Consequent Effects of Parasitism on Population Dynamics, Food Webs, and Human Health Under Climate Change

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Climate change has undoubtedly begun, and the effects have occurred in various ecological and biological systems (IPCC 2007). Numerous studies have concurrently documented changes in species distributions, population dynamics, intra- and inter-specific interactions, and community structure of free-living organisms caused by climate change (e.g., Walther et al. 2002; Parmesan and Yohe 2003; Winder and Schindler 2004; Doi 2008). However, the discussions and predictions about parasitism under climate change are still very limited. Host–parasite interactions are an important component of community and food-web structure, and have been the focus of many recent ecological studies (e.g., Lafferty et al. 2008). Also, parasites induce disease of organisms including human (Patz et al. 2008; Pascual and Bouma 2009). Thus, the importance of parasitism to ecological processes and human health would be well known, but only few review papers predicted potential links between parasitism and global climate changes (e.g., Walther et al. 2002; Brooks and Hoberg 2007). The effects of global warming on assemblages of hosts, parasites and pathogens can be numerical, functional or micro-evolutionary, and can involve cascading changes in ecosystems (Brooks and Hoberg 2007). Here, we summarize and discuss the importance of parasitism to host–parasite population dynamics, food-web structure, and human health, under future climate change.

Climate change can affect physical and biological processes differently and can have different effects on different species (Winder and Schindler 2004; Doi et al. 2008). We

predict two potential effects of climate change on host–parasite interactions. First is the shifting of the life cycles of host and parasite under climate change. Understanding a shift in the life cycle of one species relative to other species in an ecosystem is important to consider the inter-specific interaction under climate change more than the absolute timing of phenology (Walther et al. 2002; Winder and Schindler 2004), because this is the only way to determine whether species are effectively responding to climate change. Mismatches in intra- and inter-specific interactions have been reported in natural systems, and the mismatching hypothesis has been well discussed about bird, pollinator, and plankton communities (Winder and Schindler 2004; Doi et al. 2008). Mouritsen and Poulin (2002) expected that host–parasite interactions and population dynamics were influenced by climate change; climate change indirectly affected host–parasite interactions through the independent population dynamics of the host and parasites. Thus, such mismatching of their life cycles can be predicted in host–parasite interactions. Second is that the extinction of host and/or parasite. Thomas et al. (2004) estimated that 15–37% of Earth’s free-living species would be extinct due to the predicted climate change. Hechinger and Lafferty (2005) suggested that the high sensitivity of parasites to host extinction suggests that parasite extinctions might outnumber host extinctions. In contrast, Brooks and Hoberg (2007) argued that parasites are unlikely to become extinct, given their ability to switch hosts. Extinction of host and/or parasites would alter their interactions, but the process of alteration would be different among parasite species, depending on their ability to switch host species if the host extinct. Due to the above causes, host–parasite interactions would be largely altered, and consequently the changes in their interactions would alter food-web structure in the system as below.

Parasitism is the most common consumer strategy, and there has recently been a call for the inclusion of parasitism into food webs (Lafferty et al. 2008; Sukhdeo 2010). Lafferty et al. (2008) showed that host–parasite interactions dominated food-web links. A food web contained more parasite–host links than predator–prey links. Recent studies of food webs suggest that 75% of the links in food webs involve a parasitic species (Dobson et al. 2008). Thus, parasites have the potential to alter food-web structure, such as food-chain length, competence and robustness, and food-web stability due to their strong effects on the hosts (Lafferty et al. 2008). Therefore, parasitism is one of the key links in food webs and should be considered the alterations on food-web structure by changes in parasitism under climate change. We suggest direct and indirect effects on food webs due to changes in host–parasite interactions under climate change. Direct effects on food webs are due to mismatching and loss of host–parasite interactions. Consequently, the food-web structure may be changed, because the mismatching of species interaction induces changes in food-web structure (Winder and Schindler 2004). Obviously, the host and/or parasite extinction alter food-web structure. Although there is no study to actually test that changes in host–parasite interactions alter food-web structure, such importance of parasitism in food webs may allow us to expect strong impact of host–parasite mismatching on food-web structure. Indirect effects on food webs are due to changes in host feeding behavior and habitats. Parasites have been shown to modify feeding pattern of their intermediate hosts (Barnard and Behnke 1990; Miura et al. 2006). Parasite-modified behavior of hosts often results in increased success of transmission of parasites to next hosts, and changes the spatial distribution and ecological niche of the host population (Barnard and Behnke 1990; Yurlova et al. 2000; Miura et al. 2006). Moreover, hosts may try to compensate for the increased nutritional demands imposed by the parasite with increased foraging (Barnard and Behnke 1990). If the infection rate of parasite on host species changed, in a food web, the property and degree of feeding behavior and habitats of host species would be changed. Consequently, such changes of the host feeding behavior and habitats due to parasite control would alter food-web structures.

Parasite and vector interactions would be changed under climate change. The results in the vector of parasites, which are non-host-species suitable, could increase, because vectors would concentrate their bites on humans (Dobson 2009). Thus, climate change would increase infectious diseases for animals in the future and it might also be for human. The combined effects of environmentally detrimental changes in local land use and alterations in global climate disrupt the natural ecosystem and can increase the risk of transmission of parasitic diseases to the human

population (Patz et al. 2008). Also, shifting distribution of parasites would exaggerate infectious diseases. Estimates for free-living species suggest that shifts in climate suitability will tend to decrease the size of occupied ranges and, in some cases, lead to extinction (Parmesan and Yohe 2003). Infectious diseases may expand to new habitats, such as toward the north in the northern hemisphere, due to climate change (e.g., Patz et al. 2008). Lafferty (2009) suggested that a neutral starting hypothesis is that the ranges of infectious diseases will likely shift with climate change, but not necessarily expand or contract. For example, if the range of climate suitability for malaria transmission shifts, newly exposed human populations will be more susceptible to infection and likely suffer greater morbidity (Patz et al. 2008). This is particularly relevant for moderate-scale shifts in transmission that could occur within the present poverty-prone areas where malaria is endemic (Ostfeld 2009). Studies that show distribution changes in vector interaction and shifting of parasite under climate change are quite few. The gaps in knowledge indicate that future initiatives are required to protect us from new and expanding infectious diseases.

Recently, climate change research for ecological and phenological sciences has increased (Walther et al. 2002; Parmesan and Yohe 2003; Winder and Schindler 2004; IPCC 2007; Doi 2008; Doi et al. 2008), however, such researches on host–parasite interactions are still very limited. We encourage future studies in the field, because parasitism is one of the key factors that accelerate changes of ecosystem functions and services under climate change.

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