Food and Agriculture Organization of the United Nations

UN environment programme

World Health Organization

World Organisation for Animal Health
Founded as OIE

Quadripartite One Health Intelligence Scoping Study

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Final Report

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Abbreviations and acronyms

AMR	antimicrobial resistance
API	application programming interface
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
FAIR	findable, accessible, interoperable and reusable
FAO	Food and Agriculture Organization of the United Nations
GLEWS+	Joint FAO/WHO/WOAH Global Early Warning System for health threats and emerging risks at the human–animal–ecosystems interface
OHISS	One Health Intelligence Scoping Study
OHIS	One Health intelligence system
UNEP	United Nations Environment Programme
WHO	World Health Organization
WOAH	World Organisation for Animal Health (founded as OIE)

Glossary

All terms and definitions below are working definitions used in the context of the One Health Intelligence Scoping Study (OHISS) only and may be used differently elsewhere, including in other publications by FAO, UNEP, WHO and WOAH.

Application	An application program (application or app for short) is a computer program designed to carry out a specific function directly for an end user or, in some cases, for another application.
Data	A set of values of qualitative or quantitative variables about one or more persons, objects or activities.
Data harmonization	All efforts to combine data from different sources and provide users with a comparable view of data from different studies.
Dataset	A collection of data available for access or download in one or more representations.
Digitization	The process of converting something to digital form. For example, disease events used to be notified via written letters, but this is now digitized to be sent via email or through an online notification system.
Digitalization	The process of transformation of digital data. More than just making existing data digital (see digitization above), digitalization embraces the ability of digital technology to collect data, establish trends and make better business decisions. Trend analyses of disease reports would be an example.
Early warning	The provision of early and relevant information on potential or actual disasters and their impacts.[1]
Hazard	A process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption, or environmental degradation (United Nations Office for Disaster Risk Reduction, 2020).

[1] See www.fao.org/3/x6871e/x6871e01.htm.

Information system	A system designed to collect, process, store and distribute information. In this report, it is used interchangeably with *digital information system*, a specific type of information system that integrates software and hardware to enable communication and collaborative work.
Intelligence	The ability to read and respond effectively to a situation through insights and evidence. The process of intelligence is meant to provide a decision-advantage.
Interoperability	The ability of computer systems or software to exchange and make use of information. *Structural or syntactic interoperability* refers to the format of data exchange. *Semantic interoperability* is concerned with ensuring the integrity and meaning of the data across systems.
Metadata	Data about data. In this document, the term is used to refer specifically to data about a dataset or data source.
Minimum dataset	The minimum critical data values needed to execute a specific analysis or run a specific application to produce a specified output.
One Health	An integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals and ecosystems. One Health recognizes that the health of humans, domestic and wild animals, plants, and the wider environment are closely linked and interdependent. Definition adopted from the One Health High-Level Expert Panel (2021).
Open source	Open source software is computer software that is released under a licence by which the copyright holder grants users the rights to use, study, change and distribute the software and its source code to anyone and for any purpose.
Pandemic Hub	World Health Organization Hub for Pandemic and Epidemic Intelligence.
Primary data	Direct measurements of occurrence of an adverse event (for instance, disease cases) in a given population.

Quadripartite	A partnership between the Food and Agriculture Organization of the United Nations, the United Nations Environment Programme, the World Health Organization and the World Organisation for Animal Health as formalized by the *Quadripartite Memorandum of Understanding (MoU) signed for a new era of One Health collaboration.*[2]
Risk	The likelihood of the occurrence and the likely magnitude of the consequences of an adverse event during a specified period.
Riskscape	A description of the risk landscape within a certain scope, including various components and how they relate to each other, such as hazards and their associated adverse events; drivers, causes or sources of the hazard; immediate and long-term direct and indirect impacts, control measures and vulnerabilities in control measures; and critical monitoring points.
Secondary data	Secondary or *contextual* data is used to refer to indirect indicators (or indices) of health (such as vaccination coverages) or indicators used to assess disease emergence risks (for instance, measures of deforestation or livestock density). This can go as far as including data on capacity or vulnerability of specific sectors (for example, health sector or veterinary capacity).
Structured data	Any set of data that is organized and structured in a particular way. Structured data fit into predefined models and formats, allowing applications to understand them.
Surveillance	The continuous, systematic collection, analysis and interpretation of health-related data (Hoinville *et al.*, 2013).
Threat	A hazard, agent, event, concern or issue that poses risks to human, animal, plant or ecosystem health.
Unstructured data	Data that do not have any predefined model. These are usually qualitative data, such as free-text or images. Unstructured data can be very complex and require a lot of storage space.

[2] See www.unep.org/resources/publication/quadripartite-memorandum-understanding-mou-signed-new-era-one-health.

Executive summary

Global health security is under increasing threat from emerging infectious diseases and the impacts of environmental change. Intelligence systems must be able to predict, prevent and reduce the risk of ongoing and emerging threats using an integrated "One Health" approach to optimize the health of humans, animals, plants and ecosystems. Strengthening global One Health intelligence will support the identification and mitigation of risks to global health security.

In June 2021, the G7 Carbis Bay Health Summit requested that the Quadripartite partnership[3] of the Food and Agriculture Organization of the United Nations, the United Nations Environment Programme, the World Health Organization and the World Organisation for Animal Health conduct the One Health Intelligence Scoping Study (OHISS) "to identify potential opportunities for improved technical harmonization of their and other prioritized systems to strengthen One Health intelligence". The OHISS was funded by the United Kingdom of Great Britain and Northern Ireland and coordinated by the Food and Agriculture Organization of the United Nations, as the lead agency for the project. The scoping study was completed at the end of July 2022.

The following foundational activities were carried out to assess needs and opportunities within and outside the Quadripartite partners:

- An extensive literature review, which highlighted that One Health has a broad scope, and that to be effective, a One Health intelligence system (OHIS) must be adaptable to the needs of multiple users and to the risk questions they must address.
- Engagement with international experts and diverse stakeholders through two main advisory group meetings, as well as a number of individual meetings with other relevant One Health initiatives and expert groups to collect feedback on the study's activities and findings.
- A review of national critical competencies and "best practice" case studies using expert workshops, established international networks and a survey. National systems were recognized as being highly variable in capacity, coverage, reliability and transparency.
- An assessment of Quadripartite activities and prioritized information systems selected according to their potential to contribute to One Health intelligence. The range and diversity of the activities identified provides an excellent foundation for global One Health intelligence.
- A hazard identification exercise (riskscaping) with the Quadripartite to define One Health scope and priorities. For the priority hazards identified, a series of workshops were conducted with international experts to assess the "risk landscape" (riskscape). These workshops identified and prioritized multiple potential monitoring points, and highlighted needs for collaboration and risk communication.

The combined findings from these activities, summarized in this report, highlighted that the numerous international and national information systems collect a wide range of data relevant to One Health, but these are not being used enough for effective risk assessment and early warning. The study also

[3] At the time, the alliance was referred to as "the Tripartite and UNEP".

demonstrated that the incorporation of data from the environmental sector has significant potential to identify risk "hotspots", which can be monitored for early detection and targeted with risk reduction intervention.

The key recommendation of the OHISS is that immediate actions are taken to develop a global OHIS

The global OHIS would establish a framework to link, strengthen and further develop One Health intelligence activities, and would be led by the Quadripartite organizations.

To tackle the complexity of the One Health intelligence goals, we propose a modular approach to developing the global OHIS, working successively on use cases and expanding the framework progressively. After a use case is selected, existing related information-sharing mechanisms should be improved and scenario-based applications added. The proposed modular architecture is flexible, so that the system can adjust to changing stakeholder needs, ensuring that it is viable over the long term. It can also connect with complementary initiatives, such as the World Health Organization Hub for Pandemic and Epidemic Intelligence.

The proposed strategy for the development of a global OHIS is based on first supporting and strengthening current One Health intelligence coordination, then building on this foundation to expand and improve global One Health. Each cycle of development would leverage a specific use case prioritized from current One Health intelligence activities within the Quadripartite. These use cases would provide the operational model for gathering, collating and analysing existing information to produce One Health intelligence for specific use case objectives.

These needs-based, operationally focused cycles of development need to happen within an overarching framework that includes system hosting and maintenance. Quadripartite organizations are urged to jointly decide on a governance and stewardship model to start development of the global OHIS. The development of a global OHIS supports the One Health Joint Plan of Action (One Health Quadripartite, 2022), contributing in particular to the delivery of Pathway 3: Data, evidence and knowledge, which will have a cross-cutting impact across all areas. A Quadripartite-led approach to global One Health intelligence will help to reduce the threats to global health security posed by risks across the One Health spectrum, including environmental changes.

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Introduction

The **Quadripartite**[1] partners – the Food and Agriculture Organization of the United Nations (FAO), the United Nations Environment Programme (UNEP), the World Health Organization (WHO) and the World Organisation for Animal Health (WOAH, founded as OIE) – operate under the mandate of their members to perform global surveillance and intelligence activities. Working collaboratively, these partners have advocated and provided guidance on complex issues to promote effective, intersectoral collaboration at the local, national, regional and global levels. Work across the boundaries of each organization to improve decision-making and support national and global stakeholders with suitable tools to drive One Health action is critical to achieving these goals.

The Quadripartite efforts to coordinate partner activities using a One Health approach and support their respective members has recently led to the creation of the *One Health Joint Plan of Action* (One Health Quadripartite, 2022) in coordination with the *One Health High-Level Expert Panel* (OHHLEP). The One Health Joint Plan of Action aims to support the greater implementation of One Health at the global, regional and national levels, so that the world is better able to predict, prevent, detect and respond to health threats and to improve the health of humans, animals, plants and the environment while contributing to sustainable development.

In June 2021, the G7 Carbis Bay Health Summit requested that the Quadripartite[2] conduct a **One Health Intelligence Scoping Study (OHISS) "to identify potential opportunities for improved technical harmonization of their and other prioritized systems to strengthen One Health intelligence".** The OHISS was funded by the Department of Health and Social Care of the United Kingdom of Great Britain and Northern Ireland and coordinated by FAO, as the lead agency for the project. The scoping study was completed at the end of July 2022.

The threat to global health security and the need for a One Health approach

The severe acute respiratory syndrome coronavirus (SARS-CoV-2), "COVID-19", pandemic has highlighted the critical need for improved early detection, risk assessment and warning of events that may have epidemic and/or pandemic potential. Global health systems must be able to predict, prevent and reduce the risk of ongoing and emerging threats to the health of humans, animals, plants and ecosystems; generate early signals in case of occurrence of such threats; and have the capacity and capability to respond quickly, effectively and in coordination to mitigate their impact. One Health systems should also be able to monitor and support the intersectoral control of zoonoses, that is diseases transmissible from animals to humans, identifying risk pathways of transmission between animals, both wild and domesticated, and people. Including information from the environmental sector increases the likelihood and sensitivity of detecting emerging risks to health and well-being, and must be incorporated into One Health systems.

[1] See www.unep.org/resources/publication/quadripartite-memorandum-understanding-mou-signed-new-era-one-health

[2] At the time, the partnership was referred to as "the Tripartite and UNEP".

This report provides a synopsis of the findings and main recommendations of each of those activities, followed by a description of the main OHISS recommendations, and the suggested plan of action to develop a Quadripartite-led, global One Health intelligence system (OHIS).

The capabilities of existing human, animal and environmental health systems to identify and predict risks to global health security are limited by an over-reliance on siloed activities that collect health intelligence information pertaining to individual sectors. Addressing this limitation requires a coordinated cross-sectoral **One Health approach**.

> ***One Health*** *is defined as "an integrated, unifying approach that aims to sustainably balance and optimize the health of humans, animals, plants and ecosystems. One Health recognizes the health of humans, domestic and wild animals, plants and the wider environment (including ecosystems) are closely linked and interdependent."*
>
> *(One Health High-Level Expert Panel, 2021)*

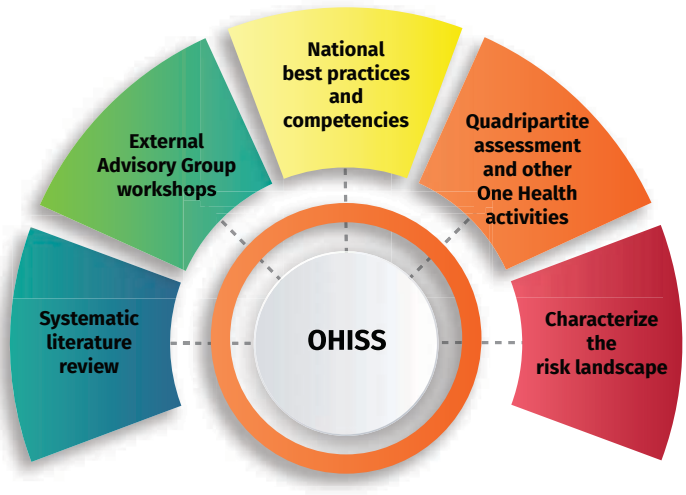
Strengthening global **One Health intelligence** is fundamental to enhancing our ability to identify and mitigate emerging diseases, reducing the impact of endemic and epidemic diseases, and addressing threats to environmental health and food security. A global One Health intelligence framework would reduce the risk that hazards at the human–animal–plant–ecosystems interface are not promptly detected, and are left unmanaged until they have already spread and caused harm, including epidemic or pandemic disease.

A Quadripartite approach to One Health intelligence

One Health intelligence requires gathering information from across the One Health landscape, including from across the human, animal, plant and environmental/ecosystem health sectors, combining and assessing their significance, and translating them into a specific decision-making context. The objectives underlying these activities to assimilate, interpret and translate information from such an array of sources vary considerably, but early warning of emerging risks to global health security and pandemic prevention are commonly considered priorities.

To identify the opportunities for such integration of One Health intelligence across the Quadripartite partners, and to provide guidance following the One Health approach, the OHISS carried out a number of foundational activities (see Figure 1).

Figure 1: Foundational activities of the One Health Intelligence Scoping Study



Source: Authors' own elaboration.

One Health intelligence systems: literature review

Cross-sectoral communication, coordination and collaboration have been used to support surveillance, intelligence, risk assessment and risk management activities for many years at the subnational, national, regional and global levels. The learnings from these systems should be considered and used to inform the development of any new OHIS, especially at a global level. The OHISS activities included different exercises to collate information from operational intersectoral intelligence systems, including a literature review, as reported in this chapter.

Objectives

The review of the published literature aimed to answer two main questions:

- What cross-sectoral or One Health intelligence systems or networks are available globally to inform early warning, rapid alert, risk assessment and ultimately risk management of One Health threats?
- What are the best practices, challenges, gaps, vulnerabilities, lessons learned and opportunities for linkages identified by these systems and networks, or by other One Health stakeholders?

Methodology

A scoping review of the literature was undertaken using the methodology for evidence synthesis described in Peters *et al.* (see Aromataris and Munn, eds, 2020). The scoping review aimed to find any publications that could contribute to answering the main questions above, respecting the following inclusion criteria: (a) the abstract was available in English; (b) the system/activity described represented at least two health sectors; (c) the primary objective of the system/activity was intelligence, surveillance or early warning; and (d) the system/activity was developed for more than one hazard.

PubMed, Web of Science and Google Scholar were searched in January 2022, with a general search strategy combining alternative terms related to "One Health", with various terms related to information and intelligence. The full terms and methodological descriptions are available as supplementary material (www.fao.org/3/cc4180en/cc4180en.pdf). Studies were screened in two stages: primary screening of the title and abstract, followed by a secondary screening based on the full text. Two or more reviewers screened references against eligibility criteria at each stage.

Results

A total of 2 157 references were screened at the first stage of review, which resulted in approval and full-text retrieval of 349 references. From those, a total of 102 references were considered eligible and included in the review. A screening flow chart is available in the supplementary material.

The search criteria employed identified a broad range of intersectoral systems/activities, including surveillance systems, data collection and visualization tools, networks of surveillance systems, information-sharing platforms, research collaborations and strategic frameworks.
The vast majority had the primary remit of zoonotic disease, food safety or antimicrobial resistance (AMR) surveillance. Very few systems identified using this methodology comprehensively and sustainably incorporated environmental or ecosystem health data.

The overall study characteristics were reviewed and tabulated for all articles. This was followed by the extraction of system details and best practices for those initiatives mentioned within articles. The complete tables of data extracted are available in the supplementary material (www.fao.org/3/cc4180en/cc4180en.pdf). The level of detail provided on these systems in the published literature varied considerably. Information available was often high-level, dependent on the context (e.g. sector, hazard, geography) and lacked details on practical aspects of the systems (e.g. cost-benefits, information technology infrastructure and data sharing agreements across sectors). Supplemental web searches (e.g. for host organizations' websites) failed to garner many additional practical details to complement details published in the literature.

The content analysis was qualitative (i.e. descriptive) in nature. Frequency counts were not included because the list of systems found in the published literature is not considered to be an exhaustive representation of existing systems.

The lessons learned in the literature review informed other OHISS activities and are summarized below.

Conclusions

The commonly described or suggested requirements and features for the effective development and operation of One Health intelligence systems, as repeated across many studies, were:

- **Buy-in:** Changing from traditional, siloed surveillance to One Health surveillance or intelligence systems has been most successfully implemented in circumstances with significant high-level support (e.g. national governmental) and engagement in the change process. Significant senior-level comprehension and buy-in to the transformation process, as well as strong monitoring and evaluation process, are important from a sustainability perspective to engage long-term support for One Health systems, especially in interepidemic periods, or in times of competing political priorities. Clearly demonstrating the value in economic and development terms, as well as in lives saved or crises averted, can provide stronger evidence for long-term investment in One Health systems.

- **Scope clarity:** The development of the OHHLEP definition of One Health, and its wider dissemination and use, help to reduce the ambiguity and variances in interpretation of the meaning of One Health. However, at a practical implementation level, an agreement of the scope of One Health and prioritization of activities/hazards in the specific circumstances or the jurisdiction under review is necessary at the development stage of any One Health system.
- **Environment integration:** The importance of greater integration of environmental/ecosystem health sectors in One Health intelligence systems has been described and recommended in the literature with regards to infectious disease risk. More research is required to understand the complex interrelationships between environmental drivers (and protectors) of other hazards (e.g. food insecurity) and health benefits (e.g. benefits derived from ecosystem services), and how best to incorporate associated data into One Health intelligence systems to support early warning and action.
- **Multidisciplinarity:** The analysis of One Health data to identify and assess emerging hazards and inform risk management (decision-making and action) demands understanding of a complex, dynamic and highly contextual environment and its interconnected systems. This requires information sharing from multiple sources (not limited to human and animal health), joint risk assessment and risk management, intersectoral and multidisciplinary teams, and strong links between research, risk assessment, surveillance and decision-making.
- **Adaptability:** Systems that are evolutive and flexible to allow progressive collaboration between sectors, and accommodate a wide variety of data types and sources, will be most adaptable to identification and assessment of known, unknown and emerging hazards or risk questions. Participatory approaches and innovative technologies may increase timeliness, sensitivity and sustainability of the system, and at the same time improve the involvement and commitment of communities (lay and expert, local to global) in the overall process.
- **Data accessibility:** One Health intelligence will benefit from the greater intersectoral availability of data, which should be driven by the FAIR principles (findability, accessibility, interoperability and reusability) (Wilkinson *et al.* 2016). Although innovative technologies may resolve practical data sharing issues, incentives for sharing, legal agreements/memoranda of understanding and frequent cross-sector feedback will be required to support evidence-driven One Health action.

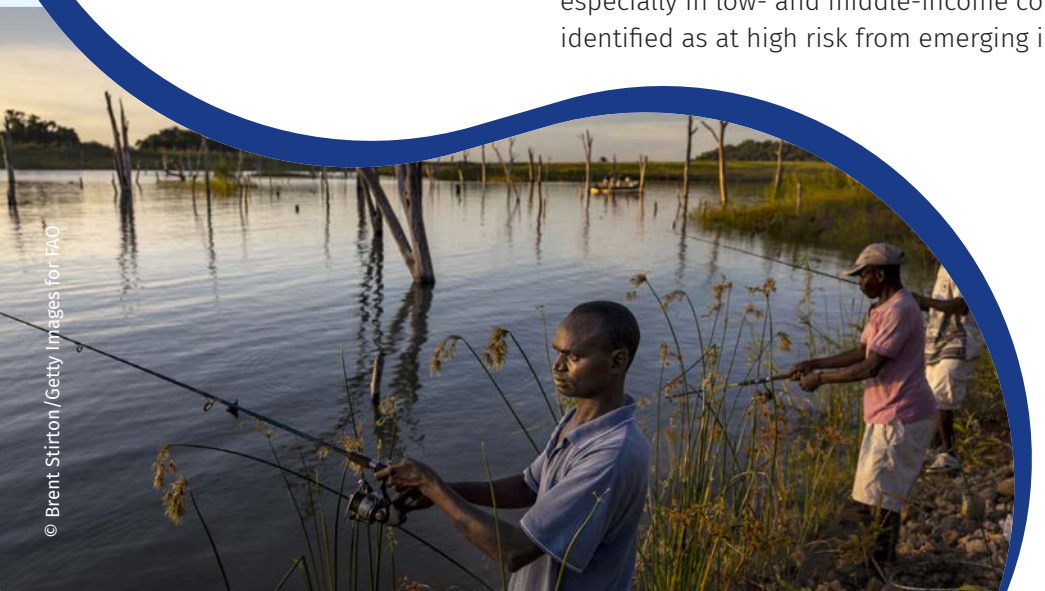
The following conclusions from the literature review apply specifically to the experience reported about the development of **national** One Health intelligence systems:

- Practical implementation of One Health approaches is challenging for all countries, regardless of their economic status. Intersectoral coordination is often compromised by budget and resource limitations and different organizational priorities. Sectors often see the financial support to One Health programmes as being “subtractive” to their budgets and not “additive”. Mapping sectoral priorities and organizational structures can identify opportunities for improved communication and collaboration, and the delivery of cost-benefit and effective One Health programmes.

National systems are often limited by poor sharing of information between authorities at the local and central levels. Non-governmental organizations and the private sector are rarely engaged, placing the onus exclusively on governmental systems to deliver on One Health priorities. Encouraging participatory community-based health services would increase subnational capacities for timely detection of emerging health issues.

- Applying participatory approaches within One Health programmes improves engagement with stakeholders. New and emerging technologies with smart information management can be used to support such engagement with improved timeliness, sensitivity and sustainability of information systems.
- There is an opportunity to learn from innovative surveillance approaches, including the establishment and continuous growth of a global network of semantically linked information from different systems and datasets, big data methodologies, artificial intelligence and mobile technologies and how these can be implemented to support subnational surveillance, especially in areas that previously had poor coverage.
- Surveillance systems at the country level often focus on specific diseases, with less emphasis on the ability to detect unknown diseases or other One Health threats. Best practices identified the need to gather baseline data; to consider non-traditional information sources, including event-based surveillance approaches; and to develop flexibility in system architecture and data capture.
- Zoonoses are recognized internationally as the most likely source of future pandemics; however, at the country level, there is often limited understanding of their burden. Advocacy is required with national leaders to develop policies and programmes to address the risk of endemic and emerging zoonoses, and their potential impact on the health and well-being of communities at all levels.
- Medical, veterinary and environmental education is sector specific with little or no reference to One Health. Further, health workers rarely receive multidisciplinary training or participate with other sectors to apply a One Health approach.

The need to support national systems was clear, including to identify strategies to incentivize reporting and avoid disincentives.
Surveillance capacity, information management and skills in epidemiology and risk assessment vary widely between sectors and between countries. Resources are generally limited, with a lack of capacity for surveillance, especially in low- and middle-income countries, many of which have been identified as at high risk from emerging infectious diseases.



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One Health intelligence experts: external engagement

There is a wealth of global experience and expertise in One Health and intersectoral work that could support the design and development of a global One Health intelligence framework. A core OHISS activity was to engage with experts in the fields of health intelligence, risk assessment and early warning systems from outside the Quadripartite structures and working in One Health, animal, human, agriculture and environmental/ecosystem health roles, as well as in auxiliary health services (e.g. food safety, defence and communication).

Objective

- Use global expertise and experience to provide guidance on the OHISS foundational activities performed, and the outputs and recommendations generated by the study.

Experts were invited to review, advise and challenge the OHISS foundational activities, and the study's recommendations for improving the global architecture of One Health intelligence.

Methodology

The OHISS engaged with external experts through different activities targeting different groups, including:

- two virtual workshops with an External Advisory Group (EAG), in January and July 2022; and
- participation in external virtual meetings and virtual bilateral meetings with other One Health groups, initiatives or expert groups.

A survey of national One Health initiatives was also conducted, as reported in the next chapter of this report. Additionally, in June 2022, the OHISS conducted a series of workshops addressing "risk landscapes" for specific health hazard groups. These workshops are also reported in a dedicated chapter in this report.

Results

External Advisory Group – Workshop 1

The first OHISS EAG virtual workshop was held on 20 January 2022.
For this initial meeting, a limited number of participants were invited from the G7 countries (reflecting the origin of the project proposal), relevant international or regional organizations, and initiatives working in One Health. From a total 60 attendees, 34 participants represented 11 organizations or initiatives outside the Quadripartite and not directly associated with the OHISS project, and were distributed over seven countries. During the workshop, which lasted two hours, attendees participated in plenary and breakout room sessions, using interactive whiteboards, chat messages and open dialogue to provide their expert opinions on: (i) examples of good practices of One Health intelligence systems; and (ii) essential components and data for One Health information systems of the future.

Examples of good practices of One Health intelligence systems

Participants of the first EAG were asked to provide names of systems at the national and international level that they believed were examples of good practices of One Health intelligence systems/initiatives. The OHISS team supplemented information provided by participants using publicly available information to determine if the suggested systems met the criteria of an OHIS.

Identifying the essential components of national and international One Health intelligence systems

In this session, participants were asked to suggest essential components of an ideal OHIS, as well as potential data and information sources for a future OHIS. This highly participatory session resulted in a wealth of suggestions and recommendations, covering aspects such as data sources, data management, processes of risk assessment, gaps and vulnerabilities in data and systems at both the national and global level, and future proofing systems. The main overarching recommendations from the participants were:

- An OHIS needs a clearly defined purpose, with prevention and/or early detection of hazards as the primary suggestions.
- The scope of an OHIS needs to be wider than infectious disease/zoonotic hazards, in line with the holistic definition of One Health, and should extend to natural and deliberate events with the potential to be hazardous to human, animal or environmental/ecosystem health.
- An OHIS needs sustained multilevel and multilateral endorsement and engagement across sectors essential to the success of the One Health approach.
- Sustainable, multidisciplinary human input/networks are an essential component of an OHIS to comprehend the complexities of baseline states; assist with screening, triage and prioritization of large volumes of potential signals; and to support rapid identification and alerting of possible hazards.

The outcomes of this session were used to inform and support the work on risk landscapes (riskscapes) and the development of the framework for the global OHIS, both reported in dedicated chapters of this report.

External Advisory Group – Workshop 2

The main purpose of the second set of EAG workshops, held on 13 and 14 July 2022, was to share the OHISS main findings and recommendations and to discuss the next steps for global One Health intelligence.
This two-hour workshop was repeated over two days to facilitate experts joining from different time zones. The invitation list from the first EAG was expanded to include key contributors from the riskscape workshops and other initiatives who indicated an interest in the OHISS. Over the two days, more than 90 individuals participated in these virtual workshops, providing valuable interpretation, commentary and questions on the outcomes of each of the distinct workstreams. All feedback was collated, reviewed and used to inform this final report.

Engagement with other groups and initiatives

Over the course of this project, the OHISS team engaged with a diverse range of other groups and initiatives working in areas relevant to One Health intelligence outside the Quadripartite. The purpose of these engagements was to explore complementarity and garner further expert opinion to inform OHISS actions. Groups contacted included:

- Africa BIO Signature Initiative (www.gpwmd.com/africa-signature-intitiative), Working Group 3 (Surveillance and Epidemic Intelligence);
- Connecting Organizations for Regional Disease Surveillance (CORDS) network (www.cordsnetwork.org);
- EcoHealth Alliance (www.ecohealthalliance.org);
- Health Data Collaborative (www.healthdatacollaborative.org), Working Group on Public Health Intelligence;
- International Pathogen Surveillance Network (IPSN);
- OHHLEP (www.who.int/groups/one-health-high-level-expert-panel);
- Preventing Zoonotic Disease Emergence (PREZODE) (https://prezode.org); and
- WHO Hub for Pandemic and Epidemic Intelligence (https://pandemichub.who.int).

Conclusions

From the inception of the OHISS, a strong emphasis was placed on ensuring regular communication and engagement with global experts on One Health. Recommendations, advice and guidance from these diverse groups of external experts facilitated the advancements of all OHISS workstreams and were central to the outcomes of the project. Continued engagement with external experts, in their role as stakeholders, providers and consumers of One Health intelligence, will be key to the success of implementing a Quadripartite-led, global OHIS and strategy.

The review and assessment of participants in the OHISS external engagement activities indicated inequity in contributions. There was a higher participation of veterinary and human health professionals, and overrepresentation of experts from higher-income countries and the Global North. To note, gender balance was not considered as part of this analysis. To improve equitable participation of experts in this One Health intelligence community, formats of engagement that support greater inclusivity need to be considered, aiming for:

- Equitable sectoral engagement with particular emphasis on facilitating the engagement of environmental/ecosystem health experts.
  An evaluation strategy should be developed to show the shared benefit of working collaboratively.
- Equitable geographical engagement, ensuring invitations have global reach (e.g. using regional One Health focal points in Quadripartite organizations) and that participation is supported (respective of working hours in multiple time zones and ensuring the use of multiple languages or tools to support non-native English speaker participation).
- Equitable gender balance should be considered and actively encouraged.

Although One Health intelligence is a topic of considerable interest to many, and experts were willing to support the Quadripartite in their endeavour to strengthen the architecture for global One Health intelligence, there were several issues encountered in terms of securing engagement. Internationally, there are many initiatives, groups and organizations working to improve early warning, surveillance and intelligence from the One Health perspective, but there is no central repository or catalogue to support collaborative working and multilateral engagement with these repositories of technical experts. Poor communication, collaboration and coordination between these expert groupings results in duplication of siloed efforts and overlap of activities, leading to inefficient use of resources and further burdening of technical experts. The Quadripartite encourages higher-level global health security governance bodies (such as those within the G7 and G20) to advocate for and leverage better coordination of these initiatives.

The Quadripartite should continue to harness expertise and develop a One Health intelligence community that can assist in the next steps of developing a global OHIS. This community should facilitate engagement with global experts, as well as better communication and collaboration between initiatives that support the improvement of a global One Health intelligence architecture.

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One Health national systems: survey

National One Health intelligence is a critical pillar of global One Health. The OHISS project included multiple activities aiming to scope the existence and functionalities of One Health intelligence systems at the country level, including the EAG workshops and literature review reported in previous sections. In this section, we report on additional activities undertaken that targeted national initiatives directly, surveying countries' experience with One Health intelligence in practice.

Objectives

- Gather information and basic details regarding One Health intelligence systems already in place or under development at the country level.
- Document best practices and lessons learned, which can be useful to other countries attempting to develop and implement One Health intelligence systems.
- Compile information that can guide the development of an OHIS.

Methodology

An online survey was conducted between May and June 2022. Health authorities of WHO and FAO Member Nations were contacted through their representatives in the networks of these two organizations. Countries were also reached through two technical networks: the International Food Safety Authorities Network (INFOSAN), a global voluntary network of national authorities with a role in food safety, coordinated by a joint FAO/WHO Secretariat; and CORDS, which comprises six regional members networks working in 28 countries in Africa, Asia, the Near East and Europe. The survey addressed the following topics: a) zoonoses reports and surveillance; b) AMR surveillance; c) One Health interagency networks; d) next-generation DNA sequencing; and e) environmental/ecosystem health information.

In addition, a list of examples of international and national systems/activities related to key competencies for assessing and monitoring ecosystem services with relevance to One Health and supporting human and wildlife health sectors at the country level was compiled with the support of UNEP.

The Millennium Ecosystem Assessment[3] defined ecosystem services as the "benefits people obtain from ecosystems" and divided them into four categories: 1) provisioning services, such as food and water; 2) regulating services, such as regulation of floods, drought, land degradation and disease; 3) supporting services, such as soil formation and nutrient cycling; and 4) cultural services, such as recreational, spiritual, religious and other non-material benefits.

[3] United Nations Secretary-General Kofi Annan called for the Millennium Ecosystem Assessment in 2000. Initiated in 2001, its objective was to assess the consequences of ecosystem change for human well-being and the scientific basis for action needed to enhance the conservation and sustainable use of those systems and their contribution to human well-being (www.millenniumassessment.org/documents/document.356.aspx.pdf).

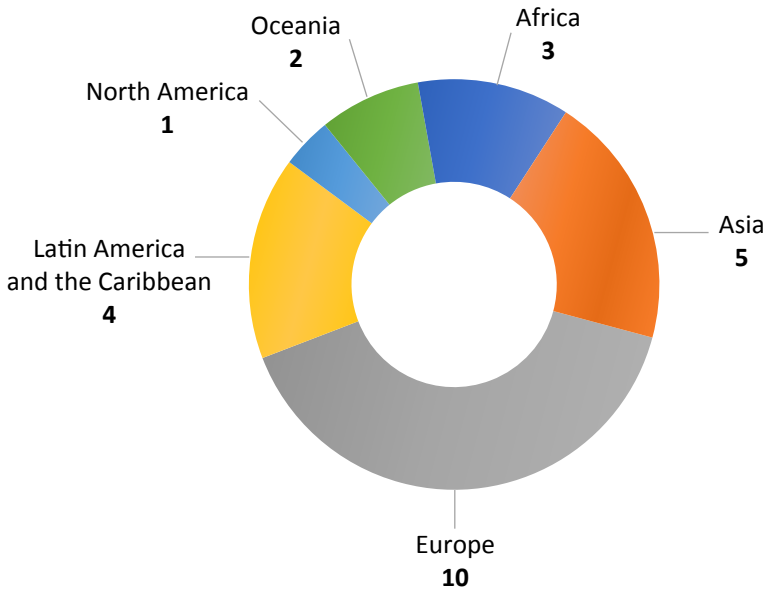
Despite the importance of ecosystems to socioeconomic development, health and well-being, decision-making has generally failed to fully consider the multiple values of biodiversity and ecosystem services, resulting in widespread biodiversity loss and a serious decline in ecosystem services. Tools and approaches that can help integrate information on biodiversity and ecosystem services into decision-making are crucial to arresting this loss and ensuring maintenance of ecosystem services and the benefits that they provide (see section below for overview).

Results

The systematic country survey received replies from 25 countries.
The distribution of countries is provided in Figure 2. The feedback received provided an overview of One Health systems in these countries. A more comprehensive and representative survey is necessary to allow more accurate characterization of national One Health intelligence globally.

Zoonosis surveillance: Almost all countries indicated that they had a zoonosis surveillance system. However, when the qualitative data provided were assessed, it appeared that in most cases there were multiple systems managed by the different sectoral authorities, and data were shared only occasionally for specific investigations and periodic reports. Data were made publicly available in many countries, either as reports or sometimes to international platforms or reports (e.g. European Food Safety Agency and WOAH). For the majority of countries, there were specific lists of prioritized zoonotic diseases based on criteria such as human health risk analysis, risk of international spread and economic impact, or international standards.

Figure 2: Geographical regions of countries responding to the national survey



Source: Authors' own elaboration.

AMR surveillance: More than 75 percent of the responding countries had some AMR surveillance system in place, and these usually also collected data on antimicrobial use. AMR systems collected data from multiple sectors, including human health, environment, livestock and animal feed. The AMR surveillance activities described in the survey responses were managed by the health authorities of the human and animal health sectors, as well as food safety agencies. Data from AMR surveillance activities were made publicly available by half of the countries.

One Health national networks and responsibilities: One Health networks, involving different authorities and institutions, were present in almost all countries – these were either formal or informal. Almost half of the countries used a One Health approach to prepare risk reduction strategies for zoonoses and emerging infectious diseases.

Next-generation sequencing: When asked about next-generation DNA sequencing, or other similar procedures for comparative microbial typing, most countries have confirmed that these are in use; information from whole genome sequencing seems to be rarely available in national open DNA libraries.

Environmental/ecosystem health information: Mechanisms or systems to link and use environmental/ecosystem-related data in a One Health approach were uncommon. The information collected was mainly being used for risk assessment purposes. There were some important exceptions (e.g. Australia One Health Surveillance Initiative) in addition to the ecosystem services assessment and monitoring examples provided by UNEP (though similarly, these are not necessarily well linked to health information systems).

Best practices at the national level

During analyses of the survey data, an attempt was made to identify best practice cases that could be used to inform One Health intelligence initiatives in other countries. One such example was the development of a One Health digital platform in Albania to serve as an integrated surveillance data portal for use by different health actors for their own surveillance purposes, as well as for improved collaboration.

Implementing operational One Health programmes at the national level is challenging and requires specific approaches and solutions. Key to their success is the identification of potential stakeholders, their roles and responsibilities, and willingness to engage. The development of appropriate, innovative and sustainable information and communications technologies presents a way forward to support coordinated health intelligence activities at the country level. Health authorities can benefit from the use of context-specific digital mechanisms to help overcome “operational brakes” in One Health procedures and to address internal obstacles at the different jurisdictional levels. Operationalizing One Health through the support of digital technologies can promote collaborative approaches and reduce fragmentation of data landscapes, with improved access to information.

Feedback from the INFOSAN and CORDS networks

A number of countries indicated that the introduction of "integrated surveillance and response", a precursor to the One Health approach, improved the detection and response to zoonoses in animals and food. A shared response strategy improved surveillance and laboratory data sharing, as well as support to decision-making by animal health, public health and food safety managers. In some countries, national intersectoral zoonoses reports may be prepared to compile outbreak information, and to highlight trends and emerging threats. In addition, in the European Union, national reports are combined by the European Centre for Disease Prevention and Control and the European Food Safety Agency, providing a Europe-wide overview of surveillance results.

Increased awareness of the threat posed by AMR has prompted many countries to develop national action plans that include elements of surveillance and information management. National public health surveillance systems commonly track changes in the antimicrobial susceptibility of prioritized bacteria from sick people, animals and animal products. The programmes help protect public health by providing information about emerging bacterial resistance and the spread of resistance. In some countries, this has led to the development and implementation of a number of successful intersectoral interventions.

Intersectoral engagement was reported in the form of improved exchange of information, updates and strengthening collaboration to address One Health threats. Secure, web-based platforms are being used to combine epidemiologic, laboratory and traceback data in real time to make collaboration easier when investigating information from different sources. Detecting and solving outbreaks faster is recognized to result in fewer illnesses and deaths.

Whole genome sequencing was reported as increasingly adopted to monitor pathogen evolution and to improve understanding of epidemiology. Systems such as "GenomeTrakr" allow sharing of data and metadata across sectors, including outbreak investigation, source attribution, pathogen reservoirs, contamination events, AMR, monitoring the evolution of virulence, and biocide resistance – supporting a full One Health approach to pathogen surveillance.

Assessing and monitoring ecosystem services – key competencies

Assessment: This competency refers to baseline assessment, risk assessment and ongoing assessment of ecosystems and the services they provide, at the international, national and/or subnational scale, for a variety of objectives and using a range of methods. There is a wide range of national and subnational assessments, ranging from national-scale assessments of ecosystem services to valuation studies of particular ecosystems and locations, as well as risk assessments for specific purposes, such as informing climate change adaptation and disaster management approaches, or biodiversity management policies.

Monitoring and reporting: This competency refers to regular and ongoing monitoring and reporting related to ecosystems and their services. In contrast to assessment, regular monitoring requires a more institutionalized process and ongoing investment, and these are often based on sectoral mandates (e.g. forest monitoring, biodiversity monitoring, water monitoring) rather than ecosystem-wide approaches.

Transparency and data sharing: Another key competency in this area is having capacity and processes in place to support the sharing of information on ecosystems and their services, such as across sectors, and to support decision-making, as well as transparent sharing of information (e.g. with the public). Public sector information policies, open data or big data initiatives, and "one-shop stops" for government data are becoming increasingly common, but environmental and particularly ecosystem data are not always well represented.

Linking to policy and action: Building on the previous competencies, this refers to the existence of capacities and processes to link data (e.g. from assessments, monitoring, platforms) to policymaking and the development and implementation of actions related to the conservation, restoration and management of ecosystems and their services. This may include the use of information in policymaking processes, as well as the development of mechanisms with strong links to ecosystem data (such as payments for ecosystem services).

Conclusions

The survey and information collected through the networks showed that despite the broad endorsement of the One Health concept at the national level, operationalizing One Health remains challenging.

The feedback from countries in the INFOSAN network highlighted that there is often no common understanding or vision of the advantages of developing integrated One Health surveillance. Frameworks to guide consistent integration and interpretation of surveillance data across sectors are needed. A critical step is the identification of potential stakeholders, their roles and responsibilities, and willingness to engage.

Intersectoral coordination is the foundation of One Health intelligence but is often not sufficient, owing to different sectoral drivers and constraints, and very different surveillance systems and information management capacities.

The siloed approach of the different health sectors is making it difficult to define, collect, integrate and analyse actionable information. The implementation of national One Health policies and programmes therefore requires the development of intelligence systems able to integrate intersectoral data from multiple sources, allowing data analysis and interpretation to promote effective collaboration among sectors and support aspects such as the early warning and risk assessment of emerging One Health threats.

Effective integration and identification of One Health risks, and the early identification of emerging threats will require a wide range of data and information. Data shared across sectors should be annotated with thorough metadata to preserve context when reused in a One Health approach.

Quadripartite One Health intelligence activities: assessment

FAO, UNEP, WHO and WOAH share a common mission to address risks at the human–animal–plant–ecosystems interface, either as independent agencies or in the collaborative form of the Quadripartite. The OHISS aimed to identify opportunities to work across the boundaries of each organization, unifying and strengthening One Health intelligence.

A fundamental step in building a framework for One Health intelligence is understanding the existing systems and describing them individually, before assessing the potential for integration of their capacities and capabilities towards the joint goal of an operational Quadripartite system. The OHISS team conducted individual organization assessments during the period February to May 2022 in collaboration with focal points from FAO, UNEP (represented by UNEP World Conservation Monitoring Centre [UNEP-WCMC]), WHO and WOAH.

In this assessment, organizational intelligence systems are presented in a simplified two-level hierarchy where the organizational system is built upon defined individual intelligence components ("activities") that are being conducted. Collaborative activities between Quadripartite organizations, and some outside of the alliance, are also documented. These are defined as follows:

> ***One Health intelligence activity***
> *Used to describe a specific One Health intelligence programme (sometimes also referred to as a tool or task) or a group of related programmes with a defined set of expected deliverables and outcomes. These can be conducted within the individual organizations, or collaboratively across two or more of the Quadripartite organizations (**collaborative activity**).*
>
> ***One Health intelligence system***
> *The set of One Health intelligence activities used within a single organization to generate information relevant to the organization's objectives.*

Objectives

- Provide a first high-level description and mapping of selected activities currently conducted by the Quadripartite organizations that could contribute to One Health intelligence.
- Provide a system-level assessment of each organization in order to identify opportunities for collaboration and data sharing (including interoperability when relevant and possible), which in later steps of the OHISS work were used to sketch an achievable framework for Quadripartite-led global One Health intelligence.

Methodology

Each organization was asked to complete a standardized template for both their overall intelligence system and a self-selection of intelligence activities that contribute to their One Health intelligence systems. A full inventory was not requested, due to time and resource constraints, and organizations selected the activities they felt most important to include in the proposed OHIS. Descriptions were collated on standardized templates to harmonize responses across organizations and to support mapping of responses with each organization and between them. Time constraints did not allow the templates to be pilot tested; however, several rounds of internal peer-review were conducted over a two-week time period to address this as best as possible. Furthermore, selected components of the template were developed and tested during the External Advisory Group workshop in January 2022.

The assessments conducted are not meant to be a complete inventory of all relevant One Health intelligence activities run and managed by the Quadripartite organizations. They serve as a first step towards assessing the potential for building a Quadripartite OHIS, and an associated system framework. Future peer-review and extension of the assessment protocol could further strengthen the scoping and provide a more comprehensive assessment of the systems' current state and potential future steps.

Results

Within FAO, the following activities have been described in detail:

- Emergency Prevention System (EMPRES) Global Animal Disease Information System (EMPRES-i+)
- Event Mobile Application (EMA-i)
- FAO's Global Surveillance and Early Warning System (GLEWS)
- Joint FAO/WHO/WOAH Global Early Warning System for health threats and emerging risks at the human–animal–ecosystems interface (GLEWS+)
- International Antimicrobial Resistance Monitoring (InFARM) IT platform (in development)
- Rift Valley Fever Early Warning Decision Support Tool (RVF-DST)
- Surveillance Evaluation Tool (SET)
- Monitoring and early warning of Transboundary Plant Pests and Diseases (TPPDs)
- *Sistema Informativo Laboratori* (SILAB) (Laboratory Information Management System) for Africa (SILAB-FA)
- Desert Locust Information Service (DLIS)
- Fall Armyworm Monitoring and Early Warning System (FAMEWS)
- Information platform to support national veterinary diagnostic laboratories (iVETNET)

Within UNEP and partners, the following activities have been described in detail:

- UN Biodiversity Lab
- Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Trade Database
- World Environment Situation Room (WESR) (including AirVisual on air quality)
- Protected Planet (on area-based conservation measures)
- Global Forest Watch
- PREDICTS database/Biodiversity Intactness Index
- International Union for Conservation of Nature (IUCN) Red List of Threatened Species
- National reporting to the biodiversity-related conventions (e.g. Convention on Biological Diversity [CBD])
- Integrated Biodiversity Assessment Tool (IBAT)
- CLIMsystems Climate Insights data portal
- INFORM Risk Index (covering humanitarian crises and disasters)
- Custom Climate Security Analytics (Strata)

Within WHO, the following activities have been prioritized, among many others, as most relevant for One Health intelligence and have been described in detail:

- Direct disease event notification and response (Event Management Suite 2 [EMS2])
- Mining and analysis of open source data and related community of practice (Epidemic Intelligence from Open Sources [EIOS])
- Information exchange (Strategic Partnership for Health Security and Emergency Preparedness)
- Multidisciplinary networks (INFOSAN and the Global Antimicrobial Resistance and Use Surveillance System [GLASS])

More WHO activities/platforms are generically applicable for One Health intelligence purposes, such as go.data or the Early Warning, Alert and Response System.

Within WOAH, the following activities have been described in detail:

- World Animal Health Information System (WAHIS)
- Official recognition of animal health status
- Self-declared Disease Status
- Observatory
- Performance of Veterinary Services (PVS) Pathway programme
- PVS Lab / Sustainable Laboratories database (Performance of Veterinary Services Sustainable Laboratories Mission)
- Epidemic Intelligence System
- Global Database on Antimicrobial Agents Used in Animals
- Global Burden of Animal Diseases (GBADs)

Conclusions

This Quadripartite assessment highlighted the large number and diversity of activities currently conducted (or engaged in) by FAO, UNEP, WHO and WOAH, which provide value and bring different perspectives to One Health intelligence at the global level. The existing activities result in the collection and generation of a large amount of data and information. However, these are currently distributed across many information systems, with different technical architectures, and varying accessibility and audiences, leading to a high risk that the activities and the information they produce are being siloed. A degree of overlap among activities conducted across and within the Quadripartite agencies could commonly be observed.

A process supporting inclusion, interoperability and awareness of ongoing activities would ensure that diverse activities are brought together to reduce duplication, while maximizing the shared value of their outputs.
The assessment also showed, however, that the Quadripartite organizations have recently invested a significant amount in modernizing their information systems. Therefore, any initiative to connect existing information should add value to existing systems, rather than attempt to replace them.

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One Health risk landscape: identification and analysis

The scope of One Health is large and different sectors will approach it with different perspectives and priorities. The needs and goals of One Health intelligence users are related to the hazards and associated risk questions they must address. While this may be specific to certain jurisdictions and sectors, a shared understanding of the One Health risk landscape (i.e. riskscape) will provide a foundation to improve intersectoral information exchange and build appropriate intelligence systems.

Objectives

A preliminary exploration of the One Health riskscape was conducted to:

- Identify key One Health hazard categories and determine which of them the Quadripartite would prioritize for an OHIS.
- Test an approach for mapping risk pathways and associated drivers, impacts, vulnerabilities and critical monitoring points on a subset of hazard categories.
- Start to develop a shared understanding of One Health intelligence scope and connections between hazards.
- Use the examples to enhance understanding of how various datasets relate to the One Health hazards of concern, in order to inform operational prioritization of data.

Methodology

A hazard identification and analysis exercise was conducted with the Quadripartite organizations in May 2022 to explore the scope of One Health hazards (i.e. hazards at the intersection of human–animal–plant–ecosystem health) and highlight key priorities for a global OHIS. The definition of hazard used for the exercise was that used by the United Nations Office for Disaster Risk Reduction (2020):

"A process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation."

To address potential differences in perspectives, the four organizations were given a chance to individually comment on priorities. Four example hazard categories were chosen from among those considered a high priority by one or more of the Quadripartite organizations. These were then used as the central focus of a series of workshops carried out from 7 to 10 June 2022, gathering a total of 273 subject matter experts. The titles of the four workshops were:

- Workshop 1: Epidemic and emerging zoonotic diseases;
- Workshop 2: Antimicrobial resistant microorganisms;
- Workshop 3: Contamination of water and soil from chemical fertilizers and pesticides; and
- Workshop 4: Non-zoonotic animal diseases affecting food security.

During the workshops, experts collaborated to build a rapid and high-level multidisciplinary illustration of risk pathways and associated critical monitoring points for each hazard, using a risk bowtie diagram approach. The risk bowtie diagram is a method of illustrating risk pathways, both before and after an adverse event, which has been used in various high-risk industries for decades (Culwick, Endlich and Prineas, 2020; Lindhout and Reniers, 2020; Wolters Kluwer, 2022). A traditional application of a bowtie diagram focuses on identifying potential barriers (i.e. prevention and mitigation measures) along the risk pathways. However, the aim of the workshops was to use a non-traditional application of a bowtie diagram, by identifying critical monitoring points along the pathways, rather than barriers.

Results

One Health hazard categories and priorities

Numerous types of One Health hazard exist, including those that are biological, chemical/radiological, meteorological/hydrological and environmental. Many hazards are also a driver or impact of other hazards. This is particularly true of environmental hazards, such as reduction/change in ecosystem services (for a definition, see the chapter on One Health national systems), which have in the past been recognized as drivers of other One Health hazards but should also be considered One Health hazards themselves.

A long list of hazard categories, including unknown and not-yet-emerged hazards, were described by the Quadripartite. The two hazard categories identified as high priorities for One Health intelligence by most Quadripartite organizations were “epidemic and emerging zoonotic diseases/human diseases with an animal origin” and “antimicrobial resistant organisms”. Other hazard categories were identified as priorities for One Health intelligence but from the perspective of only one or two organizations, including “neglected endemic zoonotic diseases”, “non-zoonotic animal diseases with indirect effects on human health and well-being”, “climate change impacts” and “pollution/environmental contamination”.
Priorities were generally consistent with organizational mandates and current strategic priorities within these organizations. In addition, these do not necessarily represent all priorities of the four organizations since there was insufficient time for extensive internal consultations.

Test an approach for mapping risk pathways

To test the risk bowtie method using a One Health approach, bowtie diagrams were created using expert opinion on drivers, impacts and critical monitoring points for the four example hazard categories chosen from among organizational priorities. The four categories were chosen to ensure priorities from all four organizations were represented. Participating experts were based around the world and came from the full spectrum of One Health sectors, from disciplines ranging from epidemiology to social sciences, and from international/national organizations to academia/research.

Links to the completed bowtie diagrams are provided as supplementary material (www.fao.org/3/cc4179en/cc4179en.pdf). The diagrams are complex, with many interlinked causal pathways leading to one or more unwanted central event(s), followed by many cascading and interlinked impacts. Feedback loops were identified, where an impact could become a driver in a cyclical pattern. It is presumed that not all possible connections were identified, especially between the various upstream drivers or long-term impacts, which are generally describing complex socioeconomic or environmental processes.

Many critical monitoring points were identified by experts in association with various pathways. Although barriers to the progression of an event/hazard were not specifically reviewed in this exercise, many failures of barriers were identified (e.g. poor biosecurity, lack of vaccination), along with a strong social science/socioeconomic component (e.g. lack of education, mis/disinformation, market factors, inequity). These highlight vulnerabilities in the system and in some cases were associated with their own monitoring points (e.g. monitoring public opinion).

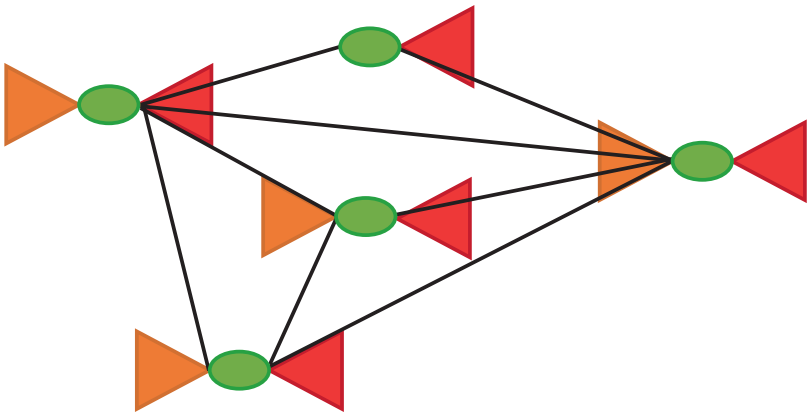
A shared understanding of One Health intelligence scope and connections

By creating a shared understanding of the One Health riskscape, individuals from different sectors and disciplines will be better placed to understand each other's perspectives and priorities. In addition, the process helps clarify the origin of drivers and impacts across the full One Health spectrum, capturing pathways more comprehensively than could be done within a single sector alone. As a result, appropriate intelligence systems can be built that are capable of handling these different needs and incorporating the complexity of these risks.

Part of this understanding comes from embracing an all-hazards approach, with definitions, such as the hazard definition, that are inclusive of these different pathways and perspectives. In addition to the guidance of the Sustainable Development Goals and the OHHLEP definition of One Health, the range of One Health hazard categories identified by the Quadripartite will increase awareness and understanding of the multitude of One Health intelligence needs and perspectives.

The assessments and scoping conducted by the OHISS reinforced that what might be identified as a driver or impact from one perspective, may be identified as the centre of a bowtie when examined from a different perspective. For example, all organizations identified "epidemic and emerging zoonotic diseases" as a priority, and when this was considered as the centre of a bowtie, the identified drivers and/or impacts included "pollution/environmental contamination", "climate change", and the "reduction/change in ecosystem services". UNEP, however, identified these to be high priorities as One Health hazards in and of themselves – not only as drivers/impacts of infectious diseases, but also as their own bowtie centres, each with its own full list of causes and consequences that cross sectors.

Figure 3: Representation of interconnected risk bowtie diagrams with hazards (green), their drivers (orange) and impacts (red)



Source: Authors' own elaboration.

The system in which One Health exists is a complicated web of interconnected bowties linked by singular or multiple connection points (Figure 3). Although it may never be possible to fully describe the system and all its connections, making some effort to identify where risk pathways connect will help identify areas of common priority that may benefit from increased intersectional work.

Inform operational prioritization of data

Using the risk bowtie approach reveals certain attributes of a monitoring point, such as which/how many hazards it relates to, which/how many risk pathways it relates to, and where on the pathway(s) it falls (including how upstream or downstream it is in relation to the event of interest). In the absence of detailed risk models, which exist for some specific hazards but not on an all-hazards scale, these factors can be used to inform decisions on the benefit that the data (if available) will provide in relation to risk. The cost and feasibility of acquiring and processing the data also needs to be taken into consideration.

The information provided in the workshops is vast, even when restricted to the four example hazard categories. Clearly, more work could be done to elaborate on these pathways and prioritize the critical monitoring points for individual risk questions and/or for global Quadripartite priorities.
To provide examples, some of the critical monitoring points identified across multiple bowties (and hence potentially applicable to multiple risk questions) included:

- monitoring of upstream ecoclimatic risks (e.g. trends/changes in rainfall and temperature, Normalized Difference Vegetation Index);
- monitoring of human and animal waste (e.g. disposal, treatment, water quality, waste from health care facilities);
- monitoring of wildlife health (e.g. morbidity, mortality, pathogens of concern for spillback events, novel pathogen strains); and
- monitoring of biodiversity/pollinator abundance and diversity through citizen science (e.g. public bird counts, pollinator diversity and number, indicator species).

Conclusions

The ideal operational OHIS needs to have the flexibility to support multiple different risk questions related to different types of hazards, and to accommodate the range of drivers and impacts important to these hazards. An “all-hazards” approach is needed, which does not focus only on infectious diseases, and truly aims to improve ecosystem health (as opposed to using environmental data only to improve risk monitoring of zoonotic diseases).

Understanding these differences in perspective is an important step towards a successful One Health approach to intelligence. Those looking to gather and use One Health intelligence should follow a risk-based, iterative process of defining the problem and determining critical monitoring points and associated data sources. Prioritization of critical monitoring points can be based on factors related to benefit (including risk) and cost.

A framework for One Health intelligence that can support prevention and prediction of hazards needs to provide tools to adopt the riskscape approach, allowing risk monitoring and consequently a shift from event response towards prevention and early warning. This will require careful mapping of drivers and triggers of hazards that threaten the health of humans, animals, plants and the ecosystem.

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Proposed framework for Quadripartite operational One Health intelligence

The findings from the OHISS foundational activities listed in previous chapters have informed the development of a proposed set of requirements for global One Health intelligence. Reflecting these requirements and considering the opportunities for collaboration and data sharing (including interoperability when relevant and possible) across health sectors, we propose an achievable, scalable and operational framework for Quadripartite-led global One Health intelligence: the global OHIS.

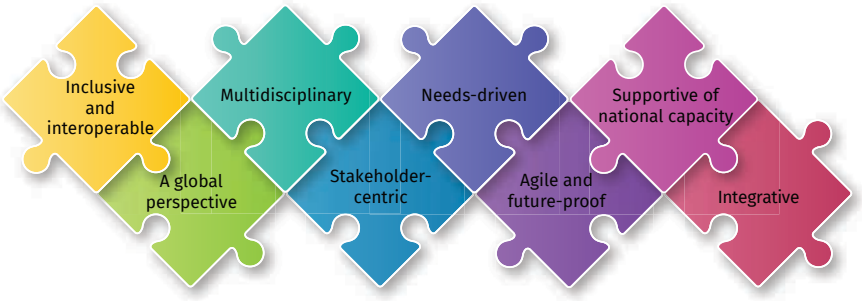
Objectives

- Propose a framework to develop Quadripartite operational global One Health intelligence.
- Outline operational features of the framework based on the foundational OHISS work.
- Outline the conceptual approach and high-level architecture of an information system to bring existing Quadripartite intelligence activities, which are at varying degrees of digitalization, into a common technology framework.

Methodology

Identifying requirements is an essential component of any system design process. Based on the OHISS foundational activities described previously, eight requirements for Quadripartite operational One Health intelligence were derived to guide framework development (see Figure 4).

Figure 4: Requirements to create an operational global OHIS



Notes: **Inclusive and interoperable:** Take advantage of existing intelligence capacity from across the various relevant sectors by integrating data from multiple sources, and respecting data confidentiality and governance. **Multidisciplinary:** Draw data from multiple sectors and contexts, but preserve data context and integrity. **Needs-driven:** Support intelligence systems with feedback to strengthen information and data systems. **Supportive of national capacity:** Consider the equity, needs and capacities of countries. **Global perspective:** Able to process data, information and intelligence at the global level. **Stakeholder-centric:** Meet the needs of different sectors and stakeholders to ensure ongoing support and commitment. **Agile and future-proof:** Able to quickly adapt to changing threats and evolving knowledge. **Integrative:** Support integration and cooperation among diverse initiatives.

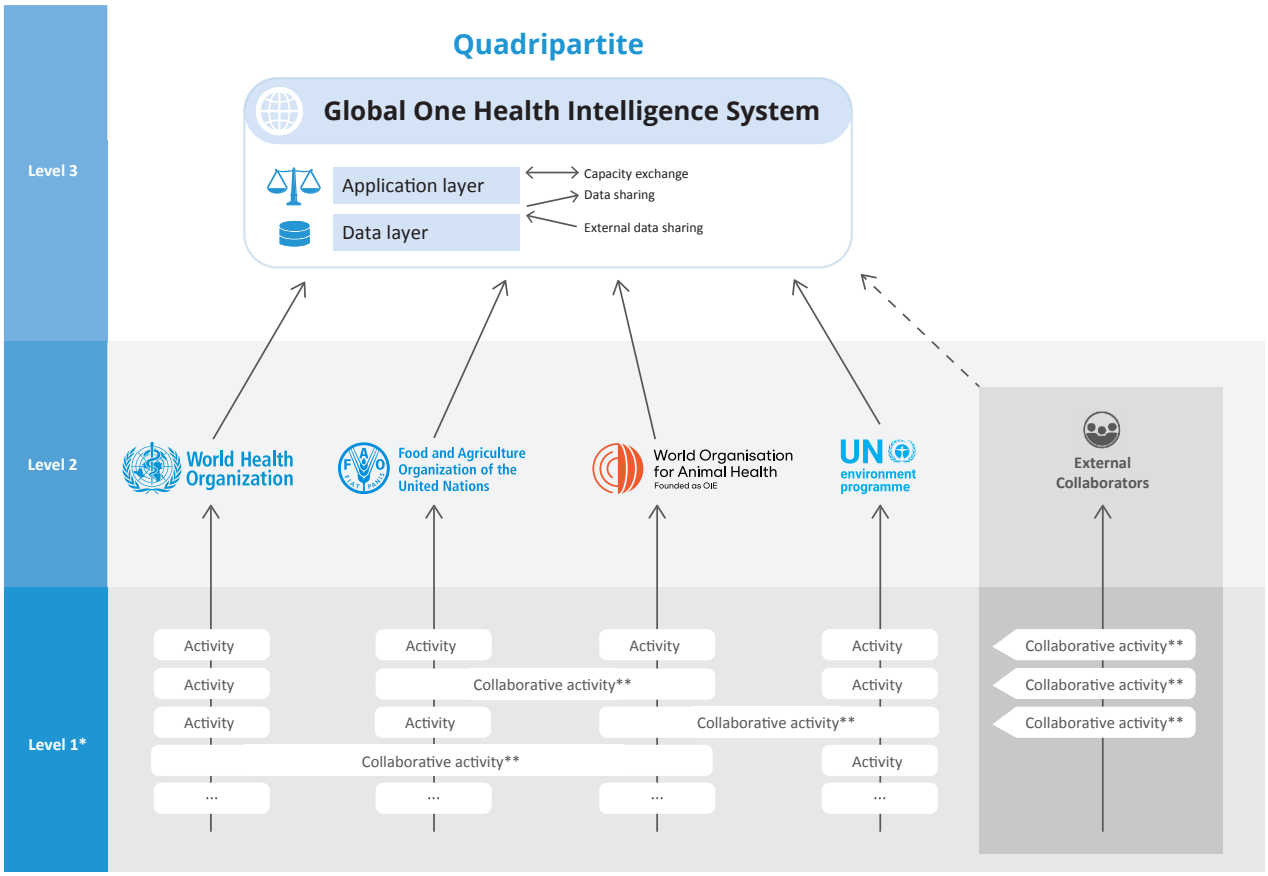
Source: Authors' own elaboration.

Results

We propose a **modular framework** to build the global OHIS on the foundation of existing Quadripartite intelligence. Starting with ongoing activities within the Quadripartite organizations, the technical needs to support specific One Health intelligence functions and objectives are translated into specific applications. These applications are added as individual "modules" in a dedicated application layer of the framework. Modules for data storage, integration and transformation are added in an independent data layer, allowing governance and access to be defined for each application and data source independently.

The global OHIS framework is further detailed in the supplementary material (www.fao.org/3/cc4181en/cc4181en.pdf).
Adding a One Health intelligence layer would not require a revision or rebuild of the individual systems, but would add value by amplifying

Figure 5: A modular umbrella framework for global One Health intelligence led by the Quadripartite



* This may include activities at country level.

** This illustration is just an example, and other collaborative activities exist among other partners.

Source: Authors' own elaboration.

individual activities and systems, and supporting collaborative activities. The global OHIS creates an umbrella framework within which existing activities can drive development, and their commonalities can be shared within the system, reducing current – and future – duplication of activities and processes.

The key features of the proposed global OHIS architecture are:

1. Flexible, yet controlled access: Access to data and applications can be customized and restricted where required. Access is controlled for all data and applications individually, allowing the system to preserve governance of all data ingested.
2. A dynamic data ingestion layer: Big data approaches can be supported through data lakes or data warehouses that store ingested and unprocessed data, as well as processed data within the system.
3. Quality documentation as a basis for collaboration: Modules in the data and application layer connect through application programming interfaces (APIs), which are thoroughly documented, so that application developers can see which data fields and functions are available. Certain APIs could also be made available to the public.
4. Efficient and FAIR use of data: The proposed framework operates under a linked-data model, which prioritizes data reusability and allows alignment with the FAIR data principles. The advancement of consensus annotation schema for datasets will provide value not only for data in the OHIS framework, but to all collaborative One Health initiatives.
5. Functionalities of the system are added as additive components in a dedicated application layer.
6. An independent and considered approach to software products: The OHIS “open architecture” would be able to host applications developed in different programming languages.
7. Explicit licences, supercharged with open source code, support internal and external collaboration.
8. Customized reporting: The global OHIS would support various forms of reporting, from self-service dashboards that operate in real time to automated reports.

Conclusions

The intelligence activities and systems already available at the Quadripartite level provide a foundational structure of data and activities on which the complex demands of One Health intelligence can successfully and sustainably build. The global OHIS should not be built as a silo of data and functions, but as a flexible umbrella framework to connect existing intelligence and make it available within an environment of connectable and evolving applications.

Data-fed, needs-driven system for agile and sustainable development: Data cleaning, annotation and integration add value to the data, which is propagated as more applications can reuse them. Applications are added to the OHIS applying a modular architecture approach, which ensures that the system development can start simply and adapt quickly to growing demands for complexity.

A focus on operational One Health intelligence: The focus on applications, informed directly by the decision-making needs of the system end users, ensures that the OHIS is designed to support the daily, operational needs of One Health.

The global OHIS strengthens, and is strengthened by, national capacity: Applications within the global OHIS can support countries as potential end users of the system. Moreover, the adoption of open source applications will enable countries to reuse and adapt applications within their own One Health intelligence systems. The global OHIS applications that attend the needs of Member Nations will provide an incentive for their continued efforts to collect and feed the system with accurate data and information.

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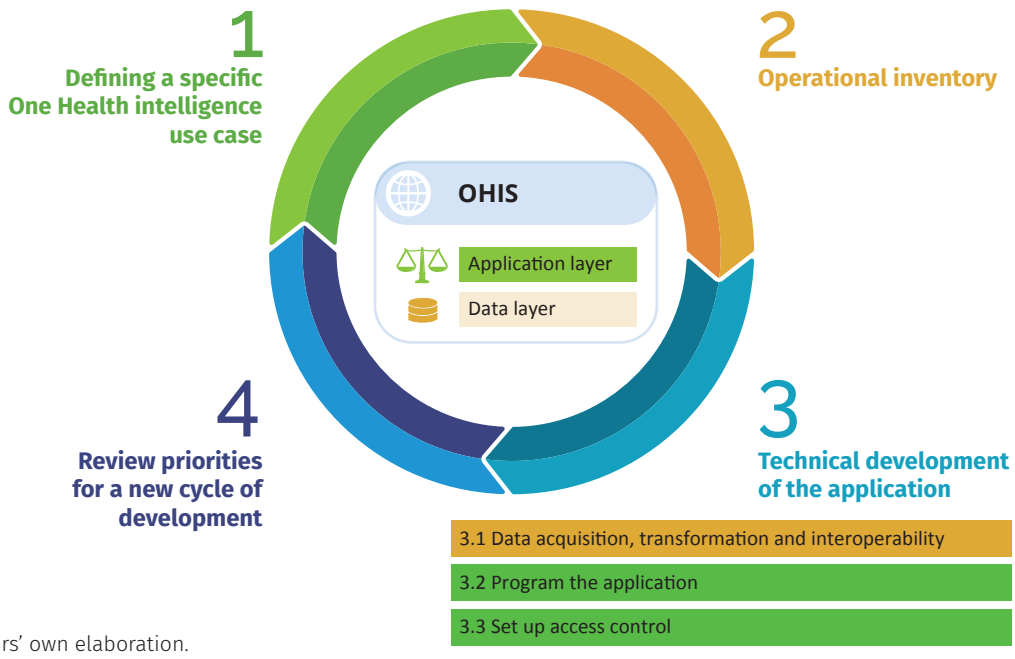
Sketching the way forward: a proposed road map for building a global One Health information system

The global OHIS would be developed in the first instance by gathering, collating and analysing existing information and producing new One Health intelligence for specific objectives. These objectives would constitute the use cases framework.[4] We propose that, in the first instance, use cases are defined from already ongoing One Health intelligence activities within the Quadripartite. This approach will provide an opportunity to strengthen and expand the collaboration around these activities, and to identify similar activities, which could be aligned to avoid duplication. Within use cases, mapping risk pathways and associated drivers, impacts, vulnerabilities and critical monitoring points on a subset of hazard categories will be key to identifying datasets, which could inform operational prioritization and data integration.

As more use cases/activities are brought into the operational framework provided by the global OHIS, existing applications can be expanded, or new applications can be designed, starting a new cycle of development.
More sources of data and more functions can be added to the framework on demand. In time, the need for new One Health intelligence activities can also be identified, allowing synergistic growth between the technical framework and the Quadripartite's operational One Health intelligence priorities.

Figure 6: Iterative cycles of development of the global OHIS based on operational One Health intelligence use cases



Source: Authors' own elaboration.

[4] Use case refers here to a specific scenario of system usage, which allows a detailed description of how the users would interact with the system, and what the requirements from these users are.

The cycles of development need to happen within an overarching framework that includes system hosting and maintenance. The following system elements need to be put in place by the Quadripartite to create the overall structure within which new development cycles can be conducted: hosting or steward organization; maintenance processes, including funding mechanisms; governance and access to data and applications; and systematic evaluation and incorporation of stakeholder needs.

Proposed pilot use case: The Joint FAO/WHO/WOAH Global Early Warning System for health threats and emerging risks at the human–animal–ecosystems interface (GLEWS+)

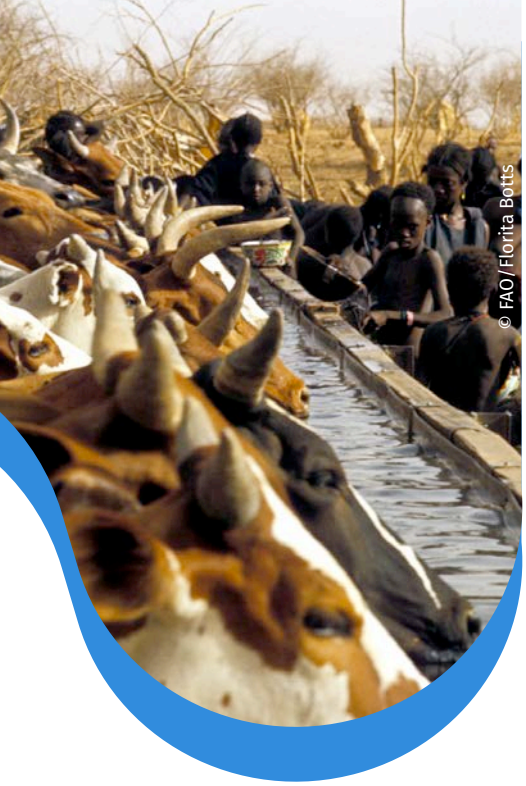
Background: GLEWS+ provides a use case that is already collaborative across three of the Quadripartite organizations. Involving UNEP would foster understanding of how ecosystem health can be included in its early warning and intelligence for better global health.

User requirements: While already strong in its One Health intelligence role, GLEWS+ as a pilot would allow development to begin with an application that has simple requirements. No databases would need to be integrated, as the focal points only need to have access to their own data, from which they collaboratively exchange warnings as well as relevant epidemiological/contextual information.

Application: Initially, reflecting the current functionality, the application can be a message board where focal points can enter alerts that are then delivered in a timely manner to the right people within the collaborating agencies. All users can respond and communicate about the alert, and past alerts and messages are documented. Further development still based on this use case is then possible by improving the communication platform to also support the transfer of epidemiological/contextual data, under specific access rules.

Access control: GLEWS+ would be simple in its requirement, as application "owners" and "users" are identical. Unlike many data analysis tools (which are developed within the organizations to serve external stakeholders), the design of a GLEWS+ functionality within the global OHIS would be informed by Quadripartite representatives that are direct users of the application and can be guided by established operational processes.

Benefits: Following the proposed approach, the system would first be built to support the current GLEWS+ network, and in time, the intelligence work performed itself would be improved. New operational requirements from the GLEWS+ team can be added to the system, reflecting, for instance, their perception of how risk landscape data could be added to the global OHIS to support even earlier signal detection. At the same time, data and functionalities added to the global OHIS by other use cases can enable the GLEWS+ team to expand their browsing, analyses and/or sharing of epidemiological data.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Conclusions

The findings from the various foundational activities have highlighted that the many international and national information systems collect a wide range of data relevant to One Health, but these are not currently being sufficiently used for effective risk assessment and early warning. The study demonstrated that incorporating the priorities, expertise and data from the environmental sector has very significant potential to identify risk "hotspots", which can then be monitored for early detection and targeted with risk reduction interventions. The transparency and insights provided by the four Quadripartite organizations indicated the wide range of systems already in place and the immediate opportunities to build on their existing platforms with greater integration, data sharing (including interoperability when relevant and possible) and further joint development. All the Quadripartite organizations already have significant information systems, and all are in the process of developing these further. There is a great opportunity to learn from and develop synergies across the Quadripartite organizations, and so to better manage complex, diverse, often disparate datasets – as has been recognized by UNEP and is increasingly being put in place for environmental monitoring.

Another finding was that there is a critical need and opportunity to better coordinate the numerous initiatives in One Health that focus on surveillance and the enhancement of One Health intelligence. The Quadripartite organizations recognize that the siloed efforts from the various One Health initiatives must be well coordinated, and that global leadership is required. For the development of a global OHIS, we propose that the Quadripartite will lead governance, advised by a steering group on One Health intelligence, which would consist of experts and global health security partners, including G7, G20 and OHHLEP, among others.

To improve the ability of surveillance systems to provide early warning and risk assessment of current and emerging One Health hazards, there is an imperative need to increase awareness of the benefits of investing in systems to prevent emerging threats, and not to rely more on response. Ongoing commitment to strengthening surveillance systems for early warning and risk assessment is required with the necessary policies, programmes and resources being made available. Integrating and analysing surveillance data and delivering One Health intelligence at the national, regional and global levels is critical to developing this capability and supports global health security.

The Quadripartite organizations are in a unique position to lead the intersectoral multidisciplinary development of One Health intelligence systems. Developing a framework for global One Health intelligence will identify opportunities, coordinate and use resources most effectively, and reduce threats to global health security from emerging infectious diseases and the impact of environmental change.

The development of a global OHIS is recommended to support and enhance early warning and risk assessment. The proposed OHIS would build on existing information systems, in the first instance, and not duplicate other Quadripartite initiatives and systems. Integrating the many existing Quadripartite and related intelligence initiatives under one umbrella can be used to build the capabilities of an OHIS, develop and support individual component activities, and increasingly deliver timely information to decision-makers as capabilities develop. The OHIS is not conceived to be a new centralized database, or a central "silo", where all information is concentrated, but as an adaptive evolving ecosystem of linked data and applications.

The global OHIS would operate in the context of an environment of accelerating One Health intelligence, and liaise closely with other One Health initiatives, such as the WHO Hub for Pandemic and Epidemic Intelligence and OHHLEP.

The development of a global OHIS supports the *One Health Joint Plan of Action* (One Health Quadripartite, 2022), contributing in particular to the delivery of Pathway 3: Data, evidence and knowledge, which will have a cross-cutting impact across all areas. A Quadripartite-led approach to global One Health intelligence will help reduce the threats to global health security posed by risks across the One Health spectrum, including environmental changes.

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