Predicting the distribution of three malaria vectors in Southeast Asia using temperature and precipitation models

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Summary

This study uses previously published data and existing climate models based on temperature and precipitation rates to describe the current and predicted future distribution of three southeast Asian malaria vectors: *Anopheles dirus, Anopheles minimus* and *Anopheles stephensi*. Interpretation of these maps suggest that these three mosquito species have the potential to shift their range northward as temperatures become more suitable. In southern areas of Thailand, Vietnam and Laos, conditions will become unsuitable for *An. dirus* and *An. minimus,* as a result of predicted rises in temperatures beyond the optimal for survival. Whilst numerous factors beyond the abiotic influence vector distribution, our findings demonstrate the sensitivity of malaria vectors to climatic changes, particularly temperature. Our results make predictions of where certain abiotic conditions will be suitable to support vector populations in the future, and can be used for estimating the future distribution of each individual species. Such information can then be experimentally verified, and could be useful for the monitoring and possible management of anopheline mosquitoes under near-future climate conditions.

Introduction

Anthropogenic driven climate change continues to cause a rise in temperature and changes to global precipitation patterns (1). One particular aspect of anthropogenic climate change that is often overlooked is that of novel emerging diseases, and expanding geographic range of existing diseases (2). For example, there is evidence that avian malaria in wild birds is increasing in range and intensity due to global warming (3). Climate change is already driving organisms' ranges to higher altitudes and latitudes (4), including vectors of infectious diseases (2). For example, the malaria vectors *An. gambiae* and *An. arabiensis* in sub-Saharan Africa were found to spread eastwards and southwards in response to climate change scenarios (5). We apply a similar methodology and approach of previous studies (5,6) to malaria vector distribution in response to predicted climate change scenarios in SE Asia. Southern and South-eastern Asia have the second highest malaria burden after sub-Saharan Africa, and approximately 2 billion people are at risk of the disease in the 22 countries where malaria is endemic (7,8).

Methods

Three anopheline species dominate the study area; *Anopheles dirus*, *Anopheles minimus* and *Anopheles stephensi* (9). The distributions of each species, based on temperature and precipitation metrics, were mapped and presented using range map shapefiles produced by (10). These shapefiles were layered onto geographical maps in ArcGIS to show the current distribution of the three chosen vector species (Fig 1). For predicted distributions, the Worldclim MIROC6 model (11) was used, as this model has been used for the most recent coupled model intercomparison project (CMIP6; 12). The MIROC6 model was used for the years 2081-2100 at the highest resolution available (2.5 minutes). The shared socio-economic pathway (SSP) 585 was selected, an updated version of the representative concentration pathway (RCP) 8.5 produced by the IPCC. Future climate projection maps were created using geotiff files from the MIROC6 model, in the Worldclim database (11). Individual geotiff files for global monthly minimum and maximum temperature, and monthly precipitation were downloaded into R v3.6.1. These were mapped using the "raster" package for the study area.

Figure 1: Current distribution of the 3 species in the study area. Maps were produced using shapefiles from Sinka *et al.* (2011), overlaid onto the study area using ArcGIS.

Results

Predicted changes in temperature and precipitation for the years 2081-2100 suggest there are new suitable ranges for each species (Fig. 2). The greatest change in distribution compared to current is in Southeast China, suggesting a northward range expansion of the 3 anopheline species. Viable min and max temperatures remain in most areas of SE Asia, although suitable conditions for *An. dirus* and *An. minimus* are no longer found in southern parts of Myanmar, Cambodia, Thailand and Vietnam, areas that are currently occupied by the species. *An. stephensi* shows no loss of range compared to current due to its large range of temperature suitability, and demonstrates this northwards shift best out of the three species. Areas with rainfall over 80 mm per month (required for mosquito breeding; 13; Fig.3) suggests that the majority of SE Asia will be significantly drier than current. The very northern area of India is predicted to receive 80-100 mm of monthly precipitation, along with the eastern coast of Vietnam. Malaysia, Indonesia and the Philippines are predicted to receive higher amounts of precipitation than current levels.

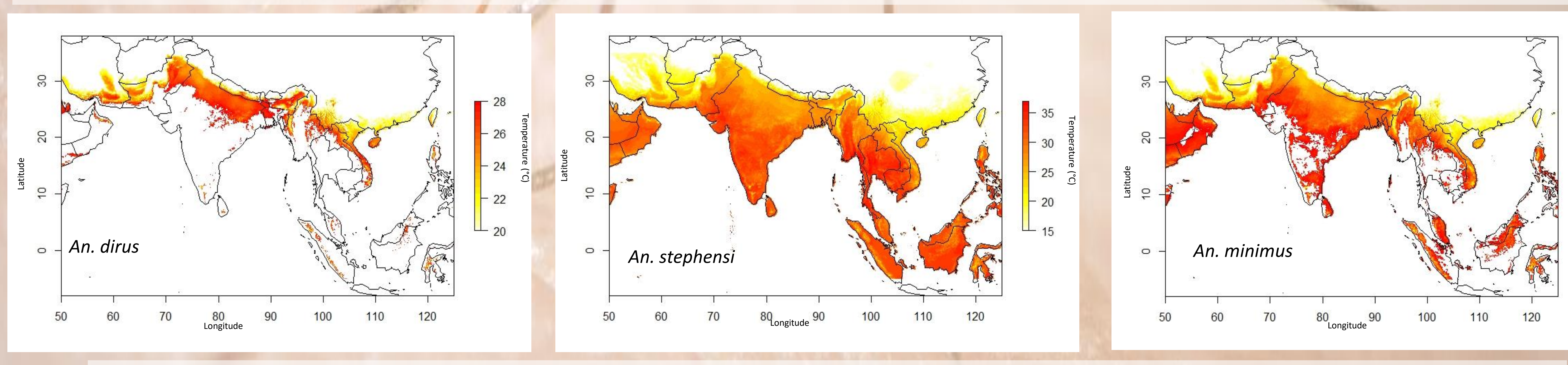

Figure 2: Predicted future distribution of *An. dirus*, *An. stephensi* and *An. minimus* throughout the years 2081-2100, based on their minimum and maximum survivable temperature.

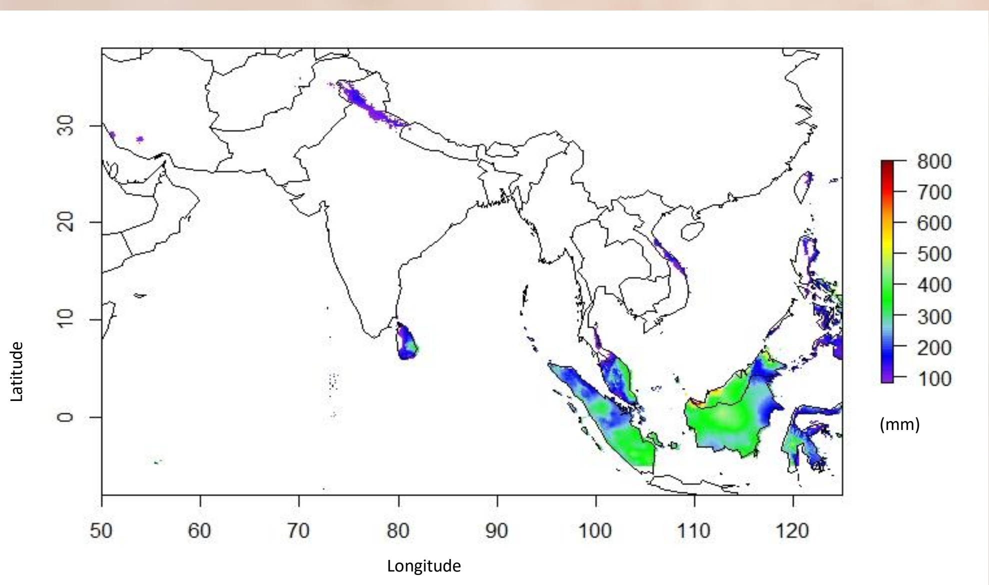

Figure 3: The predicted monthly precipitation for SE Asia with the minimum amount of precipitation set to 80 mm

Discussion

The results obtained from the MIROC6 model do not show the future distribution of the mosquitoes, rather, they show those areas that will become suitable to enable mosquito survival. Many other factors, not included in this study, influence the distribution of mosquitoes, including habitat preference, proximity to human populations, and density and proximity of urban settlements (14). These factors have not been included in the analysis as they are specific to each species, and do not detract from the underlying thesis of climatic change influencing distribution. Distribution shifts are common as mosquitoes, as arthropods, are extremely sensitive to climatic changes. In response, they can rapidly adapt to changing climates and shift their range by up to 20 km in latitude per year (15). Range shifts already occur, with the appearance of the urban malaria vector *An. stephensi* in Ethiopia and the Arabian Peninsula (16). Climate change has the potential to cause a northwards range shift of anopheline mosquitoes in Southeast Asia, exposing new populations to malaria that were not previously exposed.

References

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