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Steps towards operationalizing One Health approaches

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ABSTRACT

One Health recognizes the health of humans, agriculture, wildlife, and the environment are interrelated. The concept has been embraced by international health and environmental authorities such as WHO, WOAH, FAO, and UNEP, but One Health approaches have been more practiced by researchers than national or international authorities. To identify priorities for operationalizing One Health beyond research contexts, we conducted 41 semi-structured interviews with professionals across One Health sectors (public health, environment, agriculture, wildlife) and institutional contexts, who focus on national-scale and international applications. We identify important challenges, solutions, and priorities for delivering the One Health agenda through government action. Participants said One Health has made progress with motivating stakeholders to attempt One Health approaches, but achieving implementation needs more guidance (action plans for how to leverage or change current government infrastructure to accommodate cross-sector policy and strategic mission planning) and facilitation (behavioral change, dedicated personnel, new training model).

1. Introduction

One Health recognizes that people are having a profound impact on our environment and this, in turn, is impacting our health and well-being and of the ecosystems we co-habit [1]. The One Health concept aims to sustainably balance and optimize the health of people, animals, and ecosystems [1]. The approach aims to mobilize multiple public service sectors (including public health, environment, agriculture, and wildlife - One Health sectors), scientific disciplines, and communities at varying levels of society to work together to foster well-being and tackle threats to health and ecosystems. In a policy-making context, this requires close collaboration across policy-making authorities and public service sectors, among experts from diverse professional backgrounds, and perspectives of the public (Fig. 1).

One Health is an increasingly recognized concept to help solve local, national, regional and global problems [2], including establishment of an international panel of experts of One Health approaches (https://www.who.int/groups/one-health-high-level-expert-panel/members) by global agencies from Quadripartite organizations (i.e., WHO, WOAH, FAO, and UNEP; Quadripartite call to action for One Health for a safer world (who.int)). One Health advocates have historically been infectious disease researchers with a zoonotic disease emphasis, but One Health has broader meaning and application to other issues such as food security, pollution, or climate change [1]. This approach is critical as, for

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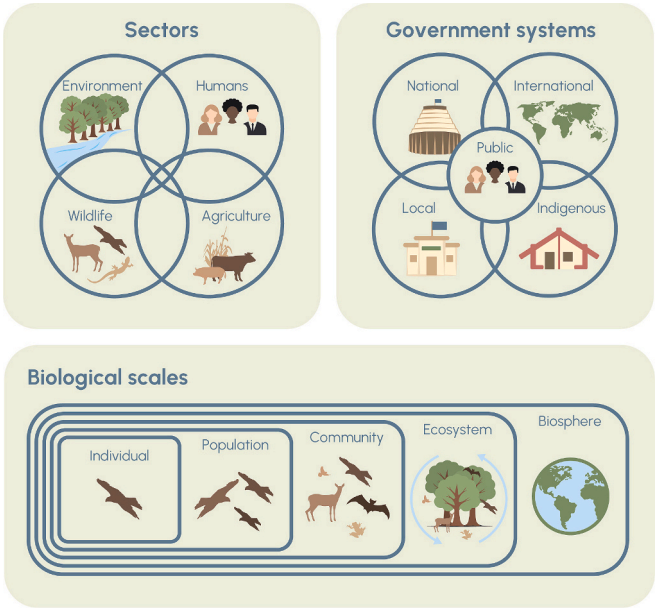

Fig. 1. Schematic showing integration of scales needed for operationalizing One Health approaches.

example, of the 36 Sustainable Development Goal (SDG) targets only two were on track in 2023 and those that showed the least or no progress included those strongly related to One Health themes, for example safe drinking water, ecosystem conservation, greenhouse-gas emissions, vaccine coverage, sustainable fishing and food security; and preventing the extinction of species [3]. Applying a One Health approach can lead to more explicit acknowledgement of both positive and negative impacts of decisions. For example, a public health decision might have positive impacts on human health in the short term, but potentially continue to erode the environment and have more negative future impacts on health through direct and indirect effects [4]. This helps inform decisions, identify complementary mechanisms that could mitigate adverse impacts, and enable more accurate assessment of costs and benefits of policy decisions.

Our objective was to identify barriers, opportunities, and priorities for implementation of One Health approaches by organizations that have the authority to set policy or provide public service following policy (i.e., government operations). To address this objective, we synthesize perspectives of 41 semi-structured interviews of professionals from different One Health sectors (Fig. S1 and Fig. S2 for study design) and organizational contexts (e.g., national government, local government, non-government agency, or research institution). We describe participant perspectives on current challenges and priorities for effective translation of One Health research to practice.

2. Results and discussion

We summarize thoughts from participants below. Direct quotes from participants are enclosed in single quotes.

Box 1
Examples of how participants described barriers of One Health implementation.

- ***Lack of cross-sector data to understand connections***: 'Understanding how decision A links to decision B'
- ***Resource and mission silos***: Sector-specific budgeting, mandates and objectives do not overlap
- ***No practical mechanism for data sharing***: Data systems and data governance systems are not interoperable
- ***Sector-specific language***: 'Speaking different languages'
- ***Unconscious discipline bias***: Being unaware of each other's drivers, lenses and challenges – potentially to different degrees across sectors
- ***Conscious cultural insularity***: Professionals 'subscribing to their own camps'
- ***Infrastructure barriers***: Systems for each sector are too structured and dynamic in their own ways
- ***Misalignment of the value system for different types of benefits***: Using and valuing different impact metrics
- ***Under-resourcing***: Maintaining capacity and capability of agencies to get together consistently to identify and implement common objectives
- ***Lack of skills for effective systems thinking***: Workforce not trained to see how methods across sectors are useful
- ***No mechanisms or incentives to guide cross-agency collaboration***: Fractured communication within and between agencies, unclear how to connect, and lack of incentives to work collaboratively
- ***Lack of desire***: People are too comfortable in their domains and cross-sector work is challenging and time-consuming
- ***Business rules do not align***: No common decision-making framework across sectors
- ***Imbalance across sectors in the value of cross-sector work due to power, professional competence, and capability differences across sectors***: 'public health professionals believe they already have all the answers', 'non-human health professionals are considered inferior and not given the same credibility', 'human health is funded at higher levels relative to other One Health sectors (agriculture, wildlife, environment) such that other sectors don't have the resources to work together in a way that is typical for human health professionals'
- ***Need to appreciate human burden of disease priorities:*** One Health priorities may not fit with priorities of sector-specific (e.g., public health) agencies for good evidence-informed reasons. Global burden of disease studies show consistently that non-communicable diseases (NCDs)/chronic diseases/long-term conditions have by far the major impact on human health (e.g., disability adjusted life years lost), especially in high-income countries. Zoonotic diseases are only a tiny contributor to that infectious disease burden in humans, with anthroponotic diseases by far the largest cause. (We note this challenge partly stems from another challenge - ***lack of clarity about the One Health concept*** – particularly that it is much broader than zoonotic disease and is meant to address potential environmental feedbacks on anthroponotic diseases, non-communicable disease, and human well-being when appropriate)
- ***No long-term vision capability***: Key professionals in government agencies that can support One Health initiatives change positions so often that it prevents growth of respect, trust, and institutional knowledge that is crucial for effective cross-sector work
- ***Challenges with developing useful translational science***: Researchers do not understand the experiences and priorities of all other actors challenging production of useful evidence.
- ***Lack of sophistication in managing the 'commercial determinants of health'***: There is an understandable perception by those working in human public health areas that many of those working in the agricultural sector have limited independence from industry interests who may not have protection of the environment and human health as top priorities. Core public health teaching devotes considerable attention to considering the determinants of human health, policy processes, and the drivers of decision-making.

3. Challenges for operationalizing of One Health

3.1. Deep-rooted silos

As previously reported [2,5], participants stated a lack of cross-sector integration as the main challenge for operationalizing One Health. However, professionals in different One Health sectors described the nature of the silo very differently, highlighting the depth of systematic barriers to integration (Box 1).

3.2. Unclear objectives and value

Several professionals thought a major obstacle was that it remains unclear what the success of One Health looks like. Participants said there have been few efforts to provide transparent evaluation of outcomes when One Health approaches are applied versus not, and that research does not have a common message about the benefits or objectives of One Health. Both sentiments are consistent with recent perspectives [6], although they report net benefits for examples of surveillance-response systems across One Health sectors. These kinds of studies may not be frequent enough yet to be convincing for skeptics.

Skeptics said that 'One Health is a popular buzzword that has been embraced by some scientists and funders but not widely accepted or implemented in practice'. Some said there is plenty of beneficial health work that can be accomplished without requiring a One Health approach and that pressure to consider a One Health paradigm to solve problems that have well-established solutions could be counterproductive. Examples provided included public health issues that are already seen to have effective solutions (e.g., mitigating specific environmental health risks for humans; Box 2; or childhood vaccination programs) or decreasing infectious disease burden in developing countries where the biggest obstacle is resources, not lack of system knowledge (e.g., decreasing brucellosis in domestic animals through vaccination). In these cases, the concern was that adding further complexity through a One Health approach may delay critical processes and spread ressources overly thin. For this reason, participants thought it's important to clarify which problems require an integrated One Health approach to find a solution or when One Health approaches provide more than the sum of their parts. One participant said this is especially important for funders who have embraced One Health approaches (e.g., [7,8], etc.) but may not have clarity about when the costs of a One Health approach outweigh the benefits given local infrastructure and governance. We note that this view reflects a deep-rooted tendency towards prioritizing immediate over long-term benefits, but that sometimes reaching some improvement in the short-term may be necessary before long-term factors can be considered.

There was also concern that One Health has overlap with traditional public health models, EcoHealth, Planetary Health, conservation medicine and pursuit of the SDGs [1,2,6] – to name a few alternative models of integrated cross-sector health disciplines. Participants thought this makes it important to clarify if and when a One Health approach should be applied over these other models.

It is notable that the One Health approach is gaining traction globally as a useful model of cross-sector health integration for a set of related issues, including emerging infectious diseases, food safety, antimicrobial resistance (AMR), ecosystem degradation, and climate change. This need has been addressed through the new OHHLEP One Health definition that has drawn on concepts from other integrated cross-sector health models and been accepted by the Quadripartite organizations, but the rebranding has likely still not reached enough stakeholders [1].

3.2.1. Science too complex for the policy-making context

Another challenge raised is that thinking through a One Health lens is seen as just too complex and fast-evolving for the level of science literacy and reasoning of most administrators in the public service agencies that set and implement health policies (through weighing a variety of factors that include but are not limited to science) and the time frames they have to grasp information. Thus, although it might be an effective research lens, participants thought it might not be as practical for policy-makers. Policy is often very reactive and less deliberative in how it addresses crises, and an overwhelming number of decisions are made routinely. Adding complex science may not align well with immediate decision-making.

The reactive nature of policy processes is the root of the issue where short-term responses are not long-term solutions. Thus, to implement One Health approaches, policy-makers will need to value and prioritize long-term policy outcomes, and broaden evaluation approaches to include long-term impacts of potential policy decisions. At a minimum, participants said scientists or science advisors will need to improve skills for communicating complex science to decision-makers regularly in very

Box 2
– "Environmental health": public health versus One Health.

Environmental health may have different meaning to professionals across One Health sectors. In human health, environmental health means how the living and non-living environment affects physical health and well-being of humans, through factors such as pollution, sanitation, and safety [13]. However, the One Health concept of environmental health means that the ecosystem is healthy from the perspective of all species and non-living attributes (e.g., biodiversity, healthy animals, healthy plants, healthy air and soil, etc.) and human cultures, thus expanding the definition to include conservation. This more inclusive definition has now been adopted by WHO [14]. We note that while the traditional human health definition of environmental health may include the living and non-living environment being free from ecologically harmful pollutants, this interpretation differs from the more recent One Health definition of environmental health in important ways. For example, disinfectants and pesticides may remove immediate human health threats in a home, local community, or ecosystem. Despite saving millions of lives directly and indirectly, the applications of these can have direct and indirect impacts on the ecosystem; they kill target and non-target species, select for resistant species, and may contribute to reduced ecosystem health and functioning, including contributions to local, regional, and global issues, such as climate change, given the scale at which these measures are taken to maintain 'environmental health' from the human health perspective. Yet these measures are likely negatively contributing to human health impacts now and will continue and increasingly do so in the future. This may be individual impacts, such as reduced microbiome diversity and potential immune-mediated diseases (sometimes referred to as the hygiene-hypothesis; [15]) through to climate change, which ultimately will have great human health impacts [16]. Indeed, the healthcare sector is already responsible for an estimated 4.4% of global greenhouse gases, 2.8% of particulate matter, 3.4% of NOx, and 3.6% of SO2 emissions, contributing to environmental degradation, health-harming pollution, and climate change [17–19]. Thus, applying the human-centric definition of environmental health can miss important feedback loops when making policy decisions. It is the recognition that these direct and indirect feedbacks of actions in one sector impacting another that has motivated interest in the One Health approach among international authorities in the Quadripartite. These feedbacks cannot be ignored when the overarching vision is to sustainably balance and optimize the health of people, animals, and ecosystems (i.e., SDGs).

succinct updates and decision-makers will need to improve decision-making efficiency and competency when considering incomplete or evolving scientific evidence.

Some thought that cross-sector decision-making would bring more policy-makers into the mix and that too many people with different values will increase the time it takes to reach consensus for decision-making and lead to non-action. How to integrate the environmental perspective with human and domestic animal health may be especially challenging because conservation and climate change policy can move much more slowly and not be very structurally compatible with other sectors. This misalignment could be amplified through how different sectors integrate or value consideration of policy inputs such as indigenous perspectives [9], how success is defined in different sectors, and differences in recognizing and managing social or cultural flow-on effects of policies. These complexities make the potential outcomes of cross-sector policy more difficult to predict.

3.2.2. Limited operational capacity

Some participants said that currently it's difficult to see the benefits of cross-sector collaboration within and across government agencies because everyone is underfunded and overworked, and the agenda is too ambitious for people's workloads and policy timelines, so business-as-usual strategies continue. Government personnel already feel that maintaining capacity for disease response readiness is challenging – adding a One Health approach to the current workload seems infeasible. For example, some felt it's more important to prioritize the limited capacity on addressing imminent biosecurity risks using current approaches rather than focusing on trying to implement a new approach while known risks 'blow in on the wind' - reflecting a feeling that there is only enough capacity for reactive approaches.

Thus, in addition to the importance of clarifying what problems need One Health approaches and net benefits of a One Health approach on those problems (as above), the comments about limited capacity highlight that operationalizing One Health approaches will require dedicated resources and personnel so that sustainable response plans can be operationalized while change is implemented. If cross-sector roles are unclear, this could lead to redundancies that agencies cannot afford.

3.2.3. Constrained operational infrastructure

Within government agencies budget cycles are short and each prioritizes work based on objectives that are respecified on short-term cycles within a long-term mission area of the agency. Participants said this structure makes it difficult to incorporate new priorities rapidly unless they include addressing an urgent event such as disaster relief or a pandemic (for which agencies may already have contingency plans). This structure is confounded by rapid turnover in government positions, which hinders the development of strong institutional knowledge, cross-agency relationships, and awareness of cross-sector concerns for making progress towards implementing One Health approaches. Participants said government agencies are not currently commissioning nor analyzing science from One Health sectors using a cross-agency, One Health lens.

One participant said researchers are getting much of the One Health funding but they are not the group that can solve the implementation problems. A few of the participants that focus on applied research and translational science stated that, of the available research funding, most is for blue skies research which is prioritized over translational science making it more difficult for research to bridge the operational gap. Currently, government agencies are only beginning to work through potential approaches for operationalization.

Conversations about how to operate within a One Health paradigm are challenging because any particular One Health problem only focuses on a subset of the mission area from each relevant agency, which leads to a lack of interest from some decision-makers. For example, some participants said One Health does not cover important disciplines of public health, such as human behavior or regulation of commercial determinants of health and it currently does not interface well with the political systems that determine health outcomes. Another participant said human and animal health have very different policy considerations in practice. Thus, some felt that the One Health concept is not relevant broadly enough in practice, which is why it has struggled to transition from the research community to practice. These coordination challenges for practicing One Health can be especially large in big, highly structured government settings or highly decentralized governments.

3.2.4. Cultural legacy

A final challenge raised by participants was that the One Health concept gained popularity mainly through a focus of researchers, human medical doctors, and veterinarians studying infectious disease transmission at the human-animal interface. Progress demonstrates that understanding interactions of host species with each other and their ecosystems is important for effective control of zoonotic disease [6,10,11]. The focus on zoonotic infectious disease emergence has made it difficult for environmental sector professionals to engage because metrics of success have been focused on physical human health (excluding environment) and methodologies from human and veterinary epidemiology are different from environmental health-focused fields (methodological misalignment [12]). Also, because of the more narrow focus on zoonotic disease outcomes in humans early on, One Health has struggled to rebrand its scope to be more inclusive (e.g., [1]) in the human health sector – where the biggest concerns are not zoonotic diseases.

4. How priorities are determined

4.1. How prioritization occurs: Not currently using a One Health lens

Most participants admitted that there is no One Health prioritization – priorities in One Health sectors are determined in isolation from other sectors rather than through a One Health lens. Thus, priorities are determined by each agency's current mission focus and generally on a tight budget (i.e., without much latitude for additional work). Currently, agencies are at the stage of identifying when their separate priorities have One Health implications and thus when they may need to consult with other agencies. This is very different from operating through a One Health prioritization scheme because it means that agencies have not collaborated on determining priorities, which results in downstream collaboration only when it's convenient.

Prioritizing One Health research is ahead of operational contexts because research priorities arise following working groups of science experts that identify highest priority research. These groups can be readily assembled and do not have infrastructure or mission area barriers that prevent forming interdisciplinary research teams to address cross-sector objectives. In contrast, agency priorities are determined based on agency-specific strategic planning involving agency-specific leaders or stakeholder elicitation and are revisited infrequently. This process considers a broader set of factors than science. Interestingly, several of the participants based in university contexts answered 'I don't know' when asked how One Health sector priorities are determined in practice, further highlighting the contextual knowledge gap at the science-operations-policy interface [20,21].

4.2. Factors at play: Urgency of the threat gets most highly prioritized

Most claimed that 'urgency of threat' is the primary determinant of prioritization in One Health sectors in government operations, despite there being substantial effort invested in prioritization methods within sectors (e.g., [22–24]). After that, priorities are determined by the amount of risk that a particular sector sees towards humans – economy and public health were mentioned most often. Factors that come into play when developing specific objectives that get implemented include infrastructure and resources already in place, political will and

legislation, social license, perceived community need, capacity of government professionals, scientific evidence, direct requests from leadership, certainty of success, ease of engagement, recent experiences that build capacity in high-priority areas or identify shortcomings that need to be addressed, effectiveness of leaders in advocating for resources, conflicts of interest, and personalities and values of those involved in strategic planning. This long, although not exhaustive, list highlights why scientific evidence may sometimes appear to have a low weight in prioritization of government objectives that are implemented [25].

5. Incorporating science in operations or policy

Some of the challenges of operationalizing One Health stem from more general challenges with incorporating science in operations or policy. Participants highlighted four main challenges that require attention for improving translation of One Health science to practice: 1) improved understanding of research contexts by government and of government contexts and policy processes by non-government research scientists; 2) greater emphasis on scientist-government relationship building; 3) increased connection to public perspectives and developing strategies for addressing misinformation, and; 4) improved science communication.

5.1. Understanding contexts

The science-policy divide [26] has continued to grow wider. Participants said non-government research scientists do not understand enough about the business culture of government institutions and policy processes to optimize science production for uptake, for example 'producing the right information at the right time'. Policy-making is a values-based process with frequent decisions that may create a 'runaway train' that evidence production struggles to keep up with. Thus, effective uptake of scientific evidence needs to begin very early and be continuous to stay on the train. This can be challenging because science can take longer than decision timelines and decision-makers are not required to wait for the best evidence. Sometimes a decision-maker may prefer other information over incomplete scientific evidence, and there are no rules against these choices. Better understanding of contexts and building long-term relationships can help with managing these misalignments [25].

Similarly, one participant said government professionals do not understand enough about the business culture of research organizations to effectively leverage science towards government needs. Additionally, government professionals may not have mechanisms in place to reach out to the right scientist at the right time. This can lead to lack of engagement with scientists even though decision-makers pointed out that good policy needs evidence and careful consideration. Also, when engagement does occur, participants said it can be through small networks of the same scientists, which limits the potential breadth and quality of evidence [25]. More opportunities are needed for scientists to be trained in how to effectively engage with policy processes and government operations (e.g., through temporary assignments/sabbaticals [27]), and for government professionals to efficiently leverage the scientific community to provide evidence in a useful format. Also, government professionals in different sectors often have sector-specific training that shapes the structure and language of regulations differently, further complicating finding agreement on One Health objectives and approaches for operationalization [28].

5.2. Relationship building

Both scientists and government professionals work most effectively through trusted relationships [25]. Participants said trusted relationships between scientists and government professionals are difficult to build and maintain due to limited capacity and differences in position longevity, such rapid turnover in government staff, but making the investment is critical for effective uptake of science. Some government professionals are struggling to figure out how to trust scientists because scientists can be highly competitive and territorial, which adds complexity to the engagement. Others explained that they are frequently asked for letters of support for funding but then are never brought into funded projects as collaborators and only receive a final report, which ends up not being useful for practice. These interactions lead to distrust and lack of desire to invest in relationships with scientists.

5.3. Misinformation and scientist disconnection with the public

Many emphasized that there has been an erosion of credible science in the public domain through overwhelming growth of misinformation availability with pseudoscience elements [29]. These sources reach decision makers more commonly than scientific literature posing challenges for uptake of rigorous scientific evidence. Some said that decision-makers give misinformation equal weighting to rigorous scientific evidence. Increasing scientific literacy in government professionals and choosing leaders that value science are important priorities for uptake and funding of One Health science in practice, and understanding how the science can be used effectively. However, government-based participants are noticing that scientists tend to be unconnected to public opinion. For example, the idea that if the public believes misinformation, that misinformation might be addressing a concern or interest that science is not. Further, scientists can be too focused on statistics (populations – the good of the group) while the public are focused on themselves (individuals). To gain public support, scientists need to address the concerns of individuals. Working to convince individuals that they should act for the good of the group is lost on many people. Science is implemented most often when it is socially and culturally appropriate and has public trust.

5.4. Science communication

With the increasing complexity of scientific knowledge and technology, it is important to continue developing easy-to-understand strategies for communicating scientific evidence and its value. For example, one participant commented that we are now in a place where only half the job of the scientist is collecting data, analyzing, and reporting results – the other half is getting decision-makers to understand the value of science through relationship building and better alignment of interests and objectives. One Health science is especially complex – spanning scales of biological organization (within host processes, individual behavior, populations, communities) and across sectors while considering feedback loops (Box 1). Tools for rapid visualization of disparate data, demonstrating how different processes interact, are crucial facilitators of science communication. More fundamentally, there is a need 'to get the right level of science on the table' – 'not too in the weeds but informs the uncertainties in the minds of decision-makers'. This requires taking the time to understand what other people need, and understanding what they know and don't know [30]. The public and decision-makers 'need to see a compelling narrative and understand why action needs to be taken'. Scientists often use the approach of delivering facts believing people will value them, and thus delivering the information by saying 'you should do this because we say you need to'. But, this narrative is only a recommendation from a small subset of society, made by people unknown to the public, and does not bring people on the journey of learning why and coming to trust the information source. Thus, participants thought scientists are failing to communicate the most important information at the right times in the right way and be a trusted information source.

6. Science and technology most needed in One Health sectors

6.1. Social science, systems science, and being more selective about the science invested in

When asked about what science or technology is most needed in One Health, many thought that the domain-specific science is already where it needs to be, but we need to continue investing in the relevant life science domains. These statements were followed up by participants saying the biggest gaps are science communication, risk communication, and social science/psychology critical to combat misinformation, understand human behavior effects on health and uptake of biosecurity policies, and develop a more trusted model of engagement between academic scientists, government, and the public. Related, there was also mention of being more selective about whether the focus should be science production or operations – 'sometimes we try to develop new science when we already understand enough to solve the problem'; i.e., in some contexts, there may be enough science to have a highly beneficial impact if the funding is directed towards operations, where in other contexts more science might be needed. The other most common theme was a need for more systems science to interpret big disparate, dynamic data across sectors. Less commonly mentioned themes were to focus on climate impacts on biosecurity risks, science that supports surveillance design, risk assessment, and evaluation of interventions from available data and science that elucidates health drivers across sectors. Thus, in general participants thought applied science, social science, and science to improve communication, collaboration, and translation (science-to-policy action) were the highest priorities.

6.2. Better, faster, cheaper data collection and analytics

Recommendations for technology development mainly concerned better, faster, cheaper diagnostics, data collection, and data analytics – e.g., real-time data capture of social license or human well-being, genomic sequencing capability, automated data interpretation tools that can drive early detection or increase detection probability, ability to collect data about the state of the environment in real time and methods to store, collate, and interrogate it, technology to leverage all the information that is being collected every day for joint inference, data and systems interoperability with appropriate privacy and security, better animal traceability technology, animal welfare methods in biosecurity responses, better ways to measure human wellbeing, effective information sharing, environmental detection, remote monitoring, modeling capacity, cross-sector surveillance systems, IT infrastructure, data pipelines, tools to navigate complex analytics. These needs were similar across all sectors and professions in One Health sectors.

6.3. The biggest gaps are not science or technology

Several participants said that the most important gaps for operationalizing One Health are not from a lack of science and technology. Examples included relationship building with local communities for better uptake of health policies (extension work), infrastructure changes to accommodate new technology, upskilling around use of technology, better workflows for taking the science all the way through from production to policy decisions, effective and efficient mechanisms of information sharing, better models of partnership, changes to institutional infrastructure, work to identify the data or knowledge that can be generated from a One Health approach that cannot be obtained through a public, animal or ecosystem health approach. Also, work related to how to effectively get science and technology into the public arena where it can help strengthen the importance of things in people's conscious minds, and develop more rigorous systems for science-informed, timely decision making, cross-sector policy development, and capacity for operationalizing One Health agendas.

7. Professionals most needed

7.1. More holistic approach to training domain-specific professionals

In alignment with the science, technology and other needs mentioned above, many participants said that the full spectrum of domain-specific life science practitioners with cross-sector training remains essential. Participants thought that there also need to be more social scientists, social psychologists, mixed methods researchers (methods for bringing together quantitative and qualitative research), network scientists, systems scientists, bioeconomists, and people with interdisciplinary quantitative skills (especially data scientists, information technology, artificial intelligence and other computer science skills, data visualization experts, bioinformatics, statisticians, and mathematicians), working together with the life science practitioners. These thoughts are reflected in a recent call for experts to participate in the OHHLEP (Call for Experts - One Health High-Level Expert Panel ("OHHLEP") (who.int)). Some thought that 'we already have the right professionals – we just need to figure out how to use them more strategically'. Many mentioned that domain-specific professionals need different training – that universities or internships need to be cohort-based where students from One Health sectors are brought together and trained to solve problems together using the One Health paradigm throughout their academic trajectory, as in [31]. Participants said this would help to develop long-term cross-sector professional relationships, while growing respect for professionals in other sectors and providing knowledge for effective cross-sector collaboration.

7.2. Systems thinkers with good leadership and soft skills

Participants also suggested more general skills to emphasize when selecting and training individuals for One Health practice. The most common skill gap described was 'people who have the ability to see the big picture', and a need to balance these 'holistic thinkers' with domain-specific experts for better cross-sector integration. Other commonly mentioned skill gaps include dedicated knowledge brokers at the interface of research, policy, management, as in [32], training policymakers to understand how to translate good science into effective policy, training for improved soft skills (e.g., individuals that can work in teams, professionals that bring scientists together for collaboration, leadership and coordination, open-mindedness, quiet ego – 'appreciating when it is and is not time for your piece in a bigger puzzle', being able to communicate to diverse stakeholders), ability to identify the behavior changes needed across systems to allow improved collaboration, and rural professionals.

8. Recommended steps towards operationalization

Some participants are feeling cynical about the future of One Health – saying 'it's very hard to change people's behaviors'. Contemporary psychology theories of leading change in organizations involve meeting three main criteria: creating motivation (making people care about the problem), providing guidance (clarifying the path to the solution), and facilitating (making the path easy to follow) [33]. Based on the challenges described above, One Health has made progress on motivation but still needs to work on guidance and facilitation. Uptake by governments was viewed as critical if One Health approaches are to become a paradigm shift for meeting SDGs. For governments that would like to implement One Health approaches, participants suggested the following actions to address the current lack of guidance and facilitation.

8.1. Guidance: Develop joint objectives and metrics of success and action plans for cross-sector work

Leaders of relevant government agencies could develop a common set of objectives and vision of success that is messaged similarly within

their respective agencies. There is a global joint plan of action from WHO, WAOH, FAO and UNEP that can be leveraged for cross-sector coordination at national scales. Leaders could mandate and reward cross-agency collaboration on these common objectives. Methods such as participatory action research, structured-decision making, or other workshop-type approaches to structured strategic planning are important for developing common objectives and performance metrics. Having a structured commitment at the policy level in centralized government will be important to prioritize One Health discussions and coordinate action. These conversations could prioritize the challenges of better integration of the environmental problems, human wellbeing as a component of human health, and how to measure and value benefits jointly across One Health sectors. Once progress is made on joint objectives and metrics of success, these conversations would need to include action plans for cross-sector work.

8.2. Facilitation: Create dedicated positions, support cross-sector training programs, and incentivize behavior change

Dedicated positions and funding to facilitate cross-agency collaboration are important. Dedicated positions could be filled with people that have cross-sector training [31] and experience working in multiple sectors. Complementary approaches include developing cross-agency details (temporary appointments) or co-appointments and cross-agency budget lines with performance metrics tied to cross-sector objectives and collaboration rather than sector-specific objectives and outcomes. Incentives for longer-term appointments and work ethics of better knowledge transfer across position succession in cross-sector positions is important for maintaining in depth cohesive thinking and consistent development of complex initiatives. A longer-term action would be for government agencies to work with universities to develop workforce training programs that have a more holistic lens in terms of both the science-operations-policy interface and the human-agriculture-wildlife-environment interface. From these initiatives there could be multisectoral cohorts that conduct internships where they work on cross-sectoral policy challenges.

Some felt it will also be necessary to facilitate behavioral change, especially soft skill development to improve listening to understand the worldview of other sectors and raising awareness and reducing sector-specific jargon (Box 1). Also, choosing leaders that do not exhibit territorial behavior, define 'winning' more broadly than the specific agency they are in charge of, and value the contribution of professionals from different sectors equally. Moving away from consortia as the primary approach to cross-sector collaboration towards a more integrated approach drawing methods from the science of collaboration [34]. In terms of commissioning science, it will be important to increase longer-term funding opportunities to enable understanding of dynamic, complex systems, and to support more applied science initiatives that are translational to operational contexts. Achieving better science translation will require implementing mechanisms for government-based professionals and policy-makers to engage with scientists in non-emergency situations where appropriate contextual learning can occur. A useful approach could be to create joint research-operations funding initiatives that include both a research and operations component (e.g., [35]), where the science needs to be applied operationally, and benefits of the approach are measured (i.e., funding mechanisms that allows 4 or more years of funding).

9. Conclusion

We are currently on a trajectory that will not achieve any of the global SDGs even by 2050, let alone 2030. These problems include our inability to continue to produce and distribute sufficient food to keep up with rising human populations, whilst reducing the many different forms of malnutrition, biodiversity loss, and adverse climate changes, which have been the costs of human population growth and consumption [1,36]. Models have demonstrated that addressing the SDGs together can be beneficial, but that more ambitious actions are required by those in operational implementation or policy-making positions [3]. These global health and sustainability challenges are complex, multiscale problems that require coordinated action across a range of sectors. A One Health approach is essential to address these effectively, by pulling on multiple levers [37] to help reverse detrimental health and sustainability trends, but it remains challenging for organizations with implementation and policy-making capabilities to transition to applying a One Health approach in a 'business as usual' format. This transition requires behavioral and infrastructure change towards closer collaboration and co-development from all actors across the science-policy interface, including those in science production, science advising, operational implementation, and policy-making, for effective translation of One Health research to practice across different One Health sectors.

10. Methods

Our study protocol was submitted to Sterling IRB (number: 10792) and determined to be exempt from review pursuant to the terms of the U. S. Department of Health and Human Service's Policy for Protection of Human Research Subjects at 45C.F.R. §46.104(d) – following a Category 2 exemption (DHHS).

We employed a qualitative case study approach [38] to interview professionals from all One Health sectors (public health, environment, agriculture, and wildlife) as described previously [25]. Briefly, we conducted semi-structured interviews to allow the interviewer to follow up and explore relevant and meaningful ideas that emerged in the course of the interview [39]. This approach facilitated the identification and exploration of themes raised by participants that were not described in our a priori interview guide. Further, the interviewer was able to focus on the specific areas of expertise of the interviewee, while contrasting perspectives of other interviewees [40]. Co-authors working in OHHLEP and on cross-agency mission areas developed the initial interview topics. Topics were reviewed by two US-based One Health professionals in operational decision-making roles and pre-tested by two other US-based One Health professionals. The interview guide was adapted during the study to most efficiently capture the insights and experiences of participants (see SI for interview guide).

We employed a non-random snowball [41] and purposive sampling [42] approach to identify participants. This involved an initial set of 7 participants who were thought to be well connected in their professional networks and represented a variety of contexts (1 national government agency, 2 non-profit research with a national mission, 1 non-profit operation with a national mission, 3 university), sectors (3 domestic animal, 1 environment, 1 public health, and 2 wildlife health), and roles (3 science producer, 2 senior or chief scientists, or 2 policy-makers). We had the following criteria for participants: (a) experience informing management or policy decisions that consider science; (b) some exposure to building, interpreting, or making decisions using science from models; and (c) a professional background within or across diverse One Health sectors (Public health, Agriculture, Wildlife, Environment). Criterion (b) was more relevant to a separate objective of our study [25]. Six out of 7 people from the initial set agreed to participate and all suggested additional colleagues. We aimed to have at least 2–3 participants working in each One Health sector and for each level of the following dimensions that were not mutually exclusive: organizational context (levels: national government, local government, university, other non-governmental organization), and professional role (levels: science production, science advisor to decision-maker, operational management, policy decision-maker). This resulted in a total of 41 interviews being conducted. Our study focused on participants residing in New Zealand who work on national-scale issues in One Health sectors, although most (66%) of the participants were trained in other countries and some are involved in international One Health research, training, or

implementation, providing perspectives from many other countries across a range of economic statuses. This approach allowed us to understand perspectives of individuals working in different contexts of the same national network, while also identifying themes that are generalizable for other national-scale governments.

Prior to the interviews, all participants were given a summary of the study and signed an informed consent form. All interviews were conducted by KMP. Interviews had a duration of 45 to 90 min, were audio recorded, and transcribed using artificial intelligence software (Descript). For verification of the transcriptions, each audio file was listened to while reading the text file, and edited for accuracy [25]. Participants then received a copy of the text transcripts to review. No errors were found that changed the meaning of the text. Content analysis of text transcripts [43] was conducted by KMP to identify and synthesize themes. A spreadsheet was developed by KMP that included interview-question topics as column headers. For each interview question topic, KMP analyzed each participant's transcript and identified themes. Consistent labelling of each theme emerged with increased analysis of transcripts and the question topics. In an iterative process, some transcripts were re-assessed to verify consistency and accuracy of each theme label. The resulting spreadsheet of all themes could be visually examined by question topic to identify and quantify themes.

CRediT authorship contribution statement

Kim M. Pepin: Conceptualization, Data curation, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources. **Keith Carlisle:** Methodology, Writing – review & editing. **Dean Anderson:** Writing – review & editing. **Richard B. Chipman:** Writing – review & editing. **Jackie Benschop:** Writing – review & editing. **Nigel P. French:** Writing – review & editing. **Suzie Greenhalgh:** Methodology, Writing – review & editing. **Scott McDougall:** Writing – review & editing. **Petra Muellner:** Visualization, Writing – review & editing. **Emil Murphy:** Writing – review & editing. **Dion R.J. O'Neale:** Writing – review & editing. **Michael J. Plank:** Writing – review & editing, Visualization. **David T.S. Hayman:** Conceptualization, Resources, Visualization, Writing – original draft, Writing – review & editing.

Declaration of competing interest

None.

Data availability

The data that has been used is confidential.

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Appendix A. Supplementary data

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