of these exports were produced domestically [9].

CURRENT SLAUGHTER METHODS

Currently, most fish farmed in Italy are subject to inhumane slaughter practices that are detrimental for fish welfare. Italian law currently provides no requirements for the slaughter of fish to be humane (see Appendix 1).

All sea bass and sea bream are killed by live chilling followed by gill cutting [10]. Fish exposed to live chilling experience intense suffering and show vigorous attempts to escape [11–13]. This suffering occurs over prolonged periods, with studies estimating that fish remain conscious for between 5 and 40 minutes [12–14].

Trout are slaughtered using a variety of methods, including immersion in ice slurry and asphyxiation in air. Asphyxiation in air is highly concerning for the welfare of the fish. Fish exposed

to this slaughter method continue moving and struggling for between 40 minutes and 3 hours [15,16]. During this prolonged period, fish experience acute suffering.

Some rainbow trout are stunned before slaughter, generally by electrical stunning [10,17] or otherwise by percussive stunning [18]. However, there is no data on the prevalence of stunning, and there have been no formal evaluations on the effectiveness of stunning at farms and abattoirs in Italy. Given this, it is unclear whether trout are being stunned effectively in practice. Incorrect implementation fails to protect fish from suffering.

POTENTIAL HIGHER-WELFARE PRACTICES

Given the fact that most fish farmed in Italy are currently slaughtered without being stunned first, there is substantial room to increase rates of stunning (Table 1) as a means of improving the welfare of fish at slaughter.

For trout, there are two methods of stunning that can be humane when performed correctly [17]. The first method is electrical stunning. This involves exposing fish to an electric current to rapidly render the fish unconscious, either temporarily or permanently. Electrical stunning is then followed by decapitation or gill cutting for large trout, or by chilling in ice slurry for small trout [17]. The second method is percussive stunning. This

**percentages based on personal communication from the Italian Fish Farmers Association*

involves the delivery of one blow to the head to stun or kill a fish instantly.

Percussive stunning can then be followed by a gill cut or decapitation for large trout [17]. It is only feasible for percussive stunning to maintain accuracy and effectiveness over long periods of time when the fish being stunned are large [19].

For sea bass and sea bream, which have smaller bodies, the only method that can lead to acceptable welfare outcomes is electrical stunning [11]. Electrical stunning is in commercial use for sea bass and sea bream in other countries [17].

It is important to note that no single stunning method has proved to be 100% effective. The parameters of the stun - including the current and duration used for electrical stunning and the strength and positioning of the blow for percussive stunning - must be carefully controlled. In addition to the primary stunning method, it is also critical for staff to be trained to provide a backup stun when staff observe signs of consciousness.

Fish species	Current slaughter methods without stunning	Current slaughter methods with stunning	Improvements required to ensure welfare
Trout	Asphyxia in air, ice, or ice slurry.	Only some are stunned - primarily by electrical stunning, less commonly by percussive stunning - followed by e.g. gills cutting or decapitation. The prevalence and effectiveness of stunning is unknown.	Electrical or percussive stunning followed by an appropriate killing method should be implemented for all trout. Stunning should be evaluated for effectiveness.
Sea bass and sea bream	Live chilling followed by gill cutting	None are stunned	Electrical stunning

Table 1: Current slaughter methods with or without prior stunning, and improvements required to ensure welfare of trout, sea bass, and sea bream.

ANALYSIS OF COSTS OF HUMANE SLAUGHTER

Our results show that the cost of implementing humane slaughter for fish is low. For both groups of fish studied, humane slaughter would be the smallest category of production costs (Figure 1A). The ex-farm prices of trout, sea bass, and sea bream would only increase by a few euro cents per kg of fish (Figure 1B).

For trout, humane slaughter would constitute 3% of production costs. The ex-farm price of trout would increase from 3.60 €/kg to 3.66 €/kg. This represents a cost increase of 6 euro cents per kg of fish. For sea bass and sea bream, humane slaughter would constitute 1.2% of production costs. The ex-farm price of sea bass and sea bream would increase from 7.20 €/kg to 7.26 €/kg. This also represents a cost increase of 6 euro cents per kg of fish. Our analysis and data sources are explained in more detail in Appendix 2.

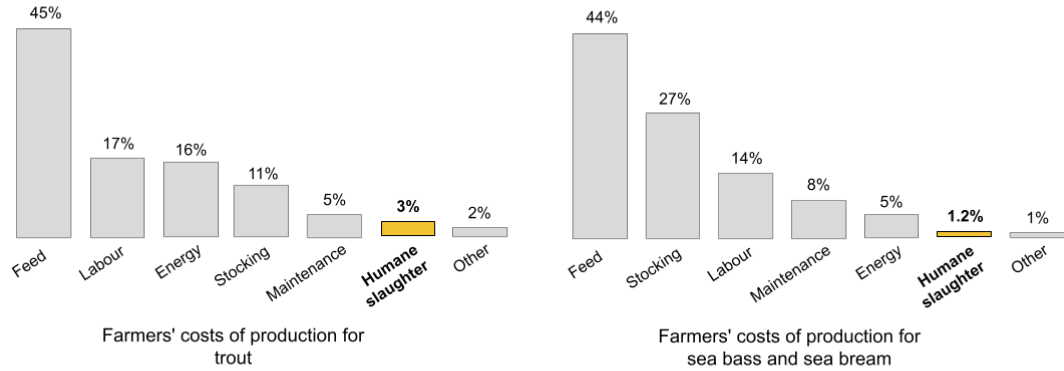
Separately, the purchase of humane slaughter equipment would require an up-front investment from farmers. For trout, this investment would be about 160,000 €. This is comparable to the annual net profit of a single small enterprise. However, since trout are typically slaughtered at shared slaughterhouses, this investment would be shared among many farmers. For sea bass and sea bream, this investment would be about 175,000 €. This is below the annual net profit of an

average enterprise. Since this is a once-off capital investment, we have not included the cost of this investment in our analysis. Separate calculations (not shown here) reveal that including this investment would mean that implementing humane slaughter is slightly more expensive, but not unreasonably so. Also, the investment would result in an asset, so including the cost of the investment would mean that our analysis would overestimate the cost to farmers.

OTHER BENEFITS FROM HUMANE SLAUGHTER

The costs of humane slaughter may be outweighed by the additional revenue that farmers are likely to obtain by selling higher-welfare fish. One survey found that many Italian consumers are willing to pay more money for higher-welfare farmed fish [1], supporting the finding that there is an increasing demand for high-welfare fish in Italy [2]. Economic studies have generally found that consumers are willing to pay extra for fish products farmed to higher welfare standards, depending on the product and the market [21–24]. Furthermore, many certification schemes are currently in the process of adding new provisions for humane slaughter (see Appendix 1). Implementing humane slaughter would enhance the reputation of farmers and enable farmers to access these certification schemes.

(A) Humane slaughter costs for farmers



(B) Humane slaughter leads to a relatively small increase in ex-farm prices

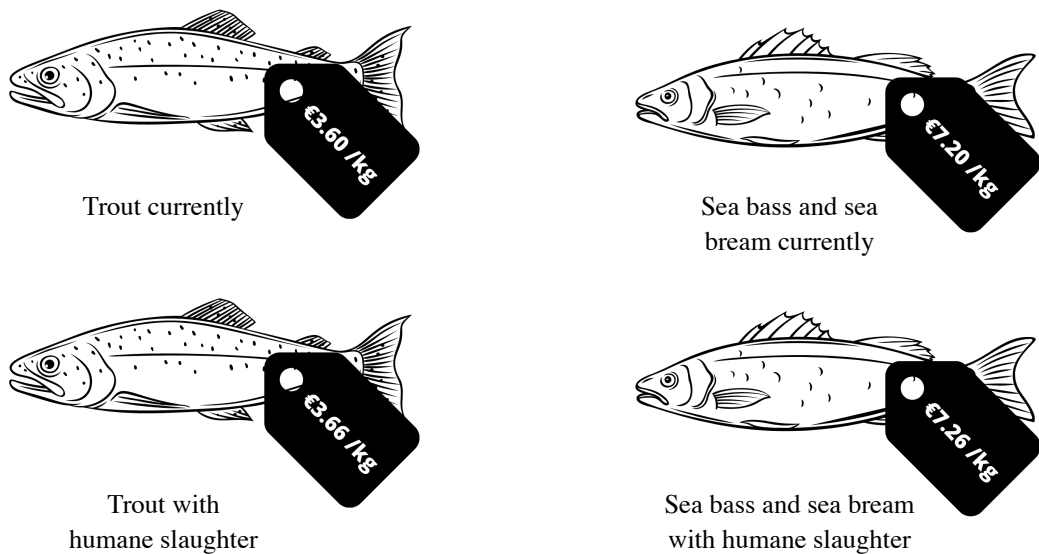


Figure 1: Results of our economic analysis on humane slaughter for aquaculture in Italy. (A) Humane slaughter makes up a small proportion of production costs; (B) humane slaughter causes a minor increase in product price. For panel (B), note that the prices are ex-farm (the prices received by the farmer). Current ex-farm prices are obtained from the European Commission [20].

WHICH EQUIPMENT TO BUY?

We spoke with a number of companies offering equipment for humane slaughter in aquaculture in Europe to validate the European Commission's figures.

For stunning equipment, we spoke to Ace Aquatec who offer in-water electrical stunners for a variety of fish species, including trout, sea bass, and sea bream. These stunners are connected to a centrifugal fish pump capturing fish from sea pens or raceways. Fish are rendered insensible in water during capture without any prior need for handling. One of their Ace Aquatec's clients, Scottish Sea Farms, found that the fish are significantly easier to handle as they are only handled when unconscious. This allowed the company to double their harvest rate using the same labour [25]. This also reduced the risks faced by staff who would otherwise have to handle large, stressed fish.

Although the true cost of this equipment will vary according to the specific context, Ace Aquatec was able to provide us with a general quote of approximately 100,000 € for a stunner for trout, and 120,000 € sea bass and sea bream. (On-boat stunners for sea bass and sea bream may cost slightly more, as indicated by the European Commission [10].)



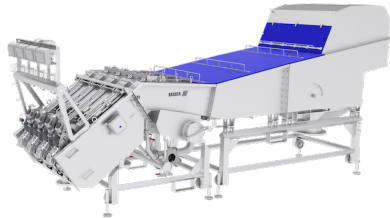
(source: Ace Aquatec)

One alternative to this is a dry stunner, such as those available from OPTIMAR which can be outfitted for both trout and sea bass/bream (<https://optimar.no>). The stunner is appropriate for capture and stunning in both freshwater and sea cage aquaculture after dewatering and has been used on small vessels.



(source: Optimar)

The final method of stunning available is percussive stunners, such as those available from BAADER (<https://fish.baader.com/products/baader-101>).



(source: BAADER)

There are a variety of pumps that can be used to capture fish prior to stunning with one of the above systems. Brands producing these pumps include FAIVRE (<http://www.faivre.fr/>), VAKI (<https://vakiiceland.is/pumps/>), Washpower (<https://washpower.com/bluecomfort/>) and Milanese (<http://www.milaneseitalia.com/en/185vs.htm>). There are pumps suitable for trout, sea bass, and sea bream of all sizes. Depending on the particular pump, the capacity ranges from 5 to 85 tons/hour, with prices varying accordingly from 20,000 to 66,000 €. For example, the pump produced by the Italian company Milanese's Art. Their '185/Maxi' pump costs 20,800 € with a 3,000 € dewatering unit, and handles fish up to 0.9kg at 30 tonnes per hour.



(source: VAKI)



(source: FAIVRE)

CONCLUSION

In Italy, producers can improve fish welfare by stunning fish before slaughter. Producers of trout can stun fish using electrical or percussive stunning, while for sea bass and sea bream, the best option is electrical stunning. Our economic analysis shows that stunning before slaughter only represents 3% of production costs for trout and 1.2% for sea bass and sea bream. Even if these additional costs were passed along entirely to consumers, we expect that the increase in retail prices would be minimal.

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APPENDIX 1: LEGISLATION AND CERTIFICATION SCHEMES

Legislation and National Quality System (NQS)

European Council Regulation (EC) No 1099/2009 on the protection of animals at the time of slaughter is the primary animal welfare legislative reference that sets out rules governing slaughter operations. The Regulation provides that, at the time of slaughter, 'animals must be spared any avoidable pain, distress or suffering' (Article 3(1)). However, unlike for terrestrial animals, the Regulation does not specify which stunning and killing methods are appropriate for farmed fish. At the same time, it refers to the international standards set by the World Organisation for Animal Health (OIE), which would allow the requirements of Article 3(1) of the Regulation to be met also for farmed fish. Consequently, it is possible to protect the welfare of fish at the time of slaughter by following the recommendations of the OIE's Aquatic Animal Health Code, which identifies the most humane stunning and slaughter practices for farmed fish.

The Italian Fish Farmers Association (Associazione Piscicoltori Italiani - API) has published a 'Code of Best Farming Practice in Aquaculture' [4]. However, the Code does not contain specific provisions for the humane slaughter of farmed fish [10]. Furthermore, although the latest version of the National Animal

Welfare Plan (2022) also applies to aquaculture, it does not contain specific guidelines for stunning and slaughtering farmed fish.

In February 2020, the Ministry of Agricultural, Food and Forestry Policies (Mipaaf) issued the national Decree officially recognising the 'Sustainable Aquaculture' Product specification within the National (Animal Breeding) Quality System (NQS) [26]. This Product specification may be applied to farmed fish, bivalve, and their processed products and it aims to 'qualify aquaculture by improving product quality, the sustainability of the production process and the welfare of farmed organisms'.

However, as far as farmed fish are concerned, the certification scheme does not require implementing any specific humane stunning and slaughter methods. This implies that the 'Sustainable Aquaculture' certification can also be granted to aquaculture products from farmed fish subject to slaughter practices detrimental to their welfare.

Private certification schemes

Private certification schemes govern aquaculture practices for some products on the Italian market. Friend of the Sea certifies many fish products sold in Italy [27]. These are generally processed fish, including canned tuna, sardines, and anchovies. Meanwhile, Aquaculture

Stewardship Council (ASC) certifies around two hundred products on the Italian market, and also certifies some trout farms within Italy [28,29]. It is unclear what proportion of certified products originate in Italy, and what proportion are produced by aquaculture rather than fisheries.

These two schemes have plans to introduce fish welfare standards for aquaculture in the future. Friend of the Sea has published a set of draft fish welfare standards, which are currently undergoing consultation. These standards would include a requirement for aquaculture operations to humanely slaughter fish. They would permit only percussive stunning, electrical stunning followed by slaughter while unconscious, or killing by electrocution [30]. Similarly, ASC is undergoing a consultation process to develop a set of fish welfare standards for aquaculture. Humane slaughter has been identified as a priority, and ASC intends to prevent at least the worst slaughter methods. This would prohibit asphyxiation in air, suffocation by carbon dioxide, the use of salt baths/ammonia, and the use of ice slurry [31].

These details may change before these new fish welfare standards are finalised and implemented, though they are still clearly signalling a growing interest in humane slaughter practices.

APPENDIX 2: ECONOMIC DATA AND ANALYSIS

In our economic analysis, we use balance sheets to calculate how the additional cost of humane slaughter would impact the finances of aquaculture operations. Specifically, we estimate the cost of humane slaughter as a proportion of production costs, estimating the price increase that would be necessary for aquaculture operators to fully compensate for this cost. Full calculations are available on request.

We obtained official data on the economics of aquaculture production from the European Commission, which gives the most comprehensive and up-to-date information [20,32]. Notably, this data is very similar to data in other sources [5,10].

For trout, our data applies to all production of portion trout in raceways and tanks. This represents the vast majority of overall trout aquaculture in Italy. We are lacking information on production of trout in lake cages, but this accounts for only a minority of trout production [2]. For sea bass and sea bream, our data applies to all sea cage production. This represents about 78% of overall sea bass and sea bream aquaculture in Italy. Notably, this means that we are lacking information on the economics of inland production of sea bass and sea bream, although this is also a minority of production.

For the costs of stunning and slaughter equipment, we surveyed European equipment manufacturers. We complemented this data with an existing, official survey of manufacturers published by the European Commission [10]. We assume that each aquaculture enterprise would purchase its own set of equipment for stunning and slaughter. In reality, many trout enterprises use cooperative slaughterhouses, which are run by a group of farmers [10,32]. In a cooperative slaughterhouse, multiple farmers would share the costs of purchasing new stunning and slaughter equipment. This means that our estimates of the costs of humane slaughter are likely to be higher than would be observed in reality - in other words, our results are a 'worst-case scenario'.

In our analysis, we measure the effects of implementing stunning on the production costs of trout, sea bass, and sea bream. For all species, we use data on electrical stunning.

This is the only stunning practice that can ensure fish welfare for sea bass and sea bream. For trout, percussive stunning is also possible, but electrical stunning has more accurate economic data and is more economically practical to implement for single farms [10].

Note that we use data from 2016-2018. This data does not capture the effects of the COVID-19 pandemic on aquaculture [33,34]. However, since the pandemic remains ongoing and aquaculture continues to change, we believe that using data from before the pandemic provides the most reliable results.