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The impact of temperature and precipitation changes on honey bees (Apis mellifera) in the Aegean region under future climate scenarios

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The Aegean region (Greece) preserves a wide genetic diversity amongst the honey bees (Apis mellifera L.) of its many islands and supports an important bee keeping industry. However, sector-specific regional impact studies, based on the latest high-resolution regional climate models (RCMs), are urgently required for developing successful local adaptation strategies for beekeeping and to preserve biodiversity under future climate change scenarios.

We evaluated direct climate change impacts on honey bees in the Aegean region through novel threshold temperature and precipitation indices, linked to critical bee behavior and colony mortality. There are strong relationships between ambient temperature and key bee colony behavior such as, for example, nest thermo-humidity regulation, annual population variability and foraging. Additionally, dry conditions and heatwaves have been empirically linked to declines in colony food stores and increased colony mortality rates. Impact projections used simulated temperature and precipitation data from an ensemble of seven RCMs under the medium (RCP4.5) and high (RCP8.5) emission scenarios for the control- (1971-2000), near future- (2031-2060) and distant future (2071-2100) periods. Simulated data were bias-adjusted using the long-term meteorological record of Naxos Island (central Aegean).

Overheating in summer constitutes a major challenge to nest temperature regulation. Thermal and humidity conditions are well-regulated in bee nests given their importance for colony health. Brood must remain at 33-36 ^{o}C and experience high relative humidity for proper development. Bees tend to start cooling nests when ambient temperatures are >25 ^{o}C. Evaporative cooling using water is of critical importance with temperatures above 35 ^{o}C and is remarkably effective in stabilising nest temperature at 36 ^{o}C, even as ambient temperatures are >60 ^{o}C. Thermoregulation is highly demanding, and brood is mainly reared during optimum periods with no/low need of regulation. Sustained high temperatures >40-45 ^{o}C cause significant colony losses. The highest foraging activity takes place in the temperature range from 12-25 ^{o}C, whereas there is no activity <7 ^{o}C and >43 ^{o}C. Winter colony mortality rates increase when the spring flowering period experiences very low rainfall and extreme temperatures.

Future climatic change projections show significant increases in seasonal temperatures and days without precipitation, which will negatively affect the region's bees. More frequent and severe heat-

extremes will characterize seasons from spring to autumn, forcing bee colonies to cool their nests more intensively. Meanwhile, the availability of water and nectar (used for evaporative cooling) will decrease during extreme warm-dry events. The increase in heat extremes will likely lead to increased colony losses. Temperatures within the range for optimal foraging activity are less likely to occur during the flowering period. Finally, years with spring seasons characterized by very low rainfall and extreme temperatures will become more frequent in the future which may result in increased winter mortality rates.