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Climate change effects on predator–prey interactions

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Predator–prey interactions can be very important to community structure and function. A growing body of research demonstrates how climate change can modify these species interactions. Climate change can modify predator–prey interactions by affecting species characteristics, and by modifying consumptive and/or non-consumptive predator effects. Current work examines how climate change and predation risk can combine to influence herbivore stoichiometry and feeding ecology. Other recent advances show how climate change can affect chemical signaling of plants and insects, as well as how pollution and other components of the environmental context can modify predator–prey interactions.

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Introduction

Global climate change will affect ecosystems in many ways. Large shifts in species' distributions and phenology are expected, and already observed in some organisms [1]. Individual performance may be affected by climate change [2], especially for ectothermic organisms where metabolic and other physiological processing rates are temperature dependent. Climate change will also affect ecosystems by altering species interactions, including predator–prey interactions.

Predation has a variety of important and far-reaching effects on ecosystems including biocontrol of pest species [3], structuring community composition [4], and influencing ecosystem processes like primary production or nutrient cycling [5]. Therefore, it is important to understand how climate change can modify predator–prey interactions.

Climate change may affect predator–prey interactions through several pathways (Figure 1). First, climate change can directly affect species by influencing factors such as behavior or distribution (Figure 1B). These changes can in turn modify how predator–prey interactions play out. Second, climate change may modify predator–prey interactions through effects on consumptive and/or non-consumptive predator effects (Figure 1C). Consumptive predator effects occur when predators kill and remove prey from the population, affecting prey density [6]. Non-consumptive effects occur when prey respond to predation risk by altering traits such as feeding behaviors, morphology, or development rates [6]. Such trait-mediated responses to predation risk can also result in changes to prey density, and may be more far-reaching than consumptive predator effects, as more individuals are likely affected by non-consumptive effects than consumptive effects [7]. The effects of climate change on species traits and on predator–prey interactions are likely to be mediated by the environmental context and by local adaptation. Finally, effects of climate change on species interactions may have community and ecosystem-level consequences (Figure 1D).

Several recent reviews discuss potential effects of climate change on species interactions generally [8–13], and on antagonistic interactions in particular [14]. Here, I briefly review responses of predator–prey interactions involving insects to climate change, with emphasis on recent research. Climate change will affect many abiotic factors that may modify species interactions (Figure 1A). I primarily focus on temperature and atmospheric CO_2 concentrations, but other factors such as drought [15] and extreme weather events like heatwaves [16–18] are also important.

Climate change effects on species: individuals to populations

Climate change can have a variety of effects on species, from effects on individual species traits to population level effects that can affect how predator–prey interactions play out. These responses to climate change will likely be modified by adaptation and phenotypic plasticity.

Predator–prey interactions can be mediated by changes in plant traits. Climate change is likely to alter plant quality by modifying nutrient content, increasing protein:carbohydrate [19], and by modifying concentrations of plant secondary compounds [20]. Such changes can alter herbivore foraging behaviors and herbivore nutrient content, which can affect predator–prey interactions. Changes in plant phenology, distribution, and abundances [21,22] are likely to mediate predator–prey interactions as well.

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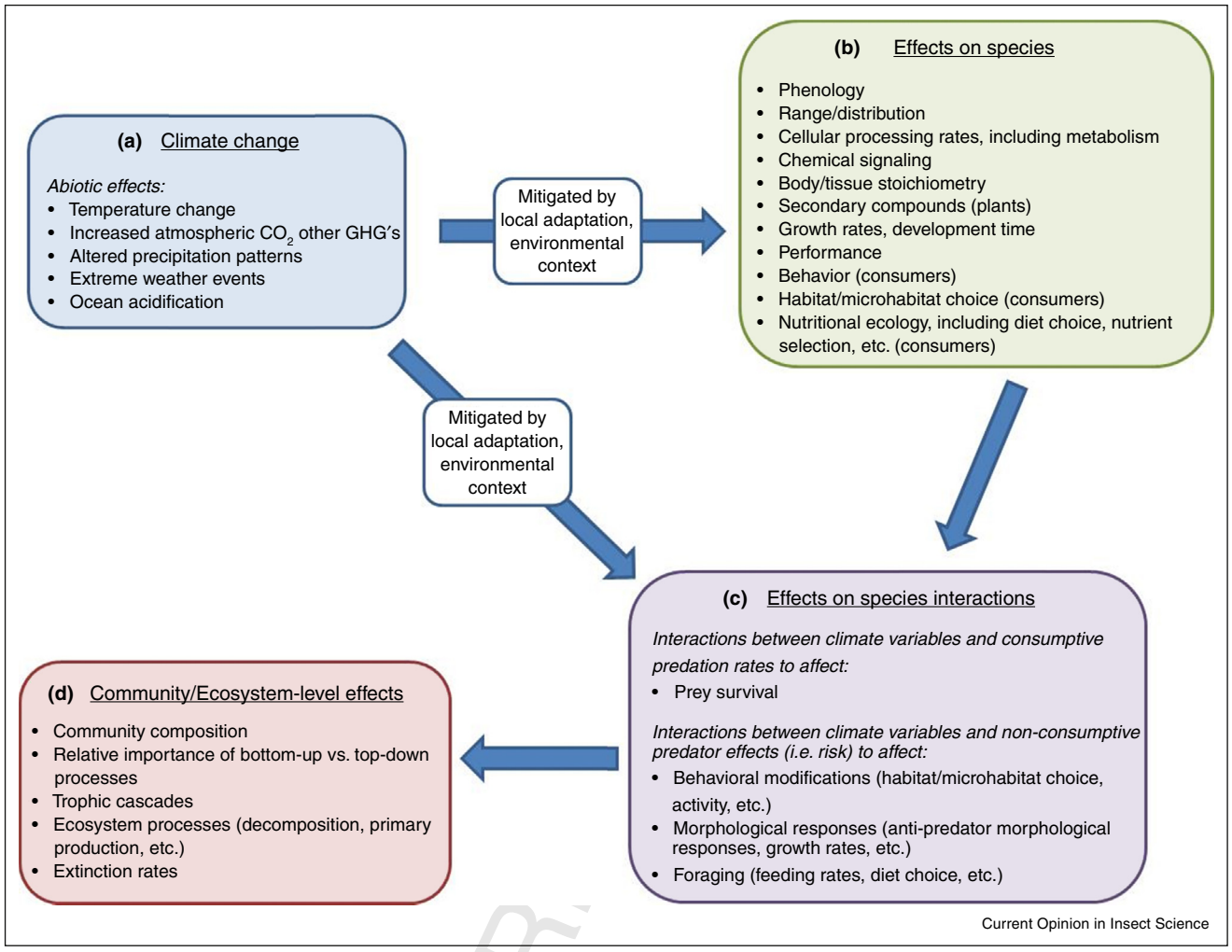
Figure 1



Conceptual diagram of the pathways by which climate change may affect predator–prey interactions. Climate change may have effects on species, such as phenology and distribution, that in turn affect species interactions. Effects of climate change on predator–prey interactions can operate through modifications of consumptive or non-consumptive predator effects. These changes in predator–prey interactions can then cascade to effects on community and ecosystem-level processes (which may also be affected directly by climate change and by climate change effects on species traits).

Temperature and other abiotic factors associated with climate change can modify species traits, such as development time [23,24], oviposition rates [25] as well as specific behavioral traits [26,27•], all of which can mediate the outcome of predator–prey interactions. While many of these responses are species-specific, some general trends are observed. For example, metabolic rates increase with temperature, increasing resource requirements [28,29]. Insects may also experience faster development time, increased voltinism, and reduced body sizes [14].

Climate change may affect predator–prey interactions by changing local community composition over space and time. As species respond to climate change by shifting their ranges, novel communities may be formed, disrupting current interactions and creating new ones. Shifting phenology in response to climate change can affect species interactions if interacting species do not respond in the same way, leading to a temporal 'mismatch' in species occurrences [30,31]. Most work on phenological responses to climate change involving insects focuses on plant-herbivore interactions, but other species interactions may also be affected [32,33]. It is still unclear how widespread mismatch will be among predator–prey interactions [34•], but the effects are likely to be context dependent and species specific, as seen with insect-plant interactions [35].

Chemical signaling

Climate change can modify species interactions by altering the efficiency of inter-specific and intraspecific

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