The environment in global health governance: an analysis of environment-related resolutions adopted at the World Health Assembly from 1948 to 2023

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Summary

Background The concept of planetary health underscores the intricate relationship between environmental concerns and global health. This interconnection raises an important question related to cross-sectoral policy development: to what extent are environmental issues integrated into global health governance? To address this question, this study examines resolutions adopted by the World Health Assembly (WHA) from 1948 to 2023.

Methods Based on a systematic text search for environmental issues, this study examines the evolution of the occurrence and content of resolutions adopted by the WHA and the structure and pattern of connectivity of the normative network of resolutions regarding environment-related resolutions from 1948 to 2023. Environment-related resolutions were processed in the Python environment using relevant packages, such as Pandas, Numpy, and Matplotlib. Regular expressions were employed to identify citations among resolutions and construct a directed citation network. The network was then examined using NetworkX and Graph-Tool.

Findings Despite important variations in the attention dedicated to environmental issues in resolutions adopted by the WHA, the proportion of environment-related resolutions adopted each year has increased. The number of topics and their diversity have also expanded. Although environment-specific resolutions are well connected to each other, they are more weakly connected to environment-related resolutions, and not well connected to non-environment-related resolutions, suggesting potential silos in policy development. This study shows that several topical entry points exist for a deeper integration of environmental concerns in global health governance.

Interpretation The findings of this study indicate not only the growing reference to environmental concerns in global health governance, but also an evolution of the understanding of the environment as a key driver of the health of the people. However, there remains room for more comprehensive integration across all areas of global health policy. The study emphasises both the need for active participation in global environmental governance processes that affect health and the importance of minimising the health sector's contribution to environmental problems.

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Introduction

Nearly one in four deaths worldwide today is attributed to environmental factors.[1] A damaged environment alters the risk of diseases (non-communicable diseases [NCDs] and emerging infectious diseases), increases the likelihood of extreme weather disasters, jeopardises food security, and reduces the wellbeing of the population.[2,3] Given the adoption of the Sustainable Development Goals as a set of interconnected goals, a key question is how global health governance has addressed environmental issues, and conversely, how environmental governance has incorporated health issues. Previous research on the topic has found that environmental treaties do contribute to global health governance.[4–6] Countries that are most affected by climate change are more engaged in mentioning health concerns in general debates of the UN.[7] However, the extent to which global health governance addresses environmental concerns remains unclear.

To address this gap, this study examines the corpus of resolutions from the World Health Assembly (WHA), the highest decision-making body of WHO. As a negotiation platform among Member States, the WHA influences national policies and international regimes,[8,9] forming a vital part of the global health system's normative function. Although not legally binding on Member States (ie, considered as soft law), WHA's consensus-based resolutions nevertheless express States' willingness to behave according to some international normative standards.[10,11] Resolutions serve as valuable sources of information, given the scarcity of international treaties and other hard law instruments (eg, International Health Regulations) that focus primarily on health.[12]

Research in context

Evidence before this study
Previous research has highlighted the interconnectedness of the environment and human health, leading to the emergence of the concepts of One Health and Planetary Health. Growing attention is being paid to the nexus of environmental and global health governance in relation to the challenges associated with climate change. A bibliometric search conducted on PubMed, Scopus, and Google Scholar on March 10, 2024, of scientific articles in English containing the terms "global health governance" and "environment" revealed few empirical studies. Previous research on the topic has found that environmental treaties do contribute to global health governance. How global health governance addresses environmental concerns remains unclear.

Added value of this study
This study represents the first effort to systematically identify all environment-related resolutions adopted by the World Health Assembly (WHA) from 1948 to 2023 and to investigate WHO's approach to addressing environmental issues over time.

The number of environment-related resolutions adopted each year by the WHA has varied and been influenced by political processes outside the global health arena. The increased relative frequency and connectivity of resolutions covering environmental topics over time suggests the growing integration of the environment topic in WHA health debates. However, the limited connectivity between environment-specific resolutions and non-environment-related resolutions shows the limits of the current integration.

Implications of all the available evidence
WHA increasingly recognises the diverse ways in which the environment acts as a key determinant of human health. WHO must continue to engage in processes of global environmental governance when they affect health, while simultaneously working to minimise the health sector's contribution to environmental issues. This continuous engagement can foster improved coordinated action in addressing the most consequential global health challenges.

By analysing environment-related resolutions within the overall body of WHA resolutions from 1948 to 2023, this study focuses on the evolution of: (1) the occurrence and content of WHO environment-related resolutions, (2) the structure of their normative citation network, consisting of all WHA resolutions including in-text citations of previously adopted resolutions, by newer ones,[13,14] and (3) their content in terms of the entities contained. Named entities provide information about the main actors involved and the diversity of governance arrangements. Given the overlapping structure of the health and environment international regimes,[4,15] the aim of this study is to unravel the alignment and interactions between environment-related resolutions from WHA, identifying key trends, relationships, and the influence of these resolutions on global health and environmental policy.

See **Online** for appendix

Methods
Data identification
Based on a previous paper which presented a network analysis of WHA resolutions from 1948 to 2022,[16] WHA resolutions from 1948 to 2023 were collected electronically as PDF documents from the Institutional Repository for Information Sharing (IRIS) database and the WHO website,[17] processed for optical character recognition with ABBYY FineReader OCR Editor (version 16.0.14.7295) and exported to text files. The network of citation was updated with the addition of the WHA resolutions adopted in 2023 by using regular expression as in the original article.[16] Considering the environment as all the external conditions affecting the life of a human being,[18] an initial list of keywords was developed based on the

WHO Environmental Health Programme,[19] The Rockefeller Foundation–*Lancet* Commission on planetary health in 2015,[3] and a bibliometric analysis of the term planetary health.[20]

This list was further expanded by conducting a search of the title of the documents and by using word embedding to find the five most similar terms based on cosine similarity (Word2Vec, BERT, and GPT2). In total, we searched for 73 keywords, details of which are available in the appendix (p 1). Regular expressions were used to search all keywords based on partial match (ie, any sequence of characters that match the characters present in the keywords (appendix p 1). For example, the search for water yielded "water", "waterborne", and "freshwater". The initial results were manually screened for relevance. Four exclusion criteria were applied: (1) at the keyword level, irrelevant terms such as "Chairperson" found for the search "air" were excluded; (2) further irrelevant results such as "political environment" were excluded based on n-grams; (3) several resolutions were excluded based on the context which indicated that the code does not refer to the natural environment; and (4) the code referred exclusively to an international entity cited with numerous other international organisations in the context of a country's membership or the code refers to the title of another cited environment-related document.

Any resolution with at least one valid code was added to the final dataset. Environment-related resolutions were then manually coded based on their main topic contained in the title of the resolution. A total of 166 unique subtopics were identified in the analysis. These subtopics were subsequently organised into 20 broader topics (appendix pp 2–6). Finally, all international system

entities (ie, actors, mechanisms, events, and documents) named in the 50th percentile of the resolutions with the highest environmental score (n=232) were manually coded using standard qualitative research procedure to assess how WHA engaged with different components of the international system over time. Identical entities cited differently were grouped together. The analysis centred on the 50th percentile to ensure that the resolutions considered were substantively relevant to environmental concerns. For legibility and practical purposes, entities related to WHO governance and financial statements, such as the Executive Board, the Tax Equalization Fund, or the Annual Report of the Director-General were not included in the entities.

Data analysis

Environment-related resolutions were analysed in the Python environment using relevant packages (Pandas, Numpy, MatPlotLib). To investigate the extent to which the environment is represented in the resolutions, we derived an environmental score for each resolution. This score is based on the number of keywords multiplied by the number of unique keywords and divided by the square root of the total number of words present in the resolution. We used the 1·5 IQR method to identify outliers and qualified those outliers as environment-specific resolutions. We aggregated the results by year to uncover potential trends in the data. Using Igraph and graph-tool packages in Python, we further analysed how new resolutions cite previously adopted ones, thus creating a directed network of environment-related resolutions for the period 1948–2023. Network metrics including degree (ie, the number of edges incident on a given node) were computed.

Based on the classification of the resolutions into environment-specific, environment-related, and non-environment-related categories, we calculated densities to assess both within-group and between-group connectivity. A higher density indicates more connections between the categories relative to the total possible connections. The density of a graph is typically defined as the ratio of the number of actual edges to the number of possible edges. For a directed graph with n nodes, the maximum number of possible edges is $n(n-1)$, as each node can have an edge to every other node except itself. For between-category, we calculated density=number of actual edges/(number of nodes in source category×number of nodes in the target category). This represents the ratio of actual connections to all possible connections between the two categories.

Eight time periods were selected to analyse the evolution of the network concerning environment-related resolutions: (1) 1948–53, (2) 1948–73, (3) 1948–88 (4) 1948–98, (5) 1948–2002, (6) 1948–2005, (7) 1948–2017, and (8) 1948–2023. They represent the state of the network at the end of different administrations that have run WHO since its creation. We applied a community

detection algorithm to the network of environment-related resolutions to identify densely connected subgroups.[21] Given its fast convergence, robustness to noise, and high resolution and accuracy, the Leiden algorithm (as implemented in Igraph) was well-suited for the detection of communities of resolutions.[22] Because a higher-resolution parameter generally yields more communities made of fewer nodes, we used different values for the resolution parameter to test how it affected the number of communities and generated a qualitative sensitivity analysis. Finally, we conducted some descriptive statistics of the communities and further analysed a range of correlations between several indicators.

Role of the funding source

There was no funding source for this study.

Results

3213 resolutions were identified from the IRIS database, of which 3204 had the full text available (figure 1). Among the 3204 full text resolutions available in the WHA

Identification of environment-related resolutions

3213 resolutions identified from the IRIS database

→ 9 resolutions did not have full text available

3204 full-text resolutions available in the database

810 resolutions identified through sequences of characters based on keywords

→ 219 resolutions excluded because the sequence of characters did not correspond to an environment-related keyword

591 resolutions screened

→ 107 resolutions excluded because the keywords were not related to the natural environment

→ 12 resolutions excluded because the only mentions of the environment are referring to an international entity cited in general terms

→ 9 resolutions excluded because the keyword was not relevant in the context of the resolution
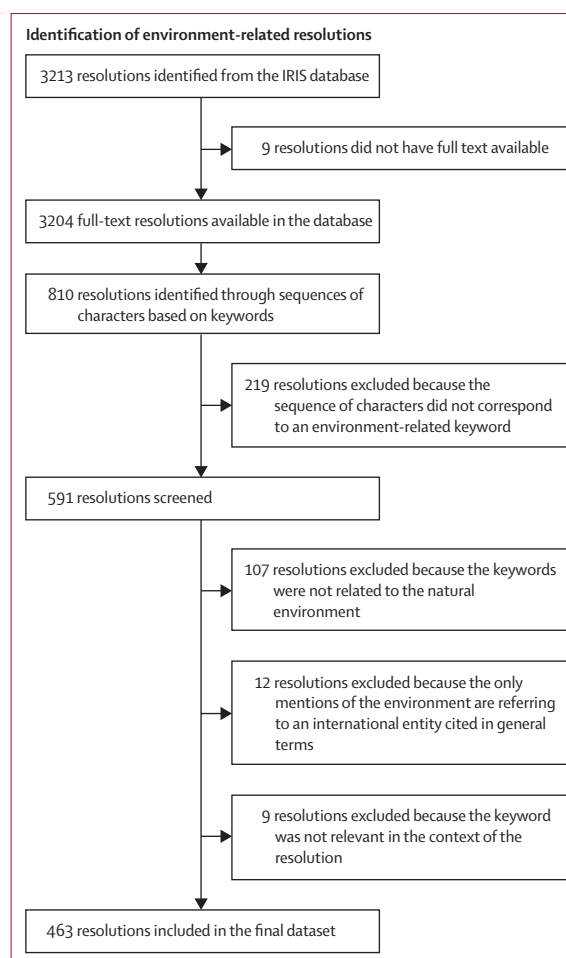
463 resolutions included in the final dataset

Figure 1: **PRISMA selection diagram**
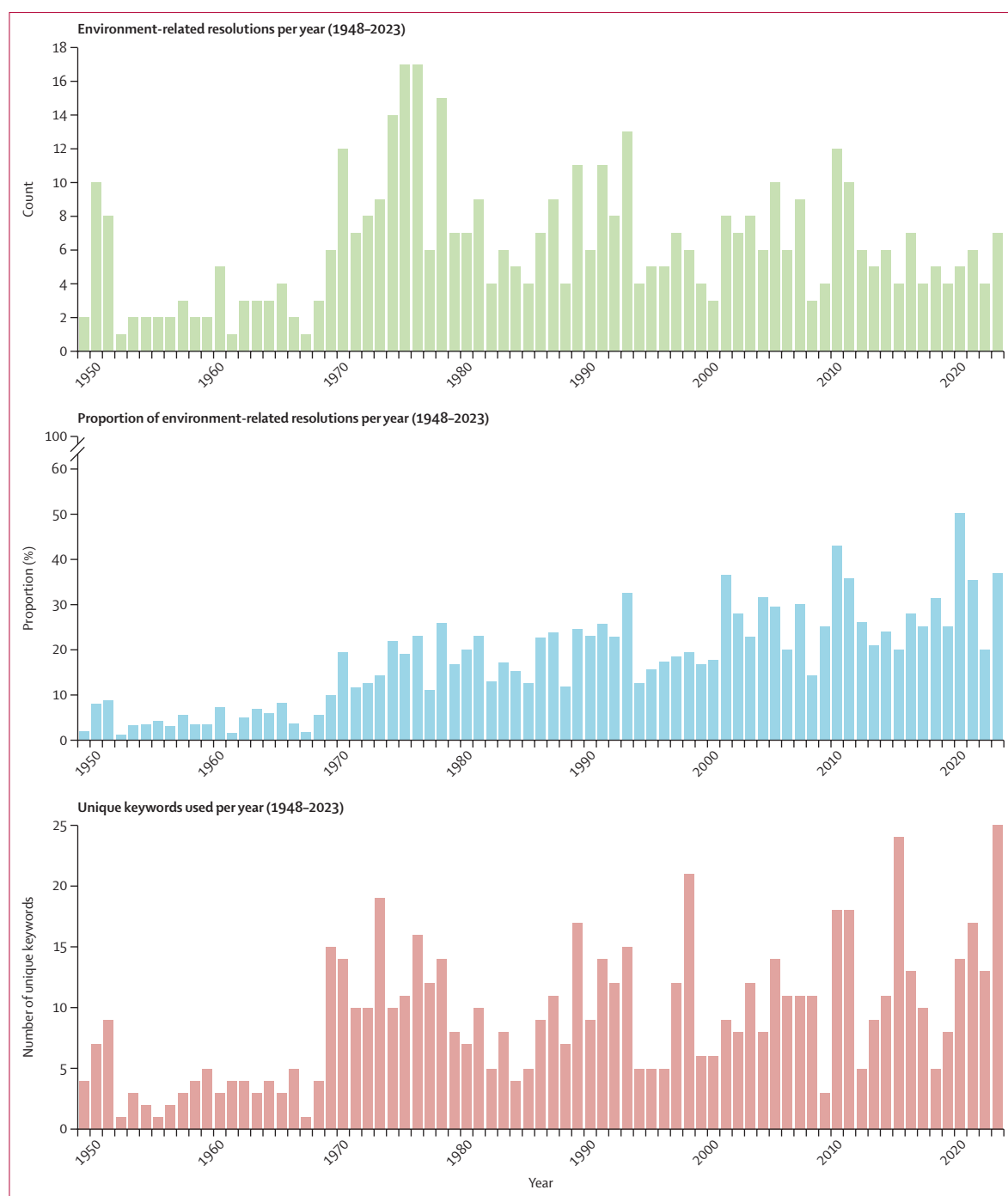IRIS=Institutional Repository for Information Sharing database.

Figure 2: Evolution by year of the number of environment-related resolutions from 1948 to 2023

dataset, a total of 463 (14%) were found to be environment-related, ranging from a single keyword related to environmental risk factors to resolutions with a strong environmental focus such as WHA61.19 on "Climate change and health" (2008; appendix pp 7–34). In total, 116 resolutions had a least one keyword in the title (environment, water, sanitation, and chemicals were the most frequent keywords). Moreover, the environmental score showed a skewed distribution with an average of 1·64 (SD 5·84). Using the IQR method, 57 resolutions (12%) were identified as environment-specific. Although most environmentally related resolutions had a few keywords related to the environment, the environment was a central concern in a few of them.

The absolute number of environment-related resolutions has notably varied over the 1948–2023 period (figure 2). After a peak of 17 environment-related resolutions in both 1975 and 1976 related to the follow-up of the 1972 UN Conference on the Human Environment and subsequent smaller peaks around 1993 and 2010 related to the 1992 and 2012 Rio conferences, the absolute number of environment-related resolutions has decreased over the years. As this decline mirrors a broader reduction in the total number of resolutions adopted by the WHA, a different pattern nonetheless emerges when examining relative trends. The proportion of environment-related resolutions compared with the total number of resolutions has risen over time. This upward trend in relative terms reached a peak in 2020, when environment-related resolutions constituted 50% of all resolutions adopted (five of ten total resolutions). The ratio of environment-specific to environment-related resolutions has increased throughout the different WHO administrations to reach 0·25 (appendix p 35). Finally, the diversity in keywords has also increased over the years and eight of the top ten resolutions for their environmental score were adopted since 2010. Overall, these trends suggest the growing integration of environmental issues into the WHA's agenda.

Based on the categorisation of the title of the 463 environment-related resolutions and their further grouping into 20 categories, the three main health topics most frequently related to the environment were infectious diseases, food agriculture and nutrition, and water sanitation and hygiene. Except for infectious diseases, which have remained relatively stable on the WHA agenda, environment-related issues covered in WHA resolutions have evolved over time. Nonetheless, no topic exceeds 30% of the total per period, except for food and nutrition in relation to the prevention of famine in the post World War 2 context (1948–59) and infectious diseases (2003–05; appendix p 35). Important topics include early resolutions on environmental sanitation, which focused mainly on waste management and water safety.[23] They were followed by resolutions on radiation, which disappeared at the end of the Cold War in the early 1990s after the WHA requested an advisory opinion on the matter to the International Court of Justice in WHA46.40.[24] Activity related to environmental pollutants (eg, chemicals including pesticides) started early in 1949 with the first session of the Expert Committee on Insecticides and peaked in 1992 with the International Programme on Chemical Safety.[25] A recent resolution (WHA76.17) adopted in 2023 covered that topic extensively.

In the 1970s, resolutions with a high environmental score, adopted in the wake of the 1972 Stockholm Conference, appear. WHO took a prominent role in this Conference (panel). This period also led to the development of the WHO Human Health and Environment Programme. The pattern of adoption

Panel: The role of WHO at the UN Conference on the Human Environment (Stockholm, 1972)

The World Health Assembly (WHA) was involved in the conference preparation, calling for attention to public health issues (both from Member States and UN agencies), while already planning to implement the Conference's outcomes regarding its environmental health programme (WHA22.57 and WHA23.60). The WHA also anticipated the possible emergence of funds resulting from the Conference by submitting beforehand its programme capabilities in the field of the environment (WHA24.47), recalled its constitutional competence and responsibility regarding the outcome of the Conference in the matter of health (WHA25.58), and eventually endorsed the recommendations made at the Conference, especially regarding its long-term programme in environmental health (WHA26.58 and WHA26.59). The Action Plan of the Conference cited WHO in 16 recommendations, from conducting research and training staff to assisting governments in the monitoring of harmful pollutants and strengthening collaboration with the UN system. Finally, the Proceedings of the Conference officially mentioned WHO as a participant and its advising role regarding the members of the First Committee at the national level, while emphasising its leading role in research.

linked to international conferences emerged again following the 1977 UN Water Conference, the 1992 UN Conference on Environment and Development and the International Conference on Water and the Environment, the 1995 Conference on the Protection of the Marine Environment from Land-based Activities, the 2002 World Summit on Sustainable Development, the 2009 International Conference on Chemicals Management, and the 2012 UN Conference on Sustainable Development (Rio+20). These events were associated with the presence of keywords related to the environment in 17 resolutions that specifically cover the budget and funding of WHO. Environmental concerns were followed by a specific budgetary allocation in the WHO budget.

The number and diversity of environment-related keywords are associated with outside political events and follow a similar pattern to the topics. For example, several new keywords appeared in 1997 and 1998, such as "desertification", "biodiversity", "ocean" or "ozone", mainly drawn from resolution WHA51.29 on climate change and ozone depletion (1998). This is the first WHA resolution that referred to climate change as a key determinant of health. Recent resolutions have the largest diversity of unique keywords. For example, resolution WHA68.8 on air pollution mentions 20 different environment-related keywords, including "nitrogen", "forest" and "ecosystem" used for the first time. This resolution was followed by WHA76.16, which focuses on the impact of chemicals, waste, and pollution on human health. As for the One Health concept, it was
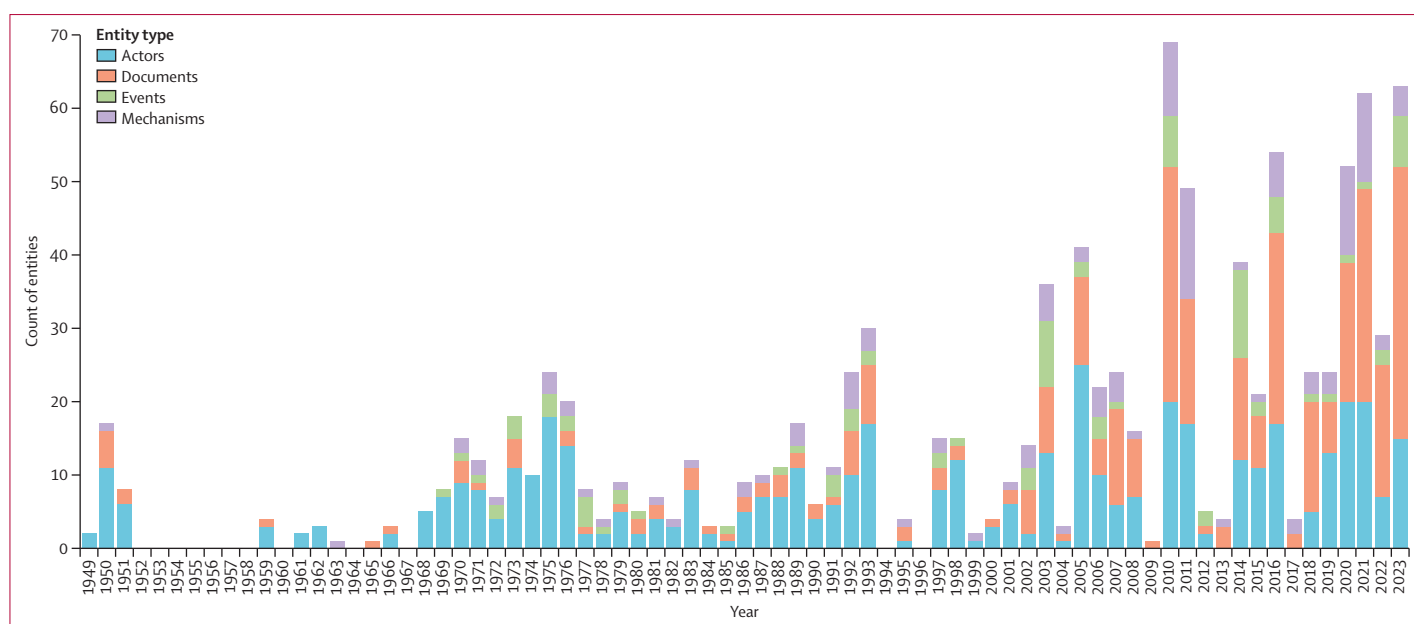
Figure 3: Evolution by year of entities of the international system cited in environment-related resolutions from 1948 to 2023

first introduced in 2013 in resolution WHA66.12 on Neglected Tropical Diseases, followed by resolutions on antimicrobial resistance in 2014, 2015, and 2019, as well as vector-borne diseases in 2017, infectious disease in 2020 and 2022, food in 2020, and health emergencies in 2020 and 2021. The past four years (2020–23) are characterised by the largest number of references to climate change and One Health. Overall, the use of these keywords suggests a growing understanding of the environment as a key health determinant in integrated social–ecological systems (ie, complex systems that encompass both ecological and social components).[26]

A total of 410 distinct entities were identified and cited 1038 times across the 232 resolutions (appendix pp 36–46). The evolution of citations by year and by type of entities, ranging from actors to events, through documents or mechanisms are presented in figure 3. The first 40 years display very few references to entities in environment-related resolutions, among which formal intergovernmental organisations (IGOs) are predominant, such as the International Atomic Energy Agency for resolutions on radiation or the UN Children's Fund, for the development of inter-agency collaboration. This is largely due to the shorter length of resolutions and the international system itself, which was mostly constituted of formal IGOs. The number of citations almost tripled in the past two decades, reflecting the densification of international institutions.[27] Most actors' citations refer to sub-entities of formal IGOs and other interinstitutional collaborations ("others" in the appendix p 47) such as the WHO Global Task Force on Antimicrobial Resistance, the Codex Alimentarius Commission, or the Intergovernmental Panel on Climate Change. Public–private partnerships and NGOs were marginally cited in the resolutions even though they are increasingly recognised by the international community.[28,29]

As for keywords, similar patterns of growth surrounded the 1972 Stockholm Conference or the 1992 Earth Summit in Rio, demonstrating the recognition of new actors such as the UN Environmental programme or the UN Development Programme, and documents or mechanisms such as Agenda 21 or the UN Framework Convention on Climate Change in global health governance. From 2005 onward, conferences, non-binding commitments (eg, WHO action plans and global strategies, political declarations from the UN General Assembly, or global conferences), global goals (eg, the Millennium Development Goals and the Sustainable Development Goals), and interinstitutional mechanisms exceeded mentions of formal treaties and IGOs (appendix p 47), reflecting a change in the international system towards greater informality.[30]

Binding international documents are also increasingly cited, although to a lesser extent than non-binding ones, and often refer to the International Health Regulations (2005), as well as the Basel (1992), Rotterdam (2004), and Stockholm conventions (2004). Finally, international mechanisms serving different functions, most predominantly awareness-raising, funding, and coordination and management, were cited extensively over the past two decades.[31] The awareness-raising function is illustrated by several references to WHO international health-related "days", "years" or "decades", while funding and coordination functions can be respectively attributed, in the recent COVID-19 context, to the Access

to COVID-19 Tools Accelerator or the COVID-19 Solidarity Response Fund.

The sub-network of environment-related resolutions is constituted of 463 nodes and 640 edges (figure 4). The global clustering coefficient and edge density of the network have increased over time, thereby suggesting that environment-related resolutions have gradually become more connected among themselves (appendix p 48).[32] In the current network, 86% of environment-related resolutions were found to have at least one link to another resolution. Their degree varies from 0 to 21, with an average degree of 2·77 and an SD of 3·60. Only 5% of these resolutions have a degree greater than 10, which reflects a similar trend to that of the overall WHA resolutions network—only a few nodes are highly cited while others are not. Environment-specific resolutions have a higher average degree of 4·09 (SD 3·20) than other environment-related resolutions (average degree 2·58 [SD 3·62]). However, some environment-specific resolutions have a degree of 0. These include WHA25.43 on water quality in international water resources, WHA32.31 on review of the medium-term programme for the promotion of environmental health, WHA43.25 on hazardous wastes management, and WHA50.14 on protection of the marine environment. These resolutions might correspond to issues that received attention at a certain point in time and have then been overlooked, hence representing failed attempts at developing international normative standards.

Community detection resulted in the identification of 24 communities of environment-related resolutions with more than four nodes (figure 4; appendix pp 49–56). 277 nodes (or 59%) are part of a community, and 232 (50%) nodes are part of the giant component. By contrast, eight communities are dissociated from the giant component, including the ones on malaria, traditional medicine, and schistosomiasis. These isolated components presumably play a less prominent role in shaping the environment-related normative network in contrast to the most connected communities (appendix p 56). Most communities are focused on the same subject matter, such as antimicrobial resistance, NCDs, or radiation, in accordance with the homophily principle,[33] but some larger communities combine different topics, reflecting a densely connected network of health issues. Moreover, when looking at all the ancestors of a recent environment-specific resolution such as WHA76.17 on the impact of chemicals, waste, and pollution on human health, this resolution relates to 13 environment-specific resolutions and 14 communities, thus suggesting that all of them contribute to the adoption of WHA76.17 as a key resolution advancing environmental concerns in global health governance (appendix p 57).

When plotting the average environmental score of nodes in a community against its average degree centrality, three outliers emerge based on the 1·5 IQR method (appendix p 58). With 31 nodes from 1978 to 2023, an average score of 12·14 (SD 17·74), and 20 environment-specific resolutions, community 2 is centrally related to water and sanitation. Community 19 (only five nodes and an average score of 10·96 [SD 9·02]) is focused on food safety in the context of the Codex Alimentarius Commission. Community 9 (12 nodes, average score 5·3 [SD 5·68]) with six environment-specific resolutions focuses on the human environment and the environment programme, which emerged from the negotiations processes surrounding the 1972 Stockholm Conference on the Human Environment. These three highly scoring communities are all part of the giant component and hence play a key role in shaping health norms related to environmental matters. Although community 9 is directly connected to only two other communities, it has a strong connectivity with community 2 (appendix p 56), suggesting that the work related to the environmental programme was used to further develop norms on water and sanitation.

The analysis of both within-group and between-group densities based on the full network of WHA resolutions provided further insights into the connectivity of environment-related resolutions (appendix pp 59–60). Although the three groups are of different sizes, overall connectivity is sparse for each group. However, environment-specific resolutions have a higher density than environment-related resolutions, which in turn have a higher density than non-environment-related resolutions. This finding is compatible with the high topicality of the environment-specific group. Furthermore, environment-specific resolutions are somewhat connected to environment-related nodes but are relatively isolated from non-environment-related nodes. This structure is compatible with a core–periphery model in which environment-related nodes act as intermediaries between environment-specific and non-environment-related resolutions. Finally, environment-specific resolutions cite more resolutions from other areas than they receive citations from. The very low number of edges between environment-specific and non-environment-related resolutions reflects the isolation of environment-specific resolutions from the rest of the corpus of WHA resolutions, thus pointing to a possible silo effect.[34]

Discussion

This study presents the first analysis of environment-related WHA resolutions from 1948 until 2023, thus providing insights into WHO's standard-setting efforts at the nexus between health and the environment. The combination of keyword analysis, entity identification, and network analysis conveys the picture of an organisation that increasingly addresses environmental issues, either by assessing the impact of other phenomena on health, or by integrating environmental elements into the main health concerns. Our study demonstrates that, in addition to specific concerns related to the environmental programmes, the

Community metacategories

- 1: Health promotion and prevention (11); Non-communicable diseases (4); Oral health (3); Social determinants (3); Family, maternal, and child health (2)
- 2: Water and sanitation (11); Chemicals (8); Health promotion and prevention (4); Cholera (2)
- 3: Health emergencies (8); International Health Regulations (5); Antimicrobial resistance (4); Preparedness (4); Health promotion and prevention (3); Universal Health Coverage (2)
- 4: Family, maternal, and child health (20); Food and nutrition (19); Infant and young child nutrition (12)
- 5: Medical assistance (11); Health emergencies (6); Drought (4)
- 6: Radiation and atomic energy (10); Chemicals (2); Health promotion and prevention (2)
- 7: Family, maternal, and child health (7); Health promotion and prevention (5)
- 8: Water and sanitation (8); Dracunculiasis (5)
- 9: Environment programme (5); Human environment (4)
- 10: Tobacco (3)
- 11: Blindness (2); Health and development (2); Universal Health Coverage (2)
- 12: Health conditions of the Arab population in the occupied Arab territories (7)
- 13: World health situation (3)
- 14: Health promotion and prevention (4)
- 15: Malaria (7)
- 16: Health conditions of the Arab population in the occupied Arab territories (4); Health promotion and prevention (2)
- 17: Traditional medicine (5)
- 18: Occupational health (2)
- 19: Food and nutrition (3)
- 20: Health systems strengthening (3)
- 21: Schistosomiasis (5)
- 22: Food and nutrition (5)
- 23: Water and sanitation (5)
- 24: International Sanitary Regulations (3)
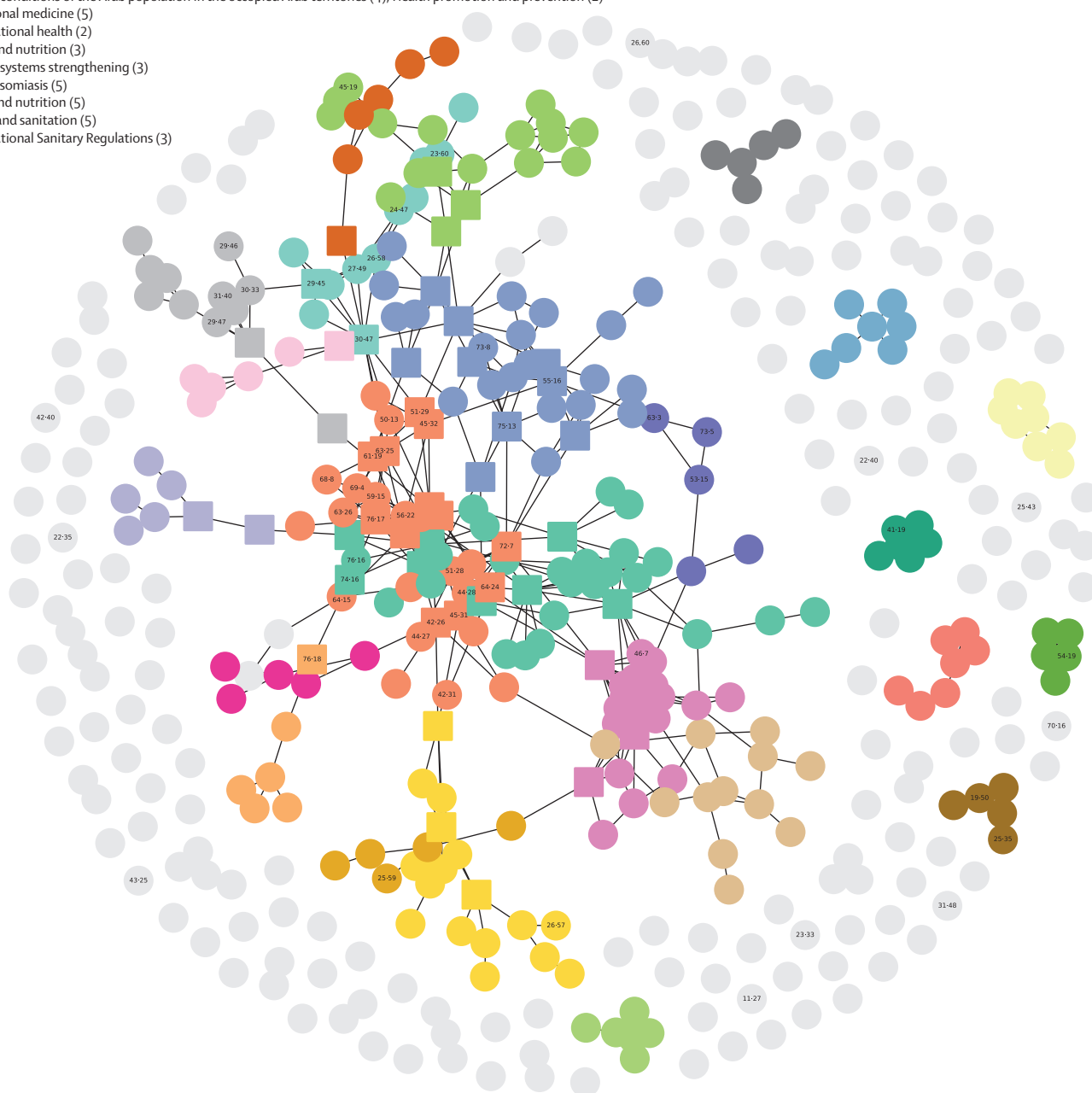
environment has been integrated into infectious diseases, water and sanitation, chemicals and pollution, and food and nutrition. These topics are all connected by the largest component of the sub-network of environment-related resolutions. However, there is a risk of environment-specific resolutions becoming isolated or siloed, where environment-specific resolutions reference each other but are seldom cited in non-environmental contexts.

With increasing evidence about different environment and health connections and related effective interventions to protect public health,[35] environmental concerns have become more prevalent in health debates, possibly signalling a stronger convergence of the health and environment agenda as captured by the concept of One Health and Planetary Health. This development runs in parallel to strengthened collaborations among the Food and Agriculture Organization of the UN, the UN Environment Programme, WHO, and the World Organization for Animal Health which adopted a Quadripartite action plan on One Health (2022–26) with six action tracks, including one that aims to integrate the environment into One Health.[36] This study's findings provide a useful foundation for strengthening the integration of the environment into the Quadripartite's work and health governance more broadly. In this regard, this study complements the previous literature which has highlighted the growing integration of health concerns into the environment,[4,5] and the need for health to be a central element of the response to climate change.[37]

The analyses conducted in this study demonstrate the notable expansion of the number of both topics addressed and entities cited by WHA resolutions. This, in turn, reflects the broader transformation of global governance since the 2000s.[38] The keyword analysis further reveals the increased variety of keywords related to the environment over the years. From our analysis, one can discern several policy framings of the environment as: (1) a reservoir for infectious diseases (pandemic, zoonosis, bilharziasis), (2) the source of natural disasters, including extreme weather events (storms, flooding), (3) an entity degraded by human activities (chemicals, pollution, air, water), (4) ecosystem services that support good health (climate change, biodiversity), and (5) a specific WHO policy priority (global environmental programme). Furthermore, community detection enabled the identification of topics that are important enough to be conveyed at the WHA

Figure 4: Communities in the network of environment-related resolutions from 1946 to 2023
Only nodes with a high environmental score are named in the graph (using the 1·5 IQR outlier detection method). Nodes with high betweenness centrality are shown as square (using the 90th percentile), while other nodes are shown as circles. The numbers in the key indicate how many resolutions cover a specific topic.

negotiation table over the years and resulted in incorporating environmental concerns in global health governance. Some resolutions are particularly significant in creating normative bridges between otherwise separated communities. Among the 47 nodes in the 90th percentile for their betweenness centrality value, 15 of them also have a high environment score (appendix pp 60–62). For example, resolution WHA30.47 on evaluation of the effects of chemicals on health connected the main environment community to resolutions on chemicals and, in turn, proved central to the recognition of the risks of chemicals to human health and the environment in the 1970s. The community detection analysis could be enhanced by implementing a longitudinal assessment, similar to approaches used in scientometric studies of scientific communities.[39]

Although several studies have demonstrated how international environmental agreements have fuelled global health efforts,[4,40] our findings suggest that political processes outside the global health arena, such as the global environmental regime, have been associated with efforts to develop an environmental programme at WHO. Network analysis and community detection bring to light multiple pathways in which health diplomats can leverage issue linkages and possibly complex contagion processes to advance topics across interconnected policy domains. The results suggest that events such as global conferences are more likely to result in the successful development of international normative standards when they relate to the primary health concerns of the time. These findings further highlight the importance of policy frames in global governance.[41,42] By contrast, resolutions associated with outside environment-related events without a direct WHO involvement in the process end up being completely isolated in the WHA network. How these findings relate to the abundant literature on normative development in international organisations should be further explored.[43]

This study has a few limitations. First, the abstract representation of the resolution network using citations simply captures the interest of Member States during WHA negotiations and hence does not capture more complex institutional interactions. It is not known yet how these institutional interactions shape the citation patterns. Unlike an interactive network capable of transmitting information in real time, the resolutions network should thus be considered as a symbolic network.[44] Second, the studied network represents only one layer of the broader global health institutional structure, leaving out agenda items, decisions, or the resolutions by the Executive Board. Yet, it provides insight into the system dynamics and probable governance outcomes initiated by WHO.

This study analysed environment-related resolutions within the entire corpus of WHA resolutions from 1948 to 2023. It shows not only the growing role of the

environment in global health governance but also the evolution of the topic itself. Because WHO is a specialised agency with a primary health mandate, it addresses environmental issues when they are related to health. However, it increasingly does so by adopting an integrated view of humans in nature. Despite important variations in the attention dedicated to environmental issues in WHA resolutions, the proportion of environment-related resolutions adopted each year by the WHA has increased over time, along with the number of topics covered, as well as their diversity. Our analysis also suggests that environment-specific resolutions have not yet been fully integrated into other health issues.

This study demonstrates the added value of data science to study the development of governance systems that integrate normative components from international organisations in non-health but related sectors. The development of computational diplomacy might help to further unravel this global complexity.[16,45] For example, inferential statistics could be useful to understand the main drivers of network development. Evidence about multilateral diplomacy processes will be crucial to inform the design of new mechanisms and institutions to better manage systemic interactions that affect global health.

As the interlinkages between health, animal, and environmental concerns are recognised, international organisations have strengthened cooperation in several areas. Relevant examples include: (1) the creation of the WHO Special Envoys for multilateral affairs in 2019, who are tasked to represent the Director-General and advocate for the organisation in international forums,[46] (2) the WHO and the UN Convention on Biological Diversity joint work programme in 2015,[47] and (3) the creation of a One Health High-Level Expert Panel which provides technical and scientific advice on One Health issues.[48] WHO must continue to engage in processes in global environmental governance when they impact health, while simultaneously working to minimise the health sector's environmental footprint, as recently recognised in resolution WHA77.14 on climate change and health. The Quadripartite should draw from the normative framework revealed in this study to strengthen the integration of the environment into its work and global health governance more broadly.

Contributors
DW conceptualised the study and provided the dataset. ME refined the methodology previously applied by AR and further conducted the entity analysis. DW and ME accessed and verified the underlying data and conducted the main analyses. ME wrote the successive drafts of the manuscript and prepared the figures and appendix. Both AR and ME worked under DW's supervision. LS, NL, BC, RB, PSJ, and J-LF provided comments and content on the manuscript. DW is responsible for the decision to submit the manuscript. All authors confirm they had access to all the data in the study and accept responsibility for the decision to submit for publication.

Declaration of interests

References
1 Prüss-Üstün A, Wolf J, Corvalán C, Bos R, Neira M. Preventing disease through healthy environments: a global assessment of the burden of disease from environmental risks. World Health Organization, 2016.
2 Corvalan C, Hales S, McMichael AJ, Butler C. Ecosystems and human well-being: health synthesis. World Health Organization, 2005.
3 Whitmee S, Haines A, Beyrer C, et al. Safeguarding human health in the Anthropocene epoch: report of The Rockefeller Foundation-Lancet Commission on planetary health. *Lancet* 2015; **386:** 1973–2028.
4 Morin J-F, Blouin C. How environmental treaties contribute to global health governance. *Global Health* 2019; **15:** 47.
5 Willetts L, Grant L. The health-environment nexus: global negotiations at a crossroads. *Lancet* 2022; **399:** 1677–78.
6 Willetts E, Grant L, Bansard J, Kohler P, Rosen T, Bettelli P. Health in the global environmental agenda: a policy guide. International Institute for Sustainable Development, 2022.
7 Dasandi N, Graham H, Lampard P, Jankin Mikhaylov S. Intergovernmental engagement on health impacts of climate change. *Bull World Health Organ* 2021; **99:** 102–111B.
8 Kitamura T, Obara H, Takashima Y, et al. World Health Assembly agendas and trends of international health issues for the last 43 years: analysis of World Health Assembly agendas between 1970 and 2012. *Health Policy* 2013; **110:** 198–206.
9 Hollway J, Morin J-F, Pauwelyn J. Structural conditions for novelty: the introduction of new environmental clauses to the trade regime complex. *Int Environ Agreement Polit Law Econ* 2020; **20:** 61–83.
10 Lee K. World Health Organisation. In: Sperling J ed. Handbook of governance and security. Edward Elgar Publishing, 2014: 504–18.
11 Moon S. Global health law and governance: concepts, tools, actors and power. In: Burci GL, Toebes B, eds. Research Handbook on Global Health Law. Edward Elgar Publishing, 2018: 24–54.
12 Gostin LO, Meier BM, Abdool Karim S, et al. The World Health Organization was born as a normative agency: seventy-five years of global health law under WHO governance. *PLoS Glob Public Health* 2024; **4:** e0002928.
13 Kajikawa Y, Ohno J, Takeda Y, Matsushima K, Komiyama H. Creating an academic landscape of sustainability science: an analysis of the citation network. *Sustain Sci* 2007; **2:** 221–31.
14 Golosovsky M, Solomon S. Stochastic dynamical model of a growing citation network based on a self-exciting point process. *Phys Rev Lett* 2012; **109:** 098701.
15 Alter KJ, Meunier S. The politics of international regime complexity. *Perspect Politics* 2009; **7:** 13–24.
16 Wernli D, Falcone J-L, Davidshofer S, Lee K, Chopard B, Levrat N. Emergent patterns in global health diplomacy: a network analysis of the resolutions adopted by the World Health Assembly from 1948 to 2022. *BMJ Glob Health* 2023; **8:** e011211.
17 WHO. Institutional Repository for Information Sharing. https://iris.who.int (accessed Aug 10, 2024).
18 Department for Economic and Social Information and Policy Analysis UN. Glossary of Environment Statistics. United Nations Publications, 1997.
19 WHO. Environmental health. https://www.who.int/health-topics/environmental-health#tab=tab_1 (accessed Aug 15, 2024).
20 Rossa-Roccor V, Acheson ES, Andrade-Rivas F, et al. Scoping review and bibliometric analysis of the term "Planetary Health" in the peer-reviewed literature. *Front Public Health* 2020; **8:** 343.
21 Fortunato S, Hric D. Community detection in networks: a user guide. *Phys Rep* 2016; **659:** 1–44.
22 Traag VA, Waltman L, van Eck NJ. From Louvain to Leiden: guaranteeing well-connected communities. *Sci Rep* 2019; **9:** 5233.

23 Brown TM, Cueto M, Fee E. The World Health Organization and the transition from "international" to "global" public health. *Am J Public Health* 2006; **96:** 62–72.

24 Rostow N. The World Health Organization, the International Court of Justice, and Nuclear Weapons. *Yale J Int'l L* 1995; **20:** 151.

25 Herrman JL. The role of the World Health Organization in the evaluation of pesticides. *Regul Toxicol Pharmacol* 1993; **17:** 282–86.

26 Wernli D, Jørgensen PS, Parmley EJ, et al. Scope and applicability of social-ecological resilience to antimicrobial resistance. *Lancet Planet Health* 2023; **7:** e630–37.

27 Raustiala K. Institutional proliferation and the international legal order. In: Dunoff JL, Pollack MA, eds. Interdisciplinary Perspectives on International Law and International Relations: The State of the Art. Kindle edition: Cambridge, 2012.

28 Betsill MM, Corell E. NGO influence in international environmental negotiations: a framework for analysis. *Glob Environ Polit* 2001; **1:** 65–85.

29 World Health Organization. Partnerships. https://www.who.int/about/collaboration/partnerships (accessed Aug 15, 2024).

30 Roger CB. The origins of informality: why the legal foundations of global governance are shifting, and why it matters. Oxford University Press, 2020.

31 Wernli D, Harbarth S, Levrat N, Pittet D. A 'whole of United Nations approach' to tackle antimicrobial resistance? A mapping of the mandate and activities of international organisations. *BMJ Glob Health* 2022; **7:** e008181.

32 Peng T-Q. Assortative mixing, preferential attachment, and triadic closure: a longitudinal study of tie-generative mechanisms in journal citation networks. *J Informetrics* 2015; **9:** 250–62.

33 McPherson M, Smith-Lovin L, Cook JM. Birds of a feather: homophily in social networks. *Annu Rev Sociol* 2001; **27:** 415–44.

34 Tett G. The silo effect: The peril of expertise and the promise of breaking down barriers. Simon and Schuster, 2016.

35 WHO. WHO launches a Repository of systematic reviews on interventions in environment, climate change and health. 2024. https://www.who.int/news/item/29-02-2024-who-launches-a-repository-of-systematic-reviews-on-interventions-in-environment--climate-change-and-health (acccessed Aug 8, 2024).

36 WHO. One Health Joint Plan of Action, 2022–2026: working together for the health of humans, animals, plants and the environment. World Health Organization, Food and Agriculture Organization of the United Nations, World Organisation for Animal Health & United Nations Environment Programme, 2022.

37 Romanello M, Napoli CD, Green C, et al. The 2023 report of the *Lancet* Countdown on health and climate change: the imperative for a health-centred response in a world facing irreversible harms. *Lancet* 2023; **402:** 2346–94.

38 McInnes C, Kamradt-Scott A, Lee K, Roemer-Mahler A, Rushton S, Williams OD. The Transformation of Global Health Governance. Palgrave Macmillan, 2014.

39 Leone Sciabolazza V, Vacca R, Kennelly Okraku T, McCarty C. Detecting and analyzing research communities in longitudinal scientific networks. *PLoS One* 2017; **12:** e0182516.

40 Lajaunie C, Mazzega P, Boulet R. Health in biodiversity-related conventions: analysis of a multiplex terminological network (1973–2016). In: Chen S-H, ed. Big Data in Computational Social Science and Humanities. Springer, 2018: 165–82.

41 Shiffman J, Shawar YR. Framing and the formation of global health priorities. *Lancet* 2022; **399:** 1977–90.

42 Dasandi N, Graham H, Hudson D, Jankin S, vanHeerde-Hudson J, Watts N. Positive, global, and health or environment framing bolsters public support for climate policies. *Commun Earth Environ* 2022; **3:** 239.

43 Finnemore M, Sikkink K. International norm dynamics and political change. *Int Organ* 1998; **52:** 887–917.

44 Kim RE. The emergent network structure of the multilateral environmental agreement system. *Glob Environ Change* 2013; **23:** 980–91.

45 Wernli D. Fostering interdisciplinary collaboration in computational diplomacy: a multi-layered network approach to improve our understanding of institutional complexity and effective governance design. *J Comput Sci* 2023; **72:** 102096.

46 WHO. Delegation of authority - Director General's Envoy, Multilateral Affairs. 2020. https://www.who.int/publications/m/item/delegation-of-authority---director-general-s-envoy-multilateral-affairs (accessed Aug 15, 2024).

47 Romanelli C, Cooper D, Campbell-Lendrum D, et al. Connecting global priorities: biodiversity and human health: a state of knowledge review. World Health Organization/Secretariat of the Convention on Biological Diversity, 2015.

48 Mettenleiter TC, Markotter W, Charron DF, et al. The One Health high-level expert panel (OHHLEP). *One Health Outlook* 2023; **5:** 18.