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LETTER TO THE EDITOR

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The Montreal Protocol and its Amendments have been highly effective in protecting the stratospheric ozone layer and preventing global increases in solar ultraviolet-B radiation (UV-B; 280–315 nm) at Earth's surface (McKenzie et al., 2019). This international agreement has also been one of the most important societal actions to mitigate global warming, as many of the ozone-depleting substances and their substitutes that are regulated by the Montreal Protocol are also potent greenhouse gases (Velders et al., 2007). Ozone depletion itself contributes to climate change in some regions (Robinson & Erickson III, 2015), and climate change modifies the exposure of humans, plants, animals, and materials to UV-B as well as UV-A radiation (315–400 nm; Barnes et al., 2019). Thus, changes in stratospheric ozone, UV radiation, and climate are inextricably linked in a number of critical ways that influence human health and the environment (Figure 1).

The Environmental Effects Assessment Panel (EEAP) of the United Nations Environment Programme regularly assesses the interactive effects of changes in stratospheric ozone, UV radiation, and climate on the environment. Findings from our updates (Neale et al., 2021) and full assessments (EEAP 2018 Assessment;

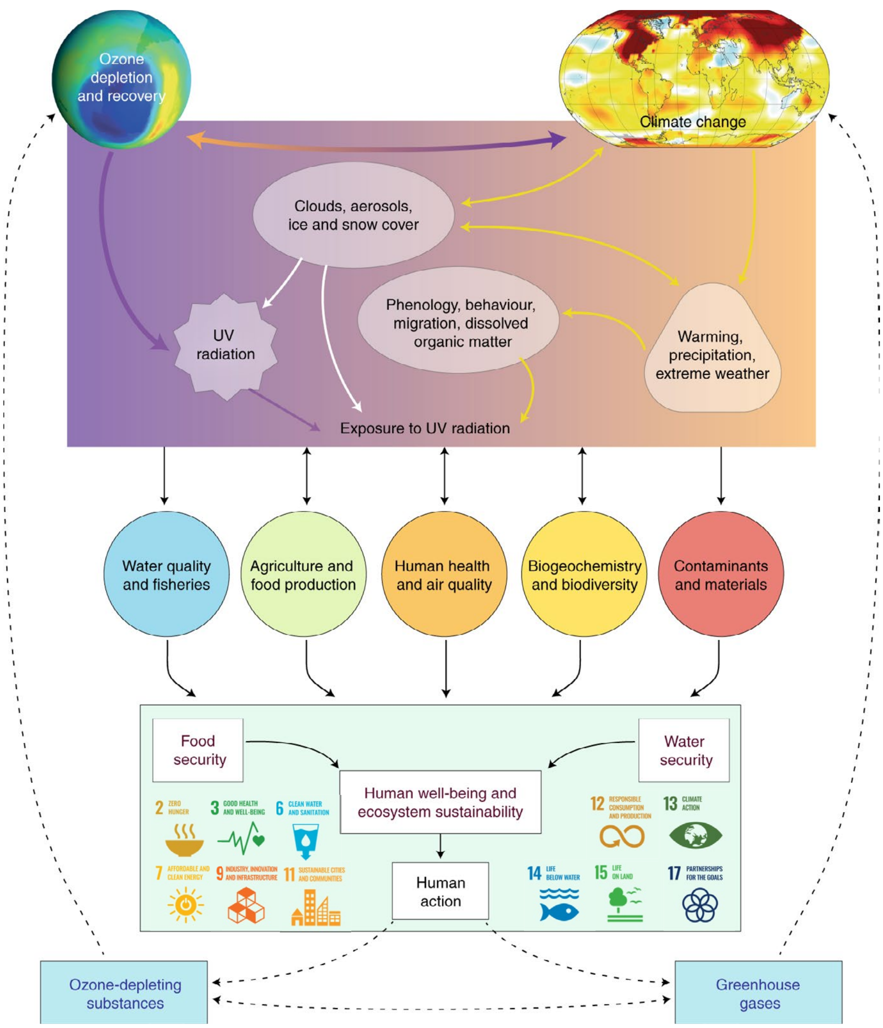

FIGURE 1 Interactions between stratospheric ozone, UV radiation, and climate, and the potential consequences for human health and the environment. Direct effects are shown as solid lines with feedback effects indicated by double arrows. Important effects driven by human action are shown as dashed lines. The contributions of the Montreal Protocol and its Amendments to the UN Sustainable Development Goals (SDGs) are shown by the SDG icons (see https://www.un.org/sustainabledevelopment/ for more information on the SDGs). Figure modified and reproduced from Barnes et al. (2019) with permission

https://pubs.rsc.org/ja/journals/articlecollectionlanding?sercode=pp&themeid=034015c8-12de-4196-9526-18090345cf96) indicate that, because of the Montreal Protocol, changes in surface UV-B radiation over the past 20 years have been relatively small (ca. <±4% per decade). For most regions over this period, changes in cloud cover and aerosols have had a larger effect than changes in stratospheric ozone on variation in UV radiation. Climate change is exerting an increasing effect on exposure to UV radiation as a consequence of changes in phenology, cloud cover, aerosols, snow and ice cover, species distributions, water quality, and extreme weather events. Moreover, stratospheric ozone depletion over Antarctica is strongly linked to the climate of the Southern Hemisphere (e.g., Damiani et al., 2020). It is estimated that by 2050 the Montreal Protocol will have prevented global warming over land of 1.5–4°C, depending on the region (Goyal et al., 2019).

While their magnitude has been limited by the Montreal Protocol, ongoing and projected changes in UV radiation and climate still pose a threat to food security, air and water quality, terrestrial and aquatic ecosystems, and construction materials and fabrics. Exposure to solar UV radiation increases the decomposition of organic matter in both terrestrial and aquatic ecosystems, which releases carbon dioxide, methane, and other greenhouse gases to the atmosphere—an important feedback effect on the climate system. Modeling studies estimate that the Montreal Protocol will prevent millions of cases of skin cancers and cataracts in the United States alone. However, exposure to solar UV radiation also has benefits for health. Most notably, it generates vitamin D (which is critical for bone and muscle health), disinfects surface waters of pathogens, and also plays an important role in immune function, an effect that is important in light of the COVID-19 pandemic. Balancing the positive and negative effects of UV exposure on human health would have been difficult to achieve in a world without the Montreal Protocol.

In today's rapidly changing world, the Montreal Protocol continues to play a critical role in protecting Earth's inhabitants and ecosystems by addressing many of the UN Sustainable Development Goals (Figure 1; Neale et al., 2021).

KEYWORDS

climate change, ecosystems, human health, Montreal Protocol, stratospheric ozone, sustainability, ultraviolet radiation, UV-B

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CONFLICT OF INTERESTS

The authors declare no competing financial or other interests.

DATA AVAILABILITY STATEMENT

Data sharing not applicable—no new data generated.

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