SCAR
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European Animal Health & Welfare Research
COLLABORATIVE WORKING GROUP

casa
Common Agricultural and wider bioeconomy reSearch Agenda

DISEASE PREVENTION IN FARMED FISH

NEW DEVELOPMENTS AND RESEARCH NEEDS

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SCAR FISH

Chair: Michalis Pavlidis (Department of Biology, University of Crete)

Vice-chair: Rosanne Metaal (LNV, Netherlands)

SCAR CWG Animal Health and Welfare Research

Chair: Marina Bagni (Italian Ministry of Health)

Co-Chair: Hermann Schobesberger (University of Veterinary Medicine, Vienna), Dominique Vandekerchove (FPS Health, Food Chain Safety and Environment)

Author

Dr. Pantelis Katharios

Hellenic Centre for Marine Research

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COLLABORATIVE WORKING GROU

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CWG AHW partners

Marina Bagni (CWG AHW Chair)

Members of the SCAR Fish involved:

Michalis Pavlidis, Giuseppe Arcangeli

European Commission Observers of the SCAR Fish involved:

Nikos Zampoukas, Marta Iglesias, Miguel Lizaso

EXPERTS PARTICIPATING IN THE FOCUS GROUP:

Hamish Rodger, Francesc Padrós i Bover, Ivona Mladineo, Niccolo Vendramin

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EXECUTIVE SUMMARY

CASA (Common Agricultural and wider bioeconomy reSearch Agenda) and the Standing Committee on Agricultural Research (SCAR) initiated a study to identify and prioritize research needs for the disease prevention in farmed fish. These needs reflected the opinion of stakeholders, including academics, fish health experts, aquaculture specialists and professionals working in the aquaculture industry but also relevant supporting sectors (Pharma, fish feeds etc.). The results of this study will support the development of the Strategic Research Agenda for disease management and prevention in aquaculture.

The study was implemented in three stages; (i) a desk study where the current advances in disease prevention were assessed and a questionnaire was built and sent to 150 recipients selected from all European countries with aquaculture activity, (ii) data analysis and (iii) a workshop in which invited experts discussed and evaluated the results.

In total, 124 responses from participants from 17 different countries were collected and analyzed. The questionnaire was organized in 7 thematic areas and consisted of 75 questions.

- **Infectious diseases caused by bacteria** and their control with either **alternative methods or increased biosecurity** was the highest priority for the hatchery stage for most of the participants irrespectively of their expertise.
- In cage aquaculture, parasitic control through **Integrated Pest Management** was the highest priority especially for the professionals who work in those type of systems.
- In inland facilities and RAS, **diseases caused by bacteria** was also a priority scored higher by the participants as it was in the case of fish hatcheries.
- The **development of rapid tests for disease diagnosis** was the topic that received the highest score not only in the Diagnostics thematic area but in all the priorities of the survey.

Vaccination was also considered an area that according to the responders has many and important research needs.

- **Development of vaccines against viral diseases** and **DNA and innovative vaccines** were selected as the top priorities in this thematic area.
- Finally, the **environmental impacts of treatments** are an area that requires more research efforts.

These priorities together with the priorities discussed by the focus group of experts like **the economics of fish diseases**, **intracellular pathogens**, **the issue of co-infections** and **the need for a holistic approach using modern analytical tools to study fish diseases** outline the current state of the research needs in the area of disease prevention in farmed fish.

BACKGROUND INFORMATION

Aquaculture is the fastest growing industry of animal production and contributes to half of the overall fisheries products worldwide. The strategy for the European aquaculture is to increase the total production to 480,000 tonnes by 2020, a 60% increase compared to previous production levels (Summary of the 27 Multiannual National Aquaculture Plans, EC 2016, https://ec.europa.eu/fisheries/cfp/aquaculture/multiannual-national-plans). Among the objectives that were identified by most participating countries in the aforementioned report is the diversification of the production with the introduction of new aquaculture species. This strategy is currently implemented in EU and several new species are being introduced to the aquaculture practice. The biggest research programme of FP7 for aquaculture, DIVERSIFY (https://www.diversifyfish.eu/) focused on the issue of aquaculture diversification. However, both increase of production and diversification create an extra pressure, related to disease outbreaks, that hampers aquaculture growth. The biggest problem is that there is no parallel growth and diversification of the tools required to prevent and combat diseases in the new species or even new emerging diseases in the already established cultured fish species. Tools that are already available cannot be used interchangeably either because they may not work in every case or because of licensing and authorization issues.

The complexity of aquaculture makes it fundamentally different from any other livestock production industries especially with regard to diseases. In Europe, fish farming includes several species like Atlantic salmon, large (>1.2kg) and portion-size (<1.2kg) rainbow trout, halibut and cod, common carp and other cyprinid species, catfish species, European eel, sturgeon, European seabass, gilthead seabream, turbot, sole, tuna and meagre. These species are cultured in different environments (marine vs freshwater, cold water vs warmer water) using different systems and methods. This complexity is also reflected in the range of the diseases that may affect aquaculture production.

Fish health and welfare is an issue of high research priority for European fish farming. Disease prevention is of prime importance for all major players involved; producers, researchers and stakeholders. In addition, public awareness towards better health and well-being of farmed animals leads to an increased interest of policy-makers, scientific community and the consumers into new methods for disease prevention.

The Standing Committee on Agricultural Research (SCAR) is a source of advice on European agricultural and wider bioeconomy research and a major catalyst for the coordination of national research programmes, where it has helped shape the beginnings

of an integrated European Research Area. The Committee plays an important role in coupling research and innovation and in removing barriers to innovation, and aims to make it easier for public-public and public-private sectors to work together in delivering innovation that tackles the challenges faced in the bioeconomy area. SCARFISH, is a subcommittee of SCAR with focus on fisheries and aquaculture. The main objectives of SCARFISH is to define EU research priorities within relevant initiatives: H2020 Work Programmes, Bioeconomy Strategy, Food & Nutrition security Strategy with inputs from SWG Food Systems, Agro-food and Forestry Strategy, Circular economy.

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'.

Recently, several Horizon 2020 and National research projects have been completed and dissemination of the new developments, as well as new prioritization of research needs is of urgent need for the sector. Besides, SCARFISH in a joint action with SCAR CWG AHW recently completed a study on fish welfare and such study completes the already published report of CWG AHW on animal welfare (March 2018). Moreover, SCAR CWG AHW SRA produced several outputs on fish health in two different exercises, FOREMED and AH SRA - ANIHWA/CWG AHW update. These outputs provided the basis for our study which was commissioned by CASA, aiming to ***identify emerging research gaps and define research priorities in disease prevention in farmed fish***.

AIMS OF THE STUDY

The aim of this study was to identify and prioritize research needs for the disease prevention in farmed fish. These needs reflect the opinion of stakeholders, including academics, fish health experts, aquaculture specialists and professionals working in the aquaculture industry but also relevant supporting sectors (Pharma, fish feeds etc.). The results of this study will support the development of the Strategic Research Agenda for disease management and prevention in aquaculture.

WORK PLAN AND METHODOLOGY

TASK 1. DESK STUDY

The first activity included a preliminary desk study. The main objective of the task was to evaluate current advances on disease prevention. Information was collected from HORIZON 2020 Programme, SRAs & other strategic papers/report on disease prevention method. In addition, this exercise was based on CWG Animal Health and Welfare SRA as well as in FOREMED. The methodology of the recent EU Animal health Strategic Research Agenda – CWG AHW update exercises was taken as basis to form the questionnaire, main tool for this study, and to design the focus group approach. This task included also the formation of a shortlist of experts in the field of fish health and aquaculture that would receive the invitation to fill in the questionnaire. The shortlist included the country representatives of the European Association of Fish Pathologists, authors of recent scientific papers published in the past 3 years in the field of aquaculture diseases, personal contacts and aquaculture specialists from all European countries. Moreover, experts from the industry (aquaculture, fish feeds, vaccine companies) were also invited to fill in the questionnaire.

A database of 150 contacts of professionals was created in collaboration with SCAR CWG AHW. It included experts from 27 countries. 105 were fish health specialist/practitioners from Academia or Industry, 18 experts were selected from the industry (fish feeds, vaccine, aquaculture), and 27 were the EAFP branch officers. They were contacted through e-mail and were asked to fill in the online questionnaire. Furthermore, they were asked to distribute the questionnaire to other colleagues working in the area of aquaculture diseases and fish health.

Figure 1 Desk study pipeline

ORGANIZATION OF THE QUESTIONNAIRE

The questionnaire was organized in 8 sections.

1) **The first section included the personal information of the responder**:
    - name (optional),
    - expertise (fish health expert, veterinarian non-fish, aquaculture, other),
    - country (drop list),
    - species expertise (salmonids, seabream/seabass, turbot/sole, eel, sturgeon, cyprinids, bivalves, shrimps, others). Regarding the fish species, the responder could opt for more than one choice.
2) **The second section referred to Hatcheries**. It included 15 Importance questions/topics
    - biosecurity,
    - live feeds as disease vectors,
    - Alternatives for bacterial control (probiotics, phage therapy etc),
    - deformities,
    - juvenile quality (disease resistance),
    - nutrition for health,
    - gut health,
    - microbiome at hatchery level,
    - welfare/stress* and disease,
    - protozoal diseases,
    - metazoan diseases,
    - viral diseases,
    - bacterial diseases,
    - transportation of juveniles,
    - early life stage vaccination (live feeds as vectors),

    ** not implying that welfare is related to stress alone*

    where the responder should assess from 1-5 (1 lowest importance, 5 highest importance) the necessity to fill research gaps in the particular topic in relation to fish health management and disease prevention. An open question where the responder could use free text was provided for indicating issues not covered by the provided questions.

3) **The third section referred to Broodstock**. It included 6 Importance questions/topics
    - disease monitoring,
    - genetic selection for disease resistance,

- vaccination,
- functional feeds for health,
- egg/quality and disinfection,
- welfare/stress* and disease,

  ** not implying that welfare is related to stress alone*

where the responder should assess from 1-5 (1 lowest importance, 5 highest importance) the necessity to fill research gaps in the particular topic in relation to fish health management and disease prevention. An open question where the responder could use free text was provided for indicating issues not covered by the provided questions.

4) **The fourth section referred to Ongrowing (land-based and RAS systems).** It included 11 Importance questions/topics
   - bacterial control,
   - protozoal diseases,
   - metazoa parasites,
   - bacterial diseases,
   - viral diseases,
   - water quality and disease,
   - non-infectious diseases other than nutritional,
   - nutritional diseases,
   - welfare/stress* and disease,
   - early warning indicators for disease onset,
   - biosecurity,

     ** not implying that welfare is related to stress alone*

   where the responder should assess from 1-5 (1 lowest importance, 5 highest importance) the necessity to fill research gaps in the particular topic in relation to fish health management and disease prevention. An open question where the responder could use free text was provided for indicating issues not covered by the provided questions.

5) **The fifth section referred to Ongrowing (cage aquaculture)**. It included 15 Importance questions/topics
   - bacterial diseases,
   - protozoal diseases,
   - life-cycle of parasites,

- Integrated Pest Management (parasite control),
- environment and water quality,
- climate change and disease,
- Automation (monitoring, IoT, big data),
- behavioral indicators for disease,
- Administration of treatments (eg bathing),
- welfare/stress* and disease,
- early warning indicators for disease onset (other than behaviour),
- interactions with feral and wild fish,
- Emerging diseases,
- Zoonotic diseases,
- Legislation,

** not implying that welfare is related to stress alone*

where the responder should assess from 1-5 (1 lowest importance, 5 highest importance) the necessity to fill research gaps in the particular topic in relation to fish health management and disease prevention. An open question where the responder could use free text was provided for indicating issues not covered by the provided questions.

6) **The sixth section referred to Vaccine Development**. It included 10 Importance questions/topics
   - lack of commercial vaccines,
   - regulation/legislation,
   - development of DNA and innovative vaccines,
   - autogenous vaccines,
   - viral vaccines,
   - bacterial vaccines,
   - vaccines for parasites,
   - adjuvants,
   - vaccination automations,
   - immunostimulants,

   where the responder should assess from 1-5 (1 lowest importance, 5 highest importance) the necessity to fill research gaps in the particular topic in relation to fish health management and disease prevention. An open question where the responder could use free text was provided for indicating issues not covered by the provided questions.

7) **The seventh section referred to Treatments**. It included 8 Importance questions/topics
    - Antibiotics (new, residues, kinetics, etc),
    - Antiparasitics,
    - Antiviral,
    - Alternative treatments,
    - legislation,
    - antibiotic resistance,
    - Reproductive hormones,
    - disinfectants,

    where the responder should assess from 1-5 (1 lowest importance, 5 highest importance) the necessity to fill research gaps in the particular topic in relation to fish health management and disease prevention. An open question where the responder could use free text was provided for indicating issues not covered by the provided questions.

8) **The eighth section referred to Diagnostics**. It included 9 Importance questions/topics
    - Standardization at diagnostic labs,
    - Molecular diagnostics,
    - rapid tests,
    - Epidemiology using NGS,
    - Serological tests non-lethal and noninvasive tests,
    - biosensors,
    - development of fish cell lines,
    - Development of Operational Welfare indicators,

    where the responder should assess from 1-5 (1 lowest importance, 5 highest importance) the necessity to fill research gaps in the particular topic in relation to fish health management and disease prevention. An open question where the responder could use free text was provided for indicating issues not covered by the provided questions.

In total the responder had to assess the urgency of filling research gaps regarding aquaculture disease management and prevention in 74 topics. In addition, the responder could suggest topics not covered by the questionnaire in the 7 thematic areas.

TASK 2. DATA ANALYSIS

The online survey was conducted with the use of Google Forms. This tool provides basic statistical analysis but also the option to download the responses in an Excel file. The analysis of the responses was based on the average values and it was organized in different thematic sections. Using pivot tables, the results could be analyzed using different filters (perspectives). The analysis presented here used the filter of the professional expertise of the responders and the fish species expertise as well as the global analysis without the use of filters.

TASK 3. WORKSHOP – FOCUS GROUP

With the prioritized list of research questions, a panel of professionals was selected to join in a consensus workshop. Professionals represented industry and academia and countries with significant aquaculture production. The experts worked on the analyzed questionnaire to draw the final recommendations / conclusions and to propose new synergies between public and private, in order to promote research and investment in the future. The list of professionals is shown below:

Name	**Affiliation**
Ivona Mladineo	Institute of Oceanography and Fisheries, Croatia
Niccolo Vendramin	Technical University of Denmark (DTU), Denmark
Hamish Rodger	VAI Consulting, Ireland
Francesc Padrós i Bover	Universitat Autònoma de Barcelona, Spain
Pantelis Katharios	Hellenic Centre Marine Research, Greece
Michalis Pavlidis	SCARFISH

The workshop was held in Brussels in June 14th 2019 with the experts as well as the representative of SWG SCARFISH, Prof. Michalis Pavlidis. Observers from EC-DG RTD were also present.

RESULTS

DEMOGRAPHICS OF THE PARTICIPANTS

A total of 124 professionals from 17 different countries responded to the questionnaire. The majority of the responders came from Spain, Greece and Italy (**Figure 2**).

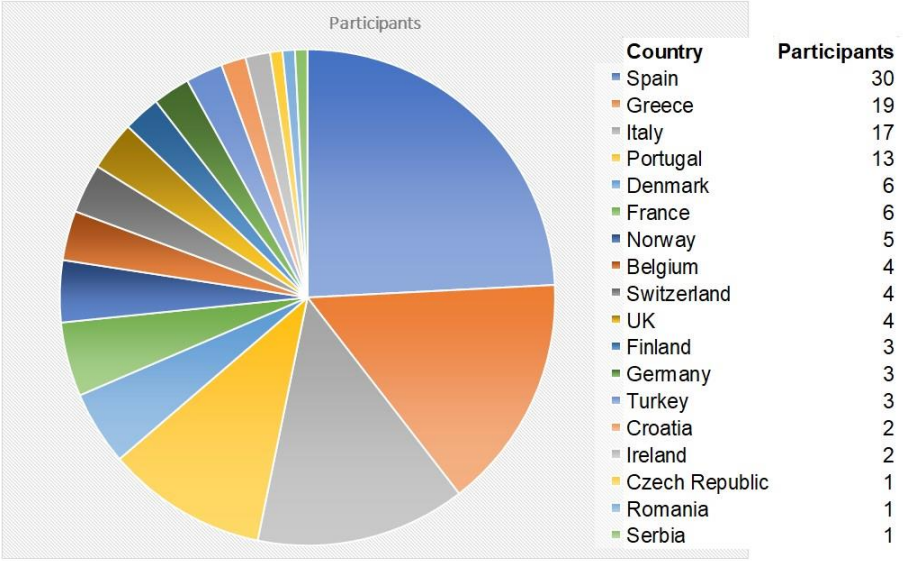


Figure 2 Schematic representation of the origin country of the survey participants

Regarding the professional expertise of the participants, the majority were fish health experts (58%), followed by aquaculture professionals and veterinarians (non-fish) (**Figure 3**).

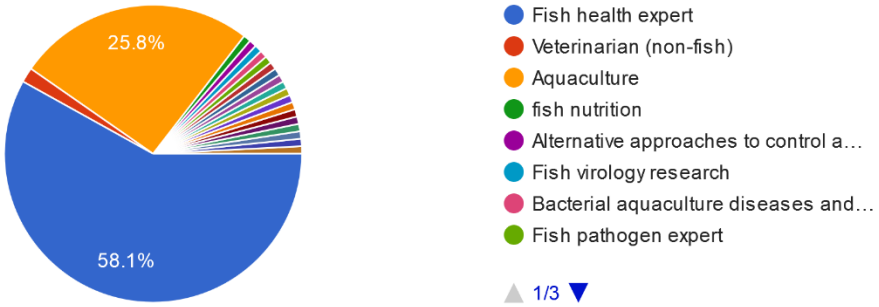


Figure 3 Professional expertise of the participants of the study.

The majority of the participants declared expertise in seabass and seabream, followed by salmonids **(Figure 4)**. It should be underlined that the participants could select more than one species.

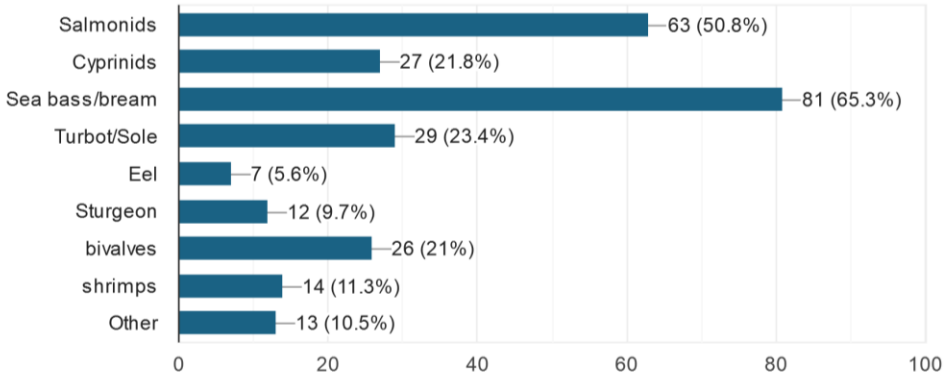


Figure 4 Expertise of the participants of the study in different aquaculture species

RESPONSES TO THE QUESTIONNAIRE

The results presented in the following part of the report are the average scores obtained per section of the questionnaire of all responses recorded in the survey. They are presented in a descending order. All responses which have achieved an average score above 4.2/5 are highlighted in bold. In **Annex 1** the analysis of the results is also given according to the professional expertise of the responders and the expertise in specific farmed animals.

SECTION 1. HATCHERY LEVEL

The highest ranked priority according to all responders was "Bacterial diseases" (Table 1). This was also the selection of the Fish Health Experts group while Aquaculture professionals selected "Alternatives for bacterial control" as the most important priority (results presented in ANNEX).

Table 1 Average scores per topic in the thematic area "Hatchery". All topics with score above 4.2 have been highlighted in bold.

Topic	Average score
Bacterial diseases	**4.37**
Viral diseases	**4.31**
Biosecurity	**4.30**
Alternatives for bacterial control (probiotics, phage therapy etc)	**4.22**
Welfare/stress* and disease	4.20
Juvenile quality (disease resistance)	4.18
Nutrition for health	4.09
Early life stage vaccination (eg live feeds as vectors)	4.02
Gut health	3.96
microbiome at hatchery	3.70
Live Feeds (as disease vectors)	3.63
Protozoal diseases	3.58
Transportation of juveniles	3.42
Diseases caused by metazoan parasites	3.35
Deformities	3.22

** not implying that welfare is related to stress alone*

SECTION 2. BROODSTOCK

The highest ranked priority for broodstock was "Disease monitoring" (Table 2). This was also the selection made by Fish Health Experts while Aquaculture professionals scored higher "Genetic Selection for disease resistance".

Table 2 Average scores per topic in the thematic area "Broodstock". All topics with score above 4.2 have been highlighted in bold.

Topic	Average score
Disease monitoring	**4.41**
Genetic selection for disease resistance	**4.26**
welfare/stress* and disease	4.04
Egg/quality and disinfection	3.99
Vaccination of the broodstock	3.97
Functional feeds for health	3.79

** not implying that welfare is related to stress alone*

SECTION 3. ON-GROWING (LAND BASED/RAS)

The highest ranked priority according to all responders was "Biosecurity" (Table 3) again in agreement with the opinion of Fish Health Experts. Aquaculture professionals scored higher "Water quality and diseases".

Table 3 Average scores per topic in the thematic area "On-growing (Land based/RAS)". All topics with score above 4.2 have been highlighted in bold.

Topic	Average score
Biosecurity	**4.38**
Water quality and diseases	**4.35**
Early warning indicators for disease onset	**4.35**
Bacterial diseases	**4.32**
Bacterial control	**4.28**
Viral diseases	**4.28**
Welfare/stress* and disease	4.08
Protozoal diseases	3.88
nutritional diseases	3.68
metazoa prasites	3.62
non-infectious diseases other than nutritional	3.37

** not implying that welfare is related to stress alone*

SECTION 4. ON-GROWING (CAGE AQUACULTURE)

The highest ranked priority by all responders was "Integrated Pest Management" (Table 4). This was in agreement with the Aquaculture professionals, while Fish health Experts scored higher "Biosecurity".

Table 4 Average scores per topic in the thematic area "On-growing (cage aquaculture)". All topics with score above 4.2 have been highlighted in bold.

Topic	Average score
Integrated Pest Management (parasite control)	**4.31**
Emerging diseases	**4.26**
Early warning indicators for disease onset (other than behaviour)	**4.23**
Bacterial diseases	4.07
Climate change and disease	4.07
Welfare/stress* and disease	4.07
Environment and water quality	3.98
Life-cycle of parasites	3.98
behavioral indicators for disease	3.97
Administration of treatments (eg bathing)	3.83
Interactions with feral and wild fish	3.82
Automation (monitoring, IoT, big data)	3.79
Legislation	3.71
Protozoal diseases	3.70
Zoonotic diseases	3.61

** not implying that welfare is related to stress alone*

SECTION 5. VACCINES

The highest ranked priority according to all responders was "Viral vaccines". This priority was also selected as the most important by Fish Health Experts. Aquaculture professionals scored higher "Improvement of available vaccines".

Table 5 Average scores per topic in the thematic area "Vaccines". All topics with score above 4.2 have been highlighted in bold.

Topic	Average score
Viral vaccines	**4.46**
Improvement of available vaccines	**4.34**

(multivalent composition, reduction of dose, etc.)	
Development of DNA and innovative vaccines	**4.34**
Bacterial vaccines	**4.30**
Lack of commercial vaccines	**4.28**
Autogenous vaccines	4.15
Regulation/legislation	3.98
Immunostimulants	3.97
Vaccines for parasitic diseases	3.92
Adjuvants	3.88
Vaccination automations	3.83

SECTION 6. TREATMENTS

The highest ranked priority was "Environmental impact of treatments in aquaculture" (Table 6). Aquaculture professionals scored higher "Alternative treatments" and "Environmental impact of treatments in aquaculture", while Fish health experts scored higher "Antiparasitics".

Table 6 Average scores per topic in the thematic area "Treatments". All topics with score above 4.2 have been highlighted in bold.

Topic	Average score
Environmental impact of treatments in aquaculture	**4.37**
Antibiotic/Antimicrobial resistance	**4.30**
Antiparasitics	**4.26**
Alternative treatments	4.18
Standardization at diagnostic labs	4.18
Antibiotics (novel products, residues, kinetics, etc)	4.07
Legislation2	4.03
Antiviral drugs	3.81
disinfectants	3.75
Reproductive hormones	3.22

SECTION 7. DIAGNOSTICS

The highest ranked priority according to all participants was "Rapid tests" (Table 7). This was in agreement with the selection made by both Aquaculture professionals and Fish health experts.

Table 7 Average scores per topic in the thematic area "Diagnostics". All topics with score above 4.2 have been highlighted in bold.

Topic	Average score
Rapid tests	**4.49**
Non-lethal, non-invasive tests	**4.40**
Molecular diagnostics	4.14
Development of operational welfare indicators	4.13
Biosensors	4.12
Epidemiology using NGS	3.98
Development of fish cell lines	3.96
Serological tests	3.82

RESEARCH PRIORITIES PER CULTURED SPECIES

In several cases, research needs are not the same in the different farmed species since they might use significantly different culture systems, or technologies and knowledge are in different stages. The results were processed according to the expertise of the participants in the culture of particular species. In some categories, the number of responders is low not allowing conclusions to be drawn (complete results are shown in ANNEX 1). The following table presents the priorities achieved the highest score in each thematic area of the survey per species (Seabass/bream, salmonids and multispecies).

Table 8 Highest ranked priorities in the different thematic areas of the survey per species. Priorities are shown in a descending order.

	thematic area	topic	Average score
Sea bass/bream	Vaccines	Viral vaccines	**4.63**
	Ongrowing (cages)	Integrated Pest Management (parasite control)	**4.58**
	Diagnostics	Rapid tests	**4.58**
	Hatchery level	Alternatives for bacterial control (probiotics, phage therapy etc)	**4.54**
	Treatments	Antiparasitics	**4.50**
	Ongrowing (RAS/Inland)	Early warning indicators for disease onset	**4.50**
	Broodstock	Genetic selection for disease resistance	**4.29**

Salmonids	Vaccines	Development of DNA and innovative vaccines	**4.55**
	Diagnostics	Rapid tests	**4.45**
	Ongrowing (RAS/Inland)	Biosecurity2	**4.45**
	Hatchery level	Alternatives for bacterial control (probiotics, phage therapy etc)	**4.36**
	Treatments	Environmental impact of treatments in aquaculture	**4.36**
	Broodstock	Disease monitoring	**4.27**
multispecies	Diagnostics	Rapid tests	**4.45**
	Broodstock	Disease monitoring	**4.43**
	Vaccines	Viral vaccines	**4.42**
	Hatchery level	Bacterial diseases	**4.38**
	Treatments	Environmental impact of treatments in aquaculture	**4.37**
	Ongrowing (RAS/Inland)	Biosecurity2	**4.36**
	Ongrowing (cages)	Integrated Pest Management (parasite control)	**4.30**

FOCUS GROUP ASSESSMENT

The panel of experts met for the workshop in Brussels, evaluated the responses in each thematic area and discussed the results.

In the **"Hatchery"** thematic area the participants selected bacterial and viral diseases as the topics having the biggest research needs. The expert panel agreed that the topics selected are of great importance and require more research, together with the development of alternative methods for disease prevention and biosecurity which were also scored high by the responders. A big part of the mortalities observed in fish hatcheries are due to infectious diseases. Microbial control at the hatchery level is a very complex and important topic since microbes can be either opportunistic pathogens responsible for the mortalities observed, or beneficial agents essential for the development of healthy juveniles.

In the **"Broodstock"** section, the responders selected disease monitoring as the area requiring more research. Disease monitoring both for maintaining the health of the broodfish but also to avoid vertical transmission of disease is an important issue that both the responders and the expert panel believe that should be addressed in future research programmes.

Several topics were considered important, requiring more research in the **"Ongrowing (Land-based/RAS)"** thematic area. These include biosecurity, bacterial control, water quality and early warning indicators for disease onset. The expert panel agreed with the selected topics **but highlighted also the importance of intracellular bacteria as an emerging problem in these systems**. This is because intracellular bacteria are hard to treat and they are poorly understood or studied in the context or aquaculture.

In the **Ongrowing (cage aquaculture)** section, the responders selected **Integrated Pest Management** as the most important topic that requires further research. Interestingly, the responders with expertise in salmonid aquaculture did not score this topic high, probably reflecting the fact that this type of parasite management is already in practice in salmon aquaculture. Participants with expertise in all other fish species but salmonids, scored higher Integrated Pest Management. The expert panel agreed that Integrated Pest Management and parasite control is the topic having the biggest research gaps especially in the non-salmonid aquaculture. It also agreed with the other topics selected by the responders, such as emerging diseases especially in the context of aquaculture diversification and climate change. The expert panel highlighted also the importance of the application/administration of treatments in cages especially in the case of bath treatments. Although the responders scored lower this topic, the panel believes that bath treatments can be quite problematic and sometimes may cause bigger mortalities than the disease itself. Moreover, bath treatments may affect the environment and therefore more research effort should be dedicated to this topic focusing on the best practices and stress indicators for improved control of the treatments. Finally, the importance of viral diseases was highlighted by both the responders of the questionnaire but also by the expert panel

Vaccines for viral and bacterial diseases, novel technologies in vaccine development, such as DNA vaccines and the lack of commercially available vaccines were the topics with the biggest gaps in the **Vaccine thematic area** of the questionnaire according to the responders. There was a consensus between the responders and the expert panel in this thematic area. The expert panel believes that biotechnological advances and DNA vaccine have great potential, **but highlighted also emerging problems in the patenting processes and legislation** (eg patenting of genomes of pathogens already in place in some countries) that may hamper the commercialization and wider application of these technologies (also applied for the diagnostics).

Environmental impact of treatments, antimicrobial resistance and lack of registered antiparasitic drugs have been identified as the topics requiring more research in the **thematic area of Treatments**. The expert panel agreed with the views of the responders.

Antimicrobial Resistance (AMR) is one of the most important topics not only for aquaculture but for all livestock production. It is acknowledged that there is urgent need for research towards the understanding of AMR in fish pathogenic bacteria and minimization of the use of antibiotics. The lack of a wider range of antiparasitic drugs creates also a large gap in the ability to control parasitic diseases especially in cage aquaculture. Both the expert panel and the responders believe that environmental impact of treatments is the topic that requires more research, a fact that reflects not only the commitment of European aquaculture to respect the environment but also the comprehension that environmental quality is directly linked with health and welfare of the animals and therefore the sustainability of the sector.

Rapid diagnostic tests and non-lethal/non-invasive tests were the topics requiring more research according to the responders in the thematic area of Diagnostics. The expert panel agreed with the views of the participants. Regarding rapid tests, the expert panel believed that indeed are of great importance, however it highlighted the fact that their use should be considered indicative and complimentary to other methods of disease diagnosis since they can be misleading.

In all sections of the questionnaire, the responders could provide topics that had not been covered. These responses were also evaluated and discussed by the expert panel. The expert panel suggested also topics that were not covered by the questionnaire but were considered important.

The first topic was **the issue of co-infections** that are quite complex to study and evaluate. Recent advances in molecular tools are now shedding light to the infection process, indicating that the infection models are much more complicated than initially thought. **Moreover, aquaculture systems, such as cage systems and the environment, need to be looked at as an ecosystem in its entirety**. There is an urgent need for a holistic approach, ideally bringing together scientists and aquaculture experts for ambitious and wide-ranging investigations. The reservoirs, especially of emerging disease agents, wild and farmed fish interaction and the importance of co-existing pathogens simultaneously infecting the same hosts are issues which are often unknown and overlooked.

Aquaculture health economics is another issue identified by the panel that requires more research. The economics of a disease include various costs such as the loss of biomass due to mortalities, the cost of treatment and prevention, the reduced performance of fish (lower SGR), higher FCR and a wide range of indirect costs such as loss of production flexibility, bad image of the industry to the public etc. Modelling of aquaculture health economics will provide an important management tool to the aquaculture industry and will help decision making not only at the farm but also at the regional level.

Microbiome was also considered a topic that needs to be elaborated through more intense research efforts**. This should be ideally linked with specific applications such as microbial manipulation/management, probiotics, alternative therapies etc**. Microbiome research is also required according to the expert panel towards the development of more efficient diets. Moreover, the panel highlighted that the fish feeds, and especially replacement of fish oils and fishmeal by alternatives (insects, vegetables, etc) has a significant impact on the health of the fish and this together with microbiome research should also be in the priorities of the Strategic Research Agenda.

Finally, the expert panel discussed about legislative issues that should be considered including **the definition of zoonotic diseases** and **the discrimination between infection and disease**. Tools for discriminating virulent isolates of farmed fish vs low virulent isolates found in wild fish are also considered important as they might affect decision making at the regional level.

FINAL REMARKS

The current study aimed at the identification and prioritization of the research needs in the area of disease prevention of farmed fish. As indicated at the beginning of the document, aquaculture is an industry that has fundamental differences compared to the other livestock production sectors. The variety of the species cultured, and the production systems used creates a significant complexity that is reflected also in the diversity of the responses received in this survey. Nevertheless, several research needs have been highlighted by the majority of the responders independently of their professional expertise or expertise in specific fish species.

- **Infectious diseases caused by bacteria** and their control with either **alternative methods or increased biosecurity** is the highest priority for the hatchery stage for most of the participants irrespectively of their expertise.
- In cage aquaculture, parasitic control through **Integrated Pest Management** is the highest priority especially for the professionals who work in those type of systems.
- In inland facilities and RAS, **diseases caused by bacteria** is also a priority scored higher by the participants as it was in the case of fish hatcheries.
- The **development of rapid tests for disease diagnosis** was the topic that received the highest score not only in the Diagnostics thematic area but in all the priorities of the survey.

Vaccination was also considered an area that according to the responders has many and important research needs.

- **Development of vaccines against viral diseases** and **DNA and innovative vaccines** were selected as the top priorities in this thematic area.
- Finally, the **environmental impacts of treatments** are an area that requires more research efforts.

These priorities together with the priorities discussed by the focus group of experts like **the economics of fish diseases**, **intracellular pathogens**, **the issue of co-infections** and **the need for a holistic approach using modern analytical tools to study fish diseases** outline the current state of the research needs in the area of disease prevention in farmed fish.

Several research projects which have relevance with aquaculture health have been funded by FP7 and H2020 (an indicative list is shown in the next section). Moreover, many projects and initiatives have also been supported by national funds of various countries. New research directions should use the results of these projects as a starting point. A wide dissemination of these results especially to the stakeholders is a prerequisite for the design of a successful research agenda. The results of this study will also help in the development of the research agenda since they reflect the current opinion of the majority of the professionals involved in disease prevention and management in aquaculture.

RECENT AND CURRENT RESEARCH PROJECTS RELEVANT TO AQUACULTURE HEALTH

Parafishcontrol, Advanced Tools and Research Strategies for Parasite Control in European farmed fish, H2020-EU.3.2. - SOCIETAL CHALLENGES - Food security, sustainable agriculture and forestry, marine, maritime and inland water research, and the bioeconomy.

Performfish, Consumer driven Production: Integrating Innovative Approaches for Competitive and Sustainable Performance across the Mediterranean Aquaculture Value Chain. SFS-23-2016 - Improving the technical performance of the Mediterranean aquaculture

Medaid, Mediterranean Aquaculture Integrated Development. SFS-23-2016 - Improving the technical performance of the Mediterranean aquaculture

SAFE-Aqua, SustainAble Farming for Effective Aquaculture, MSCA-RISE-2016 - Research and Innovation Staff Exchange

AquaExcel2020, AQUAculture infrastructures for EXCELlence in European fish research towards 2020. INFRAIA-1-2014-2015 - Integrating and opening existing national and regional research infrastructures of European interest

VIVALDI (bivalves), Preventing and mitigating farmed bivalve diseases, SFS-10b-2015 - Scientific basis and tools for preventing and mitigating farmed mollusc diseases.

PROTECTA, Pathogen-informed Resistance to Oomycete diseases in Ecosystems, Agriculture and Aquaculture, MSCA-ITN-2017 - Innovative Training Networks

Fish-AI, Developing an Artificial Intestine for the sustainable farming of healthy fish. FETOPEN-01-2018-2019-2020 - FET-Open Challenging Current Thinking

LABVaccFish, USE OF LACTIC ACID BACTERIA AS DELIVERY VEHICLE FOR ORAL VACCINATION OF FISH, MSCA-IF-2014-EF - Marie Skłodowska-Curie Individual Fellowships (IF-EF)

HappyFish, Understanding the role of the rainbow trout metagenome on growth and health in aquaculturally farmed fish, MSCA-IF-2016 - Individual Fellowships

AdriAquaNet, Enhancing Innovation and Sustainability in Adriatic Aquaculture, Interreg Italy - Croatia, 2017, Blue innovation.

Diversify, Exploring the biological and socio-economic potential of new/emerging candidate fish species for the expansion of the European aquaculture industry. KBBE.2013.1.2-09 - Diversification of fish species and products in European aquaculture

Targetfish, Targeted disease prophylaxis in European fish farming, KBBE.2012.1.2-10 - Prevention of important diseases of farmed fish species.

FISHBOOST, Improving European aquaculture by advancing selective breeding to the next level for the six main finfish species, KBBE.2013.1.2-10 - Boosting the domestication of established farmed finfish species through selective breeding

SAPRO, Sustainable Approaches to Reduce Oomycete (Saprolegnia) Infections in Aquaculture, FP7-PEOPLE-ITN-2008 - Marie Curie Action: "Networks for Initial Training"

AQUAPHAGE, Network for the development of phage therapy in aquaculture, FP7-PEOPLE-2010-IRSES - Marie Curie Action "International Research Staff Exchange Scheme"

FISHPROBIO, Metacommunity dynamics of the fish surface mircobiome in health and disease: pathogens and probiotics, FP7-PEOPLE-2011-IOF - Marie Curie Action: "International Outgoing Fellowships for Career Development"

BIVALIFE, Controlling infectious diseases in oysters and mussels in Europe, KBBE.2010.1.2-08 - Improving European mollusc aquaculture: disease detection and management - Call: FP7-KBBE-2010-4

AQUABAC, The use of potentially protective bacteria in aquaculture against fish pathogenic Flavobacterium spp. FP7-PEOPLE-2009-IEF - Marie Curie Action: "Intra-European Fellowships for Career Development"

CHLAFISH, Novel Fish Pathogens of the Chlamydiae: Genomic, Proteomic and Metabolomic Investigations, FP7-PEOPLE-2012-IEF - Marie-Curie Action: "Intra-European fellowships for career development".

NEMO, Training network on protective immune modulation in warm water fish by feeding glucans, PEOPLE-2007-1-1-ITN - Marie Curie Action: " Networks for Initial Training"

SMARTFISH, Study of specific cell mediated immunity and vaccine optimization against bacterial and viral infections in trout (Oncorhynchus mykiss), PEOPLE-2007-2-1.IEF - Marie Curie Action: "Intra-European Fellowships for Career Development"

ANNEX 1 Analysis of the results according to professional and species expertise of the responders

Table 1.1. Average scores per topic in each thematic area of the survey according to the professional expertise of the responders. All topics with score above 4.2 are in bold while the highest scores have been highlighted in green for each category.

		Aquaculture	Fish health expert	Other	Grand Total
Hatchery level	Biosecurity	**4.35**	**4.27**	**4.30**	**4.30**
	Live Feeds (as disease vectors)	3.68	3.49	4.05	3.63
	Alternatives for bacterial control (probiotics, phage therapy etc)	**4.50**	4.04	**4.35**	**4.22**
	Deformities	3.68	3.07	2.95	3.22
	Juvenile quality (disease resistance)	**4.47**	4.11	3.95	4.18
	Nutrition for health	**4.47**	3.90	4.10	4.09
	Gut health	4.12	3.90	3.90	3.96
	microbiome at hatchery	3.97	3.61	3.60	3.70
	Welfare/stress and disease	**4.38**	4.17	4.00	4.20
	Protozoal diseases	3.76	3.49	3.60	3.58
	Diseases caused by metazoan parasites	3.56	3.25	3.35	3.35
	Viral diseases	**4.24**	**4.31**	**4.45**	**4.31**
	Bacterial diseases	**4.32**	**4.41**	**4.30**	**4.37**
	Transportation of juveniles	3.59	3.27	3.70	3.42
	Early life stage vaccination (eg live feeds as vectors)	4.03	3.94	**4.25**	4.02
Broodstock	Disease monitoring	**4.26**	**4.41**	**4.65**	**4.41**
	Genetic selection for disease resistance	**4.41**	**4.31**	3.85	**4.26**
	Vaccination of the broodstock	3.94	4.01	3.85	3.97
	Functional feeds for health	3.94	3.73	3.75	3.79
	Egg/quality and disinfection	3.91	4.04	3.95	3.99
	welfare/stress and disease	4.15	3.99	4.05	4.04
Ongrowing RAS/Inland	Bacterial control	**4.26**	**4.23**	**4.50**	**4.28**
	Protozoal diseases	3.97	3.85	3.85	3.88
	metazoa prasites	3.79	3.46	3.85	3.62

	Bacterial diseases	**4.29**	**4.32**	**4.35**	**4.32**
	Viral diseases	**4.38**	**4.24**	**4.25**	**4.28**
	Water quality and diseases	**4.65**	**4.24**	**4.25**	**4.35**
	nutritional diseases	**4.21**	3.49	3.45	3.68
	non-infectious diseases other than nutritional	3.56	3.27	3.40	3.37
	Welfare/stress and disease	**4.41**	3.93	4.05	4.08
	Early warning indicators for disease onset	**4.44**	**4.31**	**4.35**	**4.35**
	Biosecurity	**4.29**	**4.38**	**4.50**	**4.38**
Ongrowing (cages)	Bacterial diseases	4.09	4.07	4.05	4.07
	Protozoal diseases	4.15	3.41	3.95	3.70
	Life-cycle of parasites	**4.26**	3.85	3.95	3.98
	Integrated Pest Management (parasite control)	**4.50**	**4.30**	4.05	**4.31**
	Environment and water quality	**4.26**	3.80	4.15	3.98
	Climate change and disease	4.18	3.99	4.20	4.07
	Automation (monitoring, IoT, big data)	4.09	3.65	3.80	3.79
	Administration of treatments (eg bathing)	3.97	3.75	3.90	3.83
	Welfare/stress and disease	**4.47**	3.97	3.75	4.07
	behavioral indicators for disease	**4.35**	3.86	3.70	3.97
	Early warning indicators for disease onset (other than behaviour)	**4.47**	4.20	3.95	**4.23**
	Interactions with feral and wild fish	3.82	3.85	3.75	3.82
	Emerging diseases	**4.24**	**4.34**	4.05	**4.26**
	Zoonotic diseases	3.97	3.42	3.65	3.61
	Legislation	3.94	3.62	3.65	3.71
Vaccines	Lack of commercial vaccines	**4.35**	**4.30**	4.10	**4.28**
	Improvement of available vaccines (multivalent composition, reduction of dose, etc.)	**4.47**	**4.32**	4.15	**4.34**
	Regulation/legislation	3.91	4.07	3.80	3.98
	Development of DNA and innovative vaccines	**4.38**	**4.28**	**4.45**	**4.34**
	Autogenous vaccines	**4.32**	4.06	4.20	4.15
	Viral vaccines	**4.44**	**4.48**	**4.40**	**4.46**
	Bacterial vaccines	**4.32**	**4.35**	4.10	**4.30**

	Vaccines for parasitic diseases	**4.21**	3.82	3.80	3.92
	Adjuvants	4.00	3.82	3.90	3.88
	Vaccination automations	4.00	3.77	3.75	3.83
	Immunostimulants	**4.26**	3.86	3.85	3.97
Treatments	Antibiotics (novel products, residues, kinetics, etc)	3.85	4.13	**4.25**	4.07
	Antiparasitics	4.18	**4.42**	3.85	**4.26**
	Antiviral drugs	3.91	3.68	4.10	3.81
	Alternative treatments	**4.38**	4.03	**4.40**	4.18
	Legislation2	4.06	3.99	4.15	4.03
	Antibiotic/Antimicrobial resistance	**4.26**	**4.37**	4.15	**4.30**
	Environmental impact of treatments in aquaculture	**4.38**	**4.32**	**4.50**	**4.37**
	Reproductive hormones	3.62	3.03	3.25	3.22
	disinfectants	3.79	3.73	3.75	3.75
	Standardization at diagnostic labs	4.15	4.11	**4.50**	4.18
Diagnostics	Molecular diagnostics	4.12	4.14	4.15	4.14
	Rapid tests	**4.74**	**4.41**	**4.35**	**4.49**
	Epidemiology using NGS	4.03	3.93	4.05	3.98
	Serological tests	3.97	3.70	4.00	3.82
	Non-lethal, non-invasive tests	**4.62**	**4.30**	**4.40**	**4.40**
	Biosensors	**4.38**	3.97	4.20	4.12
	Development of fish cell lines	4.03	3.86	4.20	3.96
	Development of operational welfare indicators	**4.53**	3.90	**4.25**	4.13

Table 1.2. Average scores per topic in each thematic area of the survey according to the species expertise of the responders. All topics with score above 4.2 are in bold.

		Sea bass/bream	Salmonids	Turbot/Sole	Cyprinids	multispecies	Grand Total
Hatchery level	Biosecurity	**4.25**	**4.27**	4.00	4.00	**4.33**	**4.30**
	Live Feeds (as disease vectors)	3.88	2.82	3.50	3.00	3.69	3.63
	Alternatives for bacterial control (probiotics, phage therapy etc)	**4.54**	**4.36**	**4.50**	**4.50**	4.09	**4.22**
	Deformities	3.67	3.09	**4.50**	2.50	3.09	3.22
	Juvenile quality (disease resistance)	**4.42**	4.00	**4.50**	4.00	4.14	4.18
	Nutrition for health	4.08	3.91	**4.50**	**4.50**	4.09	4.09
	Gut health	4.08	3.64	**4.50**	**4.50**	3.94	3.96
	microbiome at hatchery	3.88	3.64	**4.50**	**4.50**	3.63	3.70
	Welfare/stress and disease	4.17	4.18	**5.00**	**5.00**	4.17	4.20
	Protozoal diseases	3.63	3.64	4.00	4.00	3.55	3.58
	Diseases caused by metazoan parasites	3.42	3.18	4.00	4.00	3.33	3.35
	Viral diseases	4.17	**4.27**	**5.00**	**4.50**	**4.34**	**4.31**
	Bacterial diseases	**4.25**	**4.36**	**5.00**	**4.50**	**4.38**	**4.37**
	Transportation of juveniles	3.67	3.18	4.00	3.00	3.38	3.42
	Early life stage vaccination (eg live feeds as vectors)	**4.46**	3.64	**4.50**	4.00	3.93	4.02
Broodstock	Disease monitoring	**4.33**	**4.27**	**5.00**	**4.50**	**4.43**	**4.41**
	Genetic selection for disease resistance	**4.29**	3.91	**4.50**	**4.50**	**4.29**	**4.26**
	Vaccination of the broodstock	4.13	4.00	**5.00**	3.00	3.92	3.97
	Functional feeds for health	3.92	3.73	4.00	4.00	3.76	3.79
	Egg/quality and disinfection	3.92	3.91	**5.00**	4.00	4.00	3.99
	welfare/stress and disease2	4.13	4.09	**5.00**	**4.50**	3.98	4.04
Ongrowing (RAS/Inland)	Bacterial control	**4.22**	**4.45**	**5.00**	**4.50**	**4.26**	**4.28**

	Protozoal diseases2	4.04	3.36	**5.00**	4.00	3.87	3.88
	metazoa prasites	3.75	3.18	**5.00**	4.00	3.59	3.62
	Bacterial diseases2	**4.21**	**4.36**	**5.00**	**4.50**	**4.33**	**4.32**
	Viral diseases2	**4.21**	**4.27**	**5.00**	**4.50**	**4.28**	**4.28**
	Water quality and diseases	**4.46**	4.00	**5.00**	**5.00**	**4.34**	**4.35**
	nutritional diseases	3.96	3.27	**4.50**	3.50	3.64	3.68
	non-infectious diseases other than nutritional	3.67	2.91	**4.50**	3.00	3.33	3.37
	Welfare/stress and disease3	4.08	3.91	**5.00**	**4.50**	4.07	4.08
	Early warning indicators for disease onset	**4.50**	**4.36**	**4.50**	4.00	**4.31**	**4.35**
	Biosecurity2	**4.38**	**4.45**	**4.50**	**4.50**	**4.36**	**4.38**
Ongrowing (cages)	Bacterial diseases3	4.13	3.91	4.00	4.00	4.08	4.07
	Protozoal diseases3	4.08	3.45	4.00	4.00	3.60	3.70
	Life-cycle of parasites	**4.42**	3.55	**4.50**	4.00	3.90	3.98
	Integrated Pest Management (parasite control)	**4.58**	3.73	**4.50**	**4.50**	**4.30**	**4.31**
	Environment and water quality	4.13	3.27	**4.50**	**4.50**	4.01	3.98
	Climate change and disease	4.08	3.73	**5.00**	**4.50**	4.08	4.07
	Automation (monitoring, IoT, big data)	4.13	3.55	3.00	3.00	3.77	3.79
	Administration of treatments (eg bathing)	**4.25**	3.73	3.50	3.00	3.76	3.83
	Welfare/stress and disease4	**4.21**	3.82	**4.50**	**4.50**	4.05	4.07
	behavioral indicators for disease	**4.46**	3.73	**4.50**	3.50	3.86	3.97
	Early warning indicators for disease onset (other than behaviour)	**4.58**	4.18	4.00	3.50	4.16	**4.23**
	Interactions with feral and wild fish	4.00	3.73	3.50	3.50	3.80	3.82
	Emerging diseases	**4.42**	4.18	4.00	4.00	**4.24**	**4.26**
	Zoonotic diseases	**4.21**	3.55	**4.50**	4.00	3.42	3.61
	Legislation	3.83	3.36	**5.00**	4.00	3.69	3.71

Vaccines	Lack of commercial vaccines	**4.58**	**4.27**	**5.00**	4.00	4.19	**4.28**
	Improvement of available vaccines (multivalent composition, reduction of dose, etc.)	**4.42**	**4.27**	**5.00**	**4.50**	**4.30**	**4.34**
	Regulation/legislation	**4.25**	**4.27**	4.00	4.00	3.87	3.98
	Development of DNA and innovative vaccines	**4.54**	**4.55**	4.00	3.50	**4.28**	**4.34**
	Autogenous vaccines	**4.42**	4.00	**5.00**	**4.50**	4.07	4.15
	Viral vaccines	**4.63**	**4.36**	**5.00**	4.00	**4.42**	**4.46**
	Bacterial vaccines	**4.38**	**4.27**	**5.00**	**4.50**	**4.27**	**4.30**
	Vaccines for parasitic diseases	**4.33**	3.45	**5.00**	4.00	3.84	3.92
	Adjuvants	3.88	3.82	**5.00**	**5.00**	3.84	3.88
	Vaccination automations	3.96	3.55	4.00	**4.50**	3.81	3.83
	Immunostimulants	3.79	3.82	**4.50**	**4.50**	4.01	3.97
Treatments	Antibiotics (novel products, residues, kinetics, etc)	3.92	3.45	4.00	4.00	4.20	4.07
	Antiparasitics	**4.50**	3.64	**4.50**	**4.50**	**4.27**	**4.26**
	Antiviral drugs	4.08	3.36	3.00	4.00	3.80	3.81
	Alternative treatments	**4.42**	3.73	**5.00**	**4.50**	4.15	4.18
	Legislation2	**4.21**	4.00	4.00	**4.50**	3.98	4.03
	Antibiotic/Antimicrobial resistance	**4.25**	3.91	**4.50**	4.00	**4.37**	**4.30**
	Environmental impact of treatments in aquaculture	**4.29**	**4.36**	**5.00**	**4.50**	**4.37**	**4.37**
	Reproductive hormones	3.46	3.27	**4.50**	4.00	3.10	3.22
	disinfectants	3.83	3.64	4.00	4.00	3.73	3.75
Diagnostics	Standardization at diagnostic labs	**4.25**	3.82	**4.50**	**4.50**	4.20	4.18
	Molecular diagnostics	**4.21**	4.09	**4.50**	**4.50**	4.10	4.14
	Rapid tests	**4.58**	**4.45**	**5.00**	**4.50**	**4.45**	**4.49**
	Epidemiology using NGS	**4.38**	4.09	**4.50**	**5.00**	3.81	3.98
	Serological tests	4.00	3.64	**5.00**	**4.50**	3.76	3.82

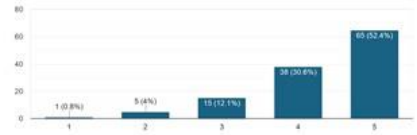
	Non-lethal, non-invasive tests	**4.46**	**4.27**	**5.00**	4.00	**4.40**	**4.40**
	Biosensors	**4.38**	3.82	**4.50**	4.00	4.08	4.12
	Development of fish cell lines	**4.42**	3.91	**4.50**	4.00	3.83	3.96
	Development of operational welfare indicators	**4.46**	4.18	**4.50**	**4.50**	4.01	4.13

ANNEX 2. Responses in the questionnaire

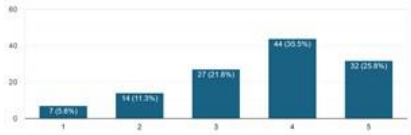
This document contains the responses to the online survey. The responses follow the organization of the survey and are presented as frequency bar charts. These results were the basis of the analysis presented in the final report as well the basis for the discussion between the experts of the meeting group which was held in Brussels.

Hatchery level: Rate from 1-5 (1 lowest importance, 5 highest importance) the urgency for filling research gaps in the following areas of fish health management and disease prevention at the hatchery level.

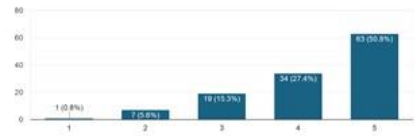
Biosecurity
124 responses



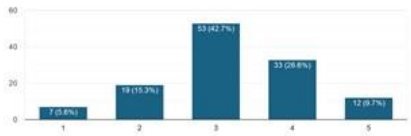
Live Feeds (as disease vectors)
124 responses



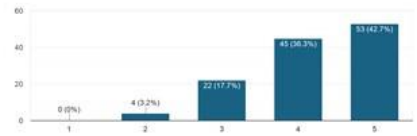
Alternatives for bacterial control (probiotics, phage therapy etc)
124 responses



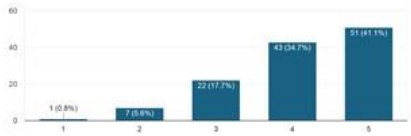
Deformities
124 responses



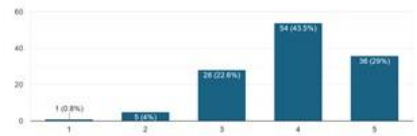
Juvenile quality (disease resistance)
124 responses



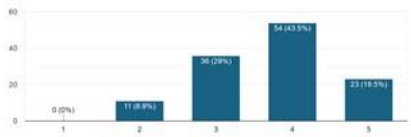
Nutrition for health
124 responses



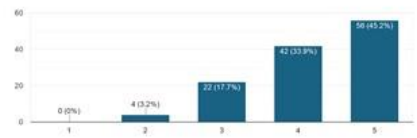
Gut health
124 responses



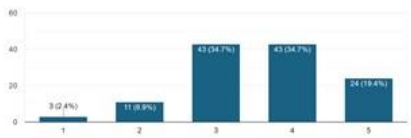
microbiome at hatchery
124 responses



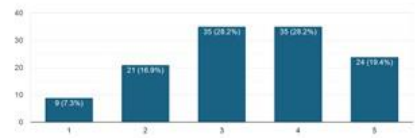
Welfare/stress and disease
124 responses



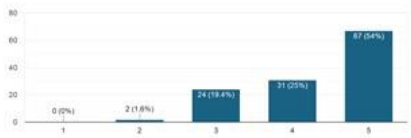
Protozoal diseases
124 responses



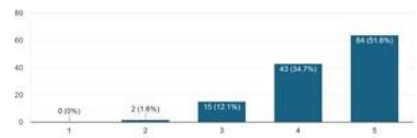
Diseases caused by metazoan parasites
124 responses



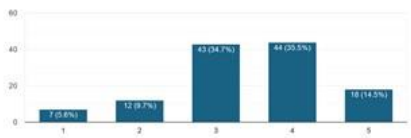
Viral diseases
124 responses

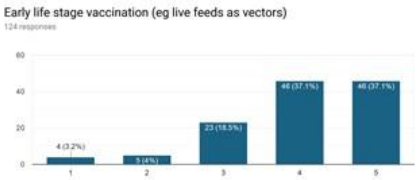


Bacterial diseases
124 responses



Transportation of juveniles
124 responses



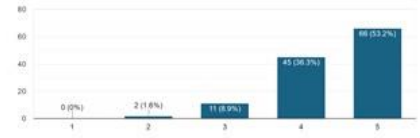


Other (free text)

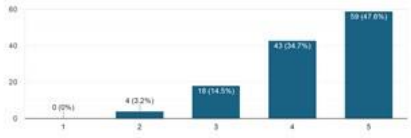
- Brood stock feeding and health management
- Evolutinary change of parasites and diseases
- Egg disinfection, disease free broodstock
- Holistic approach to fish health is required, with infectious and non-infectious elements, stress, biosecurity and welfare all vital for optimal health.
- veterinary treatments
- microbial stability - good balance K/r strategists to prevent Vibrios to express virulence through quorum sensing
- development of tools for early diagnostics
- Zootechnical aspects like tank colour, density, ...
- Virulence factors and mechanisms
- Immune system
- Research on fungus (Saprolegnia sp. etc.) and bacterial and viral diseases coexistence and their prevention in fish farm conditions.

Broodstock: Rate from 1-5 (1 lowest importance, 5 highest importance) the urgency for filling research gaps in the following areas of fish health management and disease prevention for broodstock.

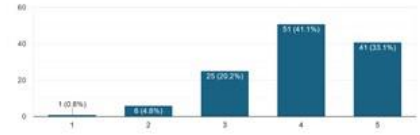
Disease monitoring



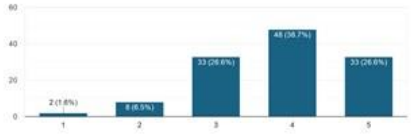
Genetic selection for disease resistance



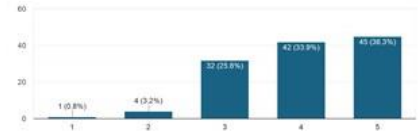
Vaccination of the broodstock



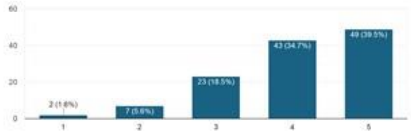
Functional feeds for health



Egg/quality and disinfection



welfare/stress and disease

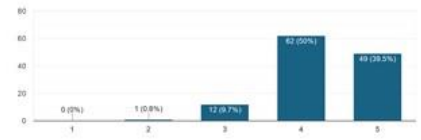


Other (free text)

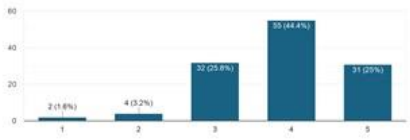
- Biosecurity
- Networking in the particular region
- New treatment methods for the infected fishes

On-growing (Land-based/RAS): Rate from 1-5 (1 lowest importance, 5 highest importance) the urgency for filling research gaps in the following areas of fish health management and disease prevention for on-growing in land-based or RAS facilities

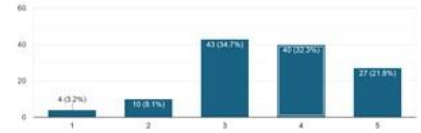
Bacterial control



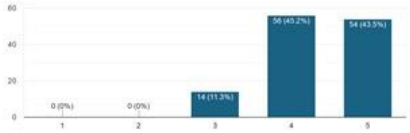
Protozoal diseases



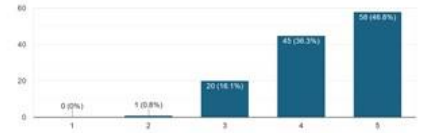
metazoa prasites



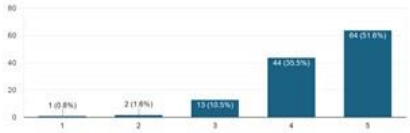
Bacterial diseases



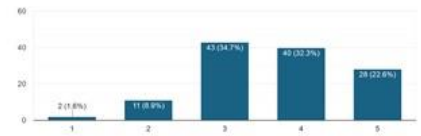
Viral diseases



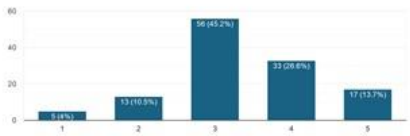
Water quality and diseases



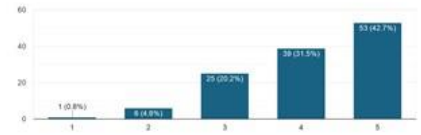
nutritional diseases



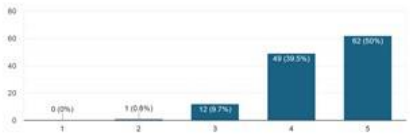
non-infectious diseases other than nutritional



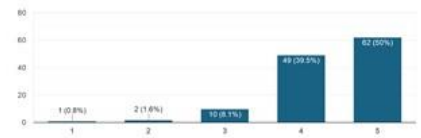
Welfare/stress and disease



Early warning indicators for disease onset



Biosecurity

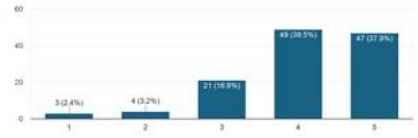


Other (free text)

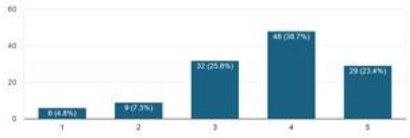
- Environmental sources of infectious agents and their effects
- veterinary treatments

On-growing (cage aquaculture): Rate from 1-5 (1 lowest importance, 5 highest importance) the urgency for filling research gaps in the following areas of fish health management and disease prevention for on-growing (cage aquaculture)

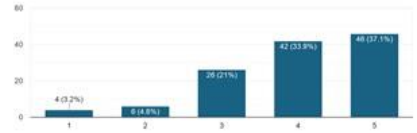
Bacterial diseases



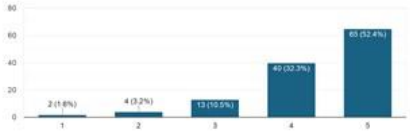
Protozoal diseases



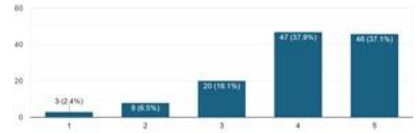
Life-cycle of parasites



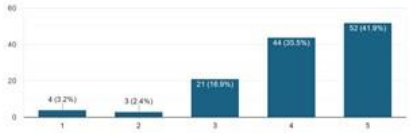
Integrated Pest Management (parasite control)



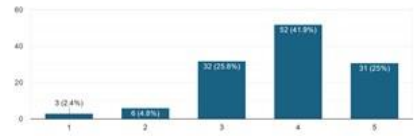
Environment and water quality



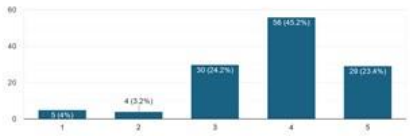
Climate change and disease



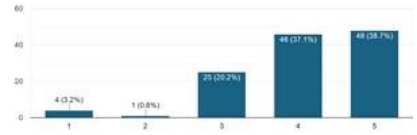
Automation (monitoring, IoT, big data)



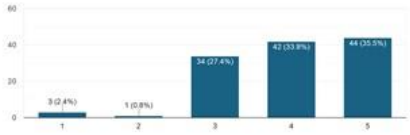
Administration of treatments (eg bathing)



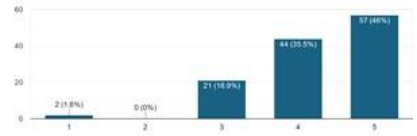
Welfare/stress and disease



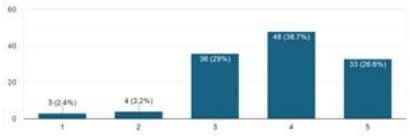
behavioral indicators for disease

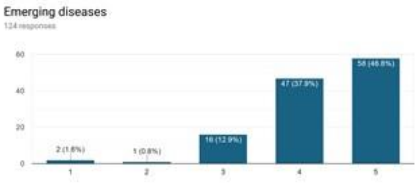


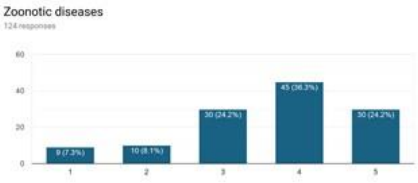
Early warning indicators for disease onset (other than behaviour)

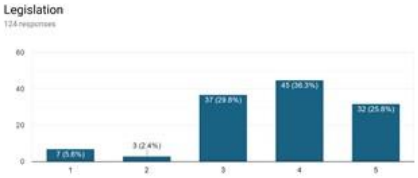


Interactions with feral and wild fish







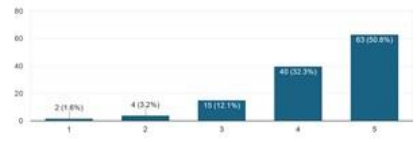


Other (free text)

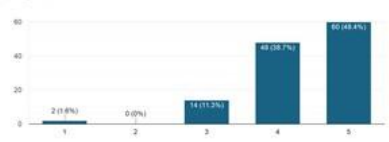
- viral diseases: high importance
- The cage based systems and environment need to be looked at as an ecosystem in its entirety. Is an urgent need for a holistic approach, ideally bringing together scientists and aquaculture experts for ambitious and wide ranging investigations. We often don't know the reservoirs, especially of emerging disease agents.
- Professional Aquaculture and Fisheries Education at a Professional universal Basic Degree.: At present Aquaculture disease management has been handed over to Veterinarians- it is a Big Professional Mistake. We need Professional Aquaculture and Fisheries Sciences Graduates taking control of Fish Health and welfare issues. Veterinary Graduates can't serve the Aquaculture and Fisheries sector as an additional side Job . Professional Aquaculture education is missing in Europe and it must take priority. We need professional Graduates on par with Agriculture and veterinary sciences.
- Viral diseases
- Not concerned
- Viral diseases - Metazoan infections
- virus and metazoan infections

Vaccine development: Rate from 1-5 (1 lowest importance, 5 highest importance) the urgency for filling research gaps in the following areas of vaccine development for aquaculture

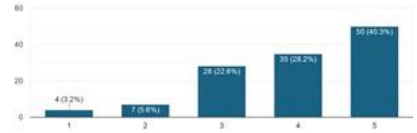
Lack of commercial vaccines



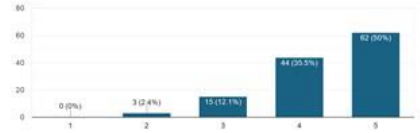
Improvement of available vaccines (multivalent composition, reduction of dose, etc.)



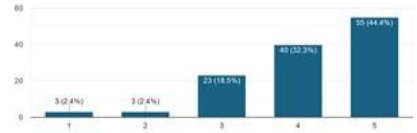
Regulation/legislation



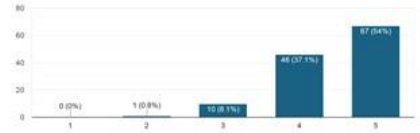
Development of DNA and innovative vaccines



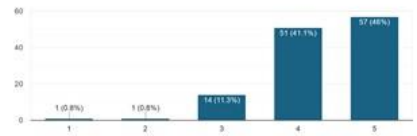
Autogenous vaccines



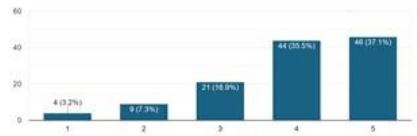
Viral vaccines



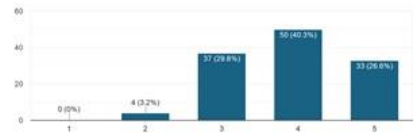
Bacterial vaccines



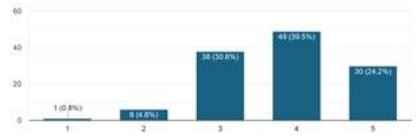
Vaccines for parasitic diseases

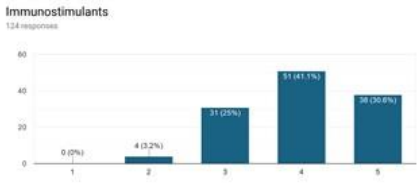


Adjuvants



Vaccination automations

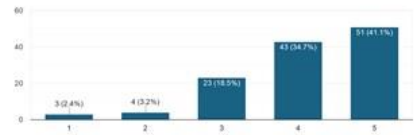




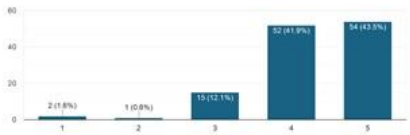
Other (free text)

Treatments: Rate from 1-5 (1 lowest importance, 5 highest importance) the urgency for filling research gaps in the following areas of treatments in aquaculture

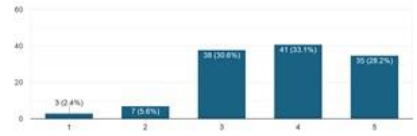
Antibiotics (novel products, residues, kinetics, etc)
124 responses



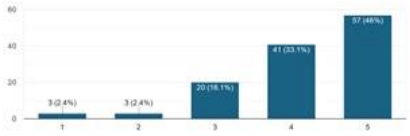
Antiparasitics
124 responses



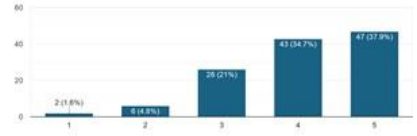
Antiviral drugs
124 responses



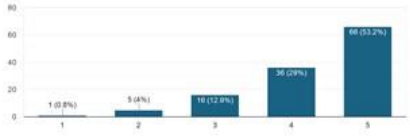
Alternative treatments
124 responses



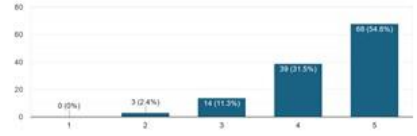
Legislation
124 responses



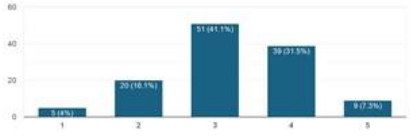
Antibiotic/Antimicrobial resistance
124 responses



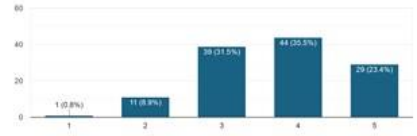
Environmental impact of treatments in aquaculture
124 responses



Reproductive hormones
124 responses



disinfectants
124 responses

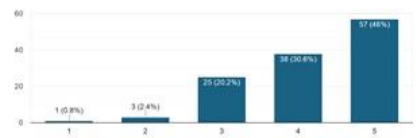


Other (free text)

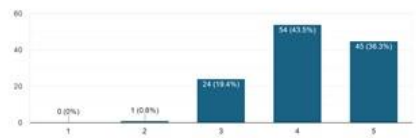
- Aquatic animal Legislation is wrong Hands Veterinarians , this must change. We have a small number of 3-4 antibiotics to use in Sea bass sea bream aquaculture, The question of Antibiotic resistance is irrelevant in our case.
- Pre- and probiotics and other biological active compounds

Diagnostics: Rate from 1-5 (1 lowest importance, 5 highest importance) the urgency for filling research gaps in the following areas of diagnostics in aquaculture

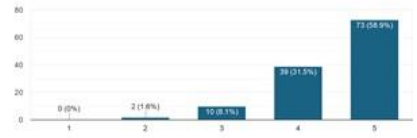
Standardization at diagnostic labs



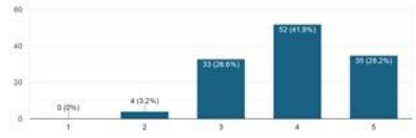
Molecular diagnostics



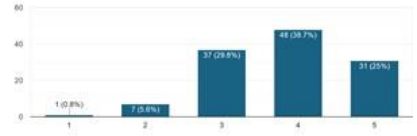
Rapid tests



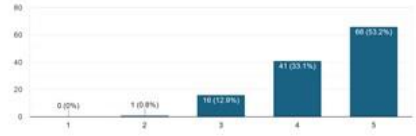
Epidemiology using NGS



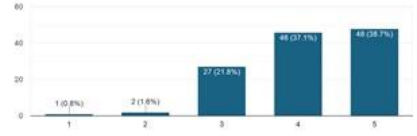
Serological tests



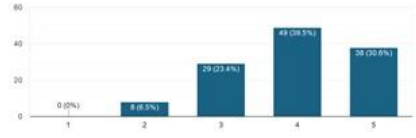
Non-lethal, non-invasive tests



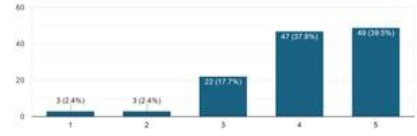
Biosensors



Development of fish cell lines



Development of operational welfare indicators



Other (free text)