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LETTER

Economics of conservation law enforcement by rangers across Asia

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Abstract

Biodiversity targets, under the Kunming-Montreal Global Biodiversity Framework, prioritize both conservation area and their effectiveness. The effective management of protected areas (PAs) depends greatly on law enforcement resources, which is often tasked to rangers. We addressed economic aspects of law enforcement by rangers working in terrestrial landscapes across Asia. Accordingly, we used ranger numbers and payment rates to derive continental-scale estimates. Ranger density has decreased by 2.4-fold since the 1990s, increasing the median from 10.9 to 26.4 km^2 of PAs per ranger. Rangers were generally paid more than the minimum wage (median ratio = 1.9) and the typical salaries in agriculture, forestry, and fishing sector (median ratio = 1.2). Annual spending on ranger salaries varied widely among countries, with a median of annual US71 km^{-2} of PA. Nearly 208,000 rangers patrolling Asian PAs provide an invaluable opportunity to develop ranger-based monitoring plans for evaluating the conservation performance. As decision-makers frequently seek an optimum number of law enforcement staff, our study provides a continental baseline median of 46.3 km^2 PA per ranger. Our findings also provide a baseline for countries to improve their ranger-based law enforcement which is critical for their Kunming-Montreal Global Biodiversity Framework targets.

KEYWORDS
Anti-poaching, conservation spending, minimum wage, ranger, wildlife economy

1 | INTRODUCTION

Protected areas (PAs) and conserved areas are perhaps the most effective tool for safeguarding species and ecosystems globally and are therefore incorporated into multiple political targets for international conservation (Graham et al., 2021; Tranquilli et al., 2014; Watson et al., 2016). Under the Convention on Biological Diversity (CBD), the Kunming-Montreal Global Biodiversity Framework includes Target 3 to protect at least 30% of the planet by 2030, with the focus on areas particularly important for biodiversity through "effectively and equitably managed" systems of PAs and other effective area-based conservation measures (CBD Secretariat, 2022).

The effective management of PAs, however, depends greatly upon resources available for their management (Appleton et al., 2022; Coad et al., 2019; Graham et al., 2021). Conservation law enforcement is an essential component for ensuring the effectiveness through reducing illegal activities, and this is often the responsibility of rangers (Critchlow et al., 2015; Kuiper et al., 2020; WWF, 2019). Although "effective and equitable management" was also emphasized in previous biodiversity targets, known as Aichi Targets (CBD, 2010). However, knowledge of management effectiveness using ranger-based law enforcement largely remains deficient (Appleton et al., 2022; Moore et al., 2018). Therefore, achieving new post-2020 agreements and targets needs to be informed by past performance, not least because this indicates the likelihood of future success.

Rangers are usually tasked with a variety of activities, including community outreach, fire prevention, and dealing with human–wildlife conflict. However, from the perspective of law enforcement, the principal task of rangers is to prevent illegal activities, such as poaching (Critchlow et al., 2015; Moore et al., 2018). Numerous studies have demonstrated the effectiveness of ranger-based law enforcement in protecting wildlife populations, reducing the threat impact levels, and increasing management effectiveness (Bruner et al., 2001; Graham et al., 2021; Leverington et al., 2010; Mohammadi et al., 2021; Tranquilli et al., 2014), particularly with the help of acoustic monitoring or local informant reports on poaching (Astaras et al., 2020; Linkie et al., 2015). The economic aspects of law enforcement affect the rangers' welfare, morale, and ultimately, their effectiveness (Leverington et al., 2010; Moreto et al., 2019; WWF, 2019). However, national-level economic variation in how rangers are deployed to protect PAs is rather little studied.

In this study, our objectives were first to quantify the number of rangers deployed in PAs and to compare numbers with those in the 1990s. We then evaluated spending on rangers and how it compares with similar sector earnings as a proxy for the importance attached to ranger-based conservation. We scoped our large-scale study on terrestrial landscapes across Asia, a continent characterized by high rates of land clearing in PAs (Watson et al., 2016) and where many countries are underperforming to secure resources for conservation (Farhadinia et al., 2022; Lindsey et al., 2017). We hope our study draws attention to the management of Asia's PAs and galvanizes a strand of research that will help law enforcement agencies to increase the efficiency of operations inside protected and conserved areas aligned with the Target 3 of the Kunming-Montreal Global Biodiversity Framework.

2 | METHODS

2.1 | Ranger density

For each country, we obtained the number of rangers working in terrestrial landscapes in 2019 using a two-step approach. We first searched the existing literatures such as governmental reports or interviews made by officials (predominantly in local language) for any ranger data. We then approached the governmental officials, facilitated by the paper's coauthors representing each Asian country, to double-check the numbers. In five cases, mostly in the Caucasus and Central Asia, we also contacted the representatives of international conservation organizations actively working in those countries to check the numbers.

As a collective term, rangers consist of wildlife wardens, forest guards, scouts, watchers, and other frontline staff (WWF, 2019). In all studied countries, the ranger job description included deterring illegal activities such as wildlife poaching and habitat conversion or the administrative staff supporting their activities. They are also engaged in a variety of other activities, such as community outreach, responding to fire prevention, and dealing with human–wildlife conflict, amongst other activities. We included rangers hired by governmental agencies, military or police staff as well as non-governmental organizations (NGOs), or private conservancies. However, we

excluded volunteer rangers protecting community forests and assisting employed rangers, as their numbers vary unpredictably.

Ranger density was then calculated based on total area of PAs within each country, divided by the number of rangers. We followed a two-step process to obtain the total area of PAs for each country. We first obtained the percentage of each country's land designated as PA from the World Database on Protected Areas (WDPA) (UNEP-WCMC, 2020) and then updated based on governmental sources. However, to develop a more Asian perspective, and also to compensate for time lags and omissions in reporting to the WDPA (Bingham et al., 2019), we checked the latest available data from WDPA (UNEP-WCMC, 2020) against several in-country sources concerning PA extent in 2020, updating where necessary (Table S1; Farhadinia et al., 2022). Although Russia and Kazakhstan span Eurasia, we included them as Asian countries because the ranger data was available only at country scale, not for a subset of the country.

We also compared the contemporary ranger density with historic data in the 1990s (James et al., 1999), available for nine Asian countries. For methodological consistency, we adopted "total staff 1000 km^{-2} of PA" which comprised field and administrative staff.

2.2 | Spending on ranger salaries

We reported five country-level economic metrics related to law enforcement by rangers as (1) ranger gross annual salary in 2019; (2) ranger salary per area (USD km^{-2}); (3) ratio of ranger salary to minimum wage; (4) ratio of ranger salary to sector-specific salary; and (5) ratio of ranger salary to gross domestic product (GDP) per capita.

We first obtained ranger gross annual salary in 2019 from governmental sources. Thus, we made inquiries to government officials working in relevant ministries/organizations to learn the ranger salary, and then those numbers were checked with at least two rangers working in the country to ensure that they are realistic. For four countries (12.1%), the ranger data was retrieved from the WWF (2019). We then multiplied the total ranger gross annual salary in 2019 and total ranger number in 2019, divided by the total area of PAs inside each country to calculate the ranger spending per km^2 of PA.

We then extracted minimum wage for each country from www.wageindicator.org, which is an independent foundation comparing labor market information. We then calculated the ratio of ranger salary to the country's minimum wage. We also carried out a sector-specific salary comparison. Accordingly, we compared the ranger salary to the mean nominal monthly salaries for agriculture, forestry, and fishing (which were assumed to be principal alternative employments in rural areas) for men (the dominant gender of rangers in surveyed countries). The sector-specific data were obtained from the International Labour Organization's Department of Statistics (www.ilo.org), which is the focal point of the United Nations on labor statistics.

Finally, the GDP per capita, defined as the total market value of all final goods and services produced in a given country divided by the population, was used as an indicator of a country's economic wealth per capita. The ratio of ranger salary to GDP per capita is, therefore, an indicator of the standing of ranger salary relative to a country's economic wealth and enabled cross-country comparisons of ranger salaries. GDP per capita (current US$) was obtained from the World Bank Indicator portal (World Bank, 2018).

All financial data were converted to USD at the average exchange rate from the year to which the data was applied (www.oanda.com). To compare temporal trends in spending, we scaled historic financial data to USD in 2019 to account for inflation (US Bureau of Labor Statistics, 2020). We obtained all metrics for 33 Asian countries, except the sector-specific earning data, which were available for only 20 countries. We used general linear modeling to evaluate the spatial variation in annual ranger spending per PA and ranger density between regions in Program R (R Development Core Team, 2013). Each metric was reported as median and interquartile range (IQR).

3 | RESULTS

3.1 | Ranger density

We estimated that there are nearly 208,000 rangers in charge of preserving the terrestrial PA networks in 33 Asian countries, corresponding to 13.2% of the continental area. The median density is 21.6 (IQR 11.9–55.8) rangers per 1000 km^2 of PA, which is equal to a median of 46.3 (IQR 17.9–84.1) km^2 of PA per ranger across Asia (Figure 1A). India had the highest ranger density with 363.6 rangers per 1000 km^2.

The ranger density has decreased by 2.4-fold since the mid-1990s, from a median of 10.9 (IQR 5.4–17.1) to 26.4 (IQR 17.4–33.7) km^2 of PA per ranger. This is equal to a median of 92.0 (IQR 59.0–186.0) for the mid-1990s to 37.9 (IQR 29.7–57.5) rangers per 1000 km^2 in 2019 across the subset of nice Asian countries for which data were available for both 1990 (James et al., 1999) and 2019 (the current study; Figure 2). There was no evidence that the current ranger density differs between regions ($F_{6, 26} = 0.81$, $p = 0.57$).

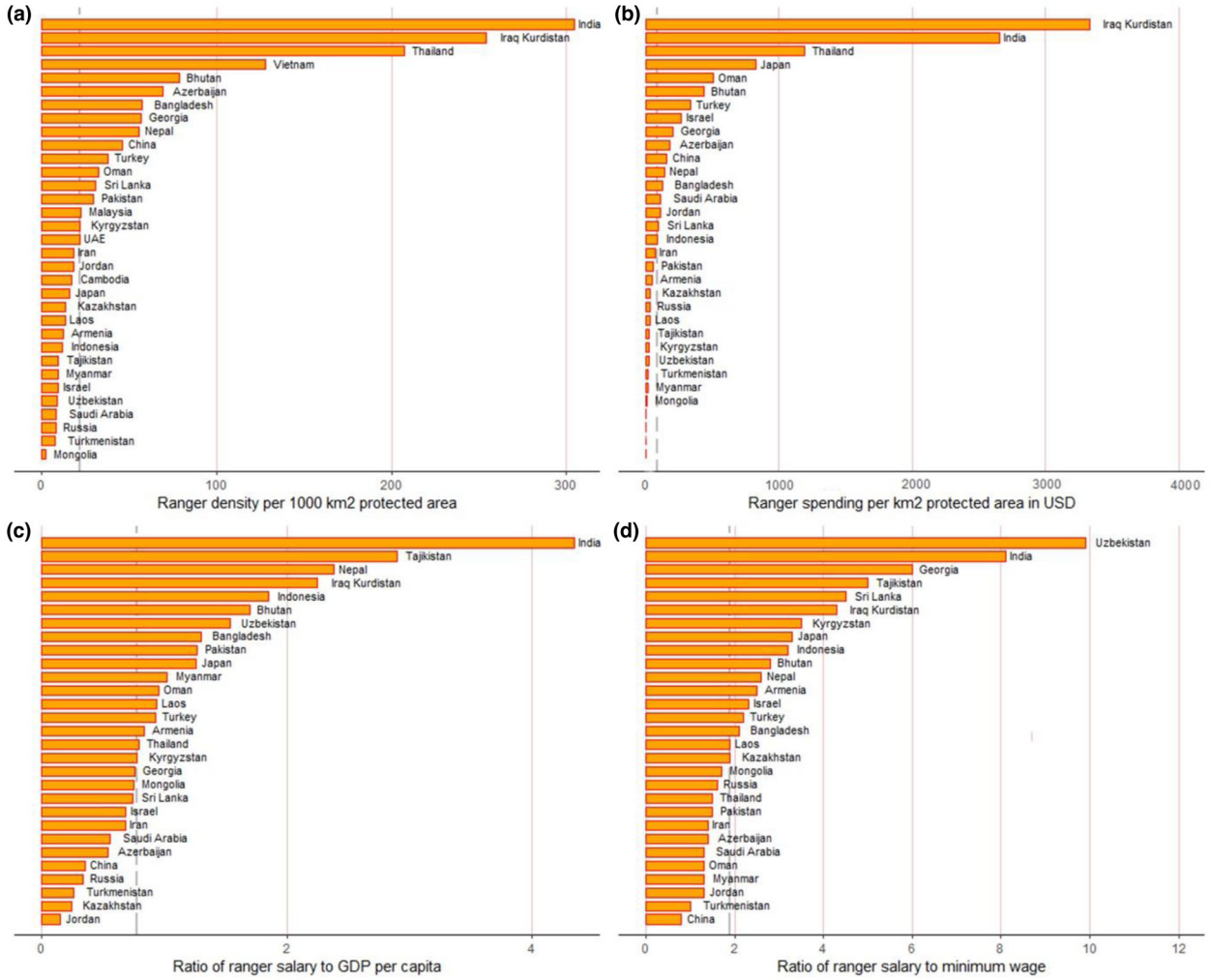

FIGURE 1 Barplots show (A) ranger density per 1000 km^2 protected area, (B) ranger spending per km^2 of protected area in USD, (C) the ratio of ranger salary to gross domestic product (GDP) per capita, and (D) the ratio of ranger salary to minimum wage in Asian countries. The dashed lines denote to the median. No data on ranger salary was available for Vietnam, Malaysia, UAE, and Cambodia.

3.2 | Spending on ranger salaries

Rangers are predominantly hired by governmental agencies. However, in a few countries, such as Nepal, Iraqi Kurdistan, Malaysia, and Vietnam, military or police staff share responsibility for anti-poaching work. Likewise, conservation NGOs or private conservancies hire fewer than 1.5% of the entire continent's rangers (3330 out of ca. 208,000). In Georgia and Armenia, the Caucasus Nature Fund subsidizes ranger salaries of 17 PAs (30% in Georgia and 50% in Armenia). In Nepal, around 7000 army staff additionally function as anti-poaching rangers.

Ranger monthly salaries varied 51-fold across the continent between USD83-4230 month^{-1}, with a median of USD294 (IQR 200–600) month^{-1} (Table S1). Rangers in Japan, Oman, Saudi Arabia and Iraqi Kurdistan earned more than the other Asian countries (>USD1000 month^{-1}). The rangers are governmental police in Iraqi Kurdistan, and their salaries depend on the military rank they hold. In contrast, rangers in central Asian countries made the lowest salary across the continent (<USD200 month^{-1}). The total spending of Asian countries on ranger salaries exceeded USD1.1 billion year^{-1}.

Annual ranger salary per area (USD km^{-2}), based on PAs, varied widely among countries, from USD7 to USD3332 km^{-2}, with a median of USD106 (IQR 32–263) km^{-2} annually. Iraqi Kurdistan, India, and Thailand ranked highest, whereas rangers in Central Asian countries and Myanmar received the least (Figure 1B). There was no evidence that annual ranger spending per PA differs between regions ($F_{6, 26} = 1.19$, $p = 0.34$).

The ratio of the median ranger salary to GDP per capita, however, showed a different pattern. Ranging from 0.2 in Kazakhstan to 4.3 in India, the median was 0.8 (IQR 0.4–1.3) times of GDP per capita in 2019 (Figure 1C), showing that the salary level for the rangers is generally slightly

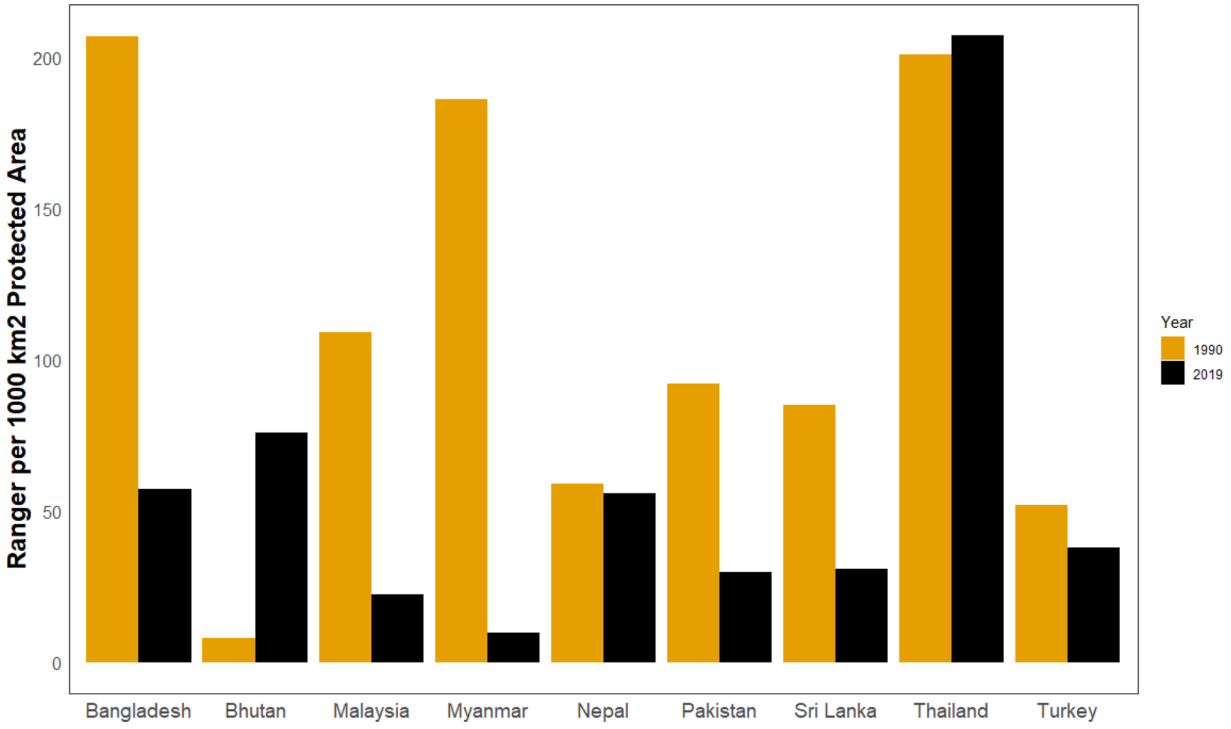

FIGURE 2 Temporal variation of ranger numbers per 1000 km^2 protected areas for 9 selected Asian countries in the 1990s based on James et al (1999) and the current study.

lower than the GDP per capita. In 53.6% ($n = 15$) of investigated countries, rangers received lower than GDP per capita (Figure 1C).

The median ratio of ranger salary to minimum wage was 1.9 (IQR 1.3–2.8), varying from 0.8 in China to 9.9 in Uzbekistan (Figure 1D). Arabian countries (Oman, Saudi Arabia, and Jordan) were ranked low with the ranger salary to minimum wage ratio of 1.3. In the Caucasus, there was a remarkable variability in the ratio between 1.4 and 6.

The median ratio between ranger salaries and earnings in the agriculture, forestry, and fishing sector was 1.2 (IQR 0.8–1.8), ranging from 0.6 (Kazakhstan and Russia) to 7.5 (Kyrgyzstan). Russia, Kazakhstan, and Mongolia were the only countries in which rangers were paid less than the mean nominal monthly earnings in similar sectors.

4 | DISCUSSION

Our study provides the most comprehensive data on ranger economics at the continental scale. Rangers are generally paid 1.9 times as much as the minimum wage and 1.2 times higher than employees in agriculture, forestry, and fish sector. Our study also revealed no evidence for spatial variability in ranger densities and payments across Asian ranges but highlighted high intercountry variation with India outperforming most Asian countries in all aspects of ranger density and spending (Figure 1).

By the end of the 2000s, the total conservation spending across Asia did not exceed USD425 million (Waldron et al., 2017). Our study showed that the total spending of Asian countries on ranger salary alone was 2.7 times higher a decade later, exceeding USD1.1 billion year^{-1}, a substantial increase in the budget allocated to ranger salaries during the 2010s. Nonetheless, it is not clear if the higher conservation spending is correlated with increased GDPs (data.worldbank.org) and/or to countries' commitments to invest in conservation (CBD, 2010).

We could not quantify the proportion of total conservation spending comprising ranger spending. Similarly, the annual conservation spending for all activities, including ranger-based law enforcement, is estimated to be a median of USD200 km^{-2} for African PAs with lions *Panthera leo* (Lindsey et al., 2018), whereas it is higher for managing tigers *Panthera tigris* in Asia with a budget of USD600 km^{-2} (Walston et al., 2010). Given the rangers' indispensable role in preserving biodiversity, the contribution of ranger spending to the total conservation spending of countries, as well as the changes in their sources through the time, helps to project the future needs and donors (Appleton et al., 2022).

The global ranger density was 2.4 times higher than the Asian ranger density. Although the median density is 46.3 km^2 of PA per ranger across Asia, it was much

higher globally with a median of 18.2 km^2 of PA per ranger (Appleton et al., 2022), confirming the lower density of rangers working in Asian countries. Importantly, our study showed that ranger density has also decreased by 2.4-fold since the mid-1990s, from a median of 92.0 (IQR 59.0–186.0) (James et al., 1999) to 37.9 (IQR 29.7–57.5) rangers per 1000 km^2 PA across selected countries. In contrast, the maximum global PA personnel density is the same as that reported in the 1990s (Appleton et al., 2022; James et al., 1999). We, therefore, conclude that Asia is a relatively underperforming continent in terms of investing in ranger numbers, and many Asian countries were not able to maintain their past ranger density. Equally important, despite the substantial increase in PA designation in many Asian countries during the 2010s (Farhadinia et al., 2022), many countries were unable to secure the resources needed to guarantee effective biodiversity conservation (Appleton et al., 2022; Coad et al., 2019).

There are nearly 208,000 rangers patrolling PAs and recording evidence of poaching and biodiversity occurrence across Asia. Ranger-based monitoring data has great potential for evaluating the effectiveness of protection-based conservation investments (Stokes, 2010) and to assess the conservation status of wildlife populations (Kuiper et al., 2020; Marescot et al., 2020). Increased collaboration between scholars and practitioners in Asia is needed to develop and apply effective and sustainable monitoring and interpret their results, for example, using the Spatial Monitoring and Reporting Tool (Cronin et al., 2021) or citizen science-based platforms (Farhadinia et al., 2018).

Anti-poaching remains a major governmental effort, given the high percentage of rangers that are government employees. This reflects the low diversity of governance types of Asia's PAs, with 80% of recorded PAs managed by government agencies (UNEP-WCMC, 2020). The second source of rangers in Asia originates from the trophy hunting industry, with rangers hired locally by conservancies and hunting concessions; this occurs in a few countries, particularly in central Asia (Table S1). Given that the ranger density in all these countries is lower than the continental median, the trophy hunting industry appears to provide an additional source of revenue for these understaffed countries (Parker et al., 2022), although it is the focus of both ethical and ecological concerns (Zhou et al., 2021).

4.1 | Conservation recommendations

Our findings highlighted three implications to improve conservation across Asia:

First, Asia has lower ranger density compared to other continents (Appleton et al., 2022). Equally important, many Asian countries did not increase, or even sustain, their ranger density in proportion with their expanding PAs. Although the expansion of PAs in regions of high importance for biodiversity is widely encouraged, the management effectiveness must also increase in parallel.

Second, increasing staff numbers alone may not guarantee the improved management effectiveness of the world's growing network of PAs (Appleton et al., 2022). Our study showed that rangers are generally paid at low rates within most Asian countries. Therefore, in addition to increasing ranger numbers, it is crucial to address their welfare and professionalization, such as capacity, resources, and working and employment conditions as they are operationally crucial aspects of conservation performance, which affects the effectiveness and misconduct of rangers (Moreto et al., 2019).

Finally, decision-makers frequently seek an optimum number of law enforcement staff. We consider that no single number could be generally applicable across landscapes with widely differing social, economic, and cultural contexts. Nonetheless, our findings provide policymakers with a continental baseline (a median number of 46.3 km^2 PA per one ranger), which facilitates comparisons of existing law enforcement spending amongst Asian countries at regional or continental scales, in order to set

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goals for improving performance and employment opportunity.

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DATA AVALAIBILITY STATEMENT

All data have been provided in Table S1.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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