Aquaculture Health Research Survey

March 2026

Report of the global consultation on aquaculture research priorities: Molluscs Section

World Organisation for Animal Health

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STAR IDAZ International Research Consortium on Animal Health

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Executive Summary

This report presents the consolidated results of the Molluscs section of the *Global Consultation on Aquaculture Health Research (2025)*, jointly organised by the World Organisation for Animal Health (WOAH) and the STAR IDAZ International Research Consortium (IRC). The consultation supports Activity 4.5 of WOAH's Aquatic Animal Health Strategy, which aims to identify global research gaps and foster coordinated investment to improve aquatic animal health.

A total of 31 experts contributed to this section. Although the number of respondents was smaller than for other sections, contributors represent a specialised group working across disease surveillance, diagnostics, epidemiology, regulatory frameworks and mollusc production systems. Their inputs provide targeted insights into global research needs for mollusc health.

Mollusc aquaculture, including, for example, oysters, mussels, clams, scallops and abalone, is globally significant and predominantly based on extensive, low input, open water systems. These systems are highly dependent on environmental conditions, making them vulnerable to disease emergence, pollution, and climate-driven ecosystem changes. Molluscs also play an important role in food safety and zoonotic risks, given their capacity to accumulate pathogens and contaminants through filter feeding.

Priority Diseases

Experts identified a consistent group of impactful diseases requiring research attention. Priority diseases include: Bonamiosis, Perkinsosis, Marteiliosis, Ostreid herpesvirus disease, Vibriosis, Abalone herpesvirus disease, Mikrocytosis, Withering syndrome, Haplosporidiosis, and Francisellosis of abalone.

Respondents emphasised that hatchery and nursery phases are critical control points, being among the few stages where biosecurity and sanitary measures can be applied. They also stressed the importance of multi-agent and environmentally driven disease scenarios, noting that pollution, degraded ecosystems and climate variability frequently act as primary triggers of disease expression.

Diagnostics Research Priorities

In the short term, respondents highlighted the need for rapid and cost-effective field diagnostic tools, greater standardisation of methods, and improved molecular and 'omics-based approaches. Expanding the use of eDNA/eRNA and biosensor technologies, together with early development of mollusc cell lines and culture platforms, was also considered important. These priorities underline the need for faster and more harmonised tools to support surveillance, certification and early warning systems.

Over the medium to long-term, priorities shift towards more holistic diagnostic frameworks that integrate environmental, host and pathogen indicators. Further development of environmental monitoring systems, sequencing-based innovation, nonlethal diagnostic approaches, and surveillance of intermediate hosts and environmental reservoirs reflects a broader transition to ecosystem-based early detection in response to climate and environmental pressures.

Prophylactics Research Priorities

Short-term priorities include strengthening environmental surveillance, improving understanding of host immunity, and advancing immunostimulants, probiotics, phage therapy and other biobased prophylactics. Respondents also noted the need for access to biobanks, reference materials, and improved hatchery biosecurity and husbandry practices.

In the longer term, the focus turns to advanced prophylactics and biotherapeutics, addressing pollution and degraded ecosystems as underlying disease drivers, and building long-term host resilience through selective breeding. Clearer regulatory frameworks will also be required. Respondents emphasised that the impact of prophylactic measures will be limited unless broader ecosystem health, particularly water quality, is improved.

Therapeutics Research Priorities

Therapeutic use remains limited in many open water systems due to a lack of feasible application routes, though it is relevant in some sectors such as abalone farming. Short-term needs include strengthening understanding of disease ecology, assessing natural and environmentally friendly compounds, developing invitro screening platforms, exploring phage-based tools and probiotics.

Over the long term, priorities include AI-supported therapeutant development, natural compounds and phage-based innovations, probiotic and nutritional approaches, and the exploration of genomic tools for disease resistance. Regulatory clarity — particularly for phytotherapy and phage therapy — remains an important challenge.

Control Strategies Research Priorities

Short-term priorities focus on improving biosecurity, zoning, and pathogen inactivation methods, alongside stronger epidemiological investigation, modelling and understanding of host–pathogen–environment interactions. Respondents also highlighted the need for clearer regulatory frameworks, standards for quarantine measures, species-specific disease-free certifications, and enhanced surveillance and early warning capacities.

In the medium to long term, priorities expand to improved data standardisation, coordinated surveillance and pathogen-agnostic screening tools, as well as system designs adapted to local environmental conditions. Further research on pathogen persistence, wildlife reservoirs and invasive species, together with ecosystem-based approaches that enhance biodiversity and reduce pollution, will be essential. Collectively, these priorities reinforce the need for integrated ecological and epidemiological approaches to effectively manage disease risks.

Final Note

For detailed results, including full response data and expert comments, readers are encouraged to refer to the full report and the complete set of survey responses, which provide additional context and evidence supporting the priorities summarised here.

Introduction

This document forms part of a series of dedicated reports produced following *the Global Consultation on Aquaculture Health Research (2025)*, co-organised by the World Organisation for Animal Health (WOAH) and the STAR IDAZ International Research Consortium (IRC) for Animal Health. The consultation was launched in January 2025 to support Activity 4.5 of WOAH's Aquatic Animal Health Strategy, which calls for identifying global research gaps and strengthening coordinated research to improve aquatic animal health.

Each report in this series focuses on one aquaculture group — finfish, molluscs, crustaceans, and amphibians — and provides a detailed analysis of the research needs identified by experts who elected to complete the corresponding section of the questionnaire. To contextualise the findings presented in this Molluscs report, the next page provides an overview of the global survey underpinning this analysis. The infographic summarises the survey's reach, respondent expertise, and methodological foundations, illustrating the diversity of contributors whose insights shaped the research priorities identified across all aquaculture sectors. The full methodology, expert background information, and transversal findings are presented in the previously published *Aquaculture Health Research Survey Report- Finfish section*, available through the WOAH publication portal and STAR IDAZ IRC website.

Although fewer respondents specialise in mollusc health compared with finfish, the sector remains strategically important for aquaculture because of its global production footprint, increasing economic value, and the growing use of extensive, low-input farming systems such as long-lines, rafts, seabed culture, and coastal farming areas. Molluscs are particularly vulnerable to disease emergence due to their strong dependence on environmental conditions and open-water production systems. At the same time, they play an important role in the epidemiology of zoonotic and food-borne risks — given their capacity to accumulate and transmit pathogens — making research into mollusc health a priority within WOAH's strategy.

Within this consultation, 31 experts elected to complete the Molluscs section. While this represents a smaller expert group, their contributions provide highly focused and technically specialised insights into the research gaps affecting mollusc health worldwide.

The analysis presented in this document focuses specifically on the research needs for mollusc diagnostics, epidemiology, prophylactics, therapeutics, and control strategies. It complements the broader cross-species assessment available in the main global report and aims to guide future research planning and coordinated investment, in alignment with WOAH's Aquatic Animal Health Strategy and the STAR IDAZ IRC objectives.

Global aquaculture survey

440
invitations distributed globally

187
countries engaged

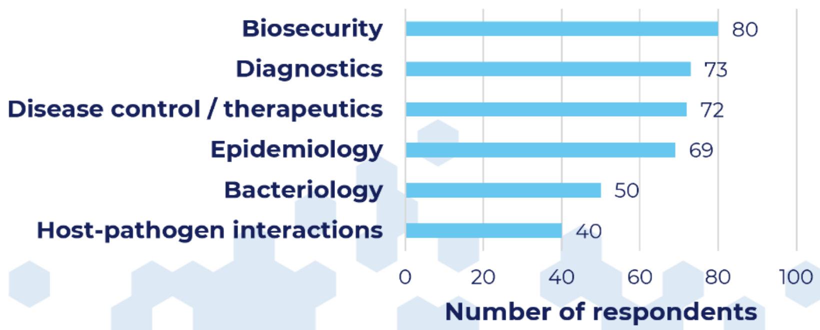
184
responses received from **89** countries

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



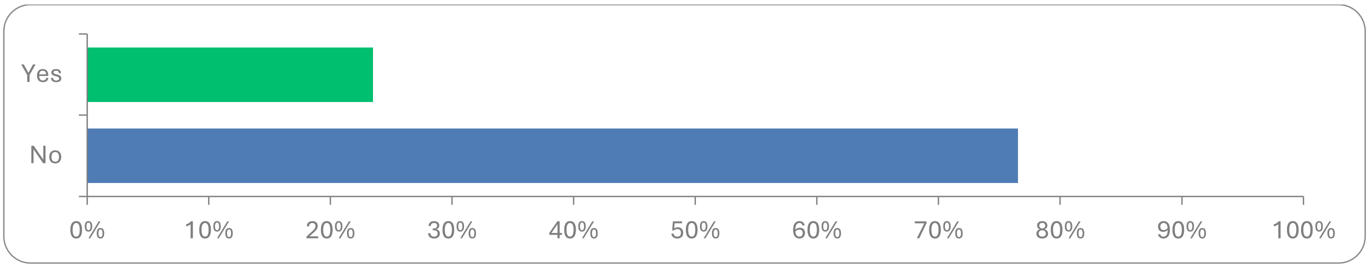
Other areas of expertise cited include:

- Virology
- Vaccine development
- Welfare
- Parasitology
- Immunology

Section: Molluscs

Q 41: Would you like to fill the section on Molluscs? Please respond to this section accordingly to your expertise. Feel free to skip questions not in your expertise.

In total, 31 experts elected to complete the Molluscs section of the global consultation for advancing aquaculture research. Most respondents chose not to complete this section, reflecting the smaller proportion of mollusc specialists within the overall survey population. Further details on respondent profiles can be found in the *Expert background* section of the main report, available on both the WOAH publication portal and STAR IDAZ IRC website.



Impactful diseases in aquatic health

Q 25: Which are the most impactful diseases in your sector for which research actions would be needed? (Please list in order of importance up to 10 diseases only for the sector you have experience on: 1. Most impactful, 10 Less impactful).

Rank	Disease / Pathogen	Comment	Category
1.	**Bonamiosis**	Includes *Bonamia ostreae* and *Bonamia exitiosa*	Parasitic disease (protozoan)
2.	**Perkinsosis**	Includes *Perkinsus marinus* and *Perkinsus olseni* (both reported equally)	Parasitic disease (protozoan)
3.	**Marteiliosis**	Includes *Marteilia refringens* and *Marteilia* spp.	Parasitic disease (protozoan)
4.	**Ostreid Herpesvirus Disease**	*OsHV-1*, including microvariants	Viral disease

5.	**Vibriosis**	Original terms in responses: Vibriosis, Bacterial disease (hatchery) – vibriosis, *Vibrio* spp., *Vibrio aestuarianus*, *Vibrio vulnificus*, *Vibrio* infection including *V. parahaemolyticus*, Infection with vibrios *V. aestuarianus* was mentioned 3x, *V. vulnificus* and *V. parahaemolyticus* were each mentioned once	Bacterial disease
6.	**Abalone Herpesvirus Disease**	*Haliotid herpesvirus 1*	Viral disease
7.	**Microcytosis**	*Mikrocytos mackini*	Parasitic disease (protozoan)
8.	**Withering Syndrome**	*Xenohaliotis californiensis*.	Bacterial disease (Rickettsia-like)
9.	**Haplosporidiosis**	*Haplosporidium nelsoni* (MSX).	Parasitic disease (protozoan)
10.	**Francisellosis of abalone**	*Francisella halioticida*	Bacterial disease

Q26: Highlights and few quotes from comments received:

"It is essential to consider multi-agent (pathobiotic) conditions, and symbiont-host-environmental interactions."
(Anonymised quote from comments)

- Diseases of shellfish are predominantly caused by protozoan parasites and viruses, although bacterial diseases also occur, including those caused by emerging pathogens such as *V. aestuarianus* and *F. halioticida*.
- In addition to protozoa, viruses, and bacteria, marine worms (*Polydora*) and transmissible neoplasia were mentioned. Transmissible neoplasia is due to the horizontal spread of cancer cells and can occur in clams, mussels, cockles, and oysters.
- Major pathogens are species-specific and the list of pathogens presented here is dominated by major shellfish species, notably oysters (e.g., genus *Ostrea*, *Crassostrea*) and abalone *(Haliotis)*.
- Disease pressures vary strongly by species and production system, among the specific taxa of *blood cockles*, *Nematopsis* spp. is the most prevalent pathogen reported whilst *Pinna nobilis* picornavirus was listed as pathogen of pen shells and *Echinomermella matsi* as castrating parasite of sea urchins (echinoderm rather than bivalves).
- Hatchery and nursery phases are critical control points for molluscs, being the only stages where biosecurity, sanitary measures and antimicrobial use can be effectively implemented. Larval mortality was listed twice as a priority disease.
- Multi-agent and pathobiotic disease scenarios should be considered more, disease emergence is often driven by interactions between pathogens, symbionts, hosts, and environmental conditions, rather than single-agent

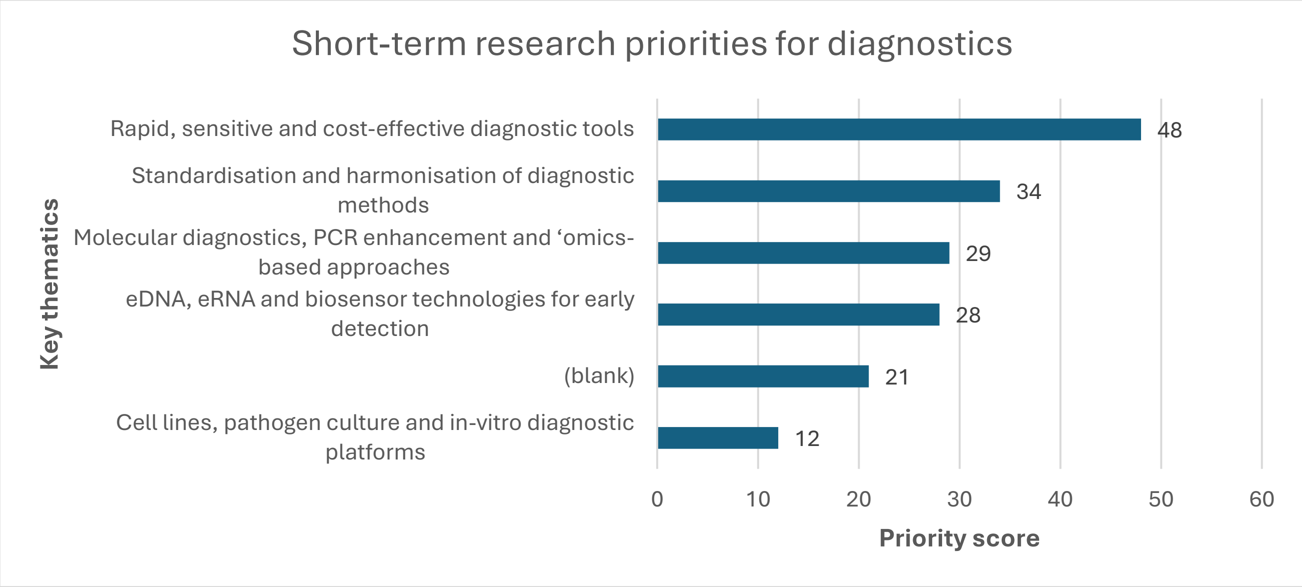
infections. Various forms of anthropogenic contamination were listed, e.g., heavy metals, pesticides, and wastewater. Collectively, they ranked 7th in the list of causes of disease (not shown).

- Stakeholders working with abalone, oysters and mussels — particularly in high-value niche markets — raised concerns about marine water quality, environmental AMR, and the impact of invasive species and climate change on long-term sustainability.
- In addition to diseases of molluscs, human diseases associated with mollusc consumption were listed, including amnesic shellfish poisoning, diarrhoeaic shellfish poisoning, paralytic shellfish poisoning, and disease due to norovirus. These diseases are caused by concentration of algae, toxins or viruses in filter feeding shellfish.
- A critical perspective warned that focusing solely on pathogens risks oversimplifying disease as a Host–Pathogen issue, whereas environmental degradation and anthropogenic impacts can also be important drivers of disease expression in molluscs.

"Marine water quality and aquatic environmental AMR increasingly have begun to raise concern for long-term sustainability."
(Anonymised quote from comments)

Diagnostic research needs

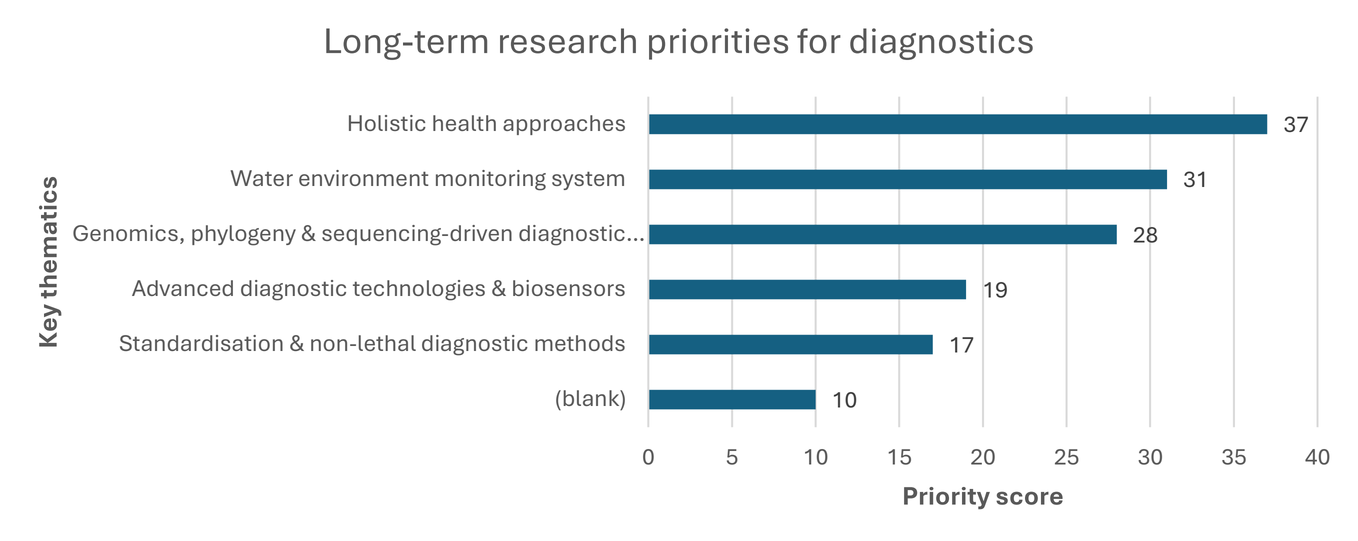
Q27: What are the short-term (within 5 years) research priorities for diagnostics, including applications to emerging disease detection, and determination of infection at the individual animal and population levels?



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

Diagnostics: Summary of short-term research priorities from top 5 key trends
1. Rapid, sensitive and cost-effective diagnostic tools (Score: 48)
• Develop cost-effective field diagnostic kits for both health and welfare indicators. • Assays for new and emerging pathogens (e.g., *Vibrio* spp., *Francisella halioticida*, Haplosporidia). • Improve sensitivity and specificity of existing diagnostic assays. • Low-cost point-of-care tools and sensors for water, oysters and contaminants. • Rapid testing innovations, including AI-enhanced tests. • Rapid and economic pooling strategies for HaHV-1 PCR. • Tank-side HaHV-1 diagnostics.
2. Standardisation and harmonisation of diagnostic methods (Score: 34)
• Develop standardised diagnostic methods and case definitions. • Improve validated diagnostic protocols for mollusc diseases. • Harmonise approaches for epidemiology and disease surveillance. • Improve surveillance of intermediate hosts and transmission pathways. • Develop non-lethal diagnostic methods for bivalve health assessment. • Integrate One Health principles (pollution, environmental health, zoonoses).
3. Molecular diagnostics, PCR enhancement and 'omics-based approaches (Score: 29)
• Application of ‘omics tools for disease investigation and emergence analysis. • Improve molecular probes, PCR sensitivity and assay performance. • Genome sequencing of pathogens to support diagnostic tool design. • Expand capacity for PCR diagnostics, including environmental PCR. • Use of whole-genome sequencing for epidemiology and pathogen characterisation.
4. eDNA, eRNA and biosensor technologies for early detection (Score: 28)
• Sensors for contaminants and multipathogen screening in water and oysters. • Develop eDNA/eRNA tools for pathogen detection and reporting. • eDNA tools for herpesvirus surveillance. • Marine biosensors for early detection in eDNA/eRNA. • Use of environmental PCR and viral load sensors. • Water environment monitoring linked to disease early warning.
5. Cell lines, pathogen culture and in-vitro diagnostic platforms (Score: 12)
• Develop of mollusc-derived cell lines for pathogen research and diagnostic validation. • Enhance virus culture capacity to support test development.

Q28: 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?



Diagnostics: Summary of long-term research priorities from top 5 key trends
1. Holistic health approaches (Score: 37)
• Develop "holistic health" toolkits integrating environmental, host, and pathogen indicators. • Assess climate change and pollution impacts on pathogen distribution. • Evaluate environmental and Blue Economy–related changes affecting water quality and disease expression. • Identify non-pathogen contributors to disease expression. • Integrate One Health principles into diagnostic frameworks. • Strengthen public health and animal feed-safety diagnostic linkages. • Improve understanding of pathobiotic mechanisms and how they can be detected and mitigated. • Incorporate environmental and anthropogenic factors that contribute to disease expression, overly pathogen-centric framing of disease.
2. Water environment monitoring systems (Score: 31)
• Assess pathogen diversity in coastal and estuarine environments. • Expand use of eDNA/eRNA for environmental surveillance. • Characterise environmental parameters that favour disease emergence. • Develop indicators of environmental health relevant to disease risk. • Identify pathogen reservoirs and vector pathways in natural ecosystems. • Implement advanced water-environment monitoring systems and software solutions.
3. Genomics, phylogeny & sequencing-driven diagnostic innovation (Score: 28)
• Genomic characterisation of isolates and strain virulence. • Improve molecular probes for high-resolution pathogen detection. • Develop nanopore sequencing and other real-time platforms for diagnostics. • Generate phylogenetic data for non-pathogenic relatives to improve specificity. • Use sequencing to enhance diagnostic throughput and accuracy. • Investigate bacterial coastal water evolution using genomic tools.

4. **Advanced diagnostic technologies & biosensors (Score: 19)**
• Low-cost point-of-care assays for contaminants and pathogens. • Improve microscopy and imaging-based diagnostic approaches. • Enhance AI-assisted rapid testing technologies. • Deploy sensors that enumerate viral load in water. • Expand biosensors for multipurpose water and oyster screening.
5. **Standardisation & non-lethal diagnostic methods (Score: 17)**
• Establish country-level standards for mollusc surveillance. • Improve surveillance of intermediate hosts involved in transmission. • Standardise non-lethal diagnostic methods for bivalve, particularly cockle health assessment. • Harmonise diagnostic procedures for long-term monitoring and comparison across regions.

Q29: Highlights and few quotes from comments received:

"We need to move beyond single-focus diagnostics to multi-agent and multi-factorial disease approaches."
(Anonymised quote from comments)

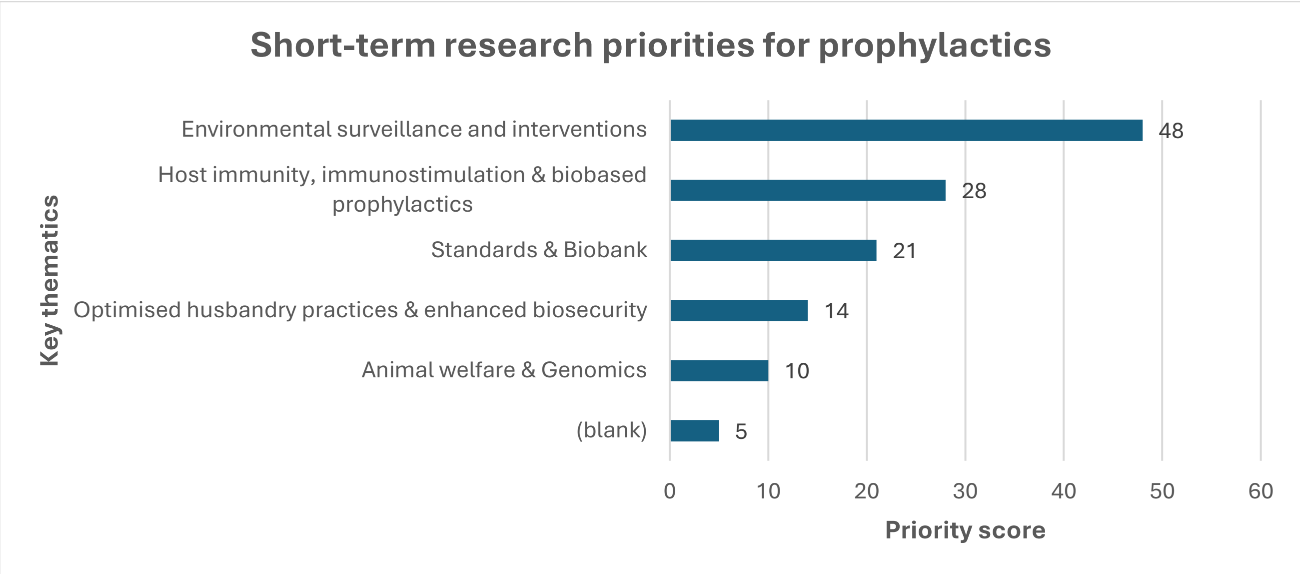
- **Need for multi-factorial and multi-agent diagnostic approaches**
  - Current diagnostics and surveillance remain too "single-pathogen" focused.
  - There is a need to **incorporate multi-agent, multi-factorial, and ecosystem-based** disease drivers.
  - Policy and legislation must adapt to support integrated, complex diagnostic frameworks.
- **Environmental degradation as a major driver of disease emergence**
  - Disease expression in molluscs is strongly linked to pollution, chemical contaminants (PFAS, PBDE, pesticides, plastics), and degraded ecosystems.
  - Identifying and correcting degraded environmental conditions is essential for disease prevention.
  - Current global standards (including WOAH) insufficiently address environmental causes of disease.
- **Importance of non-commercial and ecological roles of molluscs**
  - In some countries, molluscs are not farmed or eaten, but act as:
    - vectors of fish pathogens,
    - sources of occupational zoonotic risk, and
    - ingredients for animal feeds.
  - Diagnostics must therefore serve ecosystem, public health, and feed-safety purposes, not only aquaculture.
- **Climate change and coastal activities are altering pathogen dynamics**
  - Changing coastal environments and rising temperatures are modifying bacterial communities, especially Vibrionaceae.
  - New *Vibrio* strains threaten larval survival and enter facilities via broodstock.
  - Surveillance must adapt to detect emerging and evolving pathogens.
- **Economic and capacity challenges for producers, especially in Africa**
  - Mollusc species traded internationally (i.e. oysters, mussels and abalone) face strict SPS standards, but LMIC producers struggle with the cost of compliance.
  - There is a need for cost-effective diagnostics, local laboratory capacity, and affordable certification systems.

- Histopathology is crucial for the diagnosis and treatment of shellfish diseases but remains a significant gap, lacking skilled personnel and standardized protocols.
- Additional concerns include zoonotic and feed-safety risks in freshwater snail farming.

"For LMIC producers, the challenge is the cost of meeting SPS standards—hence the need for cost-effective diagnostics and local lab capacity."

Prophylactics

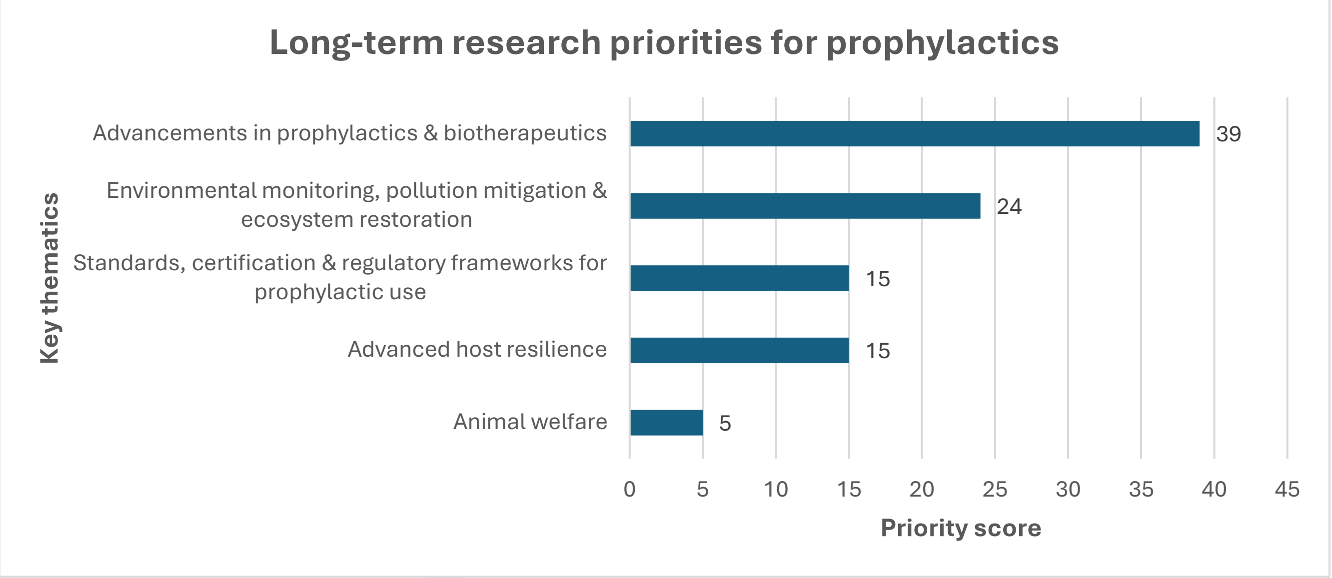
Q 30: What are the short-term (within 5 years) research priorities for development and optimal use of prophylactics?



Prophylactics: Summary of short-term research priorities from top 5 key trends
1. Environmental surveillance and interventions (Score: 48)
• Conduct environmental assessments directly linked to disease risk. • Deploy real-time environmental sensors (algal assemblages, contaminants, water quality parameters). • Expand water environment monitoring programmes. • Strengthen pathogen and vector surveillance, including *Vibrionaceae* monitoring in coastal waters. • Develop environmental microbiome interventions to reduce disease pressure. • Address pollution and ecosystem degradation as root causes of disease emergence. • Collect baseline data on blood cockle diseases. • Implement biomonitoring of wild species to support early warning systems.

2.	**Host immunity, immunostimulation & biobased prophylactics (Score: 28)**
•	Advance immunostimulation approaches for disease prevention.
•	Improve understanding of immunopriming mechanisms in shellfish.
•	Overcome barriers in prophylactic development (e.g., limited success of herpesvirus vaccines in haliotids).
•	Develop phage therapy applications for mollusc pathogens.
•	Enhance targeted use of probiotics and nutrition-based immune support.
•	Expand general therapeutant development for molluscs.
3.	**Standards & Biobank (Score: 21)**
•	Strengthen access to reference materials through biobanks.
•	Improve methods for monitoring blood cockle health status.
•	Advance research on effective quarantine measures for animal movements.
•	Develop species-specific standards for disease-freedom certification.
•	Support zoning applications with harmonised diagnostic and regulatory standards.
4.	**Optimised husbandry practices & enhanced biosecurity (Score: 14)**
•	Develop improved methods for blood cockle culture management.
•	Enhance biosecurity practices in marine ecosystems.
•	Strengthen hatchery management practices to support prophylactic uptake.
5.	**Animal welfare & Genomics (Score: 10)**
•	Integrate animal welfare considerations into prophylactic deployment.
•	Improve genomic data availability for hosts and pathogens to support precision prophylaxis.

Q31: What are the medium-long term (5-15 years) research priorities for development and optimal use of prophylactics?



Prophylactics: Summary of long-term research priorities from top 5 key trends
1. Advancements in prophylactics & biotherapeutics (Score: 39)
• Develop advanced and diversified immunostimulation strategies for long-term disease prevention. • Design new prophylactics targeting major pathogens, including *herpesviridae*. • Apply quorum sensing and quenching approaches to control pathogenic bacteria. • Expand foundational knowledge of mollusc immunity to support future prophylactic innovation. • Invest in the development of novel therapeutants and methods for preventing bivalve diseases. • Advance microbiome engineering (animal and environmental) to strengthen natural disease defences. • Further develop phage therapy and refine probiotic/nutritional prophylactic approaches.
2. Environmental monitoring, pollution mitigation & ecosystem restoration (Score: 24)
• Strengthen epidemiology of parasites and other key disease drivers. • Address root environmental causes of disease emergence, especially pollution and ecosystem degradation. • Deploy real-time environmental sensors (water quality, algal assemblages, contaminants) for predictive disease surveillance. • Improve understanding of pathogen transmission pathways to other aquatic invertebrates. • Develop advanced water environment monitoring systems and software. • Enhance long-term water quality monitoring as a foundation for disease risk reduction.
3. Advanced host resilience (Score: 15)
• Use selective breeding programmes to enhance long-term disease resistance. • Explore the potential of genetic modification for durable host resilience. • Strengthen hatchery capacity to reliably produce high-quality, disease-resilient seed. • Advance understanding of transgenerational resistance mechanisms in molluscs.
4. Standards, certification & regulatory frameworks for prophylactic use (Score: 15)
• Establish improved international standards for identifying and correcting degraded environmental conditions. • Promote regulatory action on pollutants (PFAS, PBDE, pesticides, plastics) that drive disease emergence. • Define standards for mollusc seed quality relevant to prophylactic effectiveness. • Study and validate evidence-based criteria for risk zoning and certification frameworks to support biosecure production systems and the safe movement of aquatic animals.
5. Animal welfare (Score: 5)
• Integrate animal welfare principles into long-term prophylactic disease strategies.

Q 32: Do you anticipate any regulatory or technical or social/economic challenges in developing/using new prophylactics? If yes, please specify the issue.

Highlights and few quotes from responses received:

"Vaccines won't work if host immunity is compromised. The rising water pollutant loading, reduces host resilience. The root cause of disease induction needs to be addressed directly."

(Anonymised quote from comments)

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1. **Environmental and ecosystem constraints**
- Pollution, contaminants, and poor water quality may undermine vaccine or prophylactic effectiveness by compromising host immunity.
- Environmental AMR (antimicrobial resistance) in aquatic systems could pose risks for food safety, market access, and regulatory compliance.
- Prophylactics will be limited in effectiveness if root causes of disease (e.g., environmental degradation) are not addressed.

2. **Technical and biological challenges**
- No current vaccines for molluscs, reflecting inherent biological constraints and technical difficulty.
- Unknown risks of immunopriming in molluscs require further investigation.
- Possible challenges in intersections with therapeutants important for human medicine (e.g., regulatory scrutiny, shared compounds).

3. **Regulatory challenges**
- GMO-related concerns for prophylactics delivered via feeds or engineered microbes.
- Increasing scrutiny on environmental safety and residues affecting market access, food safety, and export requirements.

4. **Economic and social considerations**
- Pollution-linked declines in host resilience may reduce farm productivity, affecting economic viability and returns.
- Regulatory restrictions tied to water quality or human health therapeutants may impose additional costs or constraints on producers.

"GMO issues with prophylaxis in feed." (Anonymised quote from comments)

Q33: Highlights and few quotes from comments received:

"Blood cockle farming relies on wild seed with no regulation on harvest limits."
(Anonymised quote from comments)

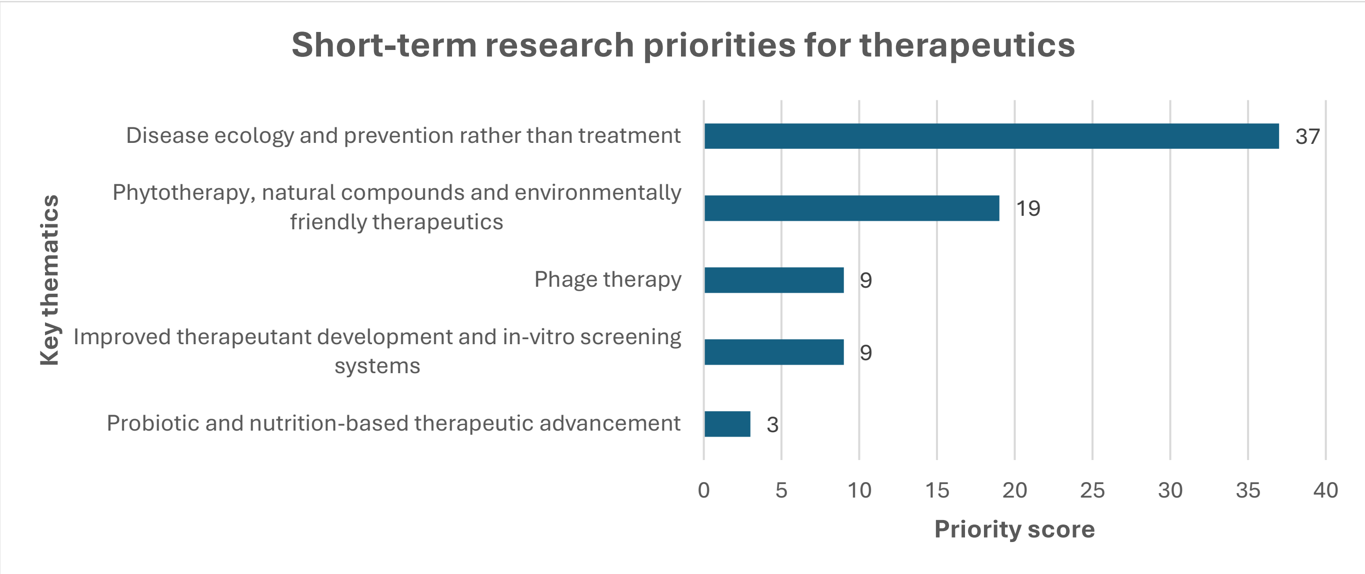
- Wild seed harvesting for blood cockle farming is unregulated, posing risks to natural population recruitment and long-term sustainability. Although no major disease outbreaks have occurred yet, there is a need for caution and for learning from past failures in other sectors (e.g., shrimp farming in the 1980s).
- Marine mollusc aquaculture is still limited in some regions, and there are no specific regulations governing mollusc farming practices.
- In the short to medium-term, priority actions include:
  - Supporting the development of the marine mollusc sector.
  - Establishing and maintaining optimal aquatic environmental standards in farming areas.
  - Reducing the costs of certification, including diagnostic and laboratory services, to enable market access and trade.

"We need to be cautious and learn our lesson from what happened to shrimp farming in the 1980's"

(Anonymised quote from comments)

Therapeutics

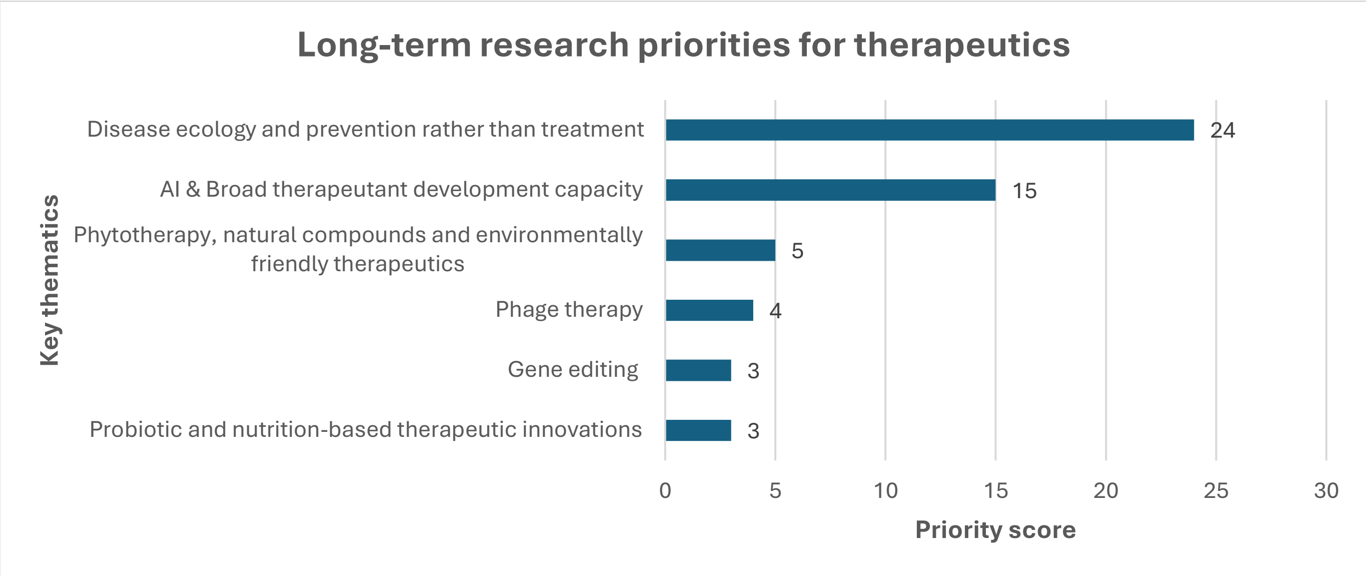
Q34: What are the short-term (within 5 years) research priorities for therapeutics (e.g. antimicrobials or alternatives to antimicrobials)?



Therapeutics: Summary of short-term research priorities from top 5 key trends
1. Disease ecology and prevention rather than treatment (Score: 37)
• For some respondents the need for therapeutics is minimal or not applicable in current systems. • Improve understanding of disease ecology to identify factors that increase or reduce pathogen loading. • Develop strategies to manipulate environmental or husbandry conditions to avoid disease induction. • Consider the feasibility and role of mollusc vaccines (noting current limits). • Integrate zoning management to reduce pathogen spread.
2. Phytotherapy, natural compounds & environmentally friendly therapeutics (Score: 19)
• Evaluate plant-based and herbal compounds for disease control. • Apply phytotherapy to manage pathogenic *Vibrio* strains. • Develop environmentally friendly therapeutic compounds suitable for molluscs. • Explore low-impact natural treatments aligned with ecosystem-based management.
3. Improved therapeutant development & in-vitro screening systems (Score: 9)
• Develop in-vitro systems to study immune responses and screen potential therapeutics. • Expand general therapeutant development tailored to mollusc physiology and production systems.

4.	**Phage therapy (Score: 9)**
•	Investigate phage therapy to reduce antimicrobial use.
•	Develop phage-based tools for targeted control of bacterial pathogens.
5.	**Probiotic and nutrition-based therapeutic advancement (Score: 3)**
•	Enhance probiotic and nutrition-based approaches to strengthen host resilience and reduce disease pressure.

Q 35: What are the medium-long term (5-15 years) research priorities for therapeutics (e.g. antimicrobials or alternatives to antimicrobials)?



Therapeutics: Summary of long-term research priorities from top 5 key trends	
1.	**Disease ecology and prevention rather than treatment (Score: 24)**
•	Strengthen understanding of disease ecology to identify factors that increase or reduce pathogen loading.
•	Develop strategies to manipulate environmental and husbandry conditions to avoid disease induction.
•	Assess long-term feasibility of vaccines for molluscs within ecological prevention frameworks.
2.	**AI-assisted and broad therapeutant development capacity (Score: 15)**
•	Apply artificial intelligence to accelerate discovery, optimisation and assessment of therapeutic options.
•	Build long-term capacity for therapeutant development tailored to mollusc species.
•	Improve understanding of pathogen drug resistance to guide future therapeutic innovation.
•	Integrate AI-based predictive tools into future disease management and treatment design.
3.	**Phytotherapy, natural compounds & environmentally friendly therapeutics (Score: 5)**
•	Advance research on plant-based and herbal compounds as sustainable alternatives to antimicrobials.
•	Explore environmentally friendly therapeutic molecules suited for long-term, low-impact aquaculture.
•	Control pathogenic *Vibrio* strains through phytotherapy and natural bioactive agents.
4.	**Phage therapy (Score: 4)**
•	Develop phage-based solutions for long-term pathogen control as alternatives to antibiotics.
•	Refine targeted phage therapy approaches suitable for mollusc production environments.

5.	**Probiotic and nutrition-based therapeutic innovations (Score: 3)**
•	Strengthen the development of probiotic and nutrition-based strategies to enhance long-term resilience.
•	Integrate host–microbiome research into next-generation therapeutics.
6.	**Gene editing and advanced genomic tools (Score: 3)**
•	Investigate gene editing as a long-term option for improving disease resistance and reducing therapeutic needs (including ethical, regulatory and technical frameworks required for future application).

Q36: 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.

Highlights and few quotes from responses received:

"Phytotherapy is not without risk, particularly for production intended for human consumption."
(Anonymised quote from comments)

- Unclear legal status of phage therapy: regulatory frameworks do not yet define how phages should be classified, approved, or prescribed for aquaculture use.
- Phytotherapy lacks regulatory clarity: herbal and plant-based treatments is not without risks for food safety, animal health, and antimicrobial resistance (AMR), and there is currently no clear legal framework governing their use or monitoring adverse effects.
- Potential conflicts with human medicine: challenges arise when therapeutants overlap with substances considered essential or restricted for human health, creating regulatory barriers.

"What will be the legal status of phages when applied as therapy?" (Anonymised quote from comments)

Q37: Highlights and few quotes from comments received:

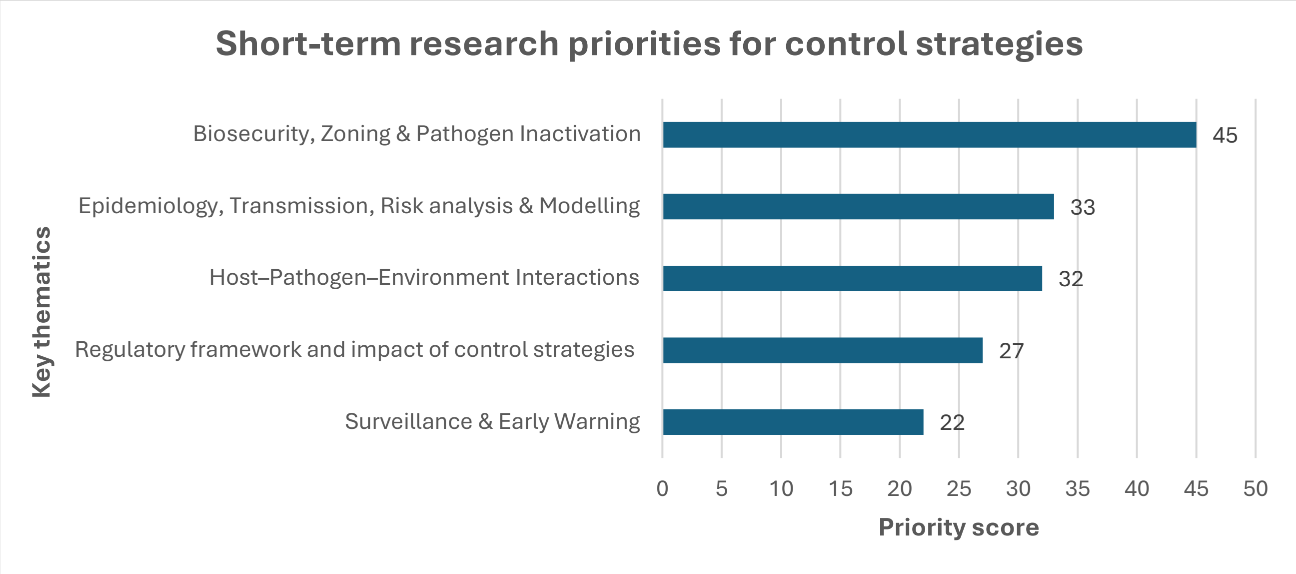
"Only two antibiotics are licensed… their repeated application represents a risk in terms of AMR occurrence."
(Anonymised quote from comments)

- Prioritise prevention-focused approaches over treatment-focused ones.
- Environmental and climate change are likely to drive future shifts in disease risk, especially in aquatic systems.
- In inland freshwater areas, bilharzia (schistosomiasis) poses a significant public health concern linked to mollusc hosts.
- There is little to no use of therapeutics in some mollusc farming systems due to the small scale of the sector, or for lack of practical application routes in open-water farming.
- In some contexts only two antibiotics are currently licensed for controlling larval shellfish mortality and repeated antibiotic use increases AMR risk, highlighting the need for alternative approaches.
- Non-antimicrobial solutions — such as improved broodstock disinfection, hatchery biosecurity, and alternative treatments for larval mortality — should be prioritised.

"Limited to no use of therapeutics in mollusc farms in my country."
(Anonymised quote from comments)

Control strategies

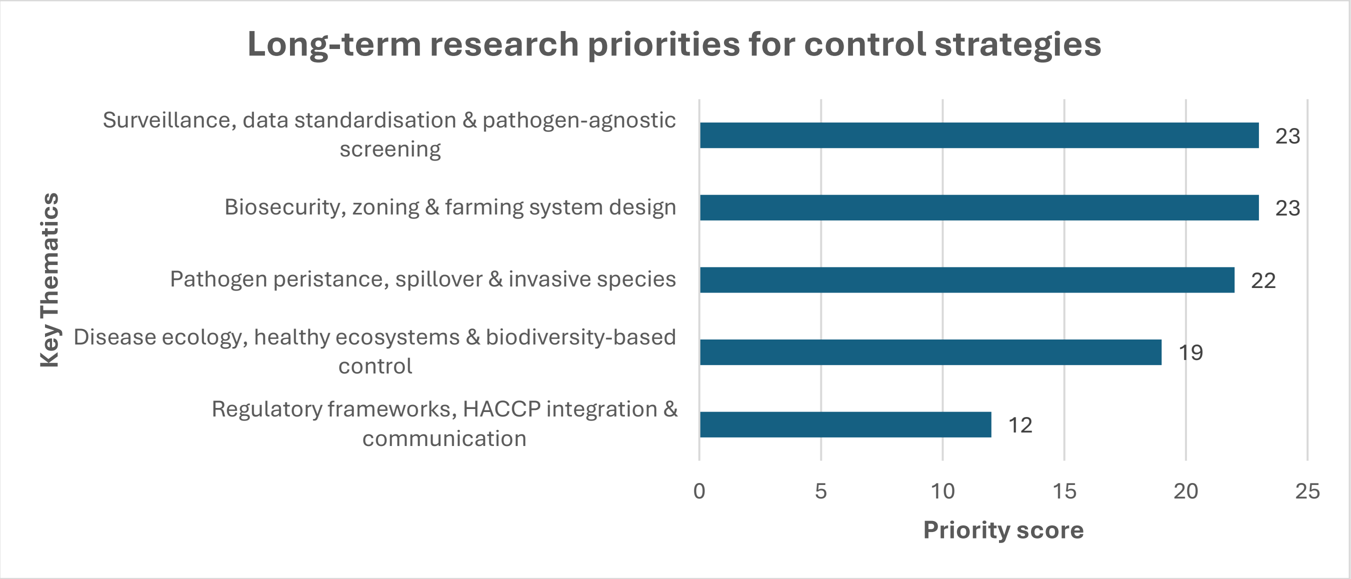
Q38: What are the short-term (within 5 years) research priorities for optimizing or implementing control strategies?



Control strategies: Summary of short-term research priorities from top 5 key trends
1. Biosecurity, Zoning & Pathogen Inactivation (Score: 45)
• Generate evidence to define optimal biosecurity and zoning models for diverse mollusc production systems. • Advance research on pathogen inactivation techniques (heat, UV, chemicals, freshwater), including comparative efficacy across species and environmental conditions. • Conduct a systematic review and experimental validation of disinfection methods for all WOAH-listed pathogens in molluscs. • Improve control of asymptomatic pathogen carriage, especially in broodstock and larval production. • Strengthen systematic epidemiological investigation methods (field studies, outbreak investigations, longitudinal studies) to identify critical ecological and operational drivers of pathogen persistence, introduction, and spread, and to inform evidence-based biosecurity and zoning measures. • Improve biosecurity strategies and its acceptability in commercial catch sectors. • Progress mitigation measures of existing and new pathogens. • Investigate quarantine effectiveness and failure points during animal movements. • Identify biological and environmental determinants of seed quality and their relation to disease susceptibility. • Develop models and indicators for predicting spread under different zoning scenarios.
2. Epidemiology, Transmission, Risk Analysis & Modelling (Score: 33)
• Advance AI and generative AI tools for real-time risk prediction, epidemiological modelling, and outcomes forecasting. • Identify drivers of disease introduction and spread, particularly those linked to environmental and climatic variability. • Evaluate how different production intensities or system designs influence pathogen amplification and outbreak probability. • Develop spatial risk models integrating hydrodynamic, climatic, and anthropogenic factors. • Generate evidence to refine risk-based surveillance frameworks, including sampling intensity and detection thresholds. • Investigate transmission pathways for aquatic AMR, including environmental reservoirs and interspecies transfer.
3. Host–Pathogen–Environment Interactions (Score : 32)
• Assess the impact of climate change variables (temperature, salinity, extreme events) on pathogen emergence and host susceptibility. • Investigate environmental determinants of Vibrionaceae and other waterborne pathogens in coastal ecosystems. • Characterise life cycles, intermediate hosts, and environmental triggers of key mollusc pathogens such as *Haplosporidium nelsoni*. • Study how biodiversity influence disease resilience in mollusc ecosystems. • Conduct research on susceptible species, vectors, and co-occurring hosts to understand cross-species transmission potential. • Analyse wildlife reservoirs and quantify their role in pathogen persistence and spillover. • Map and model vector and pathogen cycles in aquatic systems. • Advance ecological research on how farming practices, pollution, and nutrient loading alter disease dynamics, and identify potential ecological remediation strategies.

4.	**Regulatory Framework & Impact of Control Strategies (Score: 27)**
	• Conduct impact assessments to determine which regulatory measures most effectively reduce disease risk (e.g., closures, movement restrictions). • Develop evidence-based guidance for risk-based surveillance, zoning, and movement control strategies. • Analyse current regulatory gaps that limit control of priority mollusc diseases. • Characterise genetic resistance mechanisms in molluscs to support industry post outbreaks and prevent further outbreaks. • Develop efficient communication systems. • Undertake socio-environmental research to evaluate regulatory needs for managing pollution, eutrophication, and acidification as drivers of aquatic disease. • Investigate the epidemiology and burden of zoonotic risks associated with mollusc pathogens to inform cross-sector governance.
5.	**Surveillance & Early Warning (Score 22)**
	• Develop early detection systems for detecting pathogens in traded mollusc batches. • Study disease risks associated with seed and broodstock movement, developing evidence to inform certification schemes. • Advance research on diagnostics for emerging diseases. • Improve sensitivity of detection methods for covert infections. • Evaluate and optimise water monitoring programs. • Integrate environmental, climatic, and ecological data into predictive early-warning models.

Q39: 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 from top 5 key trends
1. Surveillance, data standardisation & pathogen-agnostic screening (Score: 23)
• Expand water environment monitoring programmes. • Develop pathogen-agnostic screening tools and surveillance systems able to detect multiple co-occurring pathogens. • Strengthen coordinated data standardisation, collection, sharing and analysis. • Use AI and generative AI to improve early-warning systems, pattern detection and decision-support in disease control.
2. Biosecurity, zoning & farming system design (Score: 23)
• Refine and implement biosecurity control and zoning strategies to limit pathogen spread between farms and wild populations. • Design and adapt aquaculture systems and production intensity to local environmental conditions. • Improve reproductive management and insemination practices to reduce disease risk. • Enhance seed quality and movement controls as key elements of biosecure production.
3. Pathogen persistence, spillover & invasive species (Score: 22)
• Study persistence of mollusc parasites in the environment, particularly where life cycles and reservoirs are poorly known (e.g. *P. marinus*). • Improve knowledge of wildlife diseases and real or potential spillover into farmed molluscs. • Characterise pathogen profiles in invasive species acting as potential “Trojan horses”. • Understand how different production types (bottom, suspended, surface culture) influence disease expression and risk. • Drivers of zoonotic emergence and risk-reduction strategies.
4. Disease ecology, healthy ecosystems & biodiversity-based control (Score: 19)
• Assess effects of warming waters, seasonality and climate change on pathogen distribution and prevalence (e.g. *P. marinus*, *H. nelsoni*). • Develop and apply environmental indicators, including for aquatic AMR risks and maximum residue limits (MRLs). • Investigate how increased biodiversity and ecosystem health can enhance mollusc resilience and reduce disease. • Shift from treatment to ecology-based control, including waste remediation and reduced reliance on synthetic fertilisers and pesticides. • Develop targeted control measures and advocacy to address water pollution from all sources (acidification, eutrophication, chemical contaminants).
5. Regulatory frameworks, HACCP integration & communication (Score: 12)
• Clarify and strengthen the role of mollusc disease hazards within HACCP plans and food-safety systems. • Enhance regulatory frameworks governing pollution, disease control and movement of animals and products. • Unify and streamline communication between regulators, producers, laboratories and other stakeholders to support effective implementation of control strategies.

Q40: Highlights from comments received:

"One would need to understand factors influencing the presence of pathogens in relation to the occurrence and spread of aquatic animal diseases, zoonotics, AMR and the bioaccumulation of pollutants."
(Anonymised quote from comments)

- Absence of sector-specific control systems: In some regions, marine mollusc aquaculture is still very limited, and no dedicated regulatory frameworks for mollusc culture are yet established.
- Hatchery biosecurity weaknesses: Many bacterial pathogens in shellfish hatcheries are introduced via incoming broodstock/spawners. External shell disinfection can be effective. Internal disinfection protocols remain inadequate, and improved, validated methods are urgently needed.
- Need for systematic epidemiological investigation methods: Understanding pathogen presence, disease occurrence, zoonotic risks, AMR, and pollutant bioaccumulation requires integrated epidemiological and ecological approaches capable of identifying causal relationships and critical control points.
- Need to understand wider risk factors: Effective control strategies require stronger insight into factors influencing pathogen presence and spread, including: aquatic animal diseases, zoonotic risks, antimicrobial resistance (AMR), bioaccumulation of pollutants such as pesticides and heavy metals.
  These risks are particularly important where molluscs are used as feed ingredients or natural food sources for farmed and wild aquatic species.

"Most bacterial pathogens in shellfish hatcheries are introduced with spawners… external disinfection is mastered, but internal disinfection is not controlled correctly and adequate protocols must be identified."
(Anonymised quote from comments)