# Health challenges of rangers—a planetary health workforce

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## ABSTRACT

Rangers safeguard the balance between humans and nature by protecting and managing biodiversity and natural resources. The challenging working conditions that rangers face make them vulnerable to wildlife attacks and exposure to zoonotic and vector-borne diseases. Despite all of these work-related challenges and threats to their health, a vast majority of rangers lack access to adequate medical treatment facilities. This research has used data from the one of the largest and most comprehensive surveys of rangers across multiple countries, collected as part of the Global Ranger Perception Survey, to examine the relationship between the precarious working conditions of rangers and their health outcomes. By comparing data from the 2020 World Malaria Report, our study highlights the severe malaria burden carried by rangers around the world. Malaria prevalence in rangers working in Central Africa, East Africa, and South America was estimated to be four times higher than in the general population. The results of this study are valuable because they show that rangers are a vulnerable, high-risk population of professionals and their working conditions are highly associated with their respective health outcomes. The research also makes it imperative that improving working conditions is essential for maintaining a professional ranger workforce that protects the planet's natural areas and biodiversity.

## INTRODUCTION

Rangers, typically government employees patrolling protected areas of their countries on a regular basis, play a critical role in safeguarding nature as well as cultural and historical heritage, and protecting the rights and well-being of present and future generations (International Ranger Federation 2021). Rangers are instrumental to safeguard the balance between humans and nature by protecting and managing biodiversity and natural resources (Belecky, Singh, and Moreto 2019; Singh et al. 2020). Despite being on the frontline of biodiversity conservation efforts,

rangers face a host of threats and are often exposed to challenging working conditions while performing their duties (Belecky, Singh, and Moreto 2019; Singh, et al. 2020; Anagnostou et al. 2022). There is a growing amount of research on rangers's job satisfaction and the challenges they face while on duty (Warchol and Kapla 2012; Belecky, Singh, and Moreto 2019; Singh et al. 2020; Galliers et al. 2022), but the impact of their working and employment conditions on their health has been overlooked in previous assessments (Anagnostou et al. 2022).

Rangers are routinely exposed to live animals and their body fluids, stings, bites carcasses, and, as a result, are vulnerable to zoonotic and vector-borne diseases (Adjemian et al. 2012). The risk of tick-borne disease infection was found to be three to ten times higher in park rangers in the USA and Europe than in the general population (Donohoe, Omodior, and Roe 2018). In Vietnam's Binh Phuoc province, forest rangers have been identified as a high-risk population due to their increased vulnerability to malaria infections and other vector-borne diseases. Indeed, the self-reported malaria prevalence in rangers from this area is extremely high: 80% (Son et al. 2017). In addition, 64% of the rangers interviewed in the Global Ranger Perception Survey (GRPS) consider their jobs dangerous because of the risk of wildlife attacks while on duty Belecky, Singh, and Moreto 2019). Lastly, environmental factors such as extreme weather conditions also contribute to the challenging nature of rangers's jobs and its associated health risk. For example, heat stress while working in areas with limited access to clean drinking water poses a serious challenge (Moreto 2016).

Despite all of these work-related challenges and threats to their health, 51.8% of rangers report that they lack access to adequate medical treatment facilities (Belecky, Singh, and Moreto 2019). As shown in a recent literature review (Anagnostou et al. 2022) the concept of "precarious employment" is gaining attention as a description of rangers's working conditions, which increasingly are being linked to their health and well-being. Already used in other fields of occupational epidemiology (ILO 2016; Bodin et al. 2020; Kreshpaj et al. 2020), precarious employment encompasses multifaceted challenges along multiple dimensions, including working conditions, insufficient salaries, employment insecurity, lack of access to work-related protection and rights, and little or no protection against the challenging and dangerous nature of ranger work. The scoping review (Anagnostou et al. 2022) pointed out the need for a better characterization of the association between working conditions and the health of rangers.

This study is a secondary analysis of the Global Ranger Perception Survey (GRPS) (Belecky, Singh, and Moreto 2019), the most comprehensive survey of rangers from South America, Central Africa, East Africa, South Asia and Southeast Asia. This unique survey highlighted both the challenging working conditions of rangers as well as some of their health risks but did not investigate statistically how the latter may relate to the former. In this study, we analyzed the GRPS data to assess the relationship between the precarious working conditions of rangers and their health outcomes. In addition, we compared malaria prevalence in rangers with that of the general population to highlight rangers's vulnerability to malaria as an occupational risk. These results are critical for programs and ministries to improve rangers's working conditions and protect their health for better conservation of our world.

## METHODS

### Global Ranger Perception Survey

As noted above, this study is a secondary analysis of the GRPS, conducted by WWF between September 2016 and October 2019 in 28 countries with over 7,000 responses. The GRPS was designed to better understand the working conditions and health status of rangers, who work at the frontline of the world's conservation efforts. The questions covered employment, equipment, workplace dynamics, community relations, and mental and physical health. Additional details can be found in the original publication of the survey (Belecky, Singh, and Moreto 2019).

### Regional Aggregation

The analyses were conducted at the regional level (Figure 1) to improve statistical power, to facilitate interpretation of the results, and respect country-level publishing rights that WWF is still negotiating. Similarly to the original GRPS report, neighboring countries were surveyed in the following regions: South America (Colombia, Peru, Brazil, Paraguay, Guyana), Central Africa (Cameroon, Central African Republic, Republic of Congo), East Africa (Kenya, Uganda, Tanzania), South Asia (Bangladesh, Bhutan, Nepal, Pakistan, India, Sri Lanka) and Southeast Asia (Cambodia, Vietnam, Thailand, Myanmar, Malaysia, Indonesia).

In total, responses from 5,893 rangers in 24 countries were used in this secondary analysis of GRPS. Data from GRPS's case studies in Russia and the Philippines were discarded because they followed a different survey protocol than the main survey. Data from Mexico and Mongolia were not included in our analysis because of their geographic isolation (no neighboring countries surveyed).

### Exposure: working conditions

The GRPS survey contained 20 questions pertaining to

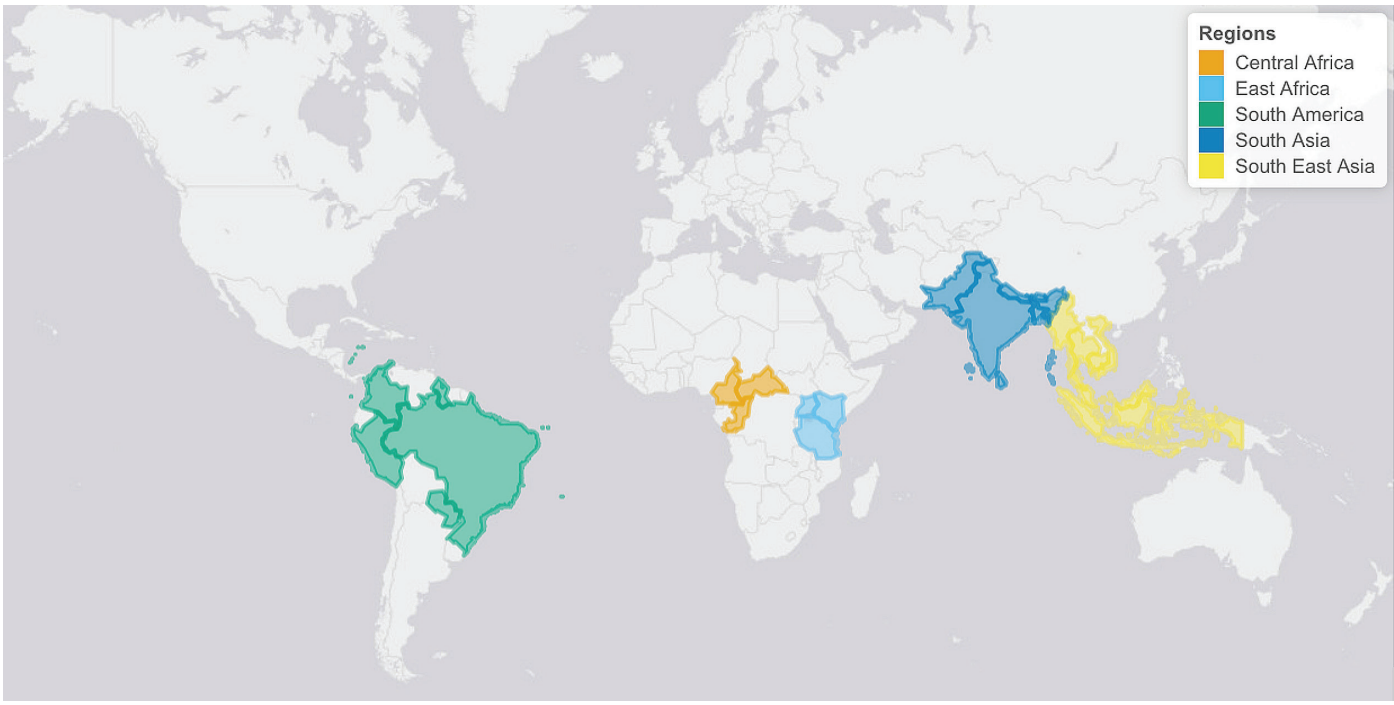


**FIGURE 1.** Study map. Data from the global ranger perception survey were analyzed across five regions: South America (Colombia, Peru, Brazil, Paraguay, Guyana), Central Africa (Cameroon, Central African Republic, Republic of Congo), East Africa (Kenya, Uganda, Tanzania), South Asia (Bangladesh, Bhutan, Nepal, Pakistan, India, Sri Lanka) and Southeast Asia (Cambodia, Vietnam, Thailand, Myanmar, Malaysia, Indonesia). The map was produced using ESRI basemap imagery in leaflet R package.

the rangers's working conditions. The first five questions asked rangers whether they have access to (1) paid sick leave, (2) paid annual leave, (3) paid supplementary hours, (4) employee insurance, and (5) first aid training. The other 15 questions asked rangers whether they "Disagreed a lot," "Disagreed," "Agreed," or "Agreed a lot" that they were provided with adequate (6) medical treatment, (7) communication devices, (8) shelter, (9) basic necessities, (10) basic equipment, (11/12) communication devices on patrol/at station, (13/14) drinking water on patrol/at station, (15/16) access to mosquito nets on patrol/at station, (17) running water at station, (18) toilets at station, (19) sleeping structure on patrol, and (20) tent on patrol. In this analysis, answers to the last 15 questions were binarized by merging "Disagree a lot" and "Disagree" answers together as well as "Agree" and "Agree a lot" together to improve statistical power and facilitate interpretation of the results.

### Outcome: health

The GRPS contained five binary measures of self-reported rangers's health: any serious infections, existing health problems aggravated by work, malaria infection, dengue infection, and broken bones in the previous 12 months.

### Covariates

Age, gender, and work experience as a ranger (measured by the number of years they have been on the job) were also extracted and used for model adjustments. These variables qualify as confounders, i.e., they may be associated with both the exposure (quality of working conditions) and the outcome (health status). Including these covariates in the statistical analyses is essential to assess the relationship between working conditions and health of rangers.

### Primary analysis: Associations between working conditions and health

For this analysis, our primary health outcome was constructed as reporting either a serious infection or an existing health problem made worse by work in the previous 12 months. Malaria and dengue infections in the previous 12 months were analyzed as secondary outcomes (results are presented in the appendix) because environmental covariates such as precipitation or temperature would most likely bias (confound) the relationship between working conditions and malaria/dengue, but were not available to be adjusted for in statistical models. Broken bones in the previous 12 months was not deemed relevant given the very low prevalence among interviewed rangers across all regions (Table S2 in the appendix).

In each of the five regions, and for each of the 20 variables on working conditions, a logistic model was run (100 runs in total) to estimate the association between working conditions and our primary health outcome of interest: a serious infection or an existing health problem made worse by work in the previous 12 months. All models were adjusted for age, gender, and work experience as a

ranger to remove their confounding biases. Country-level fixed effects were included to account for within-country variations in the outcome, and models were weighted by the inverse of the country-level sampling fractions (Table 1) to ensure representability of the results at the regional level.

Logistic models assess how much of the statistical variation in the outcome can be explained by the statistical variation in the exposure. These models typically summarize the association between exposure and outcome with an odds ratio (OR), which is the ratio of two probabilistic odds: the odds of having the outcome (e.g., poor health) in the exposed group (e.g., under good working conditions) divided by the odds of having the outcome (e.g., poor health) in the unexposed group (e.g., under poor working conditions). An odds ratio larger (respectively lower) than 1 means that the odds (and therefore the risk) of the outcome in the exposed population is larger (respectively lower) than the odds of the outcome in the unexposed population.

Ultimately, for each of the 20 working conditions, we pooled the five region-specific ORs together using inverse variance meta-analyses to compute an overall OR across regions.

### Secondary analysis: Rangers's vulnerability to malaria infections

The estimates of malaria infections prevalence in surveyed rangers are unbiased and provide a unique opportunity to compare the burden of malaria infections among rangers to that of the general population. Unlike the primary analysis, here we no longer focus on reported working conditions in the survey. Instead, we highlight rangers's vulnerability to malaria as an occupational risk.

First, malaria prevalence among rangers of a region was computed using a logistic model with no covariates. Again, country-level fixed effects were included to account for within-country heterogeneity, and models were weighted by the inverse of the ranger's country-level sampling

**TABLE 1.** Sampling fraction. Number of rangers surveyed and total estimated in each country (Belecky, Singh, and Moreto 2019).

| Country | Region | Number of rangers surveyed | Estimated number of ranger in country | Sampling fraction | Weights |
|---|---|---|---|---|---|
| Cameroon | Central Africa | 109 | 900 | 109/900 | 8.30 |
| Central African Republic | Central Africa | 37 | 247 | 37/247 | 6.70 |
| Republic of Congo | Central Africa | 88 | 177 | 88/177 | 2.00 |
| Kenya | East Africa | 514 | 3000 | 514/3000 | 5.80 |
| Tanzania | East Africa | 703 | 4000 | 703/4000 | 5.70 |
| Uganda | East Africa | 610 | 2000 | 610/2000 | 3.30 |
| Brazil | South America | 37 | 1600 | 37/1600 | 43.20 |
| Colombia | South America | 100 | 1178 | 100/1178 | 11.80 |
| Guyana | South America | 20 | 30 | 20/30 | 1.50 |
| Paraguay | South America | 35 | 115 | 35/115 | 3.30 |
| Peru | South America | 37 | 400 | 37/400 | 10.80 |
| Bangladesh | South Asia | 143 | 820 | 143/820 | 5.70 |
| Bhutan | South Asia | 54 | 1500 | 54/1500 | 27.80 |
| India | South Asia | 767 | 60000 | 767/60000 | 78.20 |
| Nepal | South Asia | 200 | 2262 | 200/2262 | 11.30 |
| Pakistan | South Asia | 474 | 1500 | 474/1500 | 3.20 |
| Sri Lanka | South Asia | 145 | 614 | 145/614 | 4.20 |
| Cambodia | South East Asia | 201 | 1300 | 201/1300 | 6.50 |
| Indonesia | South East Asia | 742 | 5604 | 742/5604 | 7.60 |
| Malaysia | South East Asia | 223 | 1408 | 223/1408 | 6.30 |
| Myanmar | South East Asia | 105 | 412 | 105/412 | 3.90 |
| Thailand | South East Asia | 409 | 5220 | 409/5220 | 12.80 |

fractions (Table 1) to ensure representability of the results at the regional level.

Second, using data from the 2020 World Malaria Report (WHO 2020), we averaged, for each country, the annual prevalence of malaria in the general population between 2016–2019. Estimates over the regions were then obtained by weighting this prevalence by countries's population size (United Nations and Social Affairs 2019).

Finally, the relative risk of malaria infections for rangers compared to the general population was calculated in each region by taking the ratio of malaria prevalence from both groups. The delta method (Dorfman 1938) was used to compute 95% confidence intervals.

Similar analyses for the other four health outcomes measured in the rangers's survey (dengue infections, broken bones, serious infections, and existing health problems intensified by work in the previous 12 months) could not be conducted because, to our knowledge, no data source provides estimates of their prevalence in the general population for all study countries.

## RESULTS

In this study, data from a total of 5,893 rangers in 24 countries were used. Missingness was low for all confounding (<10%), exposure (<30%), and outcome (<10% except for dengue) variables across all regions. Notably though, two confounding variables, gender and work experience, were missing for all 140 rangers interviewed in Vietnam, which as a result was discarded from the adjusted analysis estimating associations between health and working conditions. See Table S1 in the appendix for more details.

### Primary analysis: Associations between working conditions and health

Table 2 presents the prevalence of exposure variables and the primary health outcome across the five regions. Prevalence of our primary health outcomes of interest, serious infections or existing health problems aggravated by work in the past 12 months, was the lowest in Southeast Asia (19% [18.5; 19.6]) and the highest in Central Africa (68.5% [65.8; 71.1]). There was also a lot of heterogeneity in the prevalence of good working condition exposure variables across the regions. Overall, rangers in Central Africa reported the poorest working conditions (low prevalence, 4.6% [3.6; 5.9] of rangers in Central Africa reported access to paid sick leave) while rangers in Southeast Asia reported the best working conditions (high prevalence, 58.7% [58; 59.4] of rangers in Southeast Asia reported adequate access to medical treatment).

The results of the adjusted associations (ORs) between working condition exposure variables and the primary health outcomes are presented in Table 3. In particular, ORs lower than 1 indicate negative association, meaning that improved working conditions (e.g., access to adequate basic facilities) are associated with a lower risk for the primary health outcomes. Figure 2 proposes an alternative visualization of these results, highlighting when ORs are lower than 1 (left side of dashed vertical line), indicating a negative association, or higher than 1 (right side of dashed vertical line), indicating a positive association. The model with paid supplementary hours as the exposure in South America failed to converge because of its very low variation in this region: only 1.1% [0.8; 1.5] of rangers interviewed in South America reported access to paid supplementary hours (Table 2). Results for the ORs pooled across regions are also presented in Table 3, in the right-most column.

We noted variability in the estimated associations across regions. Most of the estimates are negative, meaning that improved working conditions are associated with lowered risks and therefore, better health outcomes. For instance, in East Africa, rangers that have access to paid sick leave have 0.87 [0.78; 0.96] the odds of reporting any serious infection or an existing health problem aggravated by work in the previous 12 months than the rangers that do not have access to paid sick leave. In all five regions, access to adequate basic necessities, equipment, shelter, and drinking water (both on patrol and at station) were associated with lowered risks for the primary health outcomes of interest. The pooled estimates across regions from the meta-analyses were statistically significantly (5% level) different from the null (and negative) for these five working condition exposures as well as for access to adequate medical treatment and toilets at station (highlighted in bold in Table 2).

Interestingly, rangers in South America reporting access to communication devices, mosquito nets, sleeping structures or tents on patrol, running water, and toilets at station, as well as employee insurance and paid annual leave, have a statistically significant (5% level) higher risk for the primary health outcomes of interest than those that did not report access to such improved working conditions (green error bars on the right side of the vertical dashed line in Figure 2).

Access to mosquito nets on patrol and paid sick leave in Central Africa were also associated with higher risk for the primary health outcomes of interest, although the 95% confidence intervals were wide (wide orange error bars on the right side of the vertical dashed line in Figure 2). The low prevalence of these working condition exposures in

**TABLE 2.** Prevalence of exposures and outcome variables. Prevalence of exposure and outcome (% [95% CI]) across regions.

| | Central Africa | East Africa | South America | South East Asia | South Asia |
|---|---|---|---|---|---|
| Serious infection or existing health problem aggravated by work in past 12 months | 68.5 [65.8; 71.1] | 43.3 [42.3; 44.4] | 39.8 [38.1; 41.5] | 19 [18.5; 19.6] | 37.4 [37; 37.7] |
| Paid sick leave | 4.6 [3.6; 5.9] | 36.1 [35.1; 37.2] | 50.5 [48.7; 52.3] | 62.5 [61.8; 63.3] | 55.9 [55.5; 56.3] |
| Paid annual leave | 25.1 [22.7; 27.6] | 89.6 [88.9; 90.2] | 59.5 [57.8; 61.3] | 63.5 [62.8; 64.2] | 58.6 [58.2; 59] |
| Paid supplementary hours | 5.5 [4.4; 6.9] | 31.1 [30.1; 32.1] | 1.1 [0.8; 1.5] | 42.5 [41.8; 43.2] | 3.8 [3.6; 3.9] |
| Employee insurance | 8.6 [7.1; 10.3] | 61.8 [60.7; 62.9] | 27.6 [26; 29.2] | 52.4 [51.6; 53.1] | 38.7 [38.3; 39.1] |
| Adequate medical treatment | 12.2 [10.3; 14.4] | 63 [62; 64] | 40 [38.2; 41.9] | 58.7 [58; 59.4] | 31.4 [31; 31.7] |
| Adequate communication devices | 21.1 [18.7; 23.7] | 69.1 [68.2; 70.1] | 31.4 [29.7; 33.2] | 48.3 [47.5; 49] | 64.8 [64.4; 65.2] |
| Adequate shelter | 17.9 [15.8; 20.3] | 30.6 [29.6; 31.6] | 56.7 [54.9; 58.5] | 57.6 [56.9; 58.3] | 59.5 [59.1; 59.9] |
| Adequate basic necessities | 13.6 [11.7; 15.9] | 43.3 [42.2; 44.3] | 58.7 [56.9; 60.5] | 71.4 [70.7; 72] | 59.4 [59; 59.8] |
| Adequate equipment | 30.4 [27.8; 33.1] | 66.3 [65.3; 67.3] | 58.1 [56.4; 59.9] | 64.4 [63.7; 65.1] | 62.3 [61.9; 62.7] |
| First aid training | 14.4 [12.6; 16.4] | 27.3 [26.4; 28.3] | 34.2 [32.6; 35.9] | 34.7 [34.1; 35.4] | 13 [12.7; 13.3] |
| Communication devices on patrol | 29.1 [26.7; 31.7] | 63.4 [62.4; 64.4] | 23.4 [21.9; 24.9] | 40.2 [39.5; 40.9] | 54 [53.6; 54.4] |
| Communication devices at station | 25.2 [22.9; 27.7] | 64.2 [63.2; 65.2] | 21.2 [19.8; 22.7] | 39 [38.3; 39.7] | 55.7 [55.3; 56.1] |
| Drinking water on patrol | 5 [3.9; 6.3] | 39.1 [38.1; 40.1] | 60.7 [58.9; 62.3] | 61.7 [61; 62.3] | 39.2 [38.8; 39.5] |
| Drinking water at station | 6 [4.8; 7.4] | 45.6 [44.5; 46.6] | 63 [61.3; 64.7] | 68.9 [68.3; 69.6] | 51.9 [51.5; 52.3] |
| Mosquito net on patrol | 4.7 [3.7; 6] | 32 [31.1; 33] | 25.8 [24.2; 27.4] | 35 [34.4; 35.7] | 8.3 [8.1; 8.6] |
| Mosquito net at station | 8.8 [7.4; 10.5] | 40.6 [39.6; 41.7] | 32.2 [30.6; 33.9] | 37.4 [36.8; 38.1] | 36.6 [36.2; 36.9] |
| Running water at station | 29.9 [27.4; 32.4] | 39.2 [38.2; 40.3] | 54.5 [52.7; 56.2] | 58.6 [57.9; 59.3] | 41.7 [41.3; 42] |
| Toilets at station | 39.2 [36.6; 41.9] | 59.5 [58.5; 60.5] | 72.1 [70.5; 73.7] | 65.8 [65.1; 66.4] | 58.6 [58.2; 59] |
| Sleeping structure on patrol | 36.7 [34.1; 39.4] | 38.7 [37.6; 39.7] | 29 [27.2; 30.9] | 31.3 [30.6; 32] | 34 [33.6; 34.4] |
| Tent on patrol | 64.9 [62.2; 67.4] | 61.5 [60.5; 62.5] | 35.1 [33.2; 37] | 59.5 [58.8; 60.2] | 10.2 [9.9; 10.5] |

**FIGURE 2.** Associations between exposures and primary health outcome. Adjusted odds ratio (points) and 95% CI (error bars) between working conditions exposure variables (facets) and any serious infection or existing health problem made worse by work in the past 12 months, across regions (colors). Note that, for the purpose of visualization, the log scale was used for the x axis. Dashed vertical black line indicates the null hypothesis (OR = 1, i.e., no associations). Estimates lower than 1 (left side of dashed vertical line) indicate negative association, meaning that improved working conditions (e.g., access to adequate basic facilities) are associated with lower risk for the primary health outcome. Figure 2 is an alternative visualization of results presented in Table 3.

**TABLE 3.** Associations between exposures and primary health outcome. Adjusted odds ratio [95% CI] between working conditions exposure variables and any serious infection or existing health problem made worse by work in the past 12 months, across regions. Estimates lower than 1 indicate negative association, meaning that improved working conditions (e.g., access to adequate basic facilities) are associated with lower risk for the primary health outcome. The rightmost column presents results from the meta-analyses that pooled OR across regions.

| | Central Africa | East Africa | South America | South East Asia | South Asia | Meta-analysis across regions |
|---|---|---|---|---|---|---|
| Paid sick leave | 4.12 [1.67; 10.15] | 0.87 [0.78; 0.96] | 1.12 [0.92; 1.36] | 0.98 [0.88; 1.09] | 1.06 [1.02; 1.1] | 1.02 [0.9; 1.16] |
| Paid annual leave | 0.52 [0.36; 0.76] | 0.62 [0.53; 0.73] | 6.24 [4.18; 9.31] | 1.06 [0.95; 1.18] | 0.79 [0.77; 0.83] | 1.06 [0.75; 1.51 |
| Paid supplementary hours | 0.68 [0.4; 1.16] | 0.68 [0.61; 0.76] | Failed | 0.71 [0.63; 0.8] | 1.38 [1.25; 1.51] | 0.84 [0.55; 1.27] |
| Employee insurance | 1.73 [1.05; 2.86] | 0.59 [0.53; 0.66] | 1.97 [1.59; 2.43] | 0.9 [0.81; 1] | 0.69 [0.67; 0.72] | 0.99 [0.74; 1.32] |
| Adequate medical treatment | 0.67 [0.43; 1.04] | 0.54 [0.5; 0.6] | 1.21 [1; 1.46] | 0.95 [0.86; 1.04] | 0.67 [0.64; 0.7] | **0.78 [0.61; 0.99]** |
| Adequate communication devices | 1.84 [1.26; 2.69] | 0.53 [0.48; 0.59] | 0.96 [0.78; 1.19] | 1.13 [1.02; 1.24] | 0.91 [0.87; 0.95] | 0.96 [0.73; 1.27] |
| Adequate shelter | 0.5 [0.35; 0.72] | 0.51 [0.46; 0.56] | 0.81 [0.68; 0.96] | 0.76 [0.69; 0.83] | 0.58 [0.55; 0.6] | **0.63 [0.53; 0.74]** |
| Adequate basic necessities | 0.27 [0.18; 0.42] | 0.54 [0.49; 0.59] | 0.35 [0.29; 0.43] | 0.85 [0.77; 0.93] | 0.56 [0.54; 0.58] | **0.51 [0.4; 0.64]** |
| Adequate equipment | 0.67 [0.5; 0.91] | 0.67 [0.6; 0.74] | 0.81 [0.68; 0.96] | 0.85 [0.77; 0.93] | 0.99 [0.95; 1.03] | **0.8 [0.67; 0.96]** |
| First aid training | 0.95 [0.66; 1.36] | 1.08 [0.98; 1.2] | 0.91 [0.76; 1.09] | 0.98 [0.89; 1.09] | 0.98 [0.93; 1.03] | 0.99 [0.95; 1.04] |
| Communication devices on patrol | 1.12 [0.83; 1.5] | 0.79 [0.71; 0.87] | 1.53 [1.25; 1.87] | 0.91 [0.83; 1] | 1.24 [1.19; 1.28] | 1.07 [0.85; 1.36] |
| Communication devices at station | 0.8 [0.59; 1.09] | 0.77 [0.7; 0.85] | 1.43 [1.14; 1.78] | 0.77 [0.69; 0.85] | 1.45 [1.39; 1.5] | 1 [0.69; 1.43] |
| Drinking water on patrol | 0.54 [0.31; 0.95] | 0.46 [0.41; 0.5] | 0.51 [0.42; 0.62] | 0.44 [0.4; 0.49] | 0.89 [0.86; 0.93] | **0.55 [0.36; 0.84]** |
| Drinking water at station | 0.91 [0.54; 1.54] | 0.57 [0.52; 0.62] | 0.7 [0.59; 0.84] | 0.62 [0.56; 0.68] | 0.92 [0.89; 0.96] | **0.71 [0.55; 0.93]** |
| Mosquito net on patrol | 4.08 [1.8; 9.27] | 0.72 [0.66; 0.8] | 1.8 [1.49; 2.17] | 0.89 [0.79; 0.99] | 1.32 [1.24; 1.41] | 1.26 [0.9; 1.79] |
| Mosquito net at station | 1.26 [0.79; 2.01] | 0.73 [0.67; 0.8] | 1.31 [1.09; 1.57] | 0.99 [0.89; 1.11] | 1.66 [1.6; 1.73] | 1.14 [0.76; 1.72] |
| Running water at station | 0.79 [0.59; 1.07] | 0.76 [0.69; 0.83] | 1.62 [1.37; 1.91] | 0.64 [0.58; 0.71] | 0.94 [0.91; 0.98] | 0.9 [0.71; 1.14] |
| Toilets at station | 0.92 [0.7; 1.19] | 0.69 [0.63; 0.76] | 1.28 [1.06; 1.55] | 0.79 [0.71; 0.87] | 0.84 [0.81; 0.88] | **0.86 [0.75; 0.99]** |
| Sleeping structure on patrol | 0.76 [0.58; 0.99] | 0.75 [0.69; 0.83] | 3.66 [2.92; 4.59] | 1.11 [1; 1.24] | 1.48 [1.43; 1.54] | 1.28 [0.87; 1.88] |
| Tent on patrol | 0.62 [0.45; 0.85] | 0.89 [0.8; 0.98] | 1.92 [1.57; 2.35] | 0.8 [0.72; 0.89] | 0.6 [0.55; 0.65] | 0.87 [0.64; 1.2] |

the region (see Table 2), hence resulting in poor variation, probably led to these imprecise estimates.

### Secondary analysis: Rangers's vulnerability to malaria infections

Table 4 displays malaria prevalence among surveyed rangers as well as in the general population. Among rangers, malaria prevalence was as high as 93.3% in Africa [91.8; 94.6], and 63.8% [62.8; 64.8] of rangers in Central and East Africa reported malaria in the previous 12 months, respectively. The relative risk shows that rangers in all regions are at much higher risk for malaria infections than is the general population. In Central Africa, East Africa and South America, the prevalence of malaria in rangers is about four times higher than in the general population. In Southeast Asia and South Asia, where malaria prevalence in the general population is particularly low, the relative risk for malaria infections among rangers was estimated to be around 30 times higher than in the general population with wide confidence intervals, with lower bounds indicating relative risks at least 10 times higher.

## DISCUSSION

As a secondary analysis of the GRPS, the largest survey of rangers to date (Belecky, Singh, and Moreto 2019), this study assessed the associations between working conditions and health among rangers in five regions of the world: South America, Central Africa, East Africa, South Asia and Southeast Asia. Our primary health outcomes of interest were any serious infections or existing health problems made worse by work in the 12 months preceding the survey. Twenty different aspects of good working conditions for rangers were considered, many of which were found to be negatively associated with our primary health outcomes in at least one region. Importantly, access to adequate basic necessities, equipment, shelter, and drinking water were found to be strongly associated with better health outcomes for rangers of all five regions (Figure 3). Pooled results across regions using inverse-variance meta-analyses additionally identified access to adequate medical treatment and toilets at station as working conditions associated with better health outcomes among rangers. All models were adjusted for gender, age, and years of work experience as a ranger.

By comparing data from the 2020 World Malaria Report (WHO 2020), our study additionally highlights the severe malaria burden carried by rangers around the world. Malaria prevalence in rangers working in Central Africa, East Africa and South America was estimated to be four times higher than in the general population. In Central Africa, where malaria prevalence in the general population is already high, 93.3% [91.8; 94.6] of rangers reported malaria infections in the 12 months prior to the survey. In Southeast Asia and South Asia, where malaria prevalence in the general population is fairly low, rangers's risk for malaria infections was found to be about 30 times higher than in the general population.

These results are important because they show that rangers are vulnerable, high-risk populations, and their working conditions are highly associated with their respective health outcomes. Investments in improving ranger working conditions are essential for maintaining a professional ranger workforce that protects the planet's natural areas

**TABLE 4.** Rangers's vulnerability to malaria. Comparison of malaria prevalence among rangers and in the general population across regions.

| | Malaria prevalence (%) among rangers | Malaria prevalence (%) in the general population | Relative risk of malaria infections among rangers compared to the general population |
|---|---|---|---|
| Central Africa | 93.3<br>[91.8; 94.6] | 25.4<br>[23.9; 27] | 3.7<br>[3.4; 3.9] |
| East Africa | 63.8<br>[62.8; 64.8] | 14.3<br>[13.3; 15.3] | 4.5<br>[4.1; 4.8] |
| South America | 2.4<br>[1.9; 3] | 0.5<br>[0.3; 0.7] | 4.6<br>[2.5; 6.8] |
| South East Asia | 10.4<br>[9.9; 10.8] | 0.3<br>[0.1; 0.5] | 29.2<br>[9.4; 49] |
| South Asia | 17.1<br>[16.8; 17.4] | 0.6<br>[0.2; 1] | 36.7<br>[10.5; 62.9] |

**FIGURE 3.** (Above) A ranger drinks water from a stream using a leaf in Cameroon. © DANIEL NELSON/WWF
(Below) Ranger using a GPS device in Royal Manas National Park, Bhutan © SIMON RAWLES/WWF-UK

and biodiversity (Singh et al. 2021). The responsibility to ensure that rangers work within the necessary working conditions to stay healthy and perform their job goes beyond that of their immediate employer. Due to rangers's key role in protecting our global biodiversity, national ministries of health should be protecting them and our societies should invest in healthy work conditions for all rangers. In particular, as the world invests in malaria eradication (WHO 2020), rangers, whose risk for malaria infections was found to be 4 to 30 times higher than in the general population, must be included in this proposition. Just as with other key high-risk populations for malaria transmission (Cotter et al. 2013), rangers must be targeted for treatment and prevention efforts.

The results from rangers in South America provide valuable insights. As pointed out in the results, many improved working conditions were found to be associated with bad health outcomes. For example, rangers with paid annual leave had 6.24 [4.18; 9.31] times the odds of reporting a serious infection or existing health problem that had been aggravated by work in the 12 months prior to the survey than rangers without paid annual leave. Similar patterns are found for access to communication devices, mosquito nets, sleeping structures or tents on patrol, running water, and toilets at station as well as for employee insurance. We suggest this is indicative of reverse causality and that programs in South America are likely already taking actions to mitigate the negative impact of working conditions on rangers's health. Results from the malaria vulnerability analysis also show that malaria prevalence among rangers in South America is much lower than among rangers working in Southeast Asia and South Asia, whereas the prevalence of malaria infections in the general population in those three regions is very similar.

A major limitation of our analysis is that both exposure and outcomes were self-reported by rangers. Survey teams limited social-desirability bias by ensuring confidentiality of rangers's answers and questions around exposure came before questions about outcomes to limit the effects of recall bias (Belecky, Singh, and Moreto 2019). Second, systematic random sampling of rangers was not possible, hence jeopardizing the representativeness of interviewed rangers within a country. Yet, considerable efforts were made to obtain the most representative sample of rangers, selecting survey sites across ministries and different conservation areas in countries (Belecky, Singh, and Moreto 2019). Third, results at the regional level may be dominated by countries with large population of rangers, such as India in South Asia. Last, our results pertain only to rangers from countries included in the GPRS survey and should not be extrapolated outside of the studied regions where other health outcomes and working conditions may be more relevant.

## CONCLUSION

In conclusion, this secondary analysis of one of the largest and most comprehensive surveys of rangers across multiple countries revealed how self-reported poor working conditions are associated with poor health outcomes and how much more vulnerable rangers are to malaria compared to the general population. Increased awareness of rangers's vulnerability and better working conditions are essential for programs across the world to ensure that rangers can stay healthy and capable of fulfilling their conservation missions.

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# Appendix

| | | Central Africa | East Africa | South America | South Asia | Southeast Asia |
|---|---|---|---|---|---|---|
| Confounders | Age | 0.4 | 1.1 | 1.3 | 0 | 0.2 |
| | Male | 0 | 3.2 | 5.7 | 0.2 | 9 |
| | Years as a ranger | 0 | 2.3 | 7.9 | 7 | 9.4 |
| Exposures | Paid sick leave | 5.1 | 14.9 | 13.5 | 7.7 | 12.6 |
| | Paid annual leave | 6 | 5.7 | 13.5 | 8.4 | 14.3 |
| | Employee insurance | 6.8 | 17.7 | 13.5 | 15.1 | 19.5 |
| | Paid supplementary hours | 5.6 | 4.9 | 6.1 | 2.8 | 10 |
| | Adequate medical treatment | 21.8 | 3.6 | 15.3 | 8.7 | 4.1 |
| | Adequate communication devices | 17.5 | 4.7 | 17.9 | 25.3 | 7.5 |
| | Adequate shelter | 16.2 | 3.2 | 13.1 | 14.3 | 6.9 |
| | Adequate basic necessities | 19.2 | 3.2 | 10.5 | 11 | 4 |
| | Adequate equipment | 13.2 | 4.6 | 7.9 | 10.7 | 3.1 |
| | First aid training | 2.6 | 2.5 | 4.4 | 3.6 | 7.7 |
| | Communication devices on patrol | 2.1 | 2.7 | 7 | 2 | 2.2 |
| | Communication devices at station | 1.7 | 3 | 10.9 | 2.4 | 2 |
| | Drinking water on patrol | 1.3 | 2.5 | 6.6 | 1.6 | 2 |
| | Drinking water at station | 0.4 | 3 | 7 | 2.5 | 2.3 |
| | Mosquito net on patrol | 2.1 | 3.2 | 12.2 | 2.4 | 2.4 |
| | Mosquito net at station | 0.4 | 3.4 | 11.8 | 2.1 | 2.8 |
| | Running water at station | 2.6 | 3.4 | 8.7 | 2.7 | 2.9 |
| | Toilets at station | 0.9 | 4.3 | 7 | 4.8 | 2.8 |
| | Sleeping structure on patrol | 2.6 | 6.7 | 29.7 | 8.7 | 6.8 |
| | Tent on patrol | 3 | 4.4 | 27.9 | 16.3 | 5.8 |
| Outcome | Serious infection or existing health problem made worse by work in past 12 months | 7.7 | 7.7 | 6.1 | 3.9 | 7.1 |
| | Serious infection in past 12 months | 9.0 | 6.5 | 4.8 | 2.9 | 5.4 |
| | Existing health problem made worse by work in past 12 months | 5.6 | 8.0 | 5.7 | 3.5 | 6.8 |
| | Malaria in past 12 months | 1.7 | 3.7 | 6.1 | 2.1 | 4.5 |
| | Dengue in past 12 months | 30.8 | 14.0 | 5.7 | 2.6 | 5.1 |
| | Broken bone in past 12 months | 5.1 | 4.6 | 5.7 | 2.2 | 4.3 |

**Table S1 – Completeness table.** *Missingness (%) for all confounders, exposures, and outcome variable across regions.*

| | Central Africa | East Africa | South America | Southeast Asia | South Asia |
|---|---|---|---|---|---|
| Malaria in past 12 months | 93.3 [91.8; 94.6] | 63.8 [62.8; 64.8] | 2.4 [1.9; 3] | 10.4 [9.9; 10.8] | 17.1 [16.8; 17.4] |
| Dengue in past 12 months | 16.4 [14.1; 19.1] | 7.5 [6.9; 8.1] | 8.9 [8; 10] | 5.9 [5.6; 6.3] | 1.9 [1.8; 2] |
| Serious infection in past 12 months | 57.6 [54.7; 60.4] | 34.4 [33.4; 35.4] | 25.9 [24.4; 27.4] | 10.3 [9.9; 10.8] | 24.2 [23.8; 24.5] |
| Existing health problem made worse by work in past 12 months | 38 [35.3; 40.8] | 21.6 [20.7; 22.5] | 26.2 [24.7; 27.7] | 12.1 [11.6; 12.5] | 21.2 [20.8; 21.5] |
| Broken bone in past 12 months | 6.8 [5.6; 8.4] | 8.3 [7.7; 8.9] | 4.6 [3.9; 5.4] | 3.9 [3.7; 4.2] | 6.6 [6.4; 6.8] |

**Table S2 – Prevalence of outcome variables.** *Prevalence (% [95% CI]) of health outcomes reported by rangers across regions.*

| | Central Africa | East Africa | South America | Southeast Asia | South Asia |
|---|---|---|---|---|---|
| Paid sick leave | 1.12 [0.36; 3.48] | 0.7 [0.63; 0.78] | Failed | 0.96 [0.85; 1.1] | Failed |
| Paid annual leave | 1.37 [0.77; 2.44] | 1.15 [0.99; 1.34] | Failed | 1.07 [0.94; 1.22] | Failed |
| Paid supplementary hours | 0.88 [0.29; 2.64] | 0.94 [0.85; 1.05] | Failed | 0.82 [0.7; 0.96] | Failed |
| Employee insurance | 2.67 [0.92; 7.73] | 0.7 [0.63; 0.78] | Failed | Failed | Failed |
| Adequate medical treatment | 0.93 [0.44; 1.95] | 0.76 [0.69; 0.83] | Failed | 1 [0.89; 1.13] | Failed |
| Adequate communication devices | 3.08 [1.3; 7.34] | 0.88 [0.79; 0.98] | 0.41 [0.11; 1.47] | 1.07 [0.94; 1.2] | Failed |
| Adequate shelter | 0.35 [0.21; 0.59] | 0.69 [0.63; 0.76] | 0.04 [0.01; 0.12] | 0.59 [0.53; 0.67] | Failed |
| Adequate basic necessities | 0.4 [0.22; 0.7] | 0.71 [0.64; 0.77] | 0.04 [0.01; 0.12] | 0.58 [0.52; 0.65] | Failed |
| Adequate equipment | 1.29 [0.77; 2.16] | 1.04 [0.94; 1.15] | 0.15 [0.05; 0.47] | 0.98 [0.87; 1.11] | Failed |
| First aid training | 0.72 [0.4; 1.31] | 0.93 [0.84; 1.03] | Failed | 1.19 [1.05; 1.35] | Failed |
| Communication devices on patrol | 0.42 [0.26; 0.68] | 0.84 [0.77; 0.93] | Failed | 0.86 [0.76; 0.97] | Failed |
| Communication devices at station | 0.99 [0.58; 1.68] | 0.78 [0.71; 0.87] | Failed | 0.79 [0.69; 0.89] | Failed |
| Drinking water on patrol | Failed | 0.46 [0.42; 0.51] | Failed | 0.65 [0.57; 0.74] | Failed |
| Drinking water at station | Failed | 0.53 [0.49; 0.59] | 0.05 [0.03; 0.11] | 0.69 [0.61; 0.78] | Failed |
| Mosquito net on patrol | 0.23 [0.12; 0.46] | 0.91 [0.82; 1] | Failed | 1.32 [1.15; 1.52] | Failed |
| Mosquito net at station | 0.35 [0.19; 0.64] | 0.87 [0.79; 0.96] | Failed | 1.63 [1.42; 1.87] | Failed |
| Running water at station | 0.4 [0.21; 0.74] | 0.63 [0.57; 0.69] | 0.07 [0.03; 0.14] | 0.82 [0.73; 0.93] | Failed |
| Toilets at station | 2.02 [1.22; 3.34] | 0.75 [0.68; 0.82] | Failed | 0.84 [0.75; 0.95] | Failed |
| Sleeping structure on patrol | 0.22 [0.13; 0.36] | 0.82 [0.74; 0.9] | Failed | 1.1 [0.96; 1.25] | Failed |
| Tent on patrol | 0.37 [0.2; 0.67] | 1.05 [0.95; 1.16] | Failed | 0.71 [0.62; 0.81] | Failed |

**Table S3 – Associations between exposures and malaria.** *Adjusted odds ratio [95% CI] between working conditions exposure variables and malaria in the past 12 months across regions.*

| | Central Africa | East Africa | South America | Southeast Asia | South Asia |
|---|---|---|---|---|---|
| Paid sick leave | 2.54 [1.09; 5.93] | 0.78 [0.64; 0.94] | Failed | 0.89 [0.75; 1.05] | Failed |
| Paid annual leave | 0.32 [0.18; 0.56] | 0.43 [0.33; 0.56] | Failed | 0.87 [0.74; 1.03] | Failed |
| Paid supplementary hours | 2.1 [0.99; 4.44] | 0.7 [0.55; 0.9] | Failed | 1.29 [1.07; 1.56] | Failed |
| Employee insurance | 4.59 [2.43; 8.66] | 0.56 [0.46; 0.68] | Failed | Failed | Failed |
| Adequate medical treatment | 2.51 [1.39; 4.56] | 0.73 [0.61; 0.87] | Failed | 0.9 [0.77; 1.05] | Failed |
| Adequate communication devices | 1.77 [1.06; 2.94] | 0.72 [0.6; 0.87] | Failed | 0.72 [0.62; 0.85] | Failed |
| Adequate shelter | 0.78 [0.43; 1.43] | 0.64 [0.52; 0.79] | Failed | 0.69 [0.59; 0.81] | Failed |
| Adequate basic necessities | 1.13 [0.58; 2.22] | 0.63 [0.52; 0.76] | Failed | 0.76 [0.65; 0.88] | Failed |
| Adequate equipment | 2.16 [1.28; 3.66] | 0.72 [0.6; 0.87] | Failed | 0.9 [0.76; 1.06] | Failed |
| First aid training | 0.36 [0.18; 0.74] | 1.1 [0.91; 1.33] | Failed | 1.3 [1.11; 1.53] | Failed |
| Communication devices on patrol | 0.37 [0.22; 0.63] | 0.61 [0.5; 0.73] | Failed | 0.48 [0.4; 0.57] | Failed |
| Communication devices at station | 0.42 [0.24; 0.74] | 0.5 [0.41; 0.6] | Failed | 0.41 [0.34; 0.5] | Failed |
| Drinking water on patrol | Failed | 0.6 [0.5; 0.73] | Failed | 0.63 [0.53; 0.75] | Failed |
| Drinking water at station | 1.72 [0.66; 4.53] | 0.46 [0.38; 0.56] | Failed | 0.42 [0.36; 0.5] | Failed |
| Mosquito net on patrol | Failed | 0.41 [0.33; 0.51] | Failed | 0.73 [0.6; 0.88] | Failed |
| Mosquito net at station | 0.33 [0.14; 0.79] | 0.48 [0.4; 0.58] | Failed | 0.45 [0.36; 0.56] | Failed |
| Running water at station | 0.7 [0.37; 1.32] | 0.48 [0.4; 0.58] | Failed | 0.71 [0.61; 0.84] | Failed |
| Toilets at station | 0.53 [0.33; 0.86] | 0.57 [0.47; 0.68] | Failed | 0.57 [0.49; 0.67] | Failed |
| Sleeping structure on patrol | 0.15 [0.09; 0.27] | 0.55 [0.45; 0.67] | Failed | 0.98 [0.82; 1.18] | Failed |
| Tent on patrol | 0.49 [0.29; 0.83] | 0.55 [0.46; 0.67] | Failed | 1.06 [0.88; 1.28] | Failed |

**Table S4 – Associations between exposures and dengue.** *Adjusted odds ratio [95% CI] between working conditions exposure variables and dengue in the past 12 months across regions.*