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Short communication **OPEN ACCESS**

Identification and early analysis of health hazards in orangutan (*Pongo* spp.) conservation in Indonesia

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Abstract

The orangutan (*Pongo* spp.) populations in Indonesia face many challenges, including diseases and other hazards that may compromise their health and viability. Across Sumatra and Borneo islands, with the unique localities, challenges, and opportunities, orangutan health management practices could look somewhat different between locations and institutions. The Orangutan Health Risk Analysis (*Analisa Risiko Kesehatan Orangutan*/ARKO in Indonesian language) is a unique attempt to build an orangutan health management strategy within the scope of rescue, rehabilitation, sanctuary, reintroduction, and post-reintroduction monitoring activities, that are integrated among all stakeholders in orangutan conservation. ARKO was conducted as a series of workshop that followed standard steps in wildlife disease risk analysis and involved nation-wide stakeholders with different expertise and roles. The result of ARKO is a document that transparently recorded the process of gathering stakeholders, defining the scope and context of orangutan health management, and followed with a series of steps on risk identification, assessment, analysis, and management of health hazards in orangutans. In addition to being provided as a full report document, ARKO is also presented in a website platform for ease of access and update. This short communication highlights two of the most important outcomes from ARKO; the comprehensive list of health hazards in orangutans and an early risk analysis of the prioritized hazards. ARKO serves as an example of an initiative to build a collaborative practice in wildlife conservation and health management.

Keywords disease risk analysis | health hazards | one health | orangutan | wildlife

Orangutans (*Pongo* spp.) are the flagship species of Indonesia and are protected under both national and international law. All three species of orangutans (*P. pygmaeus*, *P. abelii*, and *P. tapanuliensis*) are listed as Critically Endangered by the IUCN Red List (Ancrenaz *et al.*, 2024; Nowak *et al.*, 2024; Singleton *et al.*, 2024). The Ministry of Forestry of Indonesia, as the management authority of wildlife, has also listed orangutans as a protected species under various laws, with Law No. 32/2024 (replacing Law No. 5/1990) as the main legal foundation. This law was further translated into many lesser regulations and decrees, among other is the Government Regulation No. 7/1999 regarding the conservation of plant and animal species. These legal backgrounds paved the way to the National Population and Habitat Viability Analysis (PHVA) and national action plans on the conservation of orangutans. The latest PHVA workshop in 2016 listed disease as one of the main threats for the conservation of the orangutan population, and therefore, mitigation strategies, including disease risk analysis, pathogen surveillance, and communication strategy, are required (Utami-Atmoko *et al.*, 2017).

Wildlife disease risk analysis (WDRA) is an effective tool to draw collective decisions on the management and mitigation of diseases or health hazards in wildlife conservation, where there are a lot of unknowns (Jakob-Hoff, 2014). The process of WDRA, according to the manual

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published by OIE & IUCN (Jakob-Hoff, 2014), follows a set of basic steps which is started with risk communication and stakeholder analysis, problem description, hazard identification, risk assessment, risk management, and implementation and review. WDRA is highly applicable in many situations due to its logical and transparent processes that are built to achieve consensus. This tool has been used for many contexts of wildlife health and conservation programs all over the world and has been developed or modified for the specific needs of each situation (Hartley & Sainsbury, 2016; Vaughan-Higgins *et al.*, 2021). WDRA is especially useful for making management decisions on wildlife health during translocation activities, since moving animals between places poses a risk of transferring pathogens (Keet *et al.*, 2009; Dalziel *et al.*, 2016; Verant *et al.*, 2022; Wiemeyer *et al.*, 2025). More recently, the risk analysis process has been shifted from the disease focus to the more comprehensive concept of health, and therefore, the risk analysis should include all types of hazards, including those that are not caused by biological pathogens (Beckman *et al.*, 2025).

The orangutan health risk analysis (ARKO; in Indonesian: *Analisa Risiko Kesehatan Orangutan*) has attempted to include the all-hazard approach, incorporating any hazards for orangutan health, including hazards incurred by human activities and environmental conditions. The goal of ARKO is to provide an example of how to methodically conduct wildlife health risk analysis and to serve as a guideline for orangutan conservation practitioners and decision-makers in planning activities that may affect the health of orangutan population, human population, and the environment.

The ARKO process was started with a stakeholder analysis and problem description, as suggested by the manual (Jakob-Hoff, 2014). The scope of ARKO was further defined to include all orangutan conservation activities such as rescue, rehabilitation, translocation, sanctuary, reintroduction, and wild population research and monitoring. Therefore, this scope also covers all the populations of orangutans in the natural habitat, conflict areas, rehabilitation centres, and reintroduction sites, while also considering the human populations that interact with these populations. The main objective of ARKO, as stated in the report, is "Creating an orangutan health management strategy in rescue, rehabilitation, sanctuary, reintroduction, and post-reintroduction monitoring activities that is integrated and transparent between institutions to ensure the health and welfare of the orangutan population, humans, and environment within a certain time span (1, 5, 10 years), by the identified stakeholders." (ARKO Working Group, 2024).

Building on the scope and main objectives of ARKO, this short communication highlights the core steps in disease risk analysis, including hazard identification, analysis, and assessment (Jakob-Hoff, 2014). The more detailed information on the ARKO process, including the development of concepts, step-by-step explanations, construction of questions, topics, and criteria, and the detailed risk analysis results of each prioritised hazard, is accessible on the ARKO website (www.orangutanhealth.com; ARKO Working Group, 2024).

ARKO Workshop. Briefly, the ARKO Workshop was initially developed by the core team comprising the authors of this paper. This core team identified key stakeholders involved in orangutan conservation in Indonesia based on the level of interest and influence in the management of orangutan health in Indonesia. There were four categories of stakeholders: the promoters (high influence and direct interest), the latents (high influence but indirect interest), the defenders (direct interest but low influence), and the apathetics (indirect interest and low influence).

A total of 60 participants were identified to join the ARKO workshop, who are mostly those within the promoter category (technical implementation units of conservation agencies and national park authorities under the Ministry of Forestry, as well as non-governmental organizations that support the rescue, rehabilitation, and reintroduction programs). Several institutions from the other categories were also represented to a lesser degree. The workshop was run in several events, including three online meetings, and concluded with a two-day in-person meeting. The core team designed the rundown of the workshop and prepared drafts for discussion materials. Each online meeting session was designed to cover one step of WDRA. During the in-person meeting, the first three steps were reviewed and continued with the next steps of WDRA. Each session began with a brief presentation to explain the WDRA step that would be used for that session, followed by small-group discussions, and concluded with a plenary session. The core team served as discussion facilitators

Developing All-Hazard List. The hazard list was drafted by the ARKO core team, consisting of government officials, senior veterinarians, and conservation managers with extensive experience in orangutan health and conservation across Borneo and Sumatra, and most importantly, is well-connected with the network of fellow professionals in this field.

Collectively, this group listed all health hazards observed in practice and reported in the literature. The list was further divided into two groups, infectious hazards and non-disease hazards. The infectious hazard list covers diseases caused by pathogens (viruses, bacteria, fungi, and parasites), while the non-disease hazard list covers non-transmissible diseases (injuries, malnutrition, etc.) and non-disease hazards (human-wildlife conflict, pollution, habitat degradation, etc.).

A comprehensive literature review was then conducted to identify what is known so far about the causative agent (aetiology) of the infectious disease, host factors, and environmental factors. Information on the causative agent includes the category (virus, bacteria, parasite, or fungi), scientific and common name, and the reservoir niche. The host factors include the susceptibility, morbidity rate, mortality rate, and the nature of transmission to the population. The environmental factors include the route of transmission, method of exposure, geographic location, and seasonality.

The non-disease hazard list was further sectioned into sub-categories of non-infectious diseases, human-related hazards, wildlife-related hazards, and environment-related hazards. Information from literature reviews and discussions

was noted down to describe the hazards, host factors such as susceptibility (e.g., to venom, haze, and other pollutants) and behaviour (climbing ability, reaction toward humans, etc.), and environmental factors such as habitat/forest quality, local cultures, socio-economic conditions, geographic locations, and seasonality. This hazard list also identified a gap in knowledge.

During the ARKO workshops, participants were provided with the first draft of the hazard list and were asked to discuss this within small groups. This exercise was conducted with the aim of adding any information or gaps in knowledge on the listed hazards, as well as adding new hazards to the list. Discussions were facilitated by the core team. At the end of the workshop session, the revised lists of hazards were distributed back to the participants for further review.

Following the agreed list of all hazards known to orangutan health, an initial assessment was carried out to determine the top priority hazards. It was done by first defining four levels of likelihood of occurrence and four levels of consequence of the hazards. Aspects including the frequency of the hazards, the occurrence of the hazards in the region, the susceptibility of the host, and the individual or population impacts were all considered in defining each level. By combining the levels (high-moderate-low-negligible) of likelihood and consequence, each orangutan health hazard risk was weighed. Hazards that were valued for having a high level of either the likelihood or the consequence were included for further assessment.

Developing the Critical Control Points. The next step in the risk assessment is identifying the Critical Control Points (CCP) for each (prioritized) hazard. CCP is described as a point (time, location, event) where a particular hazard could happen and where an intervention could be put in place (Jakob-Hoff, 2014). To identify the CCPs of a hazard, several sub-steps were undertaken during the ARKO workshop. The first was creating a cause-impact diagram where participants were facilitated to answer a series of cascading questions of "why/how could this happen?" and "what could be the impact of this?". The "why" question was asked several times, with the next one built on from the answer to the previous question. The same process was done for the "impact" question. This exercise was then visualized into a cause-impact diagram, where participants can then pinpoint any CCPs that they think are important (ARKO Working Group, 2024). This diagram is also a powerful tool to do a qualitative assessment on the likelihood of release, likelihood of exposure, and severity of the hazard in the host or population of concern. The final step was to compile CCPs from all the hazards and merge those that are similar. The compilation was done for the infectious hazards and the non-disease hazards.

During the initial drafting of the hazard list, 32 infectious hazards and 14 non-disease hazards were identified. Following the series of discussions within ARKO workshops, the hazard lists have developed both in number and depth of information. Currently, 39 infectious hazards and 35 non-disease hazards are listed in the ARKO report. The complete list can be accessed on a website designed to share information about the ARKO (ARKO Working Group, 2024).

Participants in the ARKO workshop collectively decided on twelve prioritized hazards based on their high value of either likelihood or consequences. The twelve hazards consisted of six infectious hazards and six non-disease hazards, as shown in **Table 1**.

Table 1 List of twelve prioritized hazards that were identified during the ARKO workshop

Infectious hazards	Non-disease hazards
1. Tuberculosis	1. Degradation of orangutan's habitat
2. Malaria	2. Human-orangutan conflict
3. Helminthiasis (includes Strongyloidosis, Oesophagostomiasis, Ancylostomiasis, Trichuriasis, Filariasis, etc.)	3. Eco-tourism activities involving orangutans
4. Viral Respiratory Infection (includes RSV, influenza, Avian Influenza, SARS, Covid-19, etc.)	4. Gunshot
5. Chronic bacterial respiratory infection (ORDS)	5. Forest fire
6. Melioidosis	6. Disturbance on orangutans' mental health

A cause-impact diagram was developed for each of these hazards and complemented with CCPs that were identified afterwards. These diagrams can be accessed on the ARKO website, along with the risk assessment on the likelihood of release, likelihood of exposure, and the consequences to the populations of concern. Finally, the compiled CCPs for the infectious hazards and non-disease hazards are described in **Tables 2** and **3**.

Table 2 Critical Control Points for six prioritized infectious hazards defined in the ARKO workshop

Category	Description
CCP 1	Illegally kept orangutans (either in private ownerships or in wildlife trade).
CCP 2	Interaction between human and orangutans before orangutans were rescued and when they are rescued and rehabilitated.
CCP 3	Quarantine / isolation of newly arrived animal or those suspected having infectious disease
CCP 4	Tools and fomites used in husbandry and medical treatments.
CCP 5	Interaction between orangutans with other wildlife or their conspecific outside of their natural habitat.
CCP 6	Cages for transportation and enclosures.
CCP 7	High animal density due to limited space.
CCP 8	Environmental contamination, including the increase of pathogen-carrying vectors, increase of environmental bacteria, and improper waste and carcass disposal.
CCP 9	Diagnostic testing, including availability of human resources, infrastructure, and technology.

Table 3 Critical Control Points for six prioritized non-disease hazards defined in the ARKO workshop

Category	Description
CCP 1	Local community activities in natural habitat (including land clearing, building settlement, hunting, etc.).
CCP 2	Industrial activities including land clearing for industrial activities and road access.
CCP 3	Negative perception about orangutans (considered as pets, used for tourism interaction, etc.).
CCP 4	Economic-driven activities and settlements.
CCP 5	Law enforcement (for hunting, firearm ownership, tourism regulation, etc.).
CCP 6	Season and climate conditions (fruiting seasons, dry seasons).
CCP 7	(conflicting) Government programs (e.g. ecotourism).
CCP 8	Trauma on orangutans during conflict, rescue, and rehabilitation, including separation from mother and being too long in cages in rehabilitation centres.
CCP 9	Infection and abnormalities in orangutans' nervous system (causing mental health issues).
CCP 10	Interaction of tourists with orangutans in conservation areas.

The ARKO discussion resulted in a comprehensive list of health hazards in orangutans within the scope of the in-situ population, as well as in all conservation activities (rescue, rehabilitation, reintroduction, translocation). This list, which explores infectious diseases, non-infectious diseases, and non-disease threats, is the first attempt to collect all hazards that are relevant for orangutan conservation and human health.

While the hazard list is already a very useful resource that practitioners can benefit from, further analysis and hazards prioritization provide a more strategic guideline for management actions. Decision makers in conservation can focus their actions on the prioritized hazards. Further, management actions targeted at these prioritized hazards would most likely also address other hazards that are of a similar nature and transmission route. This strategy will increase the effectiveness of management actions as well as the efficiency of resource usage.

The collaborative atmosphere of ARKO decision-making also has the benefit of improving research strategy aimed at closing gaps in knowledge on the topic of orangutan health hazards. By having a similar list of prioritized diseases, research projects can be better aligned between regions and institutions, reducing the chance of reinventing the wheel. Indeed, disease surveillance has been identified as one of the main implementation actions needed to address gaps in knowledge, especially in the prioritized infectious diseases.

The identification of CCPs for infectious pathogens highlights three main themes that practitioners need to focus on. The first theme is the interaction between orangutans, humans, other wildlife, and the environment. Since interaction is inevitable, measures should be directed at minimizing it through the enforcement of preventive protocols, pathogen surveillance, and collaboration with other stakeholders, including the (human) public health practitioners. The second theme of the CCP is the husbandry and care of orangutans within rehabilitation centres. Intervention to these CCPs is directed at providing a comprehensive protocol on hygiene, population management, and an effective quarantine program. Lastly, it has been highlighted that diagnostic capabilities for prioritized infectious diseases should be improved and made widely accessible.

The CCPs for non-infectious and non-disease hazards are more complex and varied compared to those for infectious hazards. This is reasonable since many of these hazards involve socio-economic, political, and environmental factors. Local communities that constantly interact with orangutans and other wildlife are both important stakeholders and a CCP. Conservationists need to build strong collaborations and support them as the main role in conservation, instead of taking over the role from them. Industrial activities and the opening of road access have been identified as the second most important CCP theme that causes a significant impact on the orangutan habitat. Policy and law enforcement were considered another crucial CCP. Environmental factors such as season and climate may be mitigated, although there are obvious limitations compared to the other CCP themes. Lastly, the issue of orangutan mental health was an interesting CCP as this reflects the ARKO discussion about the main challenge in building the mental resilience of rehabilitated orangutans so that when they are reintroduced, they have a higher chance of survival.

As in any group discussion, several limitations were observed in ARKO. First, the ARKO discussion could benefit from even more varied stakeholders, including those who are negatively impacting or impacted by orangutan conservation. Time was also another significant limiting factor. Although the discussion has been designed to stretch over several online meetings prior to the final in-person meeting, the two full days of the final meeting still begged for ideally another day. Lastly, the roles of the core teams who are 'parts of the system' within orangutan conservation and health management inevitably created bias and subjectivity when drafting the pre-workshop materials and facilitating discussions.

For the next steps of implementation, the current ARKO report should be used by practitioners and decision makers in conducting their daily activities and preparing short- and mid-term planning. Conservation and health managers can consult the health hazard CCPs and identify those that are of most concern within their area of practice. Further, they can communicate and collaborate with each other to synchronize acts to reach a bigger scope and gain more significant impacts. Under the clear direction of the Ministry of Forestry, ARKO could be a powerful tool to improve the overall

conservation and health management of orangutans in Indonesia.

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