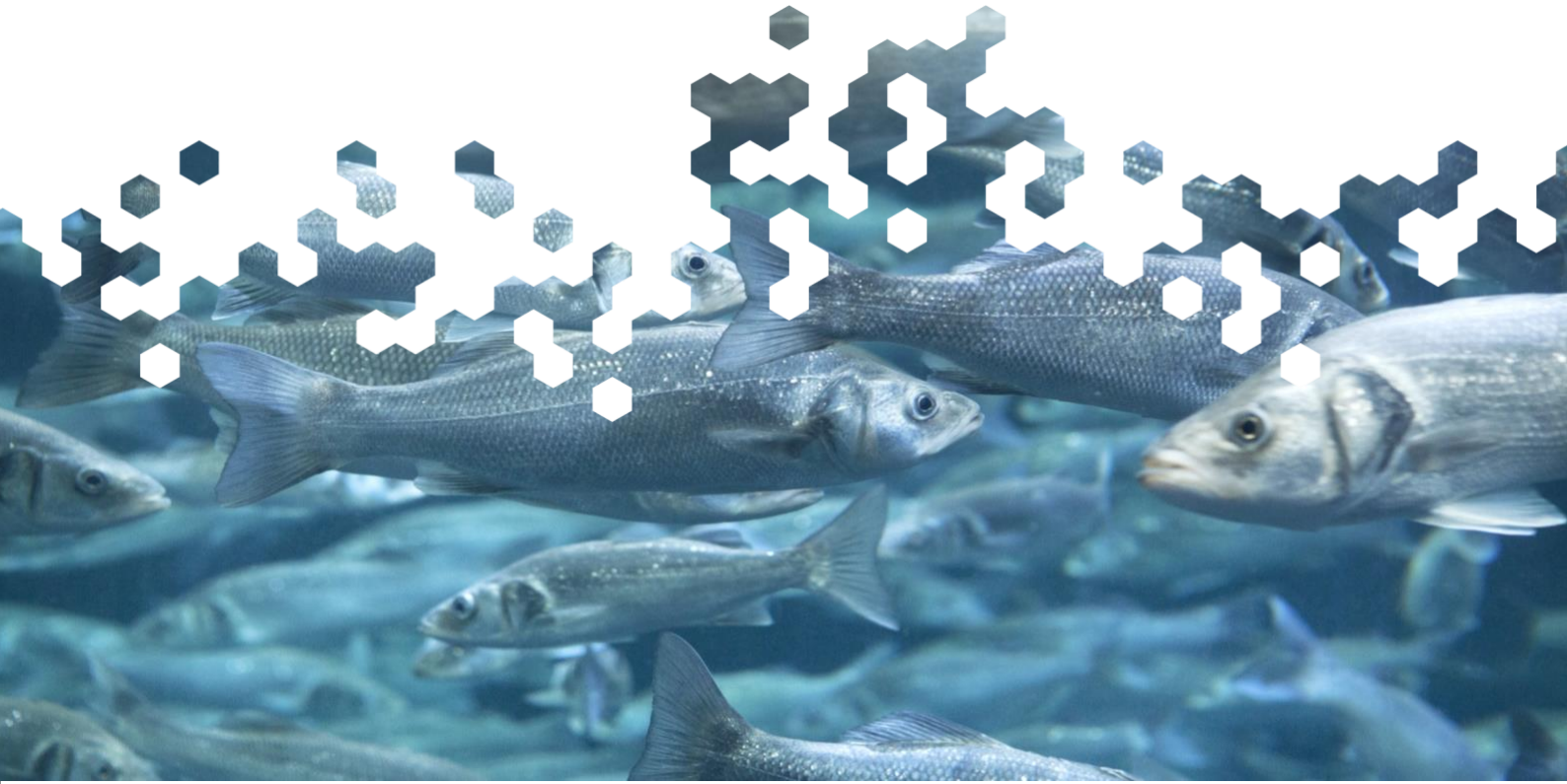
Aquaculture Health Research Survey

March 2025

Report of the pre-workshop global consultation on aquaculture research priorities: Finfish Section



World Organisation for Animal Health

www.woah.org
www.star-idaz.net

STAR IDAZ International Research Consortium on Animal Health

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Introduction

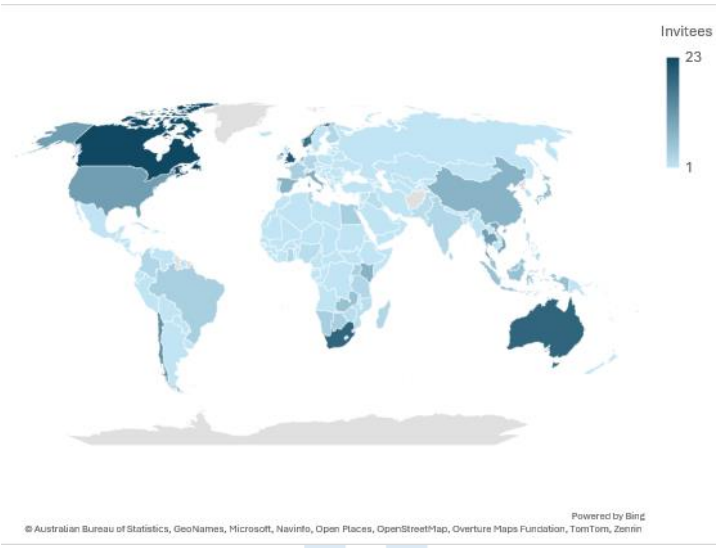
Aquatic animal production is rapidly evolving, yet a significant amount remains unknown about aquatic animal diseases. Research is key to advancing knowledge and will benefit progress in aquatic animal health prevention and control.

This Global Consultation to Identify Research Priorities for Aquatic Animal Health is part of a set of key initiatives aligned with Activity 4.5 of the WOAH Aquatic Animal Health Strategy. The Aquaculture Health and Research Survey, developed collaboratively by the World Organisation for Animal Health (WOAH) and the STAR-IDAZ International Research Consortium on Animal Health, allowed global experts to highlight the critical research needs in the field, and this report will outline the results of the survey.

In addition, the results of the finfish section of this survey informed discussions among selected international experts during the workshop held on 20–21 February 2025 at WOAH Headquarters in Paris, focusing on the identification of the highest priority research areas for finfish health. A report of the workshop is available for consultation on both the WOAH and STAR IDAZ websites.

Survey structure and invitations

The online survey, developed with the support of an ad-hoc Scientific Committee, was organised into short introductory and concluding sections, along with four main sections of approximately 20 questions each, focused on the following four categories: Finfish; Molluscs; Crustaceans; Amphibians. The full structure of the survey is shown in Appendix.



Invitations were sent out 10th of January 2025 to 393 experts, including all WOAH Reference and Collaborating centres working on Aquaculture, all WOAH National Contact Points (NCPs) for aquaculture and a series of experts suggested by the workshop Scientific Committee and Aquatic Animal Health Commission Members. There was a good balance of invited experts among the four regions: Americas; Africa & Middle East; Asia & Pacific; and Europe. Additionally, some NCPs and Aquaculture network leaders requested to further disseminate the survey to additional key experts within their network, thus the survey was sent to a total of 440 people in 187 countries as per the Figure.

Global aquaculture survey

440 invitations distributed globally

187 countries engaged

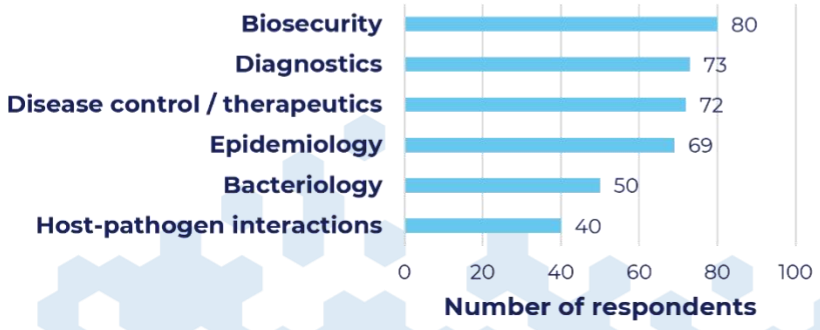
184 responses received from **89** countries

43% overall response rate

51 m 21 s average completion time

The survey had **global reach** with responses received from experts across the Americas, Europe, Africa & the Middle East, and Asia & Australasia

Respondents identified that they had **diverse expertise** across a range of topics relevant to aquaculture



Other areas of expertise cited include:

- Virology
- Vaccine development
- Welfare
- Parasitology
- Immunology

Methods for survey analysis

Responses were downloaded from SurveyMonkey and anonymised before data cleaning and analysis. Quantitative and qualitative analysis were both used depending on type of responses, with Excel used as tool for analysis. For qualitative analysis a thematic analysis was utilized. Initially, survey responses were collected and organized alphabetically in priority columns. Each response was grouped into themes, and a "Themes" and "Score" column was added for each priority. Similar responses were consolidated under common themes, and trends were identified. Priorities were scored based on expert attributed importance: e.g. 5 for Priority 1, 4 for Priority 2, and 3 for Priority 3. Using Pivot Tables, we counted the total score of themes and listed themes alphabetically. Themes were then ranked by total score, and the research needs of the top themes were analyzed further and finally all the research priorities identified were summarized using the support of AI tools. Additionally, all the responses for finfish were presented and further discussed in a dedicated workshop held in Paris, 20-21 Feb 2025[1].

Survey analysis

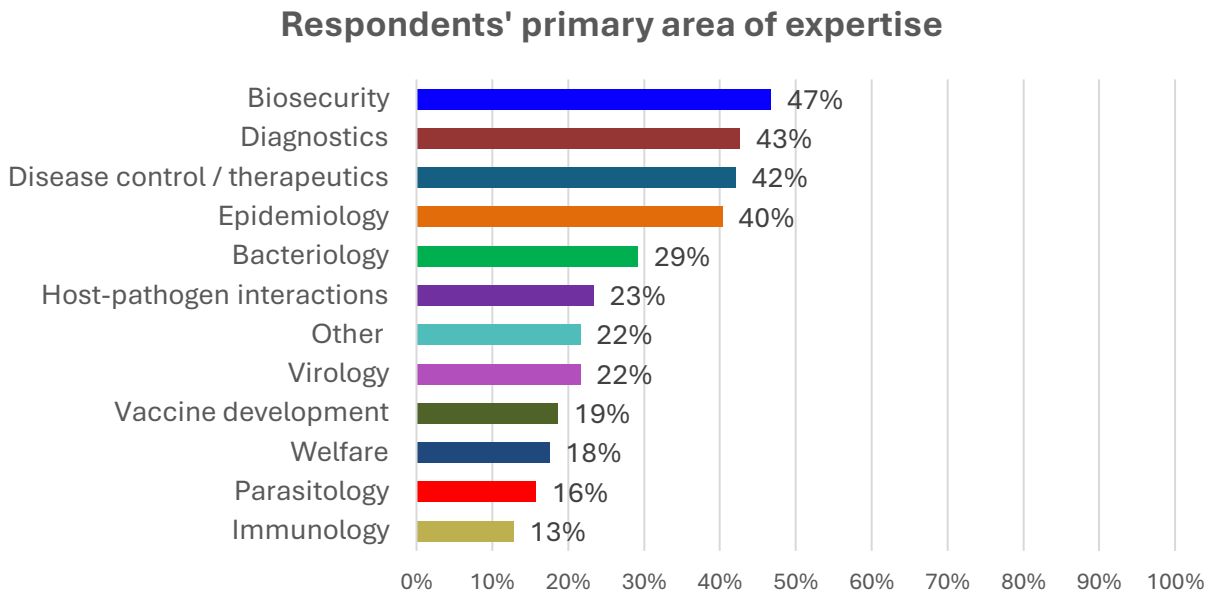
The survey received a response rate of 43% (n responses=184) over a period of 3 weeks (31 January survey closed). The overall completion rate was 63% and the average time spent on the survey was 51 min and 21 seconds. For each question, analysis of the responses is reported below.

[1] Advancing Aquaculture Health Research: A Collaborative Workshop, WOAH HQ, Paris, 20-21 February 2021. https://www.woah.org/en/event/advancing-aquaculture-health-research-a-collaborative-workshop/

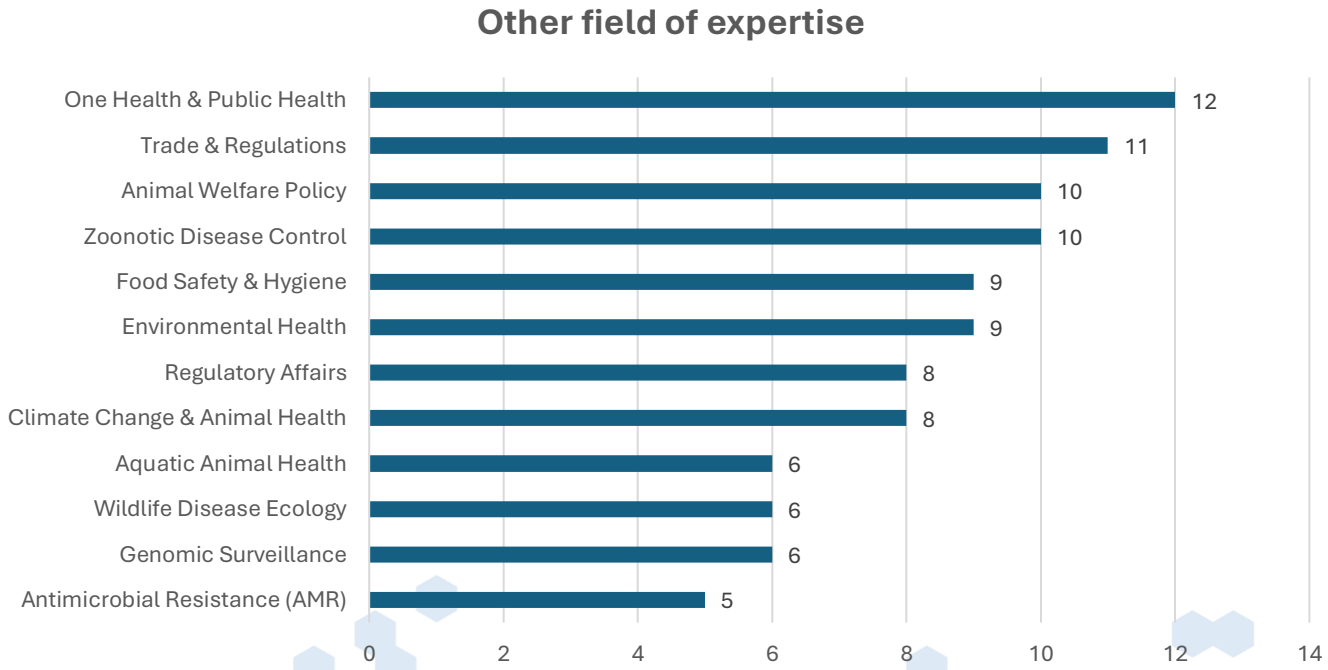
Experts background information

Q2: What is your primary area of expertise? (Multiple answers are possible)

Answered: 171 Skipped: 13

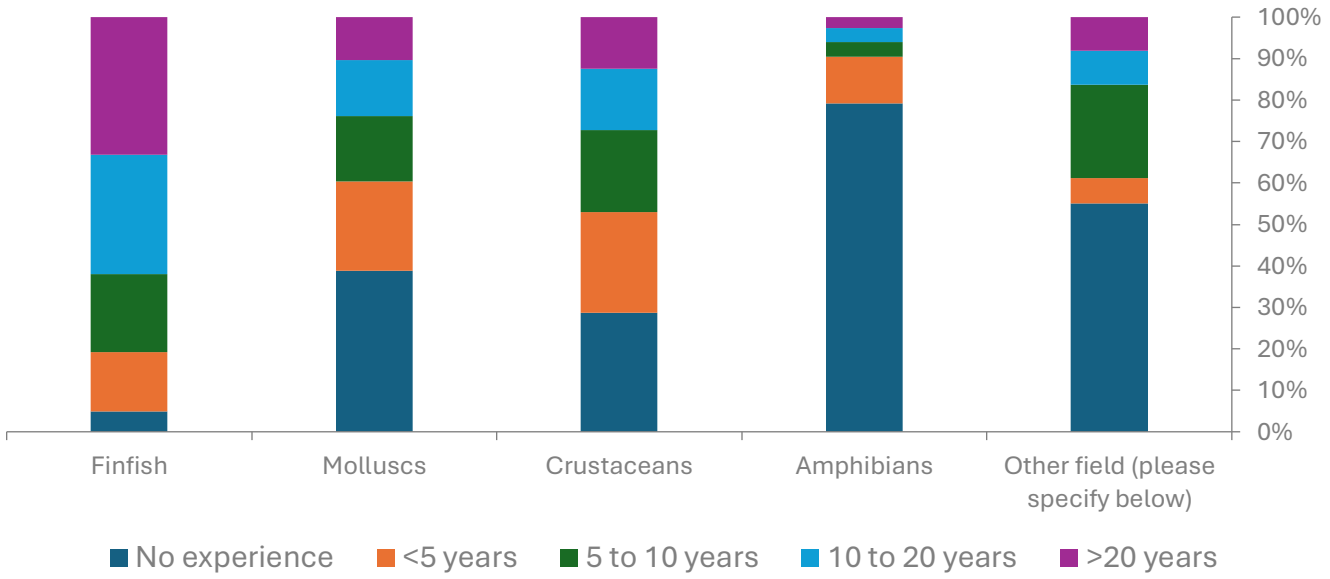


The "Other" responses (22%) reveal other areas of specialization within aquatic animal health. Key trends included:



Q3: Please specify number of years of expertise for each of the following sectors:

Answered: 171 Skipped: 13



Key insights on "Other" sectors (facultative response, n=49 responses):

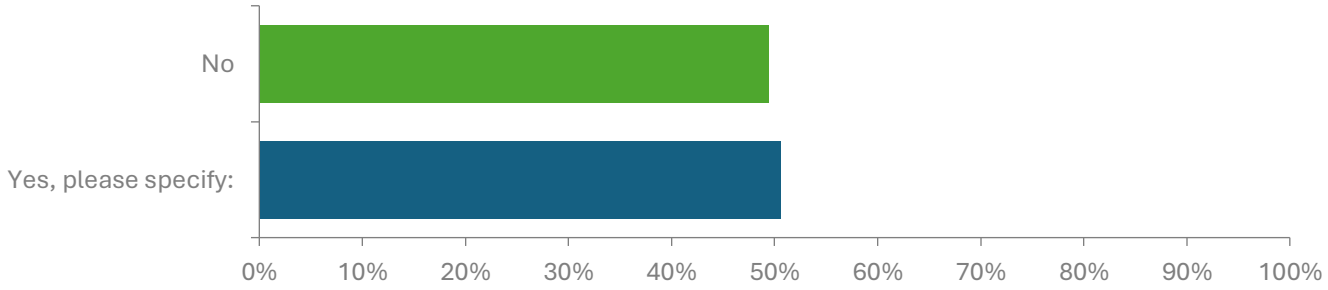
- **Aquatic Health:** Fish, aquaculture, marine mammals, environmental interactions
- **One Health & Microbial Health:** One Health, AMR, eDNA, microbiomes
- **Additional Livestock Sectors:** Crocodiles, swine, poultry, insects
- **Biotech & Chemistry:** Vaccine development, medical biochemistry
- **Quality & Accreditation:** ISO17025, WOAH policy-level experience.

Q4: Countries of respondents:

Responses were received from 89 different countries showed in the map below:

Q5: Are you currently part of any research network focused on aquatic animal health?

Answered: 170 Skipped: 14

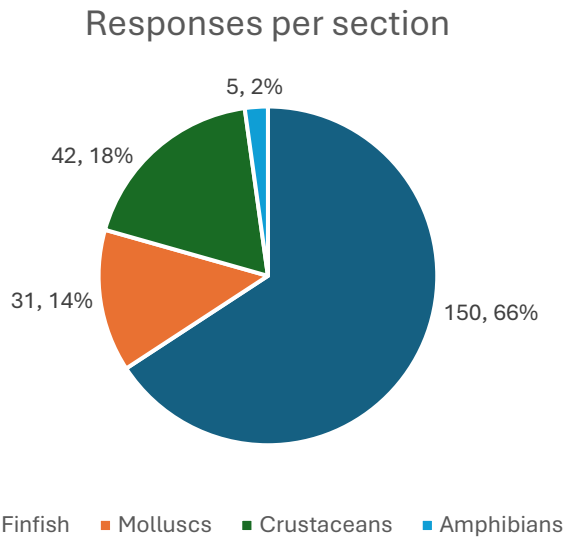


List of participants' networks:

Several respondents indicated their involvement in **national and international research networks** related to aquatic animal health. The responses include **academic institutions, governmental organizations, industry collaborations, and specialized research groups**.

Category	Organizations & Networks
International organizations, global networks & policy-driven research initiatives	WOAH (World Organisation for Animal Health) - Collaborating Centres & Reference Laboratories, FAO (Food and Agriculture Organization), NACA (Network of Aquaculture Centres in Asia-Pacific), GFCM (General Fisheries Commission for the Mediterranean), IDRC (International Development Research Centre), AU-IBAR (African Union Inter-African Bureau for Animal Resources), Pan-Atlantic Health, Defra (UK Government AAH programmes & consortia), Sanipes (Peru), Fisheries Development Board, Southern Africa Regional Aquatic Animal Health Network
Research & collaboration networks	Research Networks & Consortia: EUPAHW (European Partnership on Animal Health and Welfare), EURCAW-Aqua (European Reference Centre for Animal Welfare in Aquaculture), DECIDE EU Project, COST Action BioAqua, Horizon Project Cure4Aqua, Interreg & COST projects, BactiVac, International Veterinary Vaccinology Network (IVVN), Center for Antimicrobial Stewardship in Aquaculture, AquaEpi, Nautilus Collaboration. Thematic Research Areas: Disease Surveillance & Diagnostics (DECIDE EU Project, WOAH Collaborating Centres), Antimicrobial Resistance (AMR) (AMR & residue studies, Antimicrobial Stewardship in Aquaculture), Fish & Shellfish Health Research (Aeromonas surveillance in Tilapia, Tilapia & Catfish disease surveillance), Biosecurity & Vaccine Development (WOAH Reference Labs, Koi Herpesvirus, Cure4Aqua)
Academic & Scientific Societies	University Collaborations: Stirling University, University of Glasgow, University of Pretoria, Tshwane University of Technology, University of Queensland; Scientific Societies: EAFP (European Association of Fish Pathologists), WAVMA (World Aquatic Veterinary Medical Association), Asian Fisheries Society, SIPI (Italian Society of Fish Pathology)

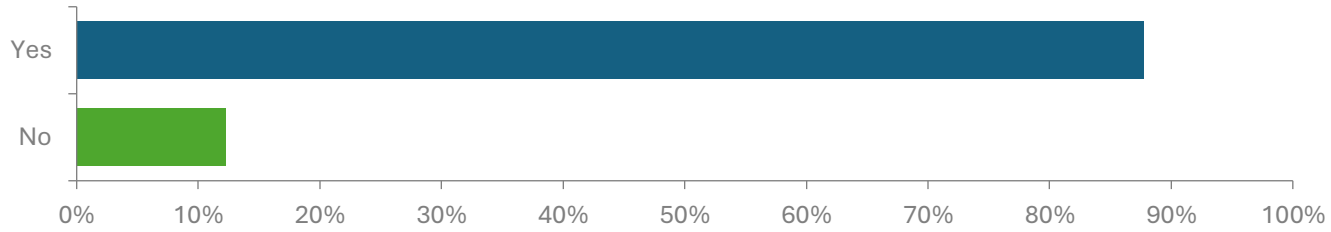
Responses received per section:



The respondent could choose one or more sections to answer, depending on their expertise. The results highlight Finfish as the dominant area of interest of participants, with Crustaceans and Molluscs showing moderate engagement and Amphibians being the section obtaining the fewest responses from participants.

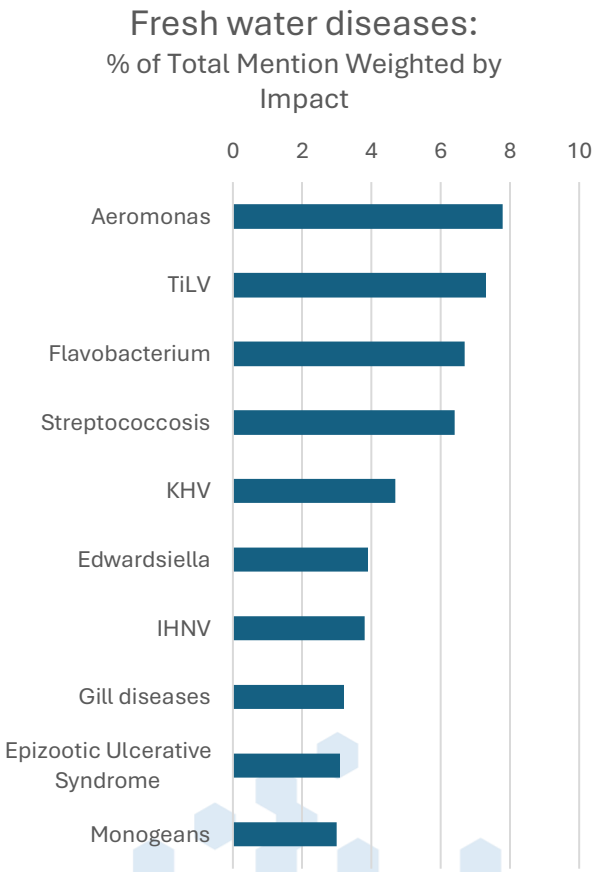
Section: Finfish

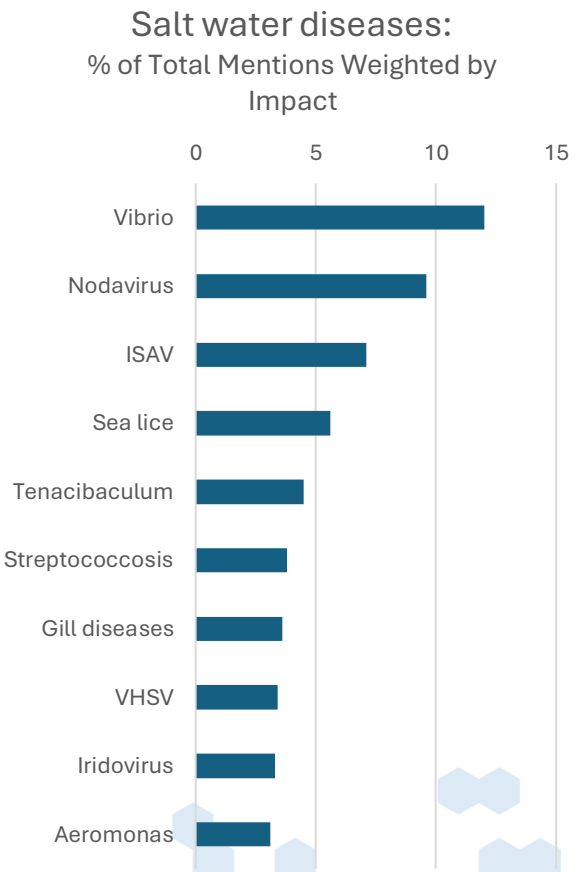
Answered: 171 Skipped: 13



Q7-Q8: Impactful diseases in aquatic health

Participants were asked which they consider the most impactful diseases in their sector for which research actions would be needed. (Diseases were listed in order of importance for up to 10 diseases, with participants only completing the sector in which they have experience: 1 = Most impactful, 10 = Less impactful).





Q9: Highlights and quotes from comments received:

> *"Research actions are needed to better understand these diseases, develop effective management strategies, and enhance the overall health of aquaculture systems."*
>
> *(Anonymized quote from comments)*

- **Disease prioritization challenges**
  - Prioritization should be dynamic and adjusted as economic risks and epidemiological factors evolve
  - Disease rankings should consider mortality, economic loss, welfare impact, and epidemiological risk, which vary by region
  - Disease rankings should be sector-specific (e.g. freshwater vs. saltwater, specific species)
  - Some diseases, such as *Streptococcus* and *Aeromonas*, are opportunistic, and exacerbated by poor conditions
  - Climate change, evolving serotypes, and new trade dynamics may alter disease impact over time
  - Disease priorities vary depending on species, geographic location, and farming intensity
  - There are gaps in both research and capacity building
  - Some low and middle-income countries (LMIC) may have limited research and diagnostic capacity for finfish diseases
  - Research is needed on emerging diseases, effective treatment strategies, and improved management practices
  - Funding, training, and laboratory infrastructure are critical to improving disease monitoring and control.
- **Key disease drivers and underlying factors**
  - The most significant contributors to disease are poor water quality, handling/husbandry issues, and nutritional deficiencies
  - Many microbial diseases are secondary to environmental stressors rather than primary pathogens
  - Emerging pathogens are increasingly relevant and may require regulatory action before being officially listed.
- **Preventative strategies and management needs**
  - Disease management must prioritize biosecurity, vaccination, and improved water quality
  - Some vaccine strategies are ineffective because of farming conditions that make fish less responsive.
  - Risk management must account for emerging diseases and infectious agents of unknown origin.
- **Economic and trade considerations**
  - The impact of diseases varies by region, species, and economic conditions
  - Some diseases, though not currently present, pose a risk because of live fish trade
  - National laboratories may have a preparedness role for potential disease incursions.

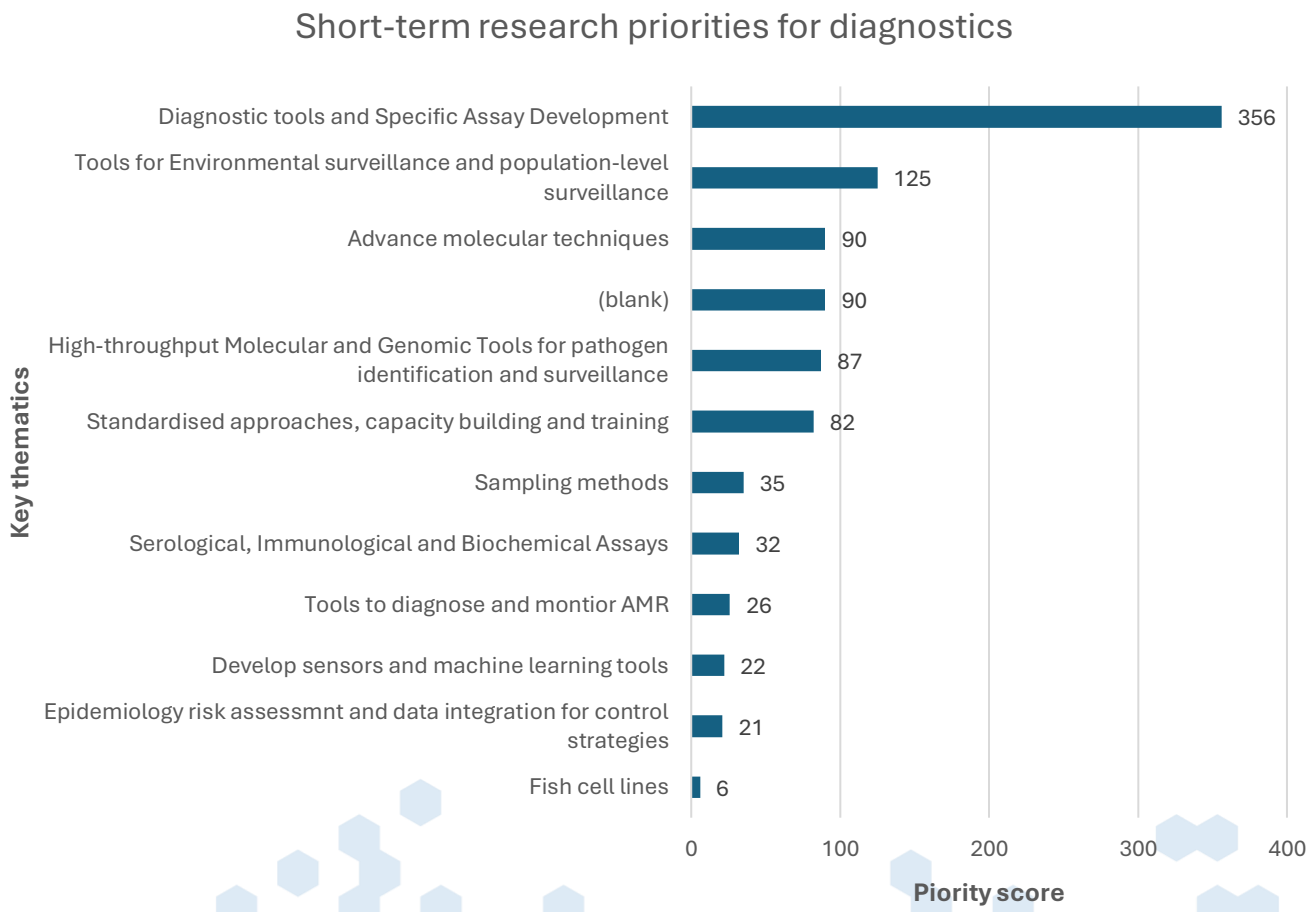
- **Increasing trends and emerging concerns**
  - Opportunistic infections are rising, highlighting the need for better environmental and husbandry practices
  - Some zoonotic diseases have high human health risks, though they occur in low numbers
  - Skeletal deformities, while not infectious, are sometimes mistakenly included in disease lists.

'It is difficult to rank diseases by decreasing order of importance. Some are emerging and might become important with climate changes (e.g. Lactococcus), others are impactful as no treatment are really available or easy to apply (e.g. Seabream sparycotyles). Their impact can be related to different factors such as new emerging serotype/efficient treatment availability.'

(Anonymized quote from comments)

Diagnostic research needs

Q10: What are the short-term (within 5 years) research priorities for diagnostics, including applications to emerging disease detection, and determination of infection at the individual animal and population levels? Please list, in order of importance, up to 3 priorities.



Diagnostics: Summary of short-term research priorities from the top 5 key trends

1. Diagnostic tools and specific assay development (356)

Develop non-invasive methods, timely, reliable, and affordable detection tools
Develop in-pond test/ field-deployable diagnostic tests (e.g. loop-mediated isothermal amplification (LAMP) assays; lateral flow devices (LFDs); multiplex detection systems)
Enhance sensitivity and specificity in pathogen detection
Standardize confirmatory tests to ensure reliability across different aquaculture settings
Research non-invasive/non-lethal diagnostic methods, particularly for high-value broodstock species
Diagnostic tests fit for purpose for control strategies, particularly to support DIVA vaccination strategies
Explore imaging-based and AI-driven diagnostics to improve accuracy and efficiency
Improved diagnostic tools for:

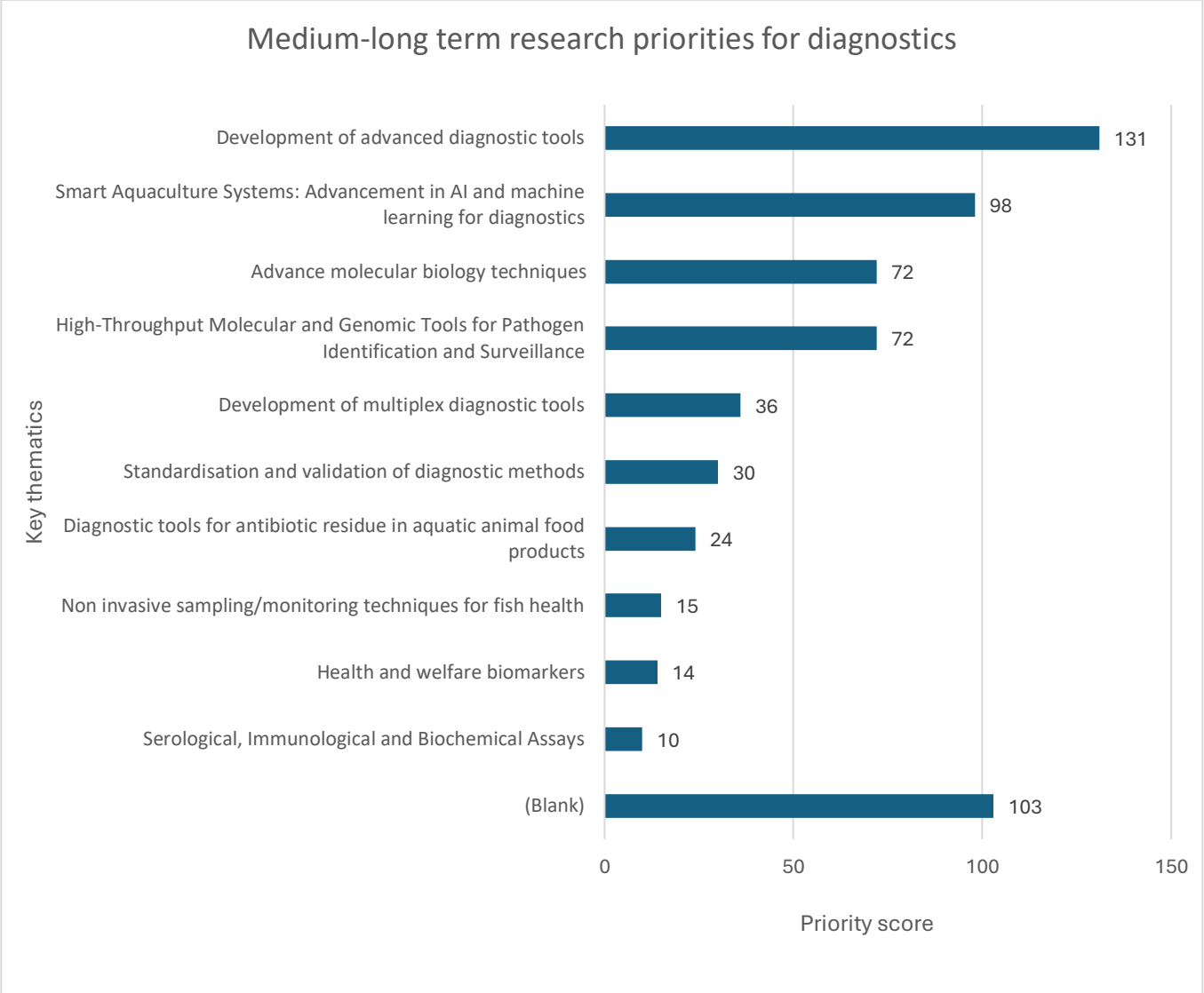
- Detection and isolation of viable pathogens for functional studies
- Development of methods to detect infection at an early stage
- Diagnostics for bacterial infections of fish affecting survival of juvenile fish
- Diagnostics of sturgeon and catfish diseases
- *Francisella noatunensis*
- Histopathology for infectious spleen and kidney necrosis virus (ISKNV)
- Improved isolation methods for *Flavobacterium* and *Tenacibaculum* species
- Infectious pancreatic necrosis in rainbow trout (IPN)
- Iridovirus in red sea bream
- *Klebsiella pneumoniae*
- Megalocytiviruses of fish
- Molecular diagnosis for *Streptococcus agalactiae* 1a and 1b
- Other aeromonads (sequencing needed to determine species today)
- Screening for sea bass disease virus (SDDV) infections in sea bass
- Screening test for viral nervous necrosis (VNN)
- Streptococcosis in tilapia
- Tilapia lake virus (TiLV)

Validation of tests for:

- Validated tests for megalocytivirus (MCV)
- Validated tests for *Saprolegnia parasitica* and other oomycetes
- Validated tests for sea lice (various species)
- Validated tests for tilapia lake virus (TiLV)
- Development and validation of confirmatory tests
- Validation and standardization of NGS platforms, raw data quality control, and bioinformatic pipelines

2. Tools for environmental surveillance and population-level surveillance (125)
Validation of eDNA for surveillance Expand the use of environmental DNA (eDNA) and metagenomics for disease monitoring Develop cost-effective tools for detecting environmental contamination and pathogen spread Implement large-area sampling techniques for early warning systems in aquatic farms Establish real-time surveillance networks to track disease outbreaks and AMR trends Integrate remote sensing and digital diagnostics for large-scale/population level disease monitoring Cost-effective detection of environmental contamination and toxicology for both wild fish and fish in aquaculture Water sampling methods
3. Advanced molecular techniques (90)
Improve polymerase chain rection (PCR)-based methods, including high-throughput and multiplex approaches Collaborative research on genomic identification and characterization of co-occurring viral and bacterial pathogens of fin fishes Enhance molecular tracing and pathogen characterization to identify disease-causing strains Adapted PCR kit for viruses to keep on room temperature Develop and validate next-generation sequencing (NGS) workflows for diagnostics Optimize molecular diagnostics for detecting subclinical infections and emerging diseases
4. High-throughput molecular and genomic tools for pathogen identification and surveillance (90)
Implement whole genome sequencing (WGS) and transcriptomics for pathogen discovery Develop high-throughput screening methods (e.g. mPCR amplicon sequencing by Nanopore; environmental DNA (eDNA), and RNA (eRNA) approaches; WGS and meta-transcriptomics) Integrate bioinformatics pipelines to analyze large-scale genomic and epidemiological data Enhance functional studies by improving the detection and isolation of viable pathogens Establish automated platforms for genomic surveillance and early pathogen detection Sequence pathogens and establish specific and sensitive *in situ* hybridization automated protocols (e.g. FISH/ RNA scope etc.)
5. Standardized approaches, capacity building, and training (87)
Develop standardized diagnostic protocols and validation frameworks for global use Strengthen capacity-building initiatives, particularly in under-resourced regions Train technical personnel in disease recognition, molecular diagnostics, and surveillance methodologies Promote taxonomic training in parasitology and emerging pathogen identification Foster collaborative networks to improve knowledge-sharing and coordinated disease control efforts Development of harmonized case definitions for emerging diseases Improve knowledge and information on diagnostic performance Development of a guide book/apps for in-field fish diagnosis including pathognomonic lesion for each disease, especially emerging diseases

Q11: What are the medium-long term (5-15 years) research priorities for diagnostics, including applications to emerging disease detection, and determination of infection at the individual animal and population levels? Please list in order of importance up to 3 priorities.



Diagnostics: Summary of long-term research priorities from the top 5 key trends
1. Development of new diagnostic methods (131)
Culture methods for unculturable agents and disease models Development of rapid detection and diagnostic kits Early detection systems and on-site testing Validation of rapid detection kits Advancements in laboratory and field diagnostics • Use of MALDI-TOF and other molecular techniques • Immunohistochemistry and molecular diagnostics (e.g., ISKNV detection) • Latency infection detection and differentiation between infection *vs.* disease • Mortality and infection detection at high frequency

Enhancing diagnostic infrastructure

- New service delivery models and diagnostic pathways
- Novel and practical diagnostic tools for farm-level application
- Development of tabletop equipment and mobile testing
- Standardization and validation of lab-on-a-chip and point-of-care testing

Cell-based and immunological approaches

- Development of cell lines for crustaceans, molluscs, and viral disease susceptibility
- *In vivo*, *in vitro*, and *ex vivo* tests for virulence assessment
- Mucus-based immune tests and reagent development for fish

Targeted and disease-specific diagnostics

- Detection methods for emerging diseases and specific pathogens (e.g. *Francisella* spp. in fish)
- Rapid molecular tests for field applications
- Tailored diagnostic strategies considering genetics, microbiomes, and environmental conditions

2. Advancements in artificial intelligence (AI) and machine learning for diagnostics (98)

AI-driven disease surveillance and predictive analytics

- AI-powered image and behavioural analysis
- Machine learning algorithms for pattern recognition
- Integration of IoT devices for real-time monitoring

Smart and automated diagnostic systems

- Advanced biosensors and automated detection tools
- Remote sensing using AI for early infection detection
- Smart aquaculture systems for disease monitoring
- Fully automated and integrated disease monitoring (e.g. smart biosensors, nanotechnology, digital PCR)

AI for early detection and forecasting

- Monitoring animal behaviour as an early disease indicator
- Real-time, high-sensitivity sensors for contaminants and environmental factors
- AI and environmental nucleic acid analysis for early disease forecasting
- AI-driven diagnostic platforms analysing multiple data sources

Automation and digital technologies in diagnostics

- Automation of histological analysis using image processing
- AI-powered histopathology assessment
- E-technology applications (e.g. E-Aquahealth app)
- Blockchain and cloud-based platforms for disease data management

Data-driven AI applications

- Coordinated disease horizon scanning using AI
- Database for fish disease diagnostics powered by AI
- AI-assisted detection of emerging diseases

3. Advancements in Molecular biology techniques (72)

PCR and related molecular diagnostics

- Establish PCR-based protocols for key aquaculture pathogens (e.g. *Vibrio* spp., *Aeromonas* spp., *Mycobacterium*)
- Real-time PCR (qPCR) for population-level pathogen quantification
- PCR combined with rapid sequencing for multi-pathogen detection
- PCR methods for environmental sample analysis
- Adapted PCR kits with consumables stable at room temperature for viral detection

Advanced molecular detection technologies

- Real-time multiplex methods for pathogen identification

- CRISPR-based diagnostic tools for precision detection
- Validation of digital PCR and high-throughput molecular detection methods for regulatory diagnostics

Pathogen typing and genetic analysis

- *Francisella* typing in freshwater and marine fish
- Molecular tracing of Koi herpesvirus (KHV)
- *Edwardsiella* spp. typing (*E. piscicida*, *E. anguillarum*, formerly *E. tarda*)
- Molecular diagnostics for infectious spleen and kidney necrosis virus (ISKNV)

Molecular approaches for disease understanding and prediction

- Research on pathogen-host interactions at the molecular level
- Updates on genetic sequences for improved diagnostics
- Rapid molecular tests for field applications

4. Advance high-throughput disease/pathogen detection and monitoring (72)

High-throughput sequencing and genomic surveillance

- Next-generation sequencing (NGS) for pathogen profiling and genetic diversity monitoring
- WGS for bacterial pathogens (e.g. *Aeromonas hydrophila*)
- High-throughput sequencing for detecting emerging diseases
- Optimization of algorithms for screening viromes and identifying new disease agents

Metagenomics and multi-omics approaches

- Implementation of metagenomics for pathogen detection and disease surveillance
- Metagenomics sequencing and big data analysis for disease modeling
- Multi-omics studies (e.g. metabolomics, proteomics, epigenetics, microbiome research)
- Host-pathogen interaction studies to develop pathogen-resistant strains

Genomics-based diagnostics and early response systems

- Integration of genomic techniques for real-time disease monitoring
- Genomic surveillance of pathogen virulence factors
- Development of genomics-based diagnostics for early disease detection and response

5. Development of multiplex diagnostic tools (36)

Multiplex diagnostic platforms

- Development of diagnostic tools for detecting multiple known and unknown pathogens
- Use of universal primers, biosensors, and adaptive molecular systems
- Multi-pathogen diagnostic panels for simultaneous detection
- Enhancing diagnostic efficiency

Evaluating the effect of sample pooling on test performance

- Advancing host-specific and multi-pathogen diagnostic tools
- Development of multiple antigen screening kits for early detection of emerging diseases

Q12: Highlights and few quotes from comments received:

> *"AI and machine learning will be increasingly utilized to analyze diverse datasets, including genomic information and environmental sensor readings, to forecast disease outbreaks before they manifest. This proactive approach will allow for the implementation of pre-emptive strategies, significantly mitigating the impact of diseases."*
>
> *(Anonymized quote from comments)*

- **Disease surveillance and modelling**

  - **Predictive modelling:** AI and machine learning should be utilised to analyze diverse data, including genomic and environmental data, and predict disease outbreaks
  - **Environmental sampling:** eDNA monitoring should be used to measure pathogen loads in bodies of water and inform strategies that seek to improve the health of aquatic organisms and their environment
  - **Testing facilities:** Establish strategic testing facilities at key entry points (e.g. hatcheries, quarantine stations, and major transport hubs) to support early detection and containment of transboundary aquatic diseases
- **Diagnostic tools**
  - **Data collation:** A world-wide database could be developed to collate information about serious, non-listed fish diseases to support rapid diagnostic test development and containment in case of emerging diseases
  - **Improving capacity:** Systematic improvements to diagnostic capacity is required at all levels. Tools should be tailored for different stakeholders and integration of new diagnostic techniques with traditional microbiology and histopathology will be essential
  - **Whole animal approach:** Improve diagnostics by considering the entire animal, rather than compartmentalizing abnormalities
  - **Pre-clinical diagnosis:** Analysis of blood and/or metabolic function could be used to detect disease prior to clinical expression.
- **Diagnostic test standardization and validation**
  - **Cross-facility standardization:** Diagnostic tests, research methodologies and pathogen categories must be standardized across different facilities, institutes and countries
  - **References materials:** The diversity of reference materials available increases the diagnostic margin of error. Improved data management and sharing would mitigate this
  - **Validation:** Diagnostic tools, including non-targeted approaches and bioinformatic analyses, must be validated. Access to positive control and reagents will be essential
- **Strategic collaboration and capacity building**
  - **Cross-border collaboration:** Diverse stakeholders, including government, industry, and research institutions must collaborate to build capacity, train personnel, and secure sustainable funding to ensure long-term effectiveness and accessibility of diagnostic infrastructure
  - **Harmonized policies:** Policy and regulatory frameworks should be standardized across different regions to facilitate data sharing, standardization of diagnostic methods, and development of coordinated response strategies
  - **Systems-thinking:** Systems-thinking approaches are required to address the complex environmental factors, including water quality, poor diet, and contaminant exposure, that appear to be driving increased rates of infection from commensal organisms through altered host resilience

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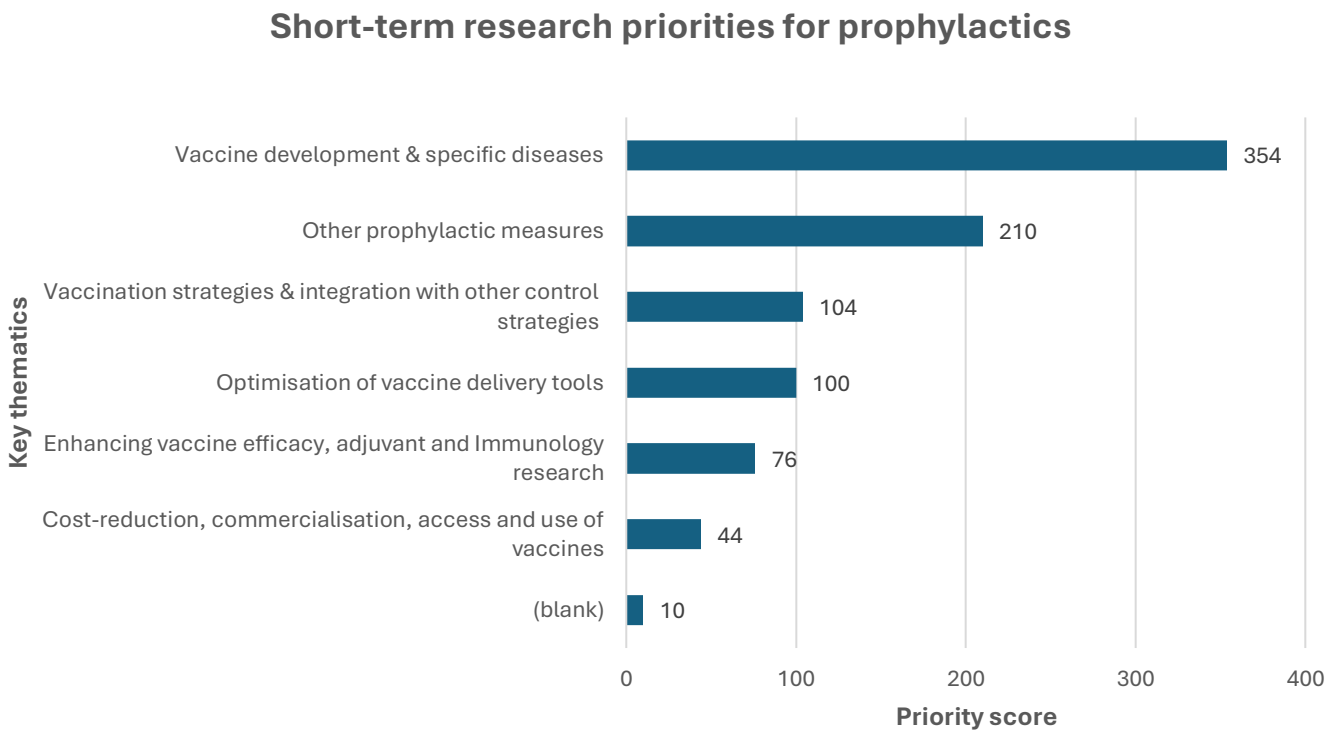
"…harmonized policies and regulatory frameworks across regions are necessary to facilitate data-sharing, standardization of diagnostic methods, and coordinated response strategies"

(Anonymized quote from comments)

Prophylactics including vaccines

*Q13: What are the short-term (within 5 years) research priorities for development and optimal use of **prophylactics including vaccines**?*



Prophylactics : Summary of identified short term research priorities from the top 5 key trends

1. Vaccine development and specific diseases (354)

Multivalent vaccines: Focus on cross-protection and multivalent vaccines for broader pathogen coverage
Autogenous vaccines: Develop low-cost, species-specific, and strain-specific vaccines, especially LMIC
Emerging diseases: Create vaccines for high-impact and emerging diseases like nervous necrosis virus (NNV), *Photobacterium damselae*, and *Aeromonas hydrophila*
Vaccine efficacy: Improve efficacy for existing vaccines like koi herpes virus, bacterial kidney disease (BKD), infectious salmon anaemia virus (ISAV), and *Lactococcus*.

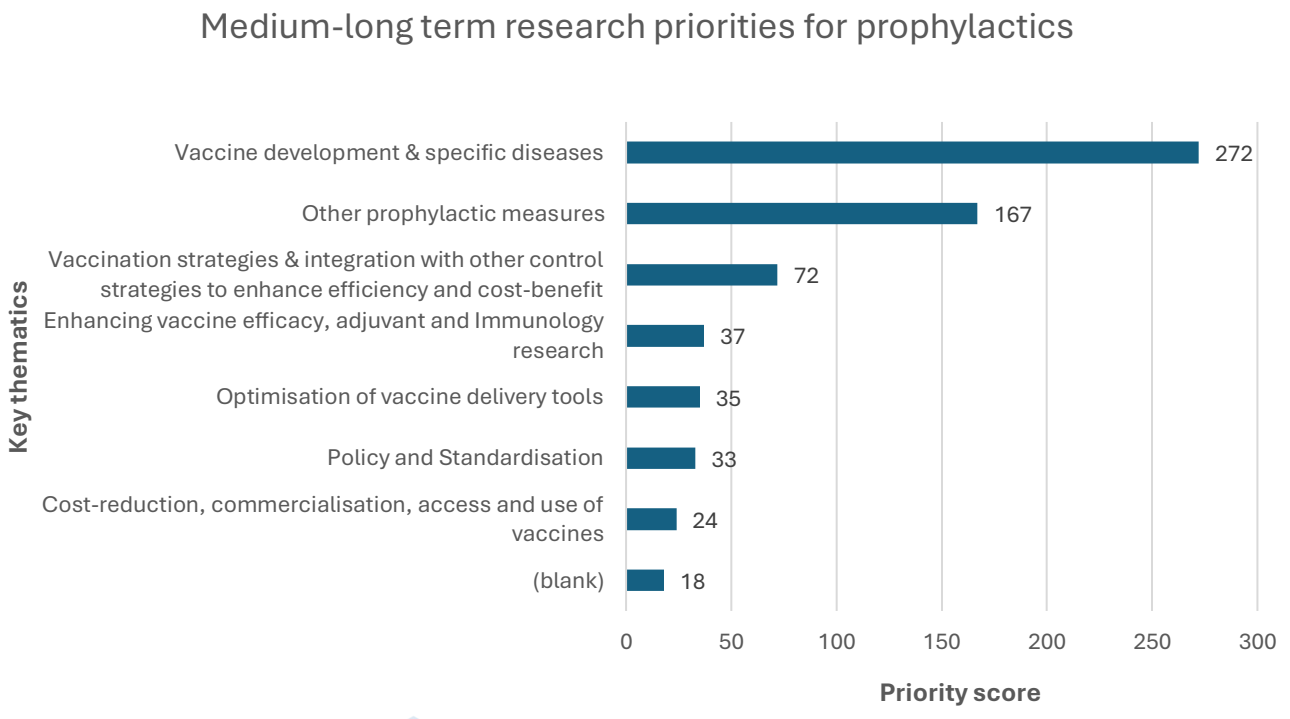
- Develop new vaccines for prevention of specific diseases:
  - *Aeromonas hydrophila*
  - *Aeromonas* infections
  - *Edwardsiella ictaluri*
  - Epizootic haematopoietic necrosis virus (EHN)
  - *Flavobacterium* spp.
  - Infectious haematopoietic necrosis virus (IHNV)
  - Infectious spleen and kidney necrosis virus (ISKNV)
  - Koi herpes virus (KHV)
  - Megalocytiviruses of fish
  - Nervous necrosis virus (NNV)
  - *Photobacterium damselae*
  - Rainbow trout fry syndrome (RTFS)
  - Renibacteriosis
  - Rickettsia-like organisms (RLOs) including *Piscirickettsia salmonis*
  - Sea lice (Arthropods)
  - Streptococcosis
  - *Streptococcus agalactiae*
  - *Tenacibaculum maritimum*
  - Tilapia lake virus (TiLV)
  - Vibrio species pathogens
  - Viral haemorrhagic septicaemia virus (VHSV)
  - Whirling disease

2. Other prophylactic measures (210)

Standardization and use of indigenous and environmental friendly treatment
Alternatives to Antimicrobials: Explore alternatives like probiotics, immunostimulants, and phytochemicals to reduce antimicrobial use
Biosecurity: Develop guidelines for different types of farms
Develop bioactive compounds to enhance farm biosecurity and water quality
Probiotics and prebiotics: Improve the effectiveness and administration of probiotics and prebiotics
Genetic improvements for fish resilience
Study for environment optimization and animal welfare to prevent disease outbreaks

1. Vaccination strategies and integration with other control strategies (104)
Cost-efficiency: Analyze the cost-efficiency of vaccination programmes and integrate them with biosecurity measures Training and capacity building: Train professionals in vaccine development and disease management Policy and regulation: Develop policies to support biosecure research and development while protecting stakeholder interests
2. Optimization of vaccine delivery tools (100)
Delivery systems: Enhance vaccine delivery methods, including oral, immersion, and automated injection systems Mass vaccination: Develop technologies for mass vaccination in various fish species
3. Enhancing vaccine efficacy, adjuvant, and immunology research (76)
Adjuvants: Research to develop safe, efficient, and organic adjuvants Immune responses: Better understand immune responses in aquatic species to optimize vaccine efficacy
4. Cost-reduction, commercialization, access, and use of vaccines (44)
Availability: Increase the availability and accessibility of vaccines, especially in LMIC Regulatory hurdles: Reduce regulatory barriers to expedite vaccine development and commercialization Social studies to implement trust and use of vaccines by farmers

*Q14: What are the medium-long term (5-15 years) research priorities for development and optimal use of **prophylactics including vaccines**?*



Prophylactics: Summary of identified long-term research priorities from the top 5 key trends

1. Vaccine development and specific diseases (Score: 272)

Development of multivalent vaccines
Development of universal and cross-species vaccines
Development of next-generation vaccines with broad-spectrum protection

- Innovative approaches:
  - AI for antigen prediction
  - Genomics-driven and precision vaccine design
  - Nanotechnology in vaccine delivery
  - Molecular and recombinant vaccines
- Vaccines for specific pathogens like:
  - *Aeromonas hydrophila*
  - Edwardsiellosis
  - Fish parasites (general)
  - Koi herpesvirus (KHV-D)
  - Motile *Aeromonas* Septicaemia
  - Sea lice (arthropods, e.g. *Cryptocaryon*)
  - *Streptococcus agalactiae*
  - *Saprolegnia*

2. Other prophylactic measures (Score: 167)

- Alternatives to antimicrobials:
  - Development of antimicrobial peptides and effective drugs for viral diseases
  - Ethnoveterinary prophylactic medicines
  - Phages against bacterial diseases
  - Plant-based sources and herbal extractions
- Biosecurity and environmental impact:
  - Biosecurity in farms
  - Research on chemical environmental impact
  - Development of disinfectants without toxicity to fish
- Genetic improvements:
  - Genetic improvement for brood stock
  - Selective breeding for disease-resistant species

3. Vaccination strategies and integration (Score: 72)

- Integrated programmes:
  - Designing control programmes integrating vaccination
  - Holistic adaptation of disease-prevention programmes to specific farm-rearing characteristics
  - Disease surveillance and epidemiology
- Cost-benefit analysis:
  - Cost-benefit studies of vaccination programmes
  - Economic impacts of disease versus vaccination

4. Enhancing vaccine efficacy, adjuvant, and immunology research (Score: 37)

- Adjuvant research:
  - Development of new and safe adjuvants
  - Revisit adjuvant technology to improve mucosal immunity
- Immune response studies:
  - Host immune response to pathogen studies
  - Long-term efficacy studies and monitoring

5. Optimization of vaccine delivery tools (Score: 35)
Development of oral and immersion vaccines Improvement of vaccine delivery systems Sustainable and automated vaccine deployment strategies
6. Policy and standardization (Score: 33)
Development of policies to facilitate product registration Reducing regulatory hurdles Standards for autogenous vaccines
7. Cost-reduction, commercialization, access, and use of vaccines (Score: 24)
Increased access to vaccines Reduced cost of production and supply Enhancing vaccine uptake for low-value fishes

Q16: Highlights and few quotes from comments received:

'Differentiating fish exposed to attenuated live vaccines from wild-type (WT) pathogens and assessing the potential impact of vaccination on pathogen evolution is essential.'

(Anonymized quote from comments)

- **Guidelines and regulation**
  - A **global guideline** for autogenous vaccine production and use is needed, involving regional experts
  - Vaccine **use should be regulated** by competent authorities, ensuring proper documentation, registration, and effectiveness through strain analysis
  - **Regulatory pathways should be streamlined**, making vaccine approval **faster, easier, and cost-effective**, particularly for fish vaccines
  - The **African Union** is developing a continental aquatic animal vaccine strategy to support policy and legal frameworks.

- **Challenges in vaccine development and use**
  - Developing new vaccines is **complex and costly**, requiring ***in vivo*** testing, expert knowledge, and multidisciplinary skills
  - **Low economic incentives** hinder vaccine investment in aquaculture due to the **relatively low value of fish production** compared with high vaccine development costs
  - **Funding models** often require contributions from pharmaceutical companies or farms, leading to ownership issues; **public domain access is needed** for industry-wide benefit
  - Autogenous vaccines are **not sustainable** as they are farm-specific and often used as treatment rather than prevention.

- **Implementation and adoption strategies**
  - **Investment in low-cost, easy-to-administer vaccines** is essential
  - **Public-private partnerships** can help **reduce vaccine development costs** and improve accessibility
  - **Farmer training programmes** should be established to improve awareness and uptake
  - **Consumer education** is needed to enhance acceptance of biotech-driven prophylactic solutions
  - **Nutritional and environmental factors** affecting vaccine efficacy should be clearly communicated to farmers
  - **Packaging improvements** can increase adoption, particularly for small- to medium-scale farmers.

- **Complementary measures**
  - **Biosecurity is essential** and cannot be replaced by vaccines; strong biosecurity improves vaccine success
  - **Underlying health issues** related to feed and environment should be addressed for better prophylactic effectiveness.

- **Future directions**
  - Advancements in **biotechnology** (reverse vaccinology, recombinant DNA, DNA/mRNA vaccines) will drive future fish vaccine development
  - A focus on **building capacity in LMIC** is crucial
  - Key vaccine targets include ***Streptococcus***, ***Aeromonas***, **and** ***Vibrio***.

'Cost of vaccine relative to price of fingerlings is always an issue.' *(Anonymized quote from comments)*

Q15: Do you anticipate any regulatory or technical or social/economic challenges in developing/using new ***prophylactics including vaccines****? If yes, please specify the issue.*

Highlights and few quotes from responses received:

'For small production systems it is difficult to get the large companies interested in developing vaccines. Even though it is a welfare concern.'
(Anonymized quote from comments)

'Newer technology vaccines can be economically challenging.' *(Anonymized quote from comments)*

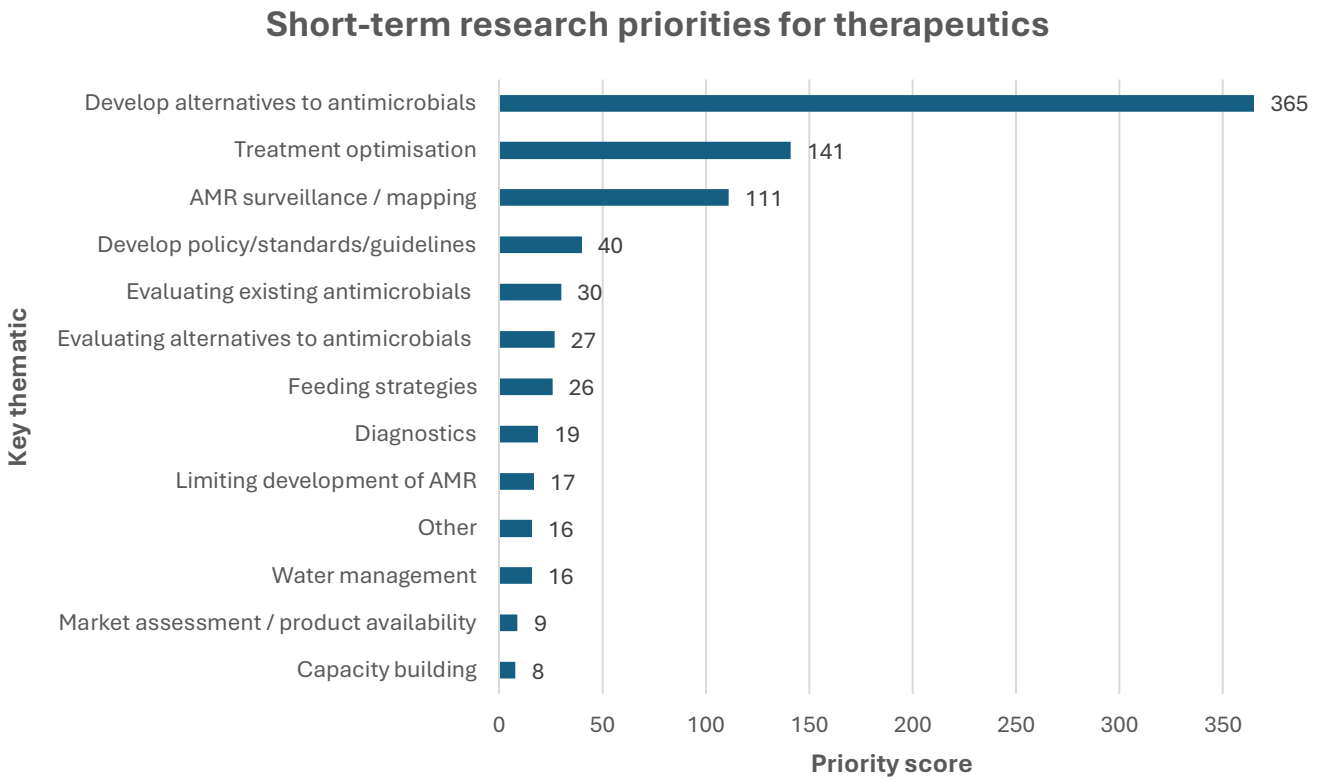
- **Regulatory and policy barriers**
  - **Complex and lengthy approval processes:** Vaccine registration is costly, slow, and bureaucratic, delaying access to effective solutions
  - **Differences in global standards:** Regulatory harmonization is lacking, leading to market fragmentation where vaccines are approved only in profitable regions, leaving small markets underserved
  - **Restrictive regulations:** The EU has very strict regulations, limiting preventive and curative options
  - **Lack of clear regulatory frameworks:** Many regions, including parts of Southeast Asia, Africa, and Latin America, lack clear or practical guidelines for vaccine approval
  - **Environmental restrictions:** Some prophylactic treatments (e.g. bath treatments) may be restricted because of environmental concerns
  - **Autogenous vaccine challenges:** Stricter good manufacturing practices (GMP) requirements in the EU may increase costs and limit availability.
- **Economic and market constraints**
  - **High cost of vaccine development and approval:** The cost of regulatory approval and vaccine production is a major obstacle, especially for small industries and low-value fish species
  - **Limited industry incentives:** Pharmaceutical companies are not interested in developing vaccines for low-value species due to poor profitability
  - **Small and fragmented markets:** The **small size of the aquaculture sector** in some regions makes it difficult to attract investment in vaccine development
  - **Farmer affordability and acceptance issues:** Many **small-scale farmers cannot afford vaccines**, leading to **low uptake**.
- **Technical and scientific challenges**
  - **Pathogen variability and vaccine efficacy:** Developing effective vaccines is complicated by pathogen diversity and immune response variability
  - **DIVA vaccine:** Differentiating fish exposed to attenuated live vaccines from wild-type (WT) pathogens and assessing the potential impact of vaccination on pathogen evolution
  - **Vaccine delivery challenges:** Some vaccines require labor-intensive administration, limiting practicality, particularly in species like tilapia
  - **Cold chain and storage issues:** Many vaccines require strict storage conditions, which pose logistical challenges in remote areas
  - **Difficulties with oral vaccines:** Finding the right dose and safe administration method for oral vaccines remains an issue.

- **Social and environmental considerations**
  - **Public perception and acceptance:** Consumer perception of biotechnology-driven prophylactics can be a barrier
  - **Biosafety and environmental risks:** Concerns over residue, transboundary movement of vaccines, and ecological impacts create additional regulatory scrutiny
  - **Need for training and awareness:** Limited veterinary expertise and low adoption of new technologies in LMIC make vaccine implementation difficult.
  - **Role of water quality:** Poor water quality and chemical pollution (e.g. PFAS contamination) can inhibit vaccine responses, making disease prevention more challenging.
- **Potential solutions and recommendations**
  - **Regulatory streamlining:** Faster and more flexible vaccine approval systems are needed
  - **Public-private partnerships:** Investment in affordable vaccines and support for autogenous vaccines in emergency cases
  - **Global harmonization:** A mutually recognized global approval system (like FDA or EMA standards) would improve market access
  - **Training and capacity building:** Training programmes for farmers and veterinarians can improve vaccine and ATA uptake
  - **Research investment:** Funding should be directed toward species-specific vaccine research and cost-effective production methods.

'Most alternatives to antimicrobials lack regulatory guidelines.'
(Anonymized quote from comments)

Therapeutics

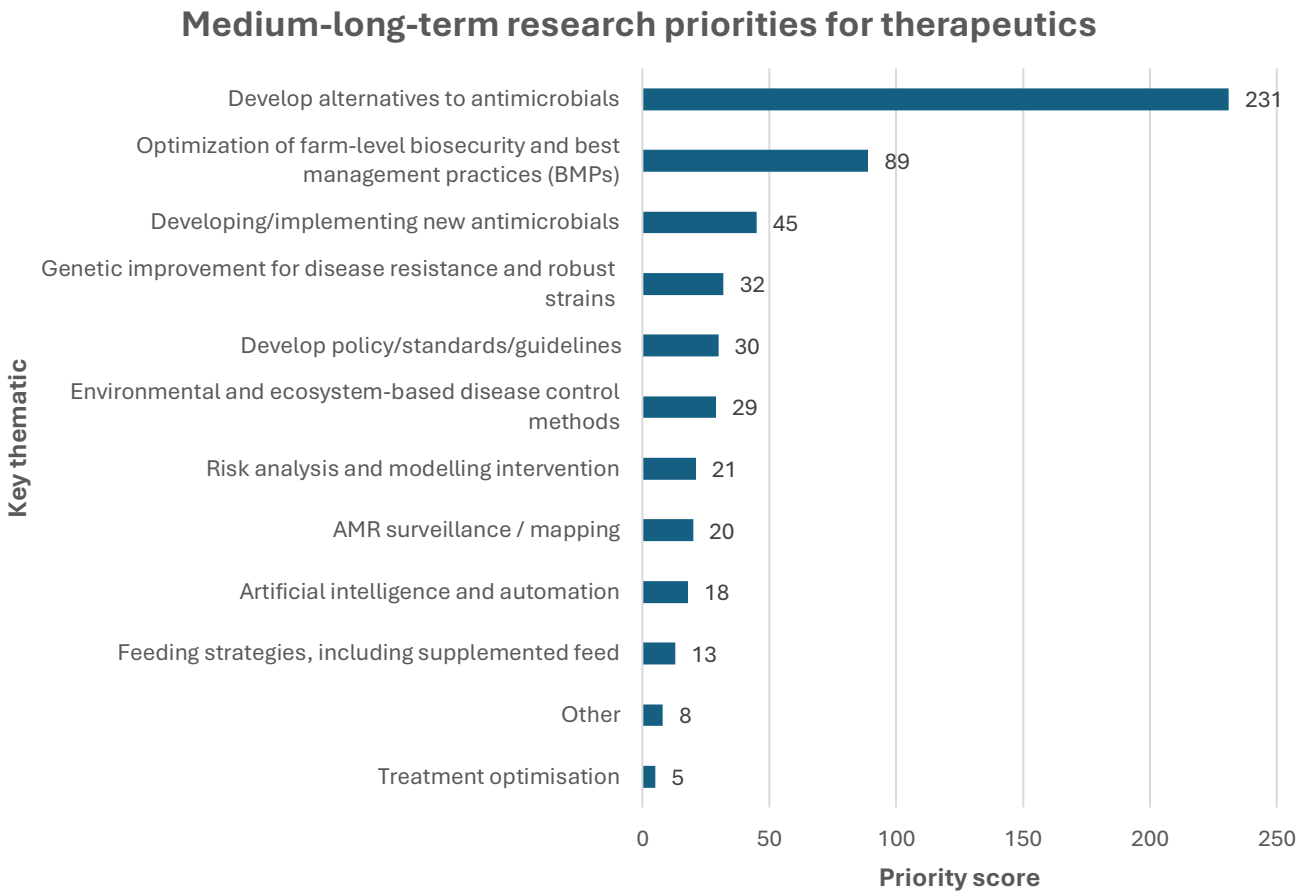
Q17: What are the short-term (within 5 years) research priorities for therapeutics (e.g. antimicrobials or alternatives to antimicrobials)?



Therapeutics: Summary of short-term research priorities for the top 5 identified trends
1. Alternatives to antimicrobials (365)
Biological and natural alternatives: • Probiotics, prebiotics, phytochemicals, plant extracts, herbal medicines, bacteriocins, antimicrobial peptides Bacteriophage therapy: • Collection, molecular interactions, and targeted treatments Immune-based strategies: • Immunostimulants and immune modulators • Oral vaccines • Nanotherapeutics Environmental and non-chemical approaches: • Manipulating conditions to reduce pathogen proliferation • Microbiota management New drug discovery: • Development of novel antimicrobials, small peptides, antivirals, and targeted treatments for specific pathogens (e.g. *Aeromonas hydrophila*) Alternative treatments for sea lice: • Non-antibiotic solutions • Mechanical removal methods

2. Treatment optimization (141)
Antimicrobial stewardship: • Reducing unnecessary use • Precision medicine approaches (e.g., rapid Antimicrobial Susceptibility Tests, pharmacokinetics) Delivery and application methods: • Ensuring effectiveness while minimizing resistance Sea lice management: • Salmon-friendly alternatives • Chemotherapeutics Responsible use and education: • Awareness programmes • Stewardship initiatives • Optimized treatment strategies
3. AMR surveillance and mapping (111)
Monitoring and data collection: • AMR gene prevalence • Antibiotic sensitivity testing • Surveillance programmes Environmental impact and resistance trends: • Tracking resistance spread in aquaculture environments Resistance management: • Developing strategies to mitigate AMR impacts on fish health and production
4. Policy, standards and guidelines (40)
Regulatory frameworks: • Global harmonization of antimicrobial approval • Off-label use restrictions • Trade-related policies Testing and evaluation: • SOPs for pharmacodynamics (PD) and minimum inhibitory concentrations (MIC) Education and training: • Awareness programmes for responsible antimicrobial use in aquaculture
5. Evaluating existing antimicrobials (30)
Effectiveness and risk assessment: • Reviewing existing treatments to optimize efficacy and minimize resistance development

Q18: What are the medium-long term (5-15 years) research priorities for therapeutics (e.g. antimicrobials or alternatives to antimicrobials)?



Therapeutics: Summary of medium-long-term research priorities for the top 5 identified trends
1. Develop alternatives to antimicrobials (231)
Biological and natural alternatives: • Probiotics, antimicrobial peptides, phytochemicals, essential oils, plant extracts • Herbal applications and indigenous knowledge-based therapeutics Bacteriophage therapy: • Research on phage therapy for bacterial, fungal, and parasitic diseases • Development of bacteriophage-based treatments and functional nucleic acids Advanced therapeutics and smart drug delivery: • Nanoparticle-based drug carriers, immune stimulants, biofilm-targeting compounds • Novel therapeutic methods, integrating biotechnology and innovative treatment strategies Sustainable and integrated approaches: • Developing non-antibiotic prophylactics for emerging diseases • Combining alternative therapeutics with improved aquaculture management

2. Optimization of farm-level biosecurity and best management practices (89)

Antimicrobial stewardship and education:
- Continued farmer education on correct use of therapeutics
- On-farm monitoring of antimicrobial use and reduction strategies

Improved disease prevention and management:
- Integrated disease management systems
- Standardizing farm records on treatment history and outcomes

Sustainable husbandry techniques:
- Minimizing antibiotic dependency through enhanced farm-level biosecurity
- Researching long-term benefits of sustainable practices, reducing the need for injectables

3. Developing/implementing new antimicrobials (45)

New drug discovery and development:
- Novel antimicrobial agents and antibiotics tailored for aquatic environments
- Development of drugs that do not overlap with human healthcare antibiotics

Optimizing antimicrobial use:
- Efficient delivery and application methods
- Matching antimicrobial use with biosecurity practices to minimize resistance risks

Targeted and sustainable treatments:
- Research on antimicrobial phytochemicals and natural substances
- Exploring alternative drugs with enhanced safety and efficacy

4. Genetic improvement for disease resistance and robust strains (32)

Genetic selection and biotechnological approaches:
- CRISPR-based gene editing, genomic selection, microbiome engineering
- Broodstock selection for disease resistance and long-term monitoring of improved strains

Microbiome research and immune enhancement:
- Understanding fish microbiomes and their role in disease prevention
- Expanding immune responses through genetic and microbiome manipulation

5. Develop policy, standards and guidelines (30)

Regulatory frameworks and compliance:
- Evidence-based policies for therapeutic use in aquaculture
- Government and private sector collaboration to validate new therapeutics

Standardization and best practices:
- Development of SOPs for antimicrobial administration
- Guidelines to facilitate compliance, ensuring equity in aquaculture health practices

Coordinated strategies for AMR reduction:
- Implementing strategies to minimize antimicrobial resistance
- Context-specific policies to balance disease control with sustainability

Q20: Highlights and few quotes from comments received:

> *"Addressing these challenges will require Investment in cost-effective production methods to make alternatives affordable for small-scale farmers.*
> *(Anonymized quote from comments)*

- **Regulatory and production challenges**
  - Regulatory reform: Need for harmonization to streamline approval pathways for innovative therapeutics
  - Cost-effective production: Investment in methods to make alternatives affordable for small-scale farmers
  - Capacity building: Outreach programmes to increase awareness and adoption of sustainable disease management strategies
  - Public-private partnerships: Funding and commercialization of novel solutions to ensure accessibility
- **Biosecurity and disease management**
  - Biosecurity: Emphasis on biosecurity as the first line of defence
  - Antimicrobials: Mixed acceptance among farmers; need for ecosystem approaches to reduce reliance on antimicrobials and injectable vaccines
  - Preventive measures: Issues with high usage of treatments without addressing root causes
- **Regulatory and practical constraints**
  - EU regulations: Impact of EU/national regulations on the availability of treatments
  - Veterinary training: Lack of veterinarians with epidemiology training leading to ineffective treatments
  - Guidelines: Need for global or regional guidelines involving regional experts
- **Therapeutic development and application**
  - Phage and probiotics: Consideration of the complexity of aquatic microbial environments before making decisions
  - Herbal doses: Difficulty in adjusting research results to real-world applications
  - Therapeutic agents: Exploration of mechanisms that limit infectivity and pathogenicity considering AMR
  - Therapeutic delivery: Importance of timing to lessen disease impact

> *"One needs to consider the extraordinary ecological and evolutionary complexity of the aquatic microbial environment relative to terrestrial animals before useful decisions can be made here."*
> *(Anonymized quote from comments)*

Q19: Do you anticipate any regulatory or technical or social/economic challenges in developing/using new therapeutics(e.g. antimicrobials or alternatives to antimicrobials)? If yes, please specify the issue.

Regulatory challenges

- **Stringent approval processes**: Lengthy and complex approval processes for novel therapeutics
- **Antimicrobial use restrictions**: Regulations limiting the use of antimicrobials
- **Lack of harmonization**: Variability in international regulatory standards
- **Emerging technologies**: Challenges in regulating new technologies like gene editing and synthetic biology

Technical challenges

- **Delivery and stability**: Issues with the delivery and stability of alternative therapeutics
- **Diagnostic infrastructure**: Limited diagnostic and monitoring infrastructure
- **Effectiveness of alternatives**: Demonstrating efficacy and safety of alternative therapeutics in varied conditions
- **Antimicrobial resistance**: Overuse or misuse leading to antimicrobial-resistant bacteria

Social and economic challenges

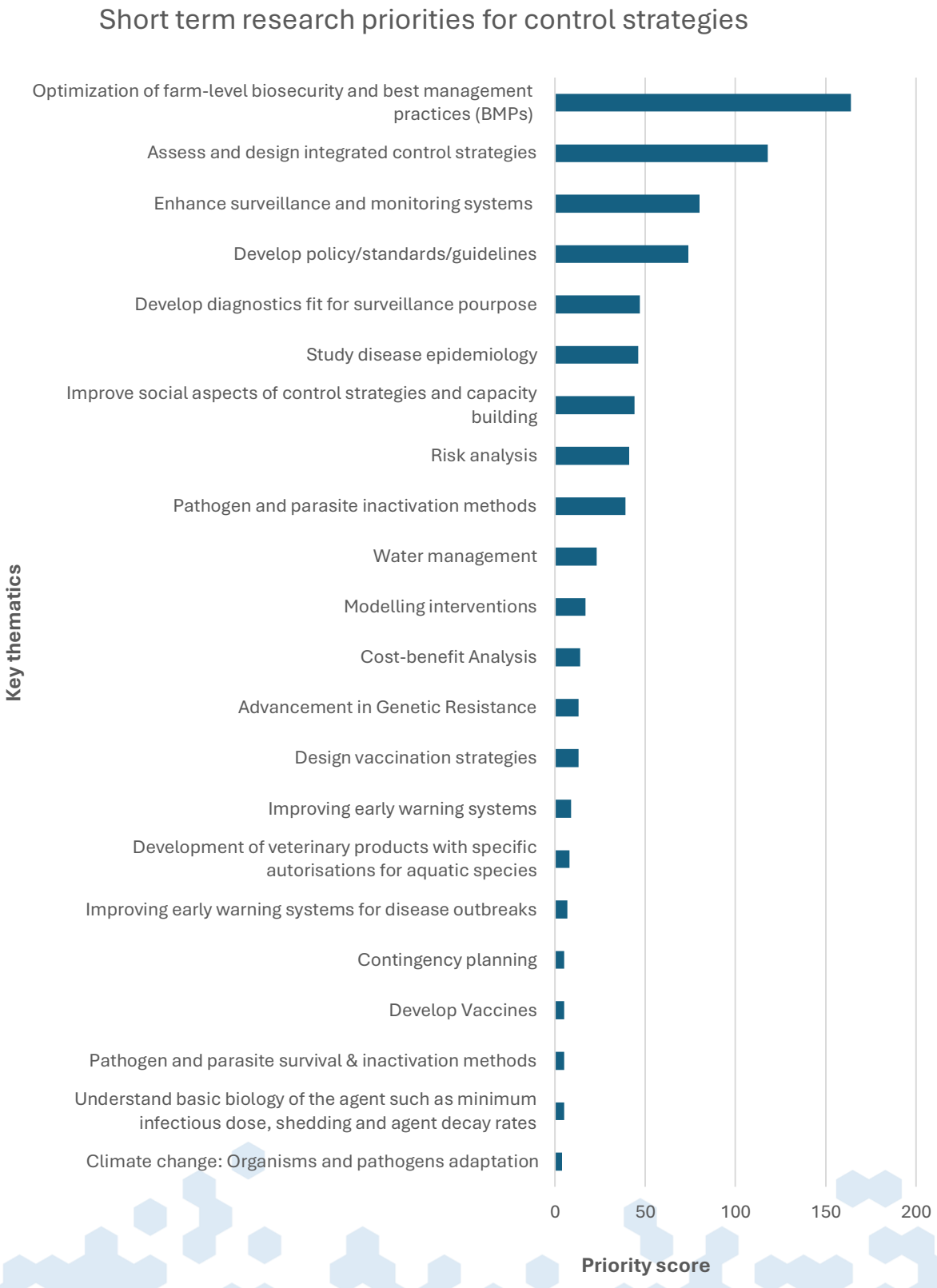
- **High costs**: Financial constraints for small-scale farmers and high costs of drug development and production
- **Farmer adoption**: Limited farmer knowledge and acceptance of new therapeutics
- **Competing interests**: Industry resistance and competing interests
- **Access to therapeutics**: Ensuring equitable access to effective and affordable therapeutics
- **Consumer perception**: Public perception and acceptance influencing market access

Additional considerations

- **Investment and research**: Lack of investment and capacity to establish research programmes
- **Trade issues**: Adapting to trade requirements and regulations of export countries
- **Environmental impact**: Potential risks to non-target organisms and ecosystems
- **Biosecurity**: Importance of biosecurity and its impact on therapeutic use

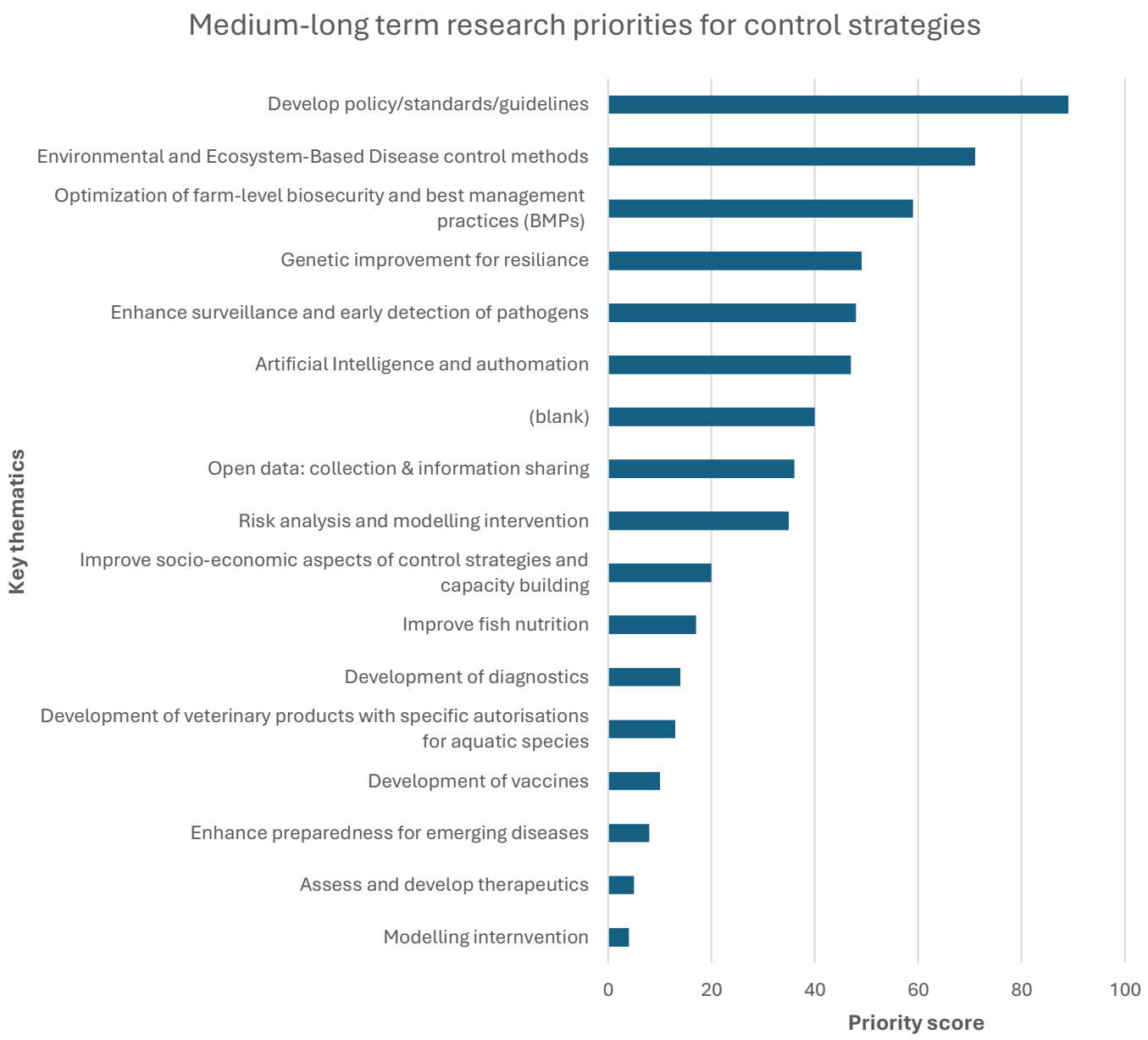
Control strategies

Q21: What are the short-term (within 5 years) research priorities for optimizing or implementing control strategies?



Control strategies: Summary of short-term research priorities for the top 5 identified trends
1. Optimization of farm-level biosecurity and best management practices (164)
Strengthening biosecurity at farm, company, and national levels Developing comprehensive biosecurity frameworks and strategies Improving hygiene management and water quality optimization Enhancing compliance with best management practices (BMPs) Innovating to improve fish health and reduce disease risks
2. Integrated disease control strategies (118)
Combining biosecurity, vaccination, therapeutics, and environmental management Developing early detection and rapid response systems Implementing alternative disease control methods (e.g. probiotics, immunostimulants) Advancing selective breeding for disease-resistant fish stocks Establishing integrated disease management protocols tailored to farming systems
3. Surveillance and monitoring systems (80)
Enhancing disease surveillance with AI and digital tools Developing risk-based surveillance programmes Improving early warning systems and real-time monitoring Strengthening antimicrobial resistance (AMR) tracking in aquaculture Establishing national and regional disease surveillance frameworks
4. Policy, standards and guidelines (74)
Developing and updating regulatory frameworks for disease control Strengthening policies on antibiotic use and biosecurity Establishing national action plans and laboratory capacity Standardizing testing protocols and certification of disease-free hatcheries Improving quarantine, inspection, and sourcing regulations
5. Diagnostic tools and epidemiology studies (47)
Developing rapid and field-ready diagnostic tests for pathogen detection Advancing non-invasive diagnostic technologies Improving virus detection capabilities and diagnostic capacity Enhancing methods to differentiate vaccinated from infected fish Conducting epidemiological studies to understand disease patterns

Q22: What are the medium-long-term (5-15 years) research priorities for optimizing or implementing control strategies?



Control strategies: Summary of long-term research priorities for the top 5 key trends
1. Develop policy, standards, and guidelines (89)
Strengthening regulations and national policies for disease control
Developing practical policies for aquatic disease mitigation
Establishing national vaccination programmes and surveillance plans
Modernizing pathways for disease freedom documentation
Promoting regional One Health monitoring and harmonized disease control strategies
Ensuring border controls, quarantine procedures, and reliable laboratory access

2. Environmental and ecosystem-based disease control (71)
Climate adaptation strategies for disease preparedness
Development of eco-friendly disease control methods
Ecosystem-based farming and disease prevention approaches
Understanding environmental impacts on host-pathogen interactions
Sustainable water quality management and biosecurity systems
Transitioning to ecosystem-level disease control strategies
3. Optimization of farm-level biosecurity and best management practices (59)
Optimize national and industry-wide biosecurity measures
Implementing biosecurity control pathways and health management areas
Development of SPF (specific pathogen free) hatcheries and broodstock
Improving hygiene and stress management in aquaculture systems
4. Genetic improvement for disease resilience (49)
Selective breeding and genetic tools for disease-resistant strains
CRISPR and genomic selection for pathogen-resistant aquaculture species
Development of climate-adapted, disease-tolerant fish breeds
5. Surveillance and early detection of pathogens (48)
Development of digital and AI-driven surveillance systems
Designing pathogen-specific surveillance programmes
Early detection tools and early warning indicators for disease outbreaks
Strengthening information sharing and epidemiological surveys

Q23: Highlights and few quotes from comments received:

> *'Aquatic animal health must shift from the current pathogen obsessed paradigm, which inherently then suggests treatment is the aim, to one which embraces the complexity of disease ecology, and seeks to understand how to create environmental conditions that prevent disease expression. This necessarily will require changes in farming systems, husbandry, environmental remediation and addressing all pollution flows.'*
>
> *(Anonymized quote from comments)*

- **Data sharing and coordination**
  - Regions like the Mediterranean need a centralized database for transparent tracking of animal and goods movements related to fish disease and biosecurity
  - Collaboration and knowledge sharing among farms, regulators, and researchers are crucial for controlling disease spread, particularly in LMIC where aquatic animal health receives minimal attention.
- **Disease causation and epidemiology**
  - A key research priority is determining whether specific microbial agents (e.g. *Tenacibaculum spp.*) are genuinely pathogenic, requiring a robust pipeline to establish disease causation
  - Many new diseases remain uncontrolled for too long; early detection and response mechanisms must be improved
  - Sampling strategies (e.g. 30 fish per farm) need reassessment for cost-effectiveness and pathogen risk assessment.

- **Environmental and climate change considerations**
  - Climate change and shifting aquatic environments are affecting water quality and disease dynamics, making disease control unpredictable even with current measures in place
  - Disease control should move beyond a pathogen-focused approach and focus on disease ecology, integrating farming system improvements, husbandry practices, and environmental remediation to create conditions that prevent disease expression
  - Many disease outbreaks stem from environmental degradation and inadequate feed formulation; addressing these underlying issues should be essential.
- **Strengthening veterinary and laboratory networks**
  - Many low-value species lack access to veterinarians with aquaculture expertise, making disease control difficult
  - Strengthening laboratory networks and capacity-building efforts is crucial for improved disease diagnostics and response
  - Integrated One Health approaches should be adopted, as recommended by the African Union Commission, to safeguard aquatic food systems and regional trade.
- **Policy and compensation mechanisms**
  - Unlike livestock farmers, most fish farms lack compensation programmes for disease outbreaks, which impacts the effectiveness of control strategies
  - Research should support control strategies at both farm and policy levels, ensuring that disease outbreaks are effectively managed.
- **Sustainable aquaculture practices**
  - Finfish aquaculture presents an opportunity for meeting global seafood demand while reducing pressure on wild fish stocks, but sustainability must be prioritized:
    - Environmental sustainability – responsible site selection, waste management, and feed efficiency
    - Animal welfare – stress reduction, humane handling, and disease prevention
    - Food safety – maintaining high quality throughout the production chain
    - Social responsibility – supporting local communities and equitable aquaculture benefits.

Section: Transversal issues

Q75: Are there any transversal issues that will be important to address to enhance Research & Development & Innovation in the aquaculture sector?

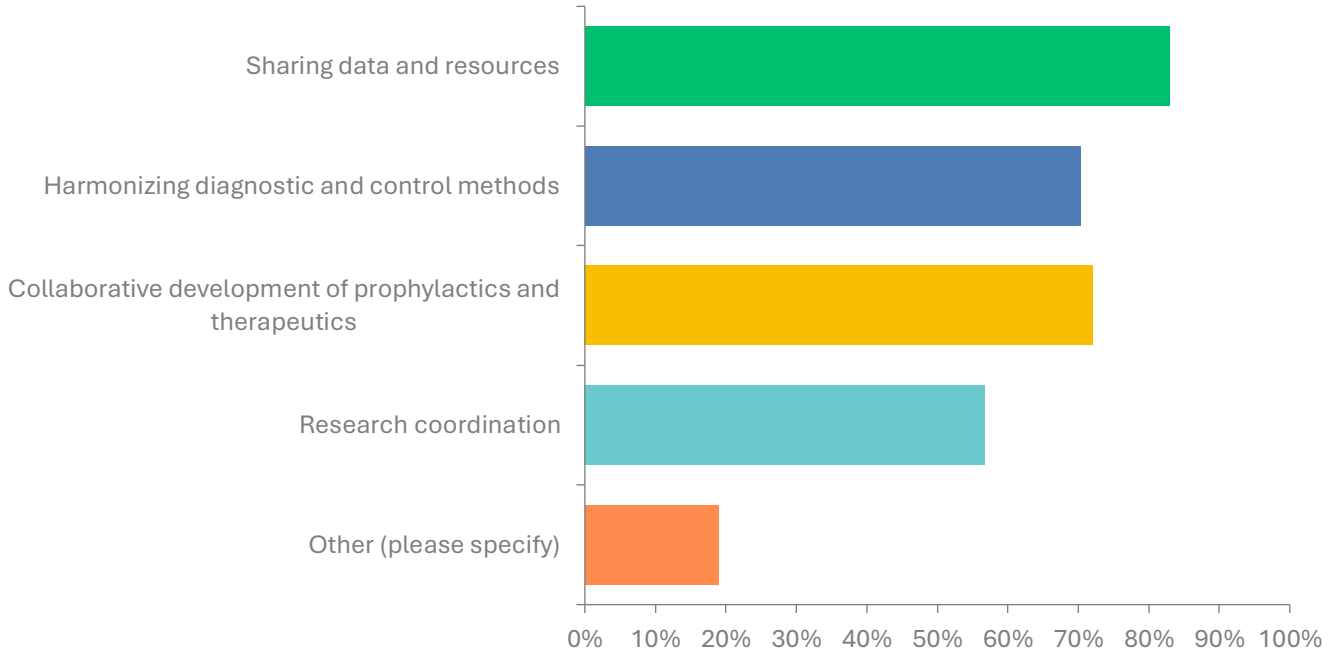
Highlights and few quotes from responses received:

"Secure long-term research funding is a critical issue for the development of diagnostic tools, understanding basic immune systems in aquatic organisms, and the development of therapeutants and prophylactics."

- **Research and innovation funding**
  - Sustainable, long-term funding for aquaculture R&D
  - Funding accessibility for developing countries and small-scale producers
  - International collaboration and investment in field research
- **Biosecurity and disease control**
  - Strengthening biosecurity to prevent disease outbreaks
  - Antimicrobial resistance (AMR) management
  - Early detection, surveillance, and diagnostic advancements
  - Zoonotic disease risks and One Health approach
- **Climate change and environmental sustainability**
  - Resilience to climate change impacts
  - Water pollution, resource conservation, and waste management
  - Sustainable feed and farming practices
  - Biodiversity protection and ecosystem health
- **Capacity building and human resource development**
  - Training and education for researchers, farmers, and technicians
  - Strengthening fish disease laboratories and diagnostic facilities
  - Knowledge sharing through interdisciplinary and global collaboration
- **Regulatory and policy frameworks**
  - Harmonization of international regulations
  - Addressing illegal trade and biosecurity risks
  - Clear guidelines on sustainability, disease management, and food safety
- **Technology and digital innovation**
  - Adoption of AI, automation, and emerging diagnostic methods
  - Data sharing, management, and open science initiatives
  - Digital tools for monitoring and disease prediction
- **Socioeconomic and ethical considerations**
  - Gender inclusivity in aquaculture research and farming
  - Socioeconomic impacts on small-scale farmers and developing economies
  - Ethical considerations in fish welfare and farming practices

Q76: What do you see as the greatest benefit of increased global collaboration in aquatic health research?

Answered: 111 Skipped: 73



Highlights from other specified

Capacity building, knowledge sharing, and collaboration

Many responses emphasized the need for training, professional networking, and equitable access to resources and technology. Transparency and public confidence in the sector are crucial for its development, helping to build trust among stakeholders. Knowledge-sharing within and across regions was highlighted as an important way to improve farming practices and strengthen industry resilience. Additionally, interdisciplinary and cross-sectoral collaboration was seen as essential, integrating veterinary science, environmental science, and economics to address complex challenges in the sector.

Governance, trade policies, and coordination

Coordination between stakeholders remained a recurring theme, particularly regarding trade policies, monitoring, and surveillance. Establishing harmonized regulations and ensuring safe trade practices were identified as key measures for preventing disease spread and maintaining sector stability. Improved governance structures and clearer communication between regulatory bodies and industry players were considered fundamental to achieving these goals.

Research prioritization, evidence-based policy, and funding

Concerns about potential duplication of research and the need for improved prioritization of funding and efforts were raised. Support for fundamental research, particularly in underexplored areas such as crustacean neurophysiology, was highlighted. A more structured and evidence- based approach to research funding and policy-making was recommended. Additionally, sustainable financial support for research, particularly for independent scientists and small-scale farmers, was suggested. Few respondents also express concerns about funding models that tend to primarily benefit large corporations rather than directly supporting farms and research providers.

Disease prevention and early warning systems

The need for better early warning systems, especially concerning the international transport of live animals, was a high priority. Some responses suggested that disease management strategies should evolve beyond simply identifying pathogens, instead focusing on broader health and environmental conditions that contribute to outbreaks. A more holistic approach to disease prevention could improve long-term resilience in the sector.

Q77: What are the greatest challenges for increased global collaboration?

The responses highlight several major challenges that hinder global collaboration, focusing on financial, regulatory, political, technological, cultural, and environmental factors.

Challenge	Key issues
Funding and resource constraints	Lack of funding, disparities between high- and low-income countries, high training and travel costs
Regulatory and policy barriers	Variability in national policies, bureaucratic hurdles, lack of harmonization
Data sharing and transparency issues	Concerns over data misuse, fear of stigma in disease reporting, limited genomic data access
Political and geopolitical tensions	Political conflicts, economic nationalism, competition for funding and influence
Technological and infrastructure gaps	Disparities in research facilities, limited technical capacity, uneven IT resources
Cultural and communication barriers	Language differences, varying research priorities, networking difficulties
Mistrust and competition	Unequal partnerships, reluctance to share sensitive data, industry secrecy
Climate change and emerging threats	Diverse regional impacts, coordination difficulties, lack of standardized monitoring

Q78: What do you see as the most significant challenge in improving sustainable farm practices and government policies for aquaculture disease management and animal health?

Challenge	Key issues
Regulatory and policy gaps	Unclear or incomplete regulations, inconsistent enforcement, lack of harmonized policies
Economic and financial constraints	High costs of sustainable practices, lack of incentives, reliance on donor funding
Limited access to disease surveillance and diagnostics	Inadequate diagnostic infrastructure, insufficient data on disease outbreaks
Farmer awareness and resistance to change	Low adoption of sustainable methods, resistance to new technologies, training gaps
Overuse of antibiotics and lack of alternatives	Excessive antibiotic use, antimicrobial resistance, slow adoption of alternative treatments
Climate change and environmental impacts	Changing disease patterns due to climate change, environmental degradation, biosecurity risks
Lack of coordination and stakeholder collaboration	Fragmented industry-government-research collaboration, lack of unified disease control strategies
Insufficient research and development funding	Limited investment in research, slow adoption of advanced technologies, knowledge gaps
Weak policy enforcement and implementation gaps	Difficulty in translating policies into actionable farm-level practices, lack of enforcement mechanisms
Mistrust in government and institutions	Distrust in policy-making processes, lack of transparency, conflicting industry-government interests

Q79: How can industry, research institutions, and policymakers better collaborate to address these challenges?

Key insights of responses
Multi-stakeholder platforms
Establish formal networks for industry, researchers, and policymakers to co-develop solutions Encourage joint decision-making and regular communication
Improved communication and coordination
Enhance dialogue through workshops, public-private partnerships, and direct engagement Promote transparency and trust among stakeholders
Joint research and development initiatives
Co-fund research projects addressing industry-relevant challenges Develop sustainable technologies and innovative disease management solutions
Policy alignment with scientific research
Ensure regulations are informed by scientific findings Align policies with industry needs to improve disease management and sustainability
Knowledge transfer and capacity building

Provide training programmes for farmers and industry professionals
Disseminate research findings and best practices effectively
Data sharing and transparency
Create shared databases for disease trends and environmental impacts
Protect intellectual property while incentivizing open data sharing
Funding and investment in sustainable practices
Increase financial support for collaborative projects
Provide incentives for industry-led sustainability efforts
International collaboration and standardization
Align international regulations for disease control and biosecurity
Develop global disease surveillance networks and best practice exchanges

Q80: Additional comments

Summary of additional comments and suggestions
Collaboration and governance
Strengthen public-private partnerships to tackle industry-wide challenges
Improve international cooperation for knowledge-sharing and trade facilitation
Develop regional and species-specific approaches to address diverse needs
Funding and capacity building
Increase financial support for research, training, and stakeholder engagement
Provide more funding opportunities for attending conferences and international events
Strengthen capacity-building programmes for farmers, researchers, and policymakers
Technology and innovation
Encourage digital tools, data analytics, and remote sensing for disease monitoring
Implement adaptive management strategies based on evolving research and conditions
Sustainability and holistic health approaches
Shift from short-term disease control to long-term environmental and economic sustainability
Expand perspectives beyond pathogen approach to a more comprehensive health approach
Community engagement and policy implementation
Involve local communities in decision-making to ensure policies are practical
Improve stakeholder transparency and collaboration to enhance policy effectiveness
Develop harmonized regulations to support sustainable practices
Recognition of expertise
Advocate for greater recognition of aquatic scientists alongside veterinarians
Ensure inclusive participation in policy discussions and research initiatives
Positive feedback
Appreciation for the initiative and its focus on sustainable aquaculture and disease management
Encouragement to continue fostering dialogue and collaboration in this field

Appendix

Survey on Aquatic Animal health Research Priorities

World Organisation for Animal Health

STAR IDAZ International Research Consortium on Animal Health