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Strengthened public awareness of one health to prevent zoonosis spillover to humans

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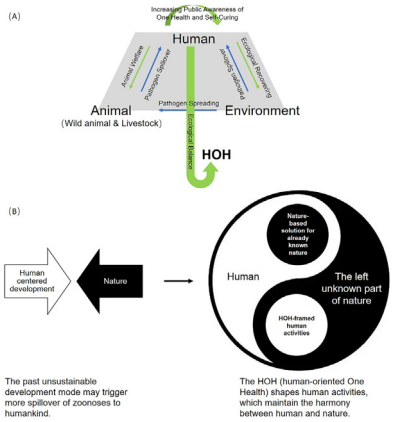
HIGHLIGHTS

- A human-oriented One Health concept was proposed.
- COVID-19 catalyzed public acceptance of One Health.
- Deepening One Health-framed environmental education is needed.

GRAPHICAL ABSTRACT



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ABSTRACT

The COVID-19 outbreak has forced the world to rethink the interconnected health of humans and nature, i.e. One Health (OH). However, the current sector-technology-based solutions have a high cost. We propose a human-oriented One Health (HOH) concept to restrain the unsustainable behaviors of natural resource exploitation and consumption, which may trigger original zoonosis spillover from an imbalanced natural ecosystem. HOH can complement a nature-based solution (NBS), where the former refers to the unknown part of nature, while the latter is based on already known natural knowledge. Additionally, a systemic analysis of popular Chinese social media during the pandemic outbreak (January 1–March 31, 2020) revealed that the wide public was influenced by OH thought. In the post-pandemic era, it is time to deepen public awareness of HOH to guide the world onto a more sustainable track and prevent more serious zoonosis spillover in the future.

1. Introduction

Outbreaks of zoonoses (e.g., SARS, MERS, and COVID-19) have seriously impacted global society. COVID-19 alone has been estimated to kill 15–20 million people (Adam, 2022) and cause losses of approximately 16 trillion USD (Cutler and Summers, 2020). Zoonoses originate from animals and spread to people, which is factually a spillover (Vora et al., 2022).

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Furthermore, a recent study discovered 102 mammalian-infecting viruses in game animals, including 21 viruses that pose a risk to humans (He et al., 2022). Moreover, climate change (Carlson et al., 2022) increases the risk of viral cross-species transmission, and deforestation brings novel pathogen-hosting wildlife to humans alongside (Gibb et al., 2020). Frequent and complex epidemics threaten human survival (Bedford et al., 2019).

To control the pandemic, community (and even entire city) lockdowns were implemented to cut off the spread chain (Cyranoski and Silver, 2020). Furthermore, therapy was offered to infected patients, and a vaccine was developed to protect healthy people (Vora et al., 2022). However, this required extensive labor, materials, and money (Vora et al., 2022), and additionally, large-scale disinfection agents increase resistance gene pollution, and disposable protective supplies release plastic waste into the environment (Rillig et al., 2021). However, solving systematic problems using sector-based operations is difficult. Therefore, we must find a more comprehensive and effective way to prevent the pandemic from recurring.

One Health (OH) recognizes the interdependent health of humans, animals, and the shared environment (defined by the World Health Organization in 2021) (Rocheleau et al., 2022). OH was first proposed in the early 2000s and reintroduced after the COVID-19 outbreak (Bonilla-Aldana et al., 2020). OH strengthened the idea that human-disturbed ecology might reverse pathogens to humans via contact or consumption (Borzée et al., 2020). The OH strategy is at the center of the world's recovery from the COVID-19 crisis (Jack et al., 2020). We found that the annual document growth rate of “One Health” titled SCI & SSCI (Science Citation Index Expanded and Social Science Citation Index) in Web of Science was 32 ± 10 % during 2019–2021. However, previous research has mainly focused on drugs and therapies for parasite-infected livestock (Innes et al., 2020), which were remedied after the crisis. Herein, we suggest that the OH approach should pay more attention to controlling the triggers of pandemics from human interventions to prevent future similar events from occurring (Fig. 1 A and Section 4.1). OH requires collaborative support from a wide social community (Ghai et al., 2022), and increasing public understanding of OH is crucial for reaching a social consensus (Rocheleau et al., 2022).

The COVID-19 outbreak provided a window (a pause) (Rutz et al., 2020) for us to investigate public understanding of zoonoses. Although

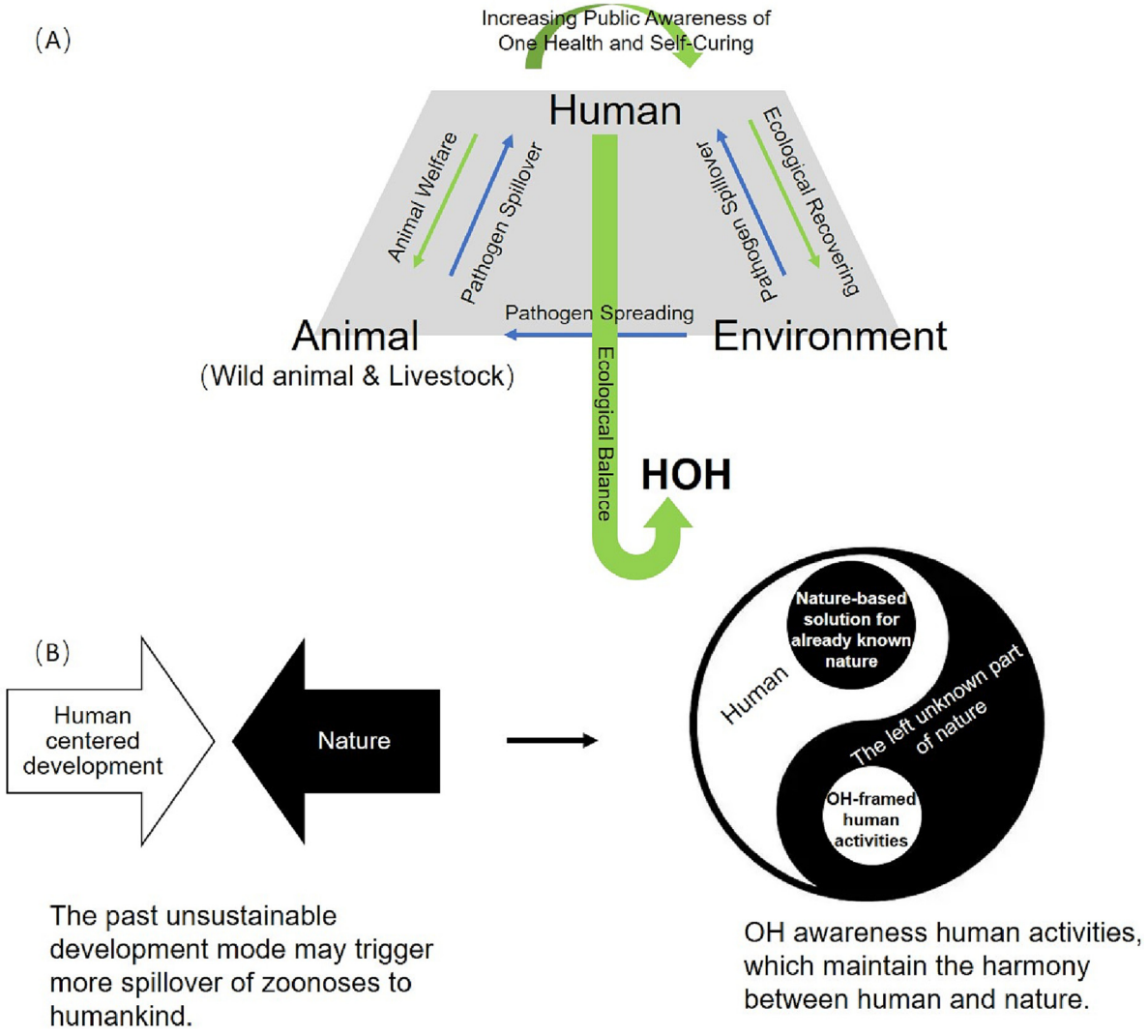

Fig. 1. Human status and functions in One Health (OH) (A): The health of humans, animals and the shared environment is interconnected (OH). Increasing public awareness of OH and guiding human behavior to be friendlier to animals and the environment. A maintained ecological balance can prevent zoonoses or environmental disease spillover to humans; The difference between human-centered development (HCD, on the left) and OH awareness-framed development (B, on the right): HCD only accepts the instrumental value of nature, which creates direct conflict between humans and nature. As a shift, HOH respects the intrinsic value (independent of people) and strengthens relational value (creating an environmentally friendly atmosphere). HOH aims to restrain unsustainable human behaviors to maintain harmony between humans and nature. HOH can complement nature-based solutions (NBS), where the former refers to the unknown part of nature, while the latter is based on already known natural knowledge.

many studies have analyzed the influence of the pandemic on public attitudes toward wildlife consumption, food safety (Xie et al., 2020), and wildlife conservation (Tarakini et al., 2021; Shi et al., 2020), OH-framed environmental awareness has not been discussed. In this study, we applied internet data technology (see Supporting Information) to mine public awareness of OH from China's most used social media platform, WeChat (founded by Tencent in 2011), which has ~1.3 billion active monthly users (Statista, 2022), during the COVID-19 outbreak in China (January 1 to March 31, 2020).

2. Methods

OH focuses on the interactions between humans and ecosystems (biological and non-biological environments), which is consistent with the general principles of environmental literacy (Pe'er et al., 2007; Scholz and Binder, 2011). Thus, in this study, we consider public awareness of One Health (PAOH) as an extension of Environmental Literacy (EL), which refers to the public understanding of the environment and human-environment interactions (Pe'er et al., 2007). Here, PAOH is the public awareness of human intervention in natural ecosystems, and human health is influenced by disturbed natural ecosystems. The three primary aspects (knowledge, attitude, and behavior) (Pe'er et al., 2007) that are included in EL were also evaluated for PAOH (Table 1). Evaluated issues were rearranged according to the 12 recommended Manhattan Principles (www.oneworldonehealth.org).

2.1. Data collection

2.1.1. WeChat Communication Index

The WeChat Communication Index (WCI) is a popular trend in keywords related to online events, similar to Google Trends. To analyze general trends of wildlife-related information, we collected four WCIs related to COVID-19 (“新型冠装病毒”), game (“野味”), wildlife conservation (“野生动物保护”), and ecological balance (“生态平衡”), during the COVID-19 outbreak in China.

WeChat article and online public comments.

WeChat official accounts (certain brand pages for individuals or institutes to facilitate cooperation and promotion) were chosen to collect posts (WeChat articles) between January 1 and March 31, 2020. Since COVID-19 was originally linked to the consumption of game meat, we chose keywords meaning “refuse to eat game meat” (“拒食野味”) (see Supporting Information). Information on poster users, public reading counts, and online comments was collected manually individually. The posters were classified into 19 groups according to the introduction of the WeChat Official Account and its released content (see the Supporting Information).

2.1.2. Pandemic data

Daily number of new confirmed cases (Jan 20–Feb 29, 2020) and provincial distribution of cumulative confirmed cases was collected from an online pandemic broadcast platform (丁香园疫情播报, https://3g.dxy.cn/newh5/view/pneumonia).

2.2. Content analysis of WeChat articles and public comments

In this section, we chose highly popular WeChat articles (reading count ≥10,000, accounting for ~83 % of total reading; see Section 3.2) to analyze influential propagated content. Since each released article was hundreds to thousands of words long with a relatively complex information structure, inductive content analysis (see Supporting Information) was applied to extract wildlife-related topics from the narrative materials. Content analysis is a reliable and valid method for narrative material analysis (Graneheim and Lundman, 2004). To effectively analyze a large number (>2000) of online public comments, machine-based text mining methods, word frequency (WF) (Brysbaert et al., 2017), and semantic web analysis (SWA, word co-occurrence) (Bullinaria and Levy, 2007) was applied in this study.

2.3. Statistical analysis

A simple moving average (k = 7) was applied to analyze the WCI development trends. The C.V. (coefficient of variation, standard deviation [SD] / mean) was used to analyze the fluctuation of the dataset. Correlations between abnormal datasets were calculated using the Spearman test. The above-mentioned statistics were performed using the R software package (version 4.1.2). The geographic distribution of post-release and reading was analyzed using ArcGIS-10.2.2 (ESRI). Gephi-0.9.2 (https://gephi.org/) was used to display the co-occurrence of high-frequency words (SWA).

3. Results

3.1. Trends and interconnection of public attention during the pandemic outbreak

Changing of daily new confirmed cases was significantly related to “COVID-19” in the WCI ($\rho = 0.87$, $P < 0.001$) during the outbreak of the epidemic (Fig. 2 A). The four selected WCIs showed an inverted U-shaped trend (C.V. = 49–77 %, Fig. 2 B). The earliest peak value appeared in COVID-19 and Game, followed by Ecological Balance and Wildlife Conservation. COVID-19 was positively correlated with Game ($\rho = 0.79$, $P < 0.001$, Fig. 2 C), and Ecological Balance ($\rho = 0.56$, $P < 0.001$). Game was positively correlated with Ecological Balance ($\rho = 0.27$, $P = 0.023 < 0.05$), but negatively correlated with Wildlife Conservation ($\rho = -0.32$, $P = 0.006 < 0.01$). Ecological Balance was positively related with Wildlife Conservation ($\rho = 0.54$, $P < 0.001$).

3.2. Analysis of social engagement

Diverse social media users ($N = 19$) participated in the release of wildlife-related information on social media platforms (Fig. 3 A). The leading groups of articles were Education ($N = 347$), News Media ($N = 279$), Business ($N = 177$), and Government ($N = 107$). The top reading count were from users of News Media ($N = 2.76 \times 10^6$), Education ($N = 1.12 \times 10^6$), Business ($N = 0.83 \times 10^6$), and Entertainment ($N = 0.77 \times 10^6$). The reading count of a single WeChat article from News Media (0.09×10^4, 0.02×10^4–0.44×10^4) was much higher than that of other users ($P < 0.001$, Fig. 3 B), but that of regular users (0.00×10^4,

Table 1
Basic Components of Public Awareness of One Health According to 12 Recommended Manhattan Principles and Environmental Literacy.

Knowledge	Attitude	Behavior
K-1: Natural ecosystem is a network K-2: Human-Nature is an interactional processing system with a shared destiny K-2-1: Humans may be infected by wild animal-hosted parasites K-2-2: Human health, society or economy can be influenced by the disturbed natural ecosystem K-2-3: Human activity is an intervention to natural ecology balance	A-1: Against damaging behaviors to nature or wildlife A-2: Support for conservation management A-3: Support for maintaining biodiversity or ecology balance A-4: Support for maintaining harmony between human and nature A-5: Support for increasing animal welfare (e.g., wildlife health science)	B-1: Conservation of environment or wildlife, e.g., resistance to consuming game meat, willingness to pay for natural recovery, report illegally damaging behaviors to the environment or wildlife B-2: Cross-sectoral and multidisciplinary movement to address threats and reduce risks of detrimental infectious diseases at the animal-human-ecosystem interface

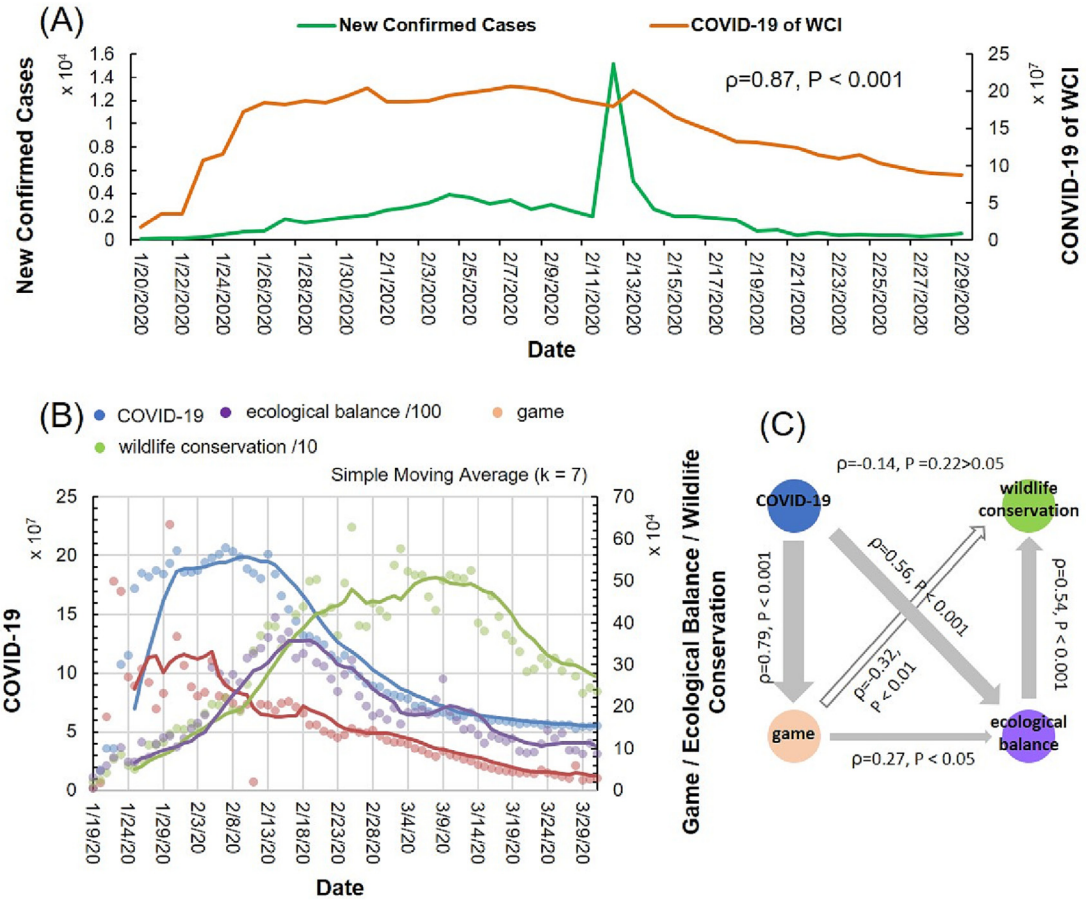

Fig. 2. Relations between pandemic development and COVID-19 in the WCI (WeChat Communication Index) trend (A), trend analysis of WCIs (B), and correlations of selected WCIs (C).

<100–0.01 × 10^4) was much lower than that of other users ($P < 0.05$, or $P < 0.001$). Reading count of a single WeChat article from Leisure (0.03 × 10^4, 0.01 × 10^4–0.13 × 10^4) was significantly higher than Medical Treatment and Health ($P < 0.05$; 0.01 × 10^4, <100–0.03 × 10^4), Government and Law ($P < 0.001$; 0.01 × 10^4, <100–0.04 × 10^4), or Education ($P < 0.05$; 0.02 × 10^4, 0.01 × 10^4–0.06 × 10^4). Reading count of a single WeChat article from Catering, Agriculture and Food (0.03 × 10^4, <100–0.16 × 10^4) was significantly higher than Government and Law ($P < 0.05$).

WeChat users from all provincial regions ($n = 32$) of mainland China participated in releasing articles supporting wildlife conservation (Fig. 3 C). Article count was positively related to newly confirmed cases ($\rho = 0.67$, $P < 0.001$), and regional GDP ($\rho = 0.89$, $P < 0.001$).

3.3. Content analysis of articles and public comments

Eight categories of content were identified from highly popular WeChat articles (reading count ≥10,000) (Fig. 4 A). Most content described the "risk of intimate touching and eating game" (~31 %, Fig. 4 A), such as "bats may carry multiple pathogens" (蝙蝠可能携带多种病原). Knowledge of disease spread from animals was mentioned extensively (Table 1, K-2-1). The second most described content was "exposing behaviors that harm wildlife" (~20 %, A-1), such as pictures of wild animals for sale, followed by "call for wildlife conservation" (~13 %, B-1), e.g., "refuse to cook game" (拒烹野味), and "popularize wildlife protection law" (i.e., "animal protection law legislation and specific regulations" [野生动物保护法或者专门的规定]) (B-1). The remaining four categories accounted for a relatively low proportion (2–8 %). A total of 36 classes of animals appeared in popular WeChat articles. The most frequently mentioned animals were *Avian* ($N = 586$), *Rodentia* ($N = 223$), insects ($N = 167$), and *Reptilia* ($N = 160$) (Fig. 4B).

We selected the 30 most frequent words (frequency ≥ 30) to analyze the SWA of public comments. "(Eating) wild animals" ([食用]野生动物) had the highest eigenvector centrality (EC) value (EC = 1). EC is used to described a node (word) influence in a net, where stronger influence has a higher value (Otero et al., 2021) in SWA (Fig. 4B). Other terms were "Natural ecology" (自然生态) (EC = 0.65), "Refuse" (拒绝) (EC = 0.60), "Epidemic / Pathogenic bacteria" (疫情或病毒) (EC = 0.53), "Publish" (惩罚) (EC = 0.54), "Respect or love" (敬爱或爱护) (EC = 0.42), "Protect" (保护) (EC = 0.34), and "Game market" (野味市场) (EC = 0.32).

"(Eating) wild animals" was frequently linked to "Refuse" (B-1), "Epidemic / Pathogenic bacteria" ($K-2-1$), "Bad habits" (陋习) / "Ignorant" (愚昧无知) (A-1), "Poultry and livestock are enough" (家禽家畜够吃) (A-1), "Teach a lesson" (教训) (A-1), and "Strengthen supervision" (加强监管) (A-2). The combined group "Protect", "Natural ecology", "Respect or love", and "Ecological balance" (生态平衡) was linked to "Wild animals (野生动物)" (A-3). The group "Wildlife Protection Act" (野生动物保护法), "Publish", "Game market", and "Hunting" (捕杀[野生动物]) was linked to "Wild animals" (B-1). "Refuse" and "(Eating) wild animals" was linked to "Personal responsibility" (从我做起) (B-1).

4. Discussion

4.1. One health-framed human behavior is suitable for building win-win outcomes for humans and nature

In this study, we aimed to increase public awareness of OH to restrain unsustainable behaviors of exploiting and consuming natural resources, prevent zoonoses, and environmental disease spillover to humankind in

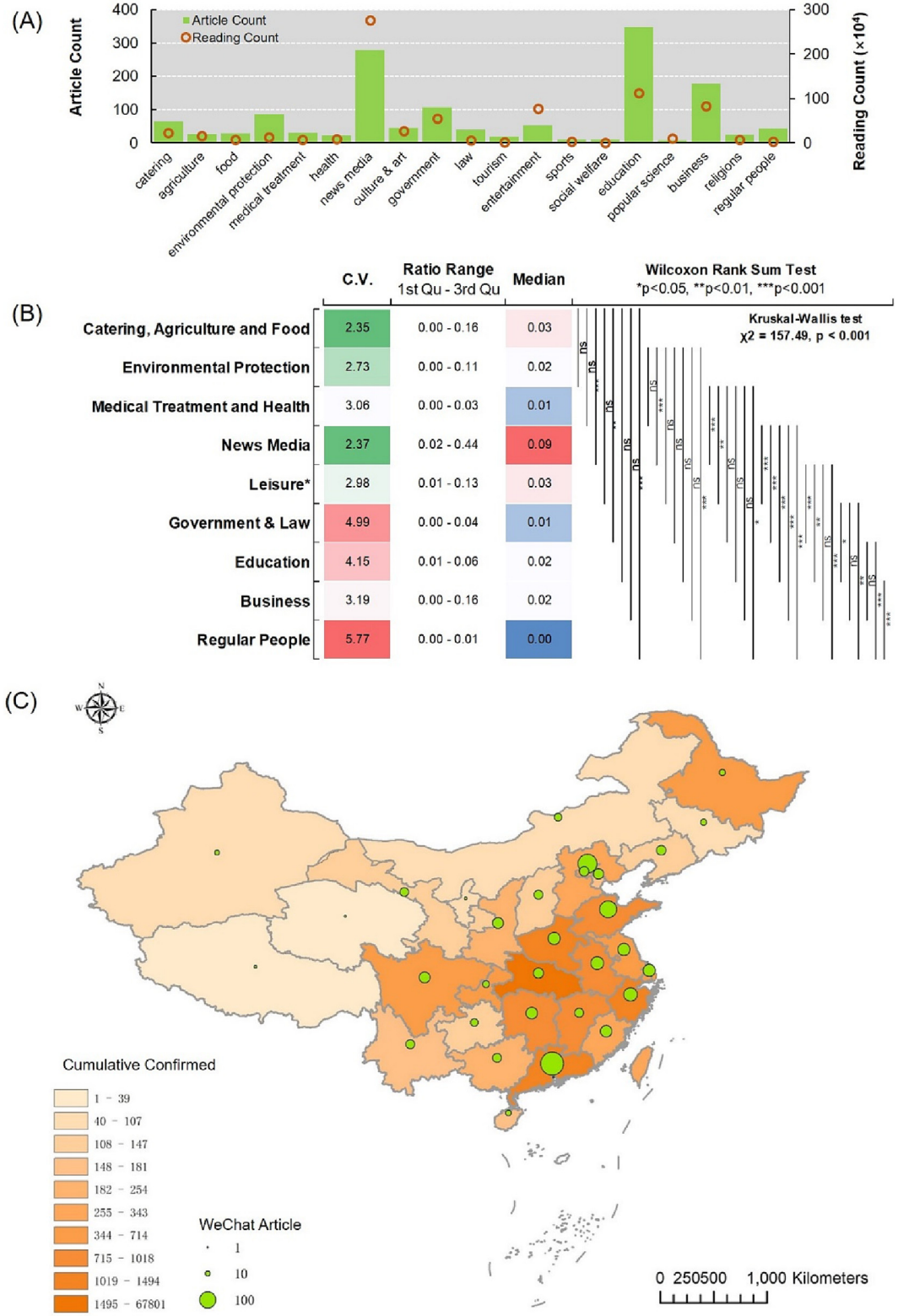

Fig. 3. Social media users' total contribution to article counts and public reading (A), induced public reading counts of a single WeChat article (B, unit: 10^4). Count distribution of new confirmed cases (Jan 20–Feb 29, 2020) and released wildlife-related WeChat articles (C).
Note: * Leisure (i.e., culture and art, tourism, entertainment, sports, social welfare, and religion).

the future. Sustainable development (SD) was formally defined by the United Nations (UN) in the late 1980s (Nesshöver et al., 2017), and a continuous increase in the global population and urbanization has caused deforestation and shrinkage of habitats for wildlife (Bedford et al., 2019). Fragmented habitats with more contact with human communities have increased the transmission of pathogens from wild animals (Borzée et al., 2020). Since 2000, several zoonoses have emerged, including SARS-CoV (2002 – 2003), H1N1 (2009–2010), Ebola (2014–2016), and COVID-19 (2019–present) (Montgomery and Macdonald, 2020). Nature-based solutions (NBS) aim to restore or reconstruct destroyed natural systems (such

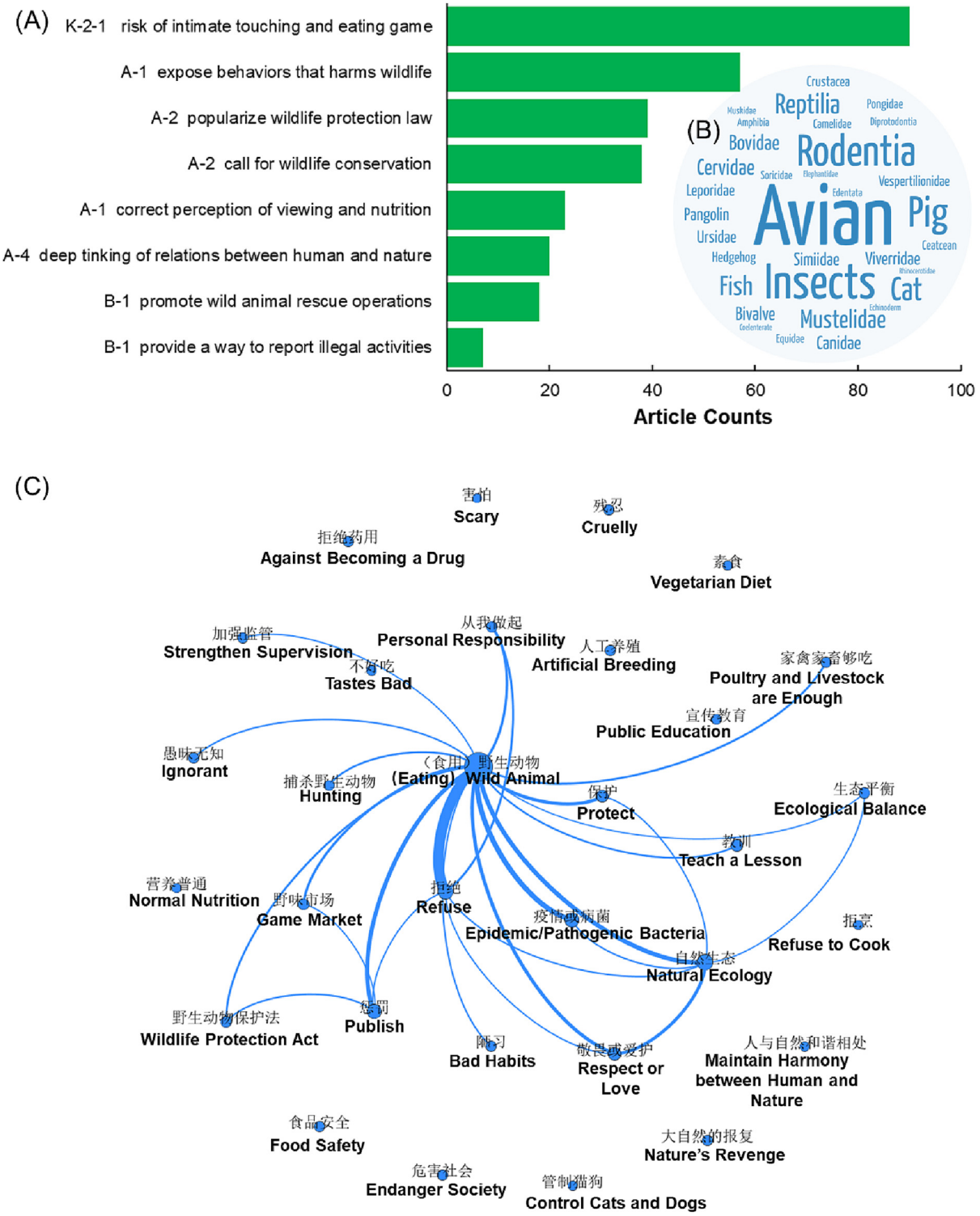

Fig. 4. Content analysis of highly popular (reading count ≥10,000) wildlife-related WeChat articles (A), mentioned animals (B), and semantic web analysis (SWA) analysis of online public comments (linkage count ≥40) (C).

as planting mangroves to capture CO_2 for mitigating global warming) and reduce disaster risk by relying on already understood natural knowledge (IUCN, 2020). The remaining unknown part of nature also has intrinsic value (independent of people) and its relational value to people should be respected by humankind (Chan et al., 2016). OH-framed human behavior aims at an unknown part of nature as a supplement to NBS (Fig. 1B).

4.2. One health thought was underlined in the public attention and opinion during the pandemic outbreak

Due to the worrisome impact on human health, the COVID-19 outbreak has attracted extensive attention from netizens (i.e., the online public) on Chinese social media platforms. In the early stages, the novel coronavirus (2019-nCoV) was speculated to have originated from wild animals

(e.g., pangolins) (Zhang et al., 2020). Wildlife meat consumption (e.g., game) has, therefore, attracted public attention. When the voices of the two previous WCIs began to decline, the public shifted to ecological balance and wildlife conservation. This indicates that the public links human health to the natural ecology. Our previous study found that normal environmental incidents without additional intervention could only maintain public attention for approximately three days, and that public opinion of the environment was very simple (Wu et al., 2020). However, public attention to the pandemic lasted for a relatively long time (approximately two months). Long-term attention has encouraged the public to understand the relationship between humans and nature.

Content analysis revealed that popular WeChat articles generally covered the three dimensions (knowledge, attitude, and behavior) of PAOH. However, deep thinking about the relationship between humans and nature (related to ecological principles) was not dominant. As ecological knowledge can significantly influence environmental behaviors (Donmez-Turan and Kiliclar, 2021), the lack of popularization of ecological principles may weaken the long-term effects of environmental lessons from the pandemic. Although the serious consequences of game consumption, shared prosocial motivation, and supportive policies or regulations can promote a strong feeling of being morally compelled and responsible to act (personal norms) (Bouman et al., 2021), caution should be exercised when overemphasizing banning wildlife consumption or the market as the only solution. Understanding and addressing the basic drivers of the spread of zoonoses are urgently needed to guide society in a more environmentally friendly way (Vora et al., 2022).

The public frequently links wild animals to human health risks and expresses refusal toward game consumption (Xie et al., 2020). The pandemic has raised public awareness of food safety and wildlife consumption (Li and Wang, 2021), and negative perceptions may reduce public demand for wildlife (Naidoo et al., 2021). However, we should avoid hatred toward wildlife, such as culling bats, for fear of spreading the virus (Vijay et al., 2021). Netizens' blame for eating games can shift some consumers to accept the social norms of supporting wildlife conservation (Bruneau et al., 2020). Similar to Zimbabwe (Tarakini et al., 2021), the Chinese public supported more serious market supervision and punishment for damaging wild animals (Liu et al., 2020). The public expressed concerns about human health risks with damaging behaviors toward wild animals and supportive attitudes toward wildlife conservation. OH thoughts were awakened by the pandemic, and the post-pandemic era is a good opportunity to deepen public awareness of wildlife conservation and allow the public to recognize that the protection of nature and biodiversity is our best solution to avoid future pandemics.

4.3. Social media-based routines to involve more social groups in promoting OH-framed environmental education

The pandemic has involved many social communities in propagating wildlife conservation on social media platforms. Users made continuous efforts (see Supporting Information) to release wildlife conservation-related articles during the pandemic. Traditional news media users with steady audiences continue to play an important role in influencing public awareness (Wu et al., 2020). Governmental users published many articles but attracted relatively fewer audiences, while the entertainment-related (leisure) group published fewer articles but attracted more reading. On social media platforms, the public seeks self-interest (mainly leisure users) rather than social change (mainly government users) on social media platforms (Smith and Taylor, 2017). Although educational users published few highly popular articles, their total reading count accounted for a high percentage, owing to their continuous efforts to release articles. The direct stakeholders of OH (Medical and Health, Catering-Agriculture-Food, and Environmental Protection) users actively participated in the propagation, but their visibility to online audiences was relatively low. To broaden OH education, we should involve more influencer users through continuous efforts, such as News Media, Leisure, and Education.

CRediT authorship contribution statement

Yinglin Wu: Project administration, Conceptualization, Sampling activities, Data curation, Analysis, Visualization, Funding acquisition, Investigation; Methodology, Writing - review & editing.
Ling Luo: Methodology, Data Analysis.
Yuxin Wang: Data Collection, Data Analysis.
Xiaoli Chen: Data Collection, Methodology.
Donghui Mo: Methodology, Validation.
Ling Xie: Project administration, Data Analysis.
Aizhen Sun: Methodology, Analysis

Data availability

The authors do not have permission to share data.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.scitotenv.2023.163200.

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