Strengthening fish welfare research through a gap analysis study

SCAR
Standing Committee on Agricultural Research
FISH Fisheries and Aquaculture Research

European Animal Health & Welfare Research
COLLABORATIVE WORKING GROUP

November 2018

casa
Common Agricultural and wider bioeconomy reSearch Agenda

EUROPEAN UNION
Project co-funded by H2020 Programme under Grant Agreement n° 727486

Authors

Amedeo Manfrin[1], Stefano Messori[2], Giuseppe Arcangeli[1,3]

[1] IZSVe- Istituto Zooprofilattico Sperimentale delle Venezie - Italy
[2] CWG AHW Secretariat
[3] SCAR Fish Member

Acknowledgements

We are grateful to the CASA project for funding this study and to:

CWG AHW partners

Marina Bagni (CWG AHW Chair), Françoise Divanach (CWG AHW AW subgroup Chair), Marta Garcia (CWG AHW AW subgroup Deputy Chair), Hermann Schobesberger (CWG Strategic Foresight Unit, former Chair).

Members of the SCAR Fish involved:

Philippe Moguedet (SCAR Fish, former Chair), Gabor Reczey, Barna Kovács, Luc van Hoof, Kjersti T. Fjalestad, Michalis Pavlidis, Nikos Zampoukas.

Experts participating in the Focus Group:

Tore Kristiansen, Andrea Fabris, Aurelio Ortega, Jordi López Ramon.

Executive Summary

Aquaculture is an important source of animal protein, and the sector is expected to grow further in order to satisfy the protein demand of an increasing human population. As this production grows, the interest of the public on the husbandry and processing practices used in aquaculture and their associated welfare issues is increasing too, stimulating the demand for high-welfare fish products.

Scientific methods for assessing fish welfare are constantly evolving. The huge variety of fish species and production methods and the limited available research funding remain major problems, resulting in a general lack of scientific data on the issue. In addition, the increasingly wide gap in priorities between animal welfare researchers and stakeholders represents an important barrier to the delivery of innovation in the field, ending up with little practical uptake of recent scientific developments. The lack of proper communication among the stakeholders seems to be a major flaw of the system, compromising progress on fish welfare.

In this framework, the prioritisation and coordination of research as well as an enhanced dialogue among stakeholders are essential to ensure improvement of fish welfare in practice.

The aim of this study was to investigate the main research gaps on fish welfare, and to reach consensus between the aquaculture industry and researchers in setting future research priorities.

The work was structured into four consecutive phases. First, i) a desk study aimed at identifying fish welfare research priorities from relevant bibliographic sources, then ii) a panel of selected international experts was asked to rank the collected research needs through an online survey. Based on the survey outcomes, iii) the main priorities were identified, and iv) discussed in a focus group of stakeholders from the industry and research sectors.

The study allowed a consensus to be reached between researchers and stakeholders on the main research needs on fish welfare for the various phases of the production and for the main farmed species. In addition, relevant enabling factors to ensure the uptake of research results, innovative technological solutions, and to better use data were identified.

The results of this report will support the SCAR and the Member States in the definition of their fish welfare research policies. In addition, this will help national research funders prioritising areas for investments and collaboration, and will assist researchers and research managers in focussing their research activities on this topic.

Acronyms

ANIHWA	Animal Health and Welfare ERAnet
CASA	Common Agricultural and wider bioeconomy reSearch Agenda
CWG	Collaborative Working Group
CWG AHW	Collaborative Working Group on Animal Health and Welfare Research
DG-SANTE	Directorate-General of the European Commission for Health and Food Safety
EFSA	European Food Safety Authority
EFTA	European Free Trade Association
ERAnet	European Research Area network
EU	European Union
FP6	6th Framework Programme of the European Commission
FP7	7th Framework Programme of the European Commission
FVE	Federations of Veterinarians of Europe
GMP	Good Management Practices
HSA	Humane Slaughter Association
MS	Member State
OIE	World Organisation for Animal Health
R&D	Research and Development
SCAR	Standing Committee on Agricultural Research
SRA	Strategic Research Agenda
SWG	Strategic Working Group

Contents

Figures

Tables

Introduction

Global aquaculture production has been steadily increasing over the past decades, and the sector is expected to grow further in the coming years so as to satisfy the protein demand of an increasing human population[1]. In contrast with the situation at world level, the production in the European Union (EU) has been stagnating[2]. In order to try to tackle this issue and stimulate growth in this sector, the European Commission published three communications (in 2002[3], 2009[4] and 2013[5]) which presented strategies to support the sustainable development of aquaculture. One of the actions considered in the proposed strategies was the establishment of a high level of protection of health and welfare in farmed aquatic animals.

There is growing evidence that fish, like other vertebrate animals, are sentient beings, and that they can experience pain and distress[6]. Sentience is usually seen as a prerequisite when considering welfare and the public, especially in the industrialised world, is increasingly considering that fish are entitled to good welfare. Thus, the interest of consumers, as well as policy makers and scientists, for husbandry practices used in aquaculture and their associated welfare issues is growing.

As consumers begin to enquire about welfare in fish farming, the production sector cannot ignore this issue so as to avoid negative impacts on sales[7]. In the terrestrial livestock sectors, many European retailers have already embraced and promoted welfare standards so as to differentiate themselves from competitors. As consumer awareness of the issue continues to rise the demand for more high-welfare products grows, giving producers who maintain high standards a potential competitive advantage[8]. While some international standards exist for fish welfare (*e.g.* by the World Organisation for Animal Health, OIE[9]), it can be expected that the market will drive further interest on these.

While scientific methods for assessing fish welfare are constantly evolving, the huge variety of fish species and production methods, as well as a general lack of scientific data, remain important issues. Nevertheless, the lack of data is not the only barrier to the delivery of research innovation in the field on fish welfare. An increasingly wide gap in priorities between animal welfare research and stakeholders, which is compromising progresses leading to little practical uptake of recent scientific developments. The lack of proper communication among the stakeholders seems to be a major flaw of the system and compromises progress on fish welfare.

The progressive reduction of public funding, as well as the increasing need for preparedness for emerging issues, make the prioritisation and coordination of research and the prevention of unnecessary duplication a fundamental priority. Research needs and priorities on fish welfare have been identified in the frame of several different initiatives, but this knowledge is not aggregated and not easily available to final users (*i.e.* research funders and industry). In order to provide guidance on research areas and to obtain an agreement on priorities, relevant information will need to be

[1] OECD/FAO (2017), OECD-FAO Agricultural Outlook 2017-2026, OECD Publishing, Paris.
[2] http://www.europarl.europa.eu/factsheets/en/sheet/120/european-aquaculture
[3] COM (2002) 0511; https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2002:0511:FIN:EN:PDF
[4] COM (2009) 016; https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2009:0162:FIN:EN:PDF
[5] COM (2013) 0229; https://ec.europa.eu/fisheries/sites/fisheries/files/docs/body/com_2013_229_en.pdf
[6] OIE (2008), Welfare of fish in aquaculture; https://www.oie.int/doc/ged/D4917.PDF
[7] Broom D.M. (2007). – Cognitive ability and sentience: which aquatic animals should be protected. Diseases of Aquatic Organisms, 75 (2), 99-108.
[8] Dalla Villa, P., Matthews, L. R., Alessandrini, B., Messori, S., & Migliorati, G. (2014). Drivers for animal welfare policies in Europe. Revue Scientifique Et Technique-Office International Des Epizooties, 33(1), 39-46.
[9] OIE (2018), Aquatic Animal Health Code. Section 7: Welfare of farmed fish.

aggregated and presented in a usable way to the end users who will then be able to properly evaluate these needs and provide a ranking.

A consensus between the aquaculture industry and researchers in the identification of knowledge gaps and setting future research priorities, taking into account their different perspectives, would provide an ideal platform for progressing fish welfare and providing clear benefits both to industry and consumers. In addition, research would provide policy makers with the necessary information to ensure the regulatory framework on animal welfare is based on scientific evidence.

In recent decades, several initiatives have been undertaken in the EU towards creation of a coherent European research area and improving research coordination. In the animal health and welfare fields, a major role was played by the Collaborative Working Groups (CWGs) and Strategic Working Groups (SWGs) of the Standing Committee on Agricultural Research (SCAR).

The SCAR has been a major catalyst for the coordination of national research programmes, where it helped initiate an integrated European Research Area. One of the aims of the SCAR is to progress the public-public and public-private collaboration in delivering innovation that tackles new challenges in the bio-economy area, which is linked with the growth-oriented approach of the Horizon 2020 Programme. The most strategic and final aim of SCAR is to provide research and innovation related policy advice toward research programme managers at national and EU level. Thematic CWGs and SWGs are working under the SCAR with the aim of coupling research and innovation and removing barriers to innovation in specific areas. The development and implementation of Strategic Research Agendas (SRA), based on a common vision of how to address major challenges in the field of agricultural research, is one of the main activities of these groups.

In order to investigate knowledge gaps on fish welfare and to establish communication among the different stakeholders in the sector on research, the SWG SCAR Fish and the CWG Animal Health and Welfare Research (CWG AHW), with the support of CASA (Common Agricultural and wider bioeconomy reSearch Agenda), initiated this study.

CASA (Common Agricultural and wider bioeconomy reSearch Agenda) is a Coordination and Support Action of the European Commission, having the overall objective of consolidating the common agricultural and wider bioeconomy research agenda within the European Research Area. CASA will achieve this by elevating the Standing Committee on Agricultural Research (SCAR), which has already contributed significantly to this objective in the past, to the next level of performance as a research policy think tank. CASA will efficiently fortify the strengths and compensate for the insufficiencies of SCAR, thus helping it evolve further into 'SCAR plus'.

The Strategic Working Group (SWG) SCAR Fish is a policy-driven strategic group having the objectives of providing the Commission and Member States with research and innovation policy advice on issues such as fisheries and aquaculture. The SCAR Fish mandate includes developing an agreed list of fisheries and aquaculture common research priorities and collating existing information and, where necessary, collecting new information in the areas of foresight, common research agendas, and mapping EU capacities to support a European research area for fisheries and aquaculture. The SCAR Fish started its activities in 2012 and has today partners from 18 countries.

The Collaborative Working Group on Animal Health and Welfare Research (CWG AHW) is a forum of research funders and programme owners, operating under the Standing Committee on Agricultural Research (SCAR), aiming to improve collaboration on research prioritisation and procurement, creating the necessary critical mass and focus needed to deliver the animal health and welfare research needs of EU policy makers and the European livestock industry. The CWG AHW started its activities in 2005 and counts today 28 partners from 20 countries. It works on emerging and major infectious diseases, production diseases, and animal welfare of production animals in the EU together with capacity and capability (including infrastructural aspects). Its scope includes fish and bees and those conditions which pose a threat to human health, but excludes food safety issues relating to the handling of livestock products and wildlife diseases, except where they act as reservoirs of infection for humans or production animals.

Aim

The aim of this study was to investigate, from relevant and reliable information sources, emerging research gaps on fish welfare in order to define research priorities and to reach agreement on these with a broad range of stakeholders including farmers, the industry, and researchers. This would contribute to improving a proper communication platform between the involved actors and creating new synergies between public and private, in order to promote research and investment in the future. The study will ultimately support the definition of a Strategic Research Agenda (SRA) on fish welfare so as to guide future research funding on the topic.

Methodology

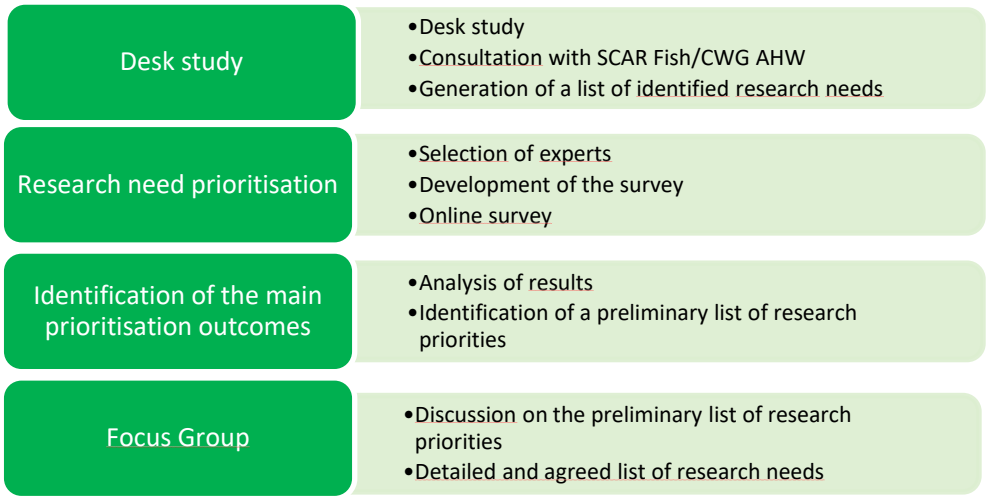
The CWG AHW conducted a project to identify research priorities on animal welfare, mainly focussing on terrestrial animals, in 2016[10]. Based on this experience, the workplan for this study was developed by the CWG AHW and the SCAR Fish and approved by CASA.

The work was structured into four consecutive phases (a summary of the steps followed is summarised in **Figure 1**)Figure 1:

1) a desk study aimed at identifying fish welfare research priorities;

2) an online survey to prioritise research topics, sent to a panel of selected experts in fish health and welfare from EU Member States (MS) and European Free Trade Association (EFTA) countries;

3) an identification of the main prioritisation outcomes that emerged from the online survey;



4) a focus group with a small panel of experts, which aimed to discuss the survey results and draw conclusions.

Figure 1: Phases of the study.

[10] CWG AHW (2016). Gap analysis on Animal Welfare research; https://www.scar-cwg-ahw.org/wp-content/uploads/2017/07/Gap-analysis-on-Animal-Welfare-research.pdf

Desk study

A desk study to investigate the state of the art for what concerns knowledge gaps on farmed fish welfare was realised with the support of the SWG Fish and CWG AHW animal welfare subgroup. Its aim was to identify a first list of research priorities to be used as a basis for the following prioritisation phases, to be conducted by *ad hoc* experts. The study initially focused on the collection and analysis of documents (*i.e.* reports, guidelines, scientific opinions, recommendations) issued by international organisations so as to start from positions already agreed by representatives of the sector rather than on the opinion of individuals (*i.e.* single scientific publications were excluded). In addition, only documents explicitly referring to identified research gaps or research needs were considered.

An online research was performed and documents from the following bodies were collected:

- World Organisation for Animal Health (OIE);
- European Commission (DG SANCO/DG SANTE);
- European Food Safety Authority (EFSA);
- Federations of Veterinarians of Europe (FVE).

In addition, other sources of information were analysed:

- previous gap analysis report produced by the CWG AHW;
- relevant national authorities' reports and guidelines;
- reports from Non-Governmental Organisations (NGOs) dealing with fish welfare;
- European legislation concerning fish protection and welfare.

All the selected documents were analysed in order to extract information on research gaps or new research needs (**Figure 2**). Whenever possible, research gaps were translated into research needs. The identified research needs were included in a matrix table according to the different phases of aquaculture production, and to the main fish species. The draft table was submitted to the SCAR Fish to be discussed during its meeting on the 10th of April. The list of research needs was finalised with the additional inputs collected during the meeting, and validated by the group.

Figure 2: List of sources analysed to obtain a list of research needs on fish welfare.

Research need prioritisation

A list of experts was selected from 30 countries (all EU MS, Luxembourg excluded, plus EFTA countries with significant aquaculture production, *i.e.* Norway, Switzerland and Iceland). At least one reference expert was selected for each country, giving preference to those who participated in one of the last 10 years' fish welfare European funded projects or networks (a list is presented at the end of this report).

A dedicated survey was developed, in order to harmonise data collection, and circulated among all selected experts. The contacted persons were given the possibility of forwarding the survey to other experts from their countries. Prior to performing the exercise, the group was informed about the aim, methodology, and expected outcomes of the study.

The survey consisted of an Excel file listing all the identified research needs, classified accordingly to the main production phase and main aquaculture fish species (**Table 1**). Email invitations were sent to all participants on the 3rd of May 2018 and two reminders were sent before the survey deadline (3rd of July). During the survey, support to participants was made available by email.

Participants were asked to rank the research needs according their urgency and relevance:

- ✓ *Fish Welfare relevance*: how relevant is the research need for ensuring an improved AW status for the reared fish (1: low relevance; 5: high relevance)? Would the meeting of this need ensure a better animal protection, or at least contribute to it, as compared to the current situation?
- ✓ *Urgency*: how urgent is the filling of this gap (1: low urgency; 5: high urgency).

For each of the research needs, the experts were given the possibility of providing a ranking for all fish species (*i.e.* if the research need's relevance/urgency regarded all species), or to one or more of the main aquaculture fish species specifically.

Production phases	Fish species
Breeding stock	Atlantic salmon /Rainbow trout
Early life	Carps
Rearing	Sea bass/bream
Transport	Turbot/Sole
Slaughtering	Eel
Other	Sturgeon
	Other

Table 1: List of the main production phases and aquaculture fish species as considered in the survey. Production phases applies to all fish species.

Identification of main prioritisation outcomes

It was recognised that the outcomes of this study would be of interest to different stakeholders and that they might require information with a different level of granularity. For this reason, it was decided to analyse the results of the survey following different approaches, leading to priorities based on different principles.

The prioritisation was performed in June 2018 in order to ensure having the priority list(s) ready prior to the focus group meeting. Four main criteria were applied in order to obtain research needs prioritised on different principles. Priority lists were obtained for:

1. *Production phase*: a sum of relevance and urgency scoring of each of the research needs for each of the production phases was calculated and corrected for the number of research needs included in each phase (*i.e.* sum of urgency and relevance score of all research needs in a phase, divided by the number of research need for that phase), as to avoid bias being due to production phases having an higher number of research needs in the initial list. This allowed to identify the production phases with the highest need for research.
2. *Research needs per production phase*: the three research needs having the highest combined score of urgency and relevance were selected per four highest scoring production phases.
3. *Research needs*: all research needs having a combined score of urgency and relevance above 100 were selected, not-considering the production phase.
4. *Research needs per species*: the three research needs having the highest combined score of urgency and relevance were selected for each of the main fish species.

The different thresholds of this selection process were selected to identify a suitable number of research needs that could be discussed during a 4-hour focus group session. The selected needs, together with background information, were provided as guidance to the focus group participants.

Focus group

Focus groups are used as a qualitative method in the field of human and social sciences. A group of persons is invited to talk, discuss and share opinions about their perception on a particular issue. Interactive questions are presented to participants to start a discussion under the guidance of a facilitator who presents the questions to participants while encouraging the free flux of ideas.

Stakeholders representing the aquaculture sector and the research community were involved in this phase. The panel was selected according to the main outcomes of the prioritisation so as to ensure that participants would have the relevant expertise. When possible, representatives of umbrella organisations were selected and efforts were made to ensure the geographical balance in the group.

The focus group was composed of 4 participants (2 representing the aquaculture industry and 2 the research sector), and met for 4 hours on the 12th of July 2018 at the Directorate-General for Research and Innovation in Brussels. One facilitator and one subject matter expert supported the group meeting. Using the main prioritisation outcomes as a basis, the group discussed the main research priorities in an interactive way. The meeting agenda is reported in **Annex I**.

Particular efforts were dedicated to aligning the obtained outcomes to the European legislative framework on animal welfare. This ensured the delivery of research needs that are in line with norms that are in place and with improving the implementation of current legislation.

The group was tasked with analysing the four lists of priorities, discussing state of the art and existing initiatives taking place in the territory, and better detailing the research needs so as to provide guidance for future actions to fill in the identified knowledge gaps.

The information gathered in the course of the meeting was analysed by the facilitator and is included in this report.

Results

Desk study

Despite the relatively broad number of sources investigated, only a few documents outlining research needs or gaps were identified. Only these were included in the study and used as a basis for the subsequent steps. The final list of research needs that were identified, classified according to the different production phases, is shown in **Table 2**.

Breeding stock	Broodstock management
	Hormonal induction of spawning
	Stripping of broodstock
	Welfare implications of triploidy
	Genetic selection to improve:
	• growth
	• feed efficiency
	• health
	• stress resistance
Early life	Indicators of stress in larvae and juveniles
	Feeding
	Grading
Rearing	Water quality parameters
	Fish density according to different species biological needs
	Welfare indicators:
	• behavioural
	• molecular
	• non-invasive physiological
	Systems for identifying scale loss/fin damage as welfare indicators
	Guidelines or protocols to improve fish welfare
	Environmental enrichment
	Assessment of welfare in Recirculating Aquaculture Systems
	Period of starvation
	Welfare during vaccination
	Design, maintenance, and servicing of equipment
Transport	Loading and unloading of trucks and well boats
	Improving water quality parameters during transport in closed systems
	Density of fish inside tanks (truck and well-boat)
	Total length/duration of transport
	Use of anaesthetics (*e.g.* clove oil) as stress reducers
	Transport without water (*i.e.* eel, turbot)
	Design and maintenance of equipment
Slaughtering	Stocking density before harvesting
	Pre-slaughter handling techniques (crowding and harvesting methods at different temperatures)
	Parameters required for humane stunning and/or killing fish by means of:

	• electrical stunning
	• manual percussion
	• mechanical devices (captive bolt pistols, automatic spiking, or percussion)
	• immersion in ice slurry
	• gas mixture
	• electric harpoon (tuna)
	• shooting (tuna)
	• hydraulic shock
	• hypoxic stunning
	• other (please specify)
	Setting up a gold standard method to evaluate the success of stunning and killing
	Relationship between flesh quality and different stunning/killing methods
	Validated protocol for stunning cage cultured marine fish
Other	Benefits of exercise for the different fish species
	Different stress coping styles in all species of farmed fish
	Fish diseases lacking treatment
	Development of licenced anaesthetic and pharmaceutical agents
	Consumer perception about fish welfare

Table 2: Final list of the identified research needs, divided for production phase.

Research need prioritisation

Of the 30 countries invited to participate in the survey, 13 filled in the questionnaire (**Table 3**). In two cases more than one answer was received from the selected countries, bringing the total number of replies to 16.

Countries participating in the survey	
Bulgaria	Norway
Denmark	Slovakia
France	Slovenia
Germany	Spain
Greece	Switzerland
Italy	UK
Netherlands	

Table 3: List of countries participating in the survey.

Five additional replies to the survey were received from SCAR fish representatives in September 2018 from Finland, Hungary, Portugal, and Sweden. Since then the focus group already took place, these additional inputs were not considered in the following steps of the study. Nevertheless, these replies are included in **Annex II**.

Identification of main prioritisation outcomes

The prioritisation exercise allowed the development of four different priority tables, having different levels of granularity.

Table 4 shows the production phases with the highest combined urgency and relevance scoring research needs, while **Table 5** contains the four[11] highest ranking priority research needs for the four highest priority production phases. **Table 6** shows the highest priority research needs, without considering the production phase. Lastly, **Table 7** lists the three highest ranking research needs that were selected for each fish species/family.

PHASES	FISH WELFARE RELEVANCE	URGENCY	TOTAL
Early life	23	23	46
Other	23	23	46
Rearing	22	21	43
Slaughtering	20	21	41
Transport	20	20	40
Breeding stock	19	20	39

Table 4: Priority production phases. The second and third columns contain, respectively, the sum of relevance and urgency scores of all research needs in the phase, divided by the number of research need for that phase. The fourth column contains the sum of the values reported in the two previous columns.

PHASE	RESEARCH NEEDS	FISH SPECIES	FISH WELFARE RELEVANCE	URGENCY	TOTAL
Early life	Indicators of stress in larvae and juveniles	All	58	58	116
	Feeding	All	46	46	92
	Grading	All	43	40	83
Rearing	Welfare indicators: behavioural	All	61	60	121
	Fish density according to different species biological needs	All	55	49	104
	Welfare during vaccination	All	55	53	108
	Assessment of welfare in Recirculating Aquaculture Systems	All	52	52	104
Slaughtering	Pre-slaughter handling techniques (crowding and harvesting methods at different temperatures)	All	50	53	103

[11] For some production phases, less than four research needs were listed in the overall table (*e.g.* early life). In these cases, less than four research needs are listed are listed in Table 5.

	Relationship between flesh quality and different stunning/ killing methods	All	47	50	97
	Stocking density before harvesting	All	44	42	86
	Validated protocol for stunning cage cultured marine fish	All	43	46	89
Other	Consumer perception about fish welfare	All	50	47	97
	Development of licensed anaesthetics and pharmaceuticals	All	48	48	96
	Different stress coping styles in all species of farmed fish	All	46	47	93

Table 5: Priority research needs per production phase. The fourth and fifth columns contain, respectively, the sum of relevance and urgency scores received by each research need. The sixth column contains the sum of the values reported in the two previous columns.

PHASE	RESEARCH NEEDS	FISH SPECIES	FISH WELFARE RELEVANCE	URGENCY	TOTAL
Rearing	Welfare indicators: behavioural	All	61	60	121
Early life	Indicators of stress in larvae and juveniles	All	58	58	116
Rearing	Welfare during vaccination	All	55	53	108
Rearing	Fish density according to different species biological needs	All	55	49	104
Rearing	Assessment of welfare in Recirculating Aquaculture Systems	All	52	52	104
Slaughtering	Pre-slaughter handling techniques (crowding and harvesting methods at different temperature)	All	50	53	103
Transport	Use of anaesthetics (*e.g.* clove oil) as stress reducers	All	49	53	102
Breeding stock	Genetic selection to improve health	All	50	50	100
Slaughtering	Stocking density before harvesting	All	44	42	86
Breeding stock	Welfare implications of triploidy	All	44	40	84

Table 6: Priority research needs. The third and fourth columns contain, respectively, the sum of relevance and urgency scores received by each research need. The fifth column contains the sum of the values reported in the two previous columns.

PHASE	RESEARCH NEEDS	FISH SPECIES	TOT
Breeding stock	Hormonal induction of spawning	Carps	**48**
Breeding stock	Genetic selection to improve: stress resistance	Carps	**44**
Early life	Indicators of stress in larvae and juveniles	Carps	**44**
Transport	Transport without water (*i.e.* eel, turbot)	Eel	**54**
Breeding stock	Broodstock management	Eel	**53**
Slaughtering	Parameters required for humane stunning and/or killing fish by means of mechanical devices	Eel	**50**
Breeding stock	Genetic selection to improve: stress resistance	Atlantic salmon /Rainbow trout	**66**
Other	Development of licensed anaesthetic and pharmaceutical agents	Atlantic salmon /Rainbow trout	**65**
Early life	Feeding	Atlantic salmon /Rainbow trout	**64**
Slaughtering	Parameters required for humane stunning and/or killing fish by means of immersion in ice slurry	Sea bass/bream	**71**
Slaughtering	Parameters required for humane stunning and/or killing fish by means of electrical stunning	Sea bass/bream	**63**
Breeding stock	Genetic selection to improve: stress resistance	Sea bass/bream	**56**
Slaughtering	Parameters required for humane stunning and/or killing fish by means of mechanical devices	Sturgeon	**61**
Rearing	Assessment of welfare in Recirculating Aquaculture Systems	Sturgeon	**52**
Slaughtering	Parameters required for humane stunning and/or killing fish by means of electrical stunning	Sturgeon	**52**
Transport	Transport without water (*i.e.* eel, turbot)	Turbot/Sole	**84**
Slaughtering	Parameters required for humane stunning and/or killing fish by means of immersion in ice slurry	Turbot/Sole	**61**
Slaughtering	Parameters required for humane stunning and/or killing fish by means of electrical stunning	Turbot/Sole	**52**

Table 7: Priority research needs per species. The fourth column contains sum of relevance and urgency scores received by each research need for The three research needs having the highest combined score of urgency and relevance were selected for each of the main fish species

Focus Group

The Group discussed the four tables of identified priority research needs, providing opinion on the given scores and better detailing the identified gaps when needed.

Priority production phases

On the ranking of the different production phases the group supported what emerged from the survey, where research needs related to farming received higher scoring than the research needs related to slaughter and transport. In fact, as events happening in early life can have a lifelong impact on the life of the fish, research to address issues in this area would be more relevant. Similarly, since transport and slaughter have short durations, conditions (*e.g*. bad management practices) affecting rearing are likely to influence fish welfare for a longer time; research on this area would then have a higher impact. In addition, while some regulations are already in place in the EU for slaughtering (although Regulation CE 1099/2009 Art. 3.1 only provides for general requirements for killing and related operations for fish) and transport of fish, norms are totally absent for fish welfare on farms. On slaughter, the experts pointed out that good management practices could contribute to solving some of the welfare issues, and that the problems need to be addressed following a holistic approach that considers aspects such as the security of workers, fish product quality, and the size of enterprises.

The group concluded that while animal welfare issues are present in all phases of production, not all of them need research to be solved as in some cases these could be addressed through the implementation of **good management practices** (GMP). The fish farmers association are working on this issue and are also aware about the importance of fish welfare during the whole cycle of production. The group also pointed out that while stress was mentioned in several of the research needs, pain levels were not and would also merit further investigations.

Priority research needs per production phases

The definition of reliable **fish welfare indicators,** both for early and adult life, was recognised as a priority. The usability of these indicators in practice is fundamental to guarantee their uptake by the aquaculture sector. Past projects aiming at defining behavioural indicators of fish welfare failed to have an impact. Farmers were reluctant to transfer the new knowledge and proposed tools in practice as they were time consuming and too complicated. Attempts were also made to build software able to automatically assess some fish welfare indicators (*e.g.* swimming type), recognising altered behaviours so as to provide alerts to the fish farmer. Nevertheless, the quality of the prototypes developed was not satisfactory enough to ensure their uptake by the sector. **Sensors** technology is evolving rapidly and the group concluded that appropriate tools might be developed in the future. The investigation of the use of sensors in the tanks to monitor fish during transport was also recognised as a research need.

Data collection on fish welfare is not the only issue. Some data are already available at farm level, but are often scarce and farmers do not know how to interpret and use these in practice. Simple tools to analyse the collected data are necessary so as to make them available for the end users and ensure uptake of new data collection systems. Predictive models should be developed and periodically tested against data. These would support setting up early warning systems able to provide farmers with alerts before an impact on food/conversion rate or mortality is observed.

The market demand for high welfare products is one of the drivers of the need to develop reliable fish welfare indicators. The number of voluntary **certification schemes** for fish production is increasing and, while these mostly focus on organic production and sustainability, some of them already also include basic welfare indicators (*e.g*. stocking density). While some indirect welfare indicators are already foreseen, in some cases by legislation (*e.g.* water quality), the

attention is shifting toward direct, or outcome-based, indicators (*i.e.* directly focussing on fish welfare rather than the resources or the management practices in place such as mortality or sea lice infestation). Information is still lacking about how outcome-based indicators should be assessed.

Strict legislation was seen as ineffective in improving fish welfare in European aquaculture. The group concluded that the application of scientifically valid GMP would represent a better strategy to improve harmonisation of implementation of state of the art of fish welfare in the EU. Research would be needed to support the development of such GMP, and legislation should encourage their use in practice.

The survey highlighted **welfare during vaccination** as a research priority, but the group disagreed, pointing out that the main need in this regard is the appropriate training of vaccinators. Nevertheless, for some species (*e.g.* salmon) the use of oil adjuvants provokes side effects and research on new adjuvants would be relevant.

Fish handling has a major impact on welfare. Crowding is one of the main issues including before vaccination, at transport, and pre-slaughter. There is a need to ensure that the stress level is low enough during the whole process, and to investigate stress levels and tolerances for different species. Different stress coping styles are used by different species of farmed fish. It would be beneficial to study how to better use the adaptive capacity of fish to improve their handling tolerance. Machines should be better designed so as to be adapted to fish rather to other needs (*e.g.* size of the boat).

The **relationship between stunning and flesh quality** needs to be investigated, as well as less stressful stunning techniques (*e.g.* more natural ways of transferring the fish to the stunner). The experts pointed out that, in order to ensure the uptake of any innovation in this sector, there is a need to find a balance between fish welfare and other aspects (*e.g.* flesh quality, personnel safety, size of the boat). In addition, the group pointed out that **validated protocols** for stunning cage cultured marine fish is one of the main priorities for the Mediterranean area, but that this would be strictly influenced by the size of the company.

The Recirculating Aquaculture System appears to be a good system for production, but its impact on fish welfare would need to be better investigated. In general, studies **comparing** the welfare impact of **different farming systems** are needed.

The group discussed some issues around **consumer perception** on fish welfare. Although wild-capture fisheries have major impacts on welfare, public attention is lower as these animals are not farmed. Communication strategies need to be established so as to guide consumers to know what the real issues are rather than the sensational ones.

Priority research needs

In addition to the topics that were discussed earlier, the group discussed other research needs that received a total score above 100.

The **use of anaesthetics (*e.g.* clove oil) as stress reducers** should not be a research priority. Its main interest will be for broodstock. In addition, clove oil is not allowed in many MS.

The use of **genetic selection** to improve health and stress resistance might positively impact fish welfare, and impact in decreasing susceptibility to some disease (*i.e.* Infectious Pancreatic Necrosis in salmons) has already been shown. While for some species (*e.g.* salmon) results could be obtained in the short-term, for other species the process would be much longer as genetic selection just started recently. In addition, big breeding companies would be needed to achieve the funding necessary for studies in this area.

Even though its overall score was lower than 100, **triploidy** was also. The group agreed that this is only a modest problem as this production system presents several drawbacks (including lower consumer acceptance) and will probably be abandoned. As data on the welfare of these fish are scarce, if this production would be continued then research would be needed.

Priority research needs per species

Some of the welfare issues are not to be generalised to all species, but are species/production specific and need to be addressed as such.

The group decided to focus the discussion only on the main species; for this reason,-*turbot and sole* were not further considered.

Carps: the use of **hormones for inducing spawning** is not a welfare issue but rather an ethical one, as a pituitary extract from other fish is used for this purpose. The main welfare issue for this family are the **predators** both in cages and in ponds. This has both direct effects through predation, and indirect effects through stressing the remaining fish that consequently become more prone to diseases. Effective systems to deter predators are needed.

Atlantic salmon /Rainbow trout: **genetic selection for stress resistance** is one important need. The lack of licensed anaesthetics is mostly related to trout rather than salmon. Feeding should not be a priority.

Seabass/seabream: all the research needs in the table were discussed and should be considered as priorities.

Eel: as reproduction in captivity of eels is not yet a reality, there is no broodstock management for this species. The topic to be investigated is how farming could be done, but in the view of the group it should not be considered as a priority. Electrical stunning followed by killing of the stunned in animal in a mixture of ice water and salt appear to provide effective protection of eels.

Sturgeon: further studies on slaughtering would be relevant. The group also pointed out that, for sturgeons, only male subjects undergo electrical stunning and that is not used on females that produce the caviar.

General discussion

The group pointed out that important research needs exist on other species that were not considered in the survey (*i.e.* tuna fish and cephalopods):

Tuna fish: appropriate slaughter systems.

Cephalopods: some serious issues related to stress and pain indicators, use of anaesthetics, and juvenile nutrition (autophagia) exist, and a COST action was launched on cephalopods' welfare.

The lack of authorised veterinary medicinal products for aquaculture also represents a threat to the welfare of farmed species. Some initiatives are already in place to target this issue and increase availability of medicines and vaccines for fish (*e.g.* the 'FishMedPlus Coalition'), but research in the area is also needed to support the development of adequate medical products for the different species.

Lastly, the group highlighted that every new research programme needs to consider a plan for **knowledge transfer** toward stakeholders. Training should be conducted at horizontal rather than at vertical level. New tools and results should be presented in practice in the field.

Final remarks

Animal welfare is an issue of growing interest, especially in western societies. In Europe, over the last ten years animal welfare research is growing twice the rate of animal health research. The interest toward the welfare of fish emerged at a later stage as compared to the main terrestrial livestock species, and is also increasing significantly. Due to the relative novelty of the topic, and to the high number of species of interest, research coordination is necessary to avoid unnecessary duplication and the dispersion of the limited funding available.

Several European research projects on fish welfare were funded in the last three Framework Programmes (FP6, FP7 and H2020), either directly or through ERAnets (see dedicated section at the end of this report). COST actions were funded too, with the aim of creating a connection between researchers and stakeholders with an interest in the welfare of farmed fish. Although these projects contributed to advancing knowledge on the topic, additional research efforts are needed to provide the sector with the needed solutions and tools to improve the welfare of fish.

This report has been developed to support SCAR and the MS in the definition of their fish welfare research policies. It will help national research funders to prioritise areas for investments and collaboration, as well as assist researchers and research managers in focussing their research activities on this topic.

The promotion of the direct participation of different stakeholders, such as industry, in identifying research priorities and in drafting science policy was one of the goals of this study. The common objectives and shared vision agreed among various stakeholders reached within this exercise contribute to filling the existing gap between research funders and the private sector. This will encourage the joining of efforts, facilitating the achievement of shared objectives and the reaching of common goals.

As individual funders will not be able to solve all the identified issues alone, the alignment of the national (and supranational) research agendas shall be promoted. The CWG AHW and the SCAR Fish together could play an important role in supporting this alignment by promoting dialogue among the interested parties, coordinating transnational research efforts, and providing the adequate structures to ensure the maintenance of these actions.

Lastly, this study has highlighted that research gaps are not the only limiting factor to the improvement of fish welfare. Other issues (*e.g.* economics, poor use of data, training) were often mentioned as a major impairment and need targeted actions to addressed them. The dissemination of the proper information to the appropriate stakeholders will be paramount to ensure improvements in the welfare of farmed fish.

This report should not be considered as a final outcome, but rather as a milestone in a continuous process. The identified research areas and priorities will need to be updated regularly, mapping progress that will happen on the research side and taking into account new production methods or new species that will be used. Providing the possibility of a periodic meeting to a range of experts and stakeholders in different fields would consolidate the network, supporting the creation of a cohesive and transversal fish welfare research network. The CWG AHW and the SCAR Fish seems to be best suited to follow up with the regular update of this study.

References

Council Regulation (EC) No 1/2005 of 22 December 2004 (2005). On the protection of animals during transport and related operations and amending Directives 64/432/EEC and 93/119/EC and Regulation (EC) No 1255/97. Official Journal of the European Union, L 3, 1-43.

Council Regulation (EC) No 1099/2009 (2009). On the protection of animals at the time of killing. Official Journal of the European Union, L 303, 1-30.

CWG AHW (2016). Gap analysis on Animal Welfare research. Working toward common goal for researchers, farmers and the industry. 20 pp.

Dalla Villa, P., Marahrens, M., Velarde Calvo, A., Di Nardo, A., Kleinschmidt, N., Fuentes Alvarez, C., Truar, A., Di Fede, E., Otero, J.L. Müller-Graf, C. (2009): Final report on project to develop animal welfare risk assessment guidelines on transport-project developed on the proposal CFP/EFSA/AHAW/2008/02. 127 pp.

EFSA (2004) Opinion of the Scientific Panel on Animal Health and Welfare (AHAW) on a request from the Commission related to the welfare of animals during transport. Question N°EFSA-Q-2003-094 The EFSA Journal, 44, 181 pp. Journal, 844, 1-89.

EFSA (2008): Scientific report of EFSA on Animal welfare aspects of husbandry systems for farmed trout. (Question No EFSA-Q-2006-147). Annex I to the EFSA Journal, 796, 1-97.

EFSA (2008): Scientific report of EFSA on Animal welfare aspects of husbandry systems for farmed common carp. (Question No EFSA-Q-2006-148). Annex I to the EFSA Journal, 843, 1-81.

EFSA (2009): Species-specific welfare aspects of the main systems of stunning and killing of farmed Atlantic salmon. The EFSA Journal, 2012, 1-77.

EFSA (2009): Species-specific welfare aspects of the main systems of stunning and killing of farmed sea bass and sea bream The EFSA Journal, 1010, 1-52.

EFSA (2009). Species-specific welfare aspects of the main systems of stunning and killing of farmed carp. The EFSA Journal, 1013, 1-37.

EFSA (2009). Species-specific welfare aspects of the main systems of stunning and killing of farmed rainbow trout. The EFSA Journal, 1013, 1-55.

EFSA (2013): Guidance on the assessment criteria for studies evaluating the effectiveness of stunning interventions regarding animal protection at the time of killing. The EFSA Journal, 11(12):3486, p 1-41.

EUROPEAN COMMISSION Directorate-General for Health and Food Safety. Directorate G — Crisis management in food, animals and plants Unit G2 — Animal Health and Welfare Brussels. Welfare of farmed fish: Common practices during transport and at slaughter. Final Report doi: 10.2875/172078 - ISBN 978-92-79-75336-7

Fish Med Plus Coalition – FVE report. Fish diseases lacking treatment – Gap analysis outcome. On-line survey 2016.

HSA (Humane Slaughter Association) 2007. Compiled report from a meeting on Fish welfare during transport, Thistle Hotel, Inverness, Oct 25th 2006, pp. 32.

Italian Ministry of Health. Manuale per la gestione del controllo del benessere dei pesci durante il trasporto su strada. Nota protocollo N. 2705/2017/436-317CS.

Norwegian Scientific Committee for Food Safety Opinion of the Panel on Animal Health and Welfare of the Norwegian Scientific Committee for Food Safety 14 May 2008. Transportation of fish within a closed system. ISBN-number: 978-82-8082-242-0

OIE Aquatic Animal Health Code - Welfare of farmed fish. Chapter 7., 2017.

EU projects

AQUAFIRST "Combined genetic and functional genomic approaches for stress and disease resistance marker assisted selection in fish and shellfish" (FP6-Project ID: 513692; Coordinator: Patrick PRUNET, INRA, France). Duration: 2004-2008.

FASTFISH "On farm assessment of stress level in fish" (FP6-Project ID: 22720; Coordinator: Tore S. KRISTIANSEN, IMR, Norway). Duration: 2006-2008.

EUROCARP "Disease and Stress Resistant Common Carp: Combining Quantitative, Genomic and Proteomic and Immunological marker technologies to identify high performance strains, families and individuals" (FP6-Project ID: 022665; Coordinator: Zsigmond JENEY, HAKI, Hungary). Duration: 2006-2009.

BENEFISH "Evaluation and Modeling of Benefits and Costs of Fish Welfare-Interventions in European Aquaculture" (FP6-Project ID: 44118; Coordinator: John DALLIMORE, TRANSNATIONAL CONSULTING PARTNERSHIP EWIV, Germany). Duration: 2007-2010.

COPEWELL "A new integrative framework for the study of fish welfare based on the concepts of allostasis, appraisal and coping styles" (FP7-Project ID: 265957; Coordinator: Tore S. KRISTIANSEN, IMR, Norway). Duration: 2011-2015.

WINFISH "Welfare, Health and Individuality in Farmed fish" (Funded under the second call of the FP7–EraNET ANIHWA, Project ID: 291815; Coordinator: Erik HÖGLUND, DTU, Denmark). Duration: 2016-2018.

MedAID "Mediterranean Aquaculture Integrated Development" (Horizon 2020-Project ID: 727315; Coordinator: Bernardo BASURCO, IAMZ-CIHEAM, Spain). Duration: 2017-2020.

COST actions

COST Action 867 "Welfare of fish in European aquaculture" (Coordinator: Anders KIESSLING, Sweden). Duration: 2005-2011.

COST Action FA1301 "A network for improvement of cephalopod welfare and husbandry in research, aquaculture and fisheries" (Coordinator: Giovanna PONTE, Italy). Duration: 2013-2017.

Annexes

Annex I: Focus Group agenda

Time	Activity	
10.00-10.15	Welcoming and introduction to the workshop: CASA and CWGs	Stefano Messori
10:15-10:30	Strengthening fish welfare research through a gap analysis study: project overview	Stefano Messori and Amedeo Manfrin
10.30-11.00	Survey result overview	Amedeo Manfrin
11.00-11.15	Coffee break	All
11.15-11.30	Introduction of participants	Stefano Messori
11.30-13:30	Guided discussion	All
13:30-14.00	Conclusions and next steps	Amedeo Manfrin and Stefano Messori
14.00	End of the meeting	

Annex II: Online prioritisation results: final score including additional replies

Priority research needs for the four most relevant production phases:

PHASE	RESEARCH NEEDS	FISH SPECIES	FISH WELFARE RELEVANCE	URGENCY	TOTAL
Early life	Indicators of stress in larvae and juveniles	All	80	80	160
	Feeding	All	65	64	129
	Grading	All	59	56	115
Rearing	Welfare indicators: behavioural	All	81	79	160
	Fish density according to different species biological needs	All	75	68	143
	Welfare during vaccination	All	75	71	146
	Assessment of welfare in Recirculating Aquaculture System		77	76	153
Slaughtering	Pre-slaughter handling techniques (crowding and harvesting methods at different temperature)	All	68	70	138
	Relationship between flesh quality and different stunning/killing methods	All	65	67	132
	Stocking density before harvesting	All	59	59	118
	Validated protocol for stunning cage cultured marine fish.	All	63	67	130
Other	Consumer perception about fish welfare	All	67	65	132
	Development of licenced anaesthetic and pharmaceutical	All	69	68	137
	Different stress coping styles in all species of farmed fish	All	61	60	121

Priority research needs having an average score above 100.

PHASE	RESEARCH NEEDS	FISH SPECIES	FISH WELFARE RELEVANCE	URGENCY	TOTAL
Early life	Indicators of stress in larvae and juveniles	All	80	80	160
Rearing	Welfare indicators: behavioural	All	81	79	160
Rearing	Assessment of welfare in Recirculating Aquaculture System	All	77	76	153
Rearing	Welfare during vaccination	All	75	71	146
Rearing	Fish density according to different species biological needs	All	75	68	143
Breeding stock	Genetic selection to improve health	All	70	69	139
Transport	Improving water quality parameters during transport in closed systems	All	69	70	139
Transport	Use of anaesthetics (e.g. clove oil) as stress reducers	All	68	71	139
Slaughtering	Pre-slaughter handling techniques (crowding and harvesting methods at different temperature)	All	68	70	138
Other	Development of licenced anaesthetic and pharmaceutical	All	69	68	137
Slaughtering	Relationship between flesh quality and different stunning/killing methods	All	65	67	132
Other	Consumer perception about fish welfare	All	67	65	132
Breeding stock	Genetic selection to improve stress resistance	All	67	64	131
Transport	Total length/duration of transport	All	64	67	131
Slaughtering	Validated protocol for stunning cage cultured marine fish	All	63	67	130
Early life	Feeding	All	65	64	129
Other	Different stress coping styles in all species of farmed fish	All	61	60	121
Slaughtering	Stocking density before harvesting	All	59	59	118
Early life	Grading	All	59	56	115
Breeding stock	Welfare implications of triploidy	All	58	54	112