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Review Article

Trends In The Effects Of Climate Change On Terrestrial Ecosystems In The Republic Of Korea.

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Abstract

Based on a variety of ecological and biogeographical data, our goal in this review was to compile the existing knowledge regarding the observed and anticipated impacts of climate change on the ecosystems of Korea (also known as South Korea or the Republic of Korea, or ROK), as well as the primary reasons for vulnerability and adaptation options in these ecosystems. We did this by compiling a list of peer-reviewed articles that have been published since 2014.

In the field of plant phenology and physiology, we discovered that the number of climate-related research published has declined, but in the field of plant and animal community ecology, such publications have significantly increased, reflecting the range shifts and changes in abundance brought on by climate change. According to research on plant phenology, climate change has lengthened growing seasons by delaying the time of leafing out and accelerating the timing of flowering and budburst.

According to community ecology studies, the ranges of warm-adapted organisms may grow and/or move toward the regions that the previously mentioned cold-adapted biota occupied, while the ranges of cold-adapted plants and animals may shrink or move toward northern and high-elevation areas. This review offers valuable data and fresh perspectives that will further knowledge of how climate change affects Korean ecosystems. It will also be a resource for legislators looking to create sectoral adaptation plans for future climate change mitigation

Keywords : *Climate change, Projected effects, Korea, Ecosystem, Phenology, Diversity.*

INTRODUCTION

There are numerous ongoing effects of climate change on ecosystems. Crucially, the loss of an ecosystem's biodiversity—that is, the existence of a diverse range of organisms—would be irreversible. However, since the problems caused by climate change may not immediately harm or bother humans, unlike circumstances in other socioeconomic domains, their consequences on ecosystems may be outside the public interest (Park et al. 2019). Nonetheless, it is widely acknowledged that ecosystems are going through difficult and upsetting times right now.

Due mostly to its increased use of fossil fuels to fuel its fast industrialization and urbanization, Korea has been more severely impacted by climate change than many other regions of the world (Korea Meteorological Administration (KMA) 2012). The most distinct change in the Korean climate is an increase in the range of temperature swings throughout the seasons (Chung et al. 2004; National Institute of Meteorological Sciences (NIMS) 2018). While summertime maximum precipitation has grown, the frequency of record minimum temperature days has significantly decreased (Jung et al. 2004; Kim et al. 2007; National Institute of Meteorological Sciences (NIMS) 2018).

The Korean Ministry of Environment has so far released two volumes of the Korean Climate Change Assessment Report, covering the ecological year 2013 in 2011 and 2015. The third report of its kind, the Korean Climate Change Assessment Report 2020 (KCCAR 2020; Bae et al. 2020), was released as a compilation of studies conducted over the previous six years from a range of industries, including agriculture, forestry, water resources, ecosystem services, energy, health, human settlement, and welfare, as well as from adaptation plans and policies. Here, we update the Climate Change Impact and Adaptation chapter on ecosystems in KCCAR 2020.

Using a variety of ecological and biogeographic data, this review summarizes the state of knowledge about the known and anticipated impacts of climate change on Korean

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ecosystems, as well as the primary reasons for susceptibility and available adaptation strategies. Our goal was to give policymakers a reference point for future sectoral adaptation options to safeguard against climate change, as well as practical data and fresh perspectives that enhance knowledge of how climate change affects Korean ecosystems.

MATERIALS AND METHODS

In order to accomplish our goals, we examined the biota's observed changes, such as phenology, distribution, species composition, diversity, and physiological or genetic changes, as well as the ecosystems' susceptibility to climate change and its effects, as assessed by modeling, and potential future developments. In particular, we gathered a collection of peer-reviewed publications and reports released since 2014 in order to evaluate the effects of climate change that have been seen in Korea, assist in preventing potential harm from climate change on Korean ecosystems, and develop adaptation techniques appropriate for Korea. As a result, we were able to compile the findings of the most recent national and international studies on the implications of climate change on the Korean peninsula and potential countermeasures. Additionally, we used the collected results on effects and adaptations to develop a database.

RESULTS AND DISCUSSION

Ecosystems

Habitat

The subalpine region, inland wetland, and coastal habitats—the three main ecosystems in Korea most at risk from climate change—were chosen to be the target of the threat factors of climate change against biota.

The land area

Using electromagnetic climate data from 30 years of normal climate data for the entire region, the warmth index and Köppen climate classification were used to classify the climate zone of the Korean peninsula; future changes to the climate zone were forecasted under the Representative Concentration Pathway (RCP) 8.5 scenario (Kim et al. 2017a).

While the alpine belt is expected to significantly contract, the subtropical zone is expected to considerably expand upward and northward. The dry-winter humid subtropical climate zone (Köppen climate zone of Cwa) is predicted to cover about 75% of Korea, while the humid subtropical climate zone (Köppen climate zone of Cfa) will cover around 25%. These findings suggest that climatic patterns that differ by region can be progressively simplified, even if they were acquired under the fairly extreme RCP 8.5 scenario (Kim et al. 2017a).

A climate change vulnerability assessment was carried out for 21 national parks across the country using the RCP 8.5 scenario and the basic statistical data from national parks; vulnerability types were assessed and categorized according to climate exposure, sensitivity, and adaptability (Kim and Kim 2016). The results imply that as regional climate environments of national parks differ in terms of climate exposure, sensitivity, and adaptation capability, it is preferable to develop adaption strategies that take into account the climate characteristics of each area.

Forecasts for change until the late twenty-first century (2071–2100) in the Mt. Hallasan alpine area, where anthropogenic effects cause climate change to appear vertically, were examined by combining 10-year (2003–2012) meteorological observation data with future climate change scenario data derived from high-resolution regional climate models (Choi 2017). According to the results, the subtropical climatic zones will reach mid-altitudes by the end of the twenty-first century as a result of less cold stress during the winter. However, there is a chance that the range of subtropical climatic zones will increase as a result of more high-temperature stress during the summer in mountainous areas.

This finding is significant because it suggests the prospect of continuous climate zone movement by examination of high-resolution modeling data, which complements the restricted data from automatic weather observation networks. Furthermore, it suggests that further research on climatic elements other than temperature and changes in climatic occurrences is necessary, as well as that greater efforts would be needed in the late 21st century to maintain the species richness of subalpine ecosystems.

Rivers and wetlands

Urban rivers are more susceptible to both internal and external causes because of their poor environmental conditions brought on by industrialization and overcrowding (Lee et al. 2017). Water quality and diatom communities in urban rivers, as well as the structure and function of aquatic ecosystems, are adversely affected by environmental disturbance brought on by local climate change-related drought and excessive rain, according to research.

Using multitemporal aerial photos and climate data from 1975 to 2012, the land cover change in mountainous wetland areas was verified. The findings indicated that anthropogenic factors, like the construction of golf courses, and a sharp rise in mean annual temperature since 1980 had changed the distribution of flora and decreased the area of wetland (Jang and Kim 2013). Specifically, it was determined that the drying of the soil moisture in the research region due to the rise in the average springtime temperature had an impact on the wetland's incubation.

Coastal region

Sea level rise brought on by climate change would have a direct impact on the coastal region, which is a delicate environment (Lee et al. 2006; Yu et al. 2016; Moon et al. 2017). Based on climate change scenarios, the effects of climate change on coastal and island areas can be categorized as follows (Choi and Park 2018): (1) lowland flooding brought on by sea level rise, wetland loss, seawater inflow, and collapse of occupants' living quarters; (2) physiological characteristics of organisms and behavior, ocean acidification, and coral reef destruction that impact population dynamics; and (3) reduction of available water resources due to increased salt concentrations, such as saltwater penetrating groundwater.

Due to high salt concentrations, the salt marsh, which combines terrestrial and marine ecological traits, has a special ecosystem with environmental significance and a restricted plant distribution (Kim and Myeong 2014). Basic monitoring data on the features of halophyte habitats and changes in environmental elements were obtained, and changes in climatic and soil environments were traced in Suncheon Bay's halophyte habitats. Temperature, precipitation, relative humidity, and sunshine duration were compared between data from the previous 40 years (1973–2013) and the last 4 years (2010–2013). The results indicated that, although temperature increased significantly and precipitation and relative humidity decreased significantly, there was no discernible change in sunshine duration.

The pH, soil moisture content, salinity, and electrical conductivity of the climate-influenced soil environment all markedly rose, whereas the amount of organic matter dramatically reduced.According to a simulation based on the sea level rise scenario developed by the Intergovernmental Panel on Climate Change (IPCC), salt marshes will be 20–45% smaller in 2100 than they are now. It is anticipated that these ecological changes will negatively impact ecosystem services as well as biodiversity; for this reason, suitable responses and management strategies are crucial.

ECOSYSTEM

Phenology

The impact of climate change on plant phenology and the growing season has been the subject of numerous studies (Hur et al. 2014; Hur and Ahn 2015; Ahn et al. 2016; Choi et al. 2016; Lee et al. 2018). The majority of plant phenology investigations have been carried out at the monitoring level at national research institutes' long-term ecological study sites. A few studies looked at the relationships between temperature and plant phenology, including the relationships between temperature and variations in the timing of budburst and blooming. In one study, satellite imagery was used to predict the timing of the budburst over a whole Korean forest; the timing was strongly correlated with the mean temperature of April and the average temperature of the budburst date (3 °C, 12 days) (Choi et al. 2016).

Five subalpine plant species—Lilium cernuum, Primula modesta var. hannasanensis, Trientalis europaea subsp. arctica, Ligusticum tachiroei, and Disporuum ovale—were studied for five years, from 2012 to 2016, on Mt. Gayasan. The flowering times of these five plant species showed a strong correlation with one another. Data gathered from 19 meteorological stations in Korea between 1970 and 2013 was used to study the growing season shift on a national level (Jung et al. 2015). According to these analyses, budburst time advance (an average of 2.7 days/10 years) resulted in an average 4.2 days/10 year increase in growing season length, whereas leafing out was delayed by an average of 1.4 days/10 years (Jung et al. 2015).

However, a local-scale study carried out in Suwon City, an urban area, found that the advanced timing of budburst (~ 4.1 days/10 years) and the delayed timing of leafing out (~ 2.7 days/10 years) resulted in an increase in the growing season of roughly 6.8 days/10 years (Jung et al. 2014). The growing season of spruce increased as a result of climate change between 1972 and 2006, which advanced the start date of spruce growth and delayed the end date, according to another local scale study on a spruce community in a mountainous area, Mt. Gyebangsan. However, there was no statistically significant correlation between the growing season and spruce growth (Jang et al. 2015).

By examining changes in plant growth under elevated CO2 and temperature in combination with other environmental parameters like soil moisture and nutrients, the consequences of climate change on plant growth and physiology have been predicted. In a warming environment, Sarcandraglabra demonstrated a greater tolerance to moisture conditions and soil organic matter content, indicating that these factors do not restrict this species' growth (Lee et al. 2018). Bupleurum latissimum's growth was more responsive to elevated CO2 and temperature than to other environmental factors like light, moisture, and nutrients; a rise in temperature, CO2, and nutrients produced the greatest growth increase (Ahn et al. 2016).

Changes in diversity and distribution range

Plants

In order to predict the consequences of climate change on species compositions and range dynamics, species range shifts have been examined in accordance with elevational gradients. Plant range shifts brought on by climate change were primarily predicted at the regional level, such as the Korean peninsula, but infrequently at the local level, such as mountain regions. According to Shin et al. (2018), Koo et al. (2015), Koo et al. (2016), Park et al. 2016b, Koo et al. 2017b, Koo et al. 2017c, Koo et al. 2018; Park et al. 2019), such predictions have been produced for species that are vulnerable to climate change.According to climate change data, long-term area changes of coniferous forests in subalpine regions across the country were examined using time-series satellite image analysis spanning 20 years since the mid-1990s (Kim et al. 2019a).

While rare and endemic plants decline with height, the percentage of cold-adapted plants, such as alpine and subalpine plants, found in high-elevation regions of Mt. Jirisan and Mt. Gayasan rises (Kim et al. 2018a; Kim et al. 2017b). At Mt. Taebaeksan, the species diversity of vascular plants often declines with elevation (An et al. 2019). According to An et al. (2019), when human disturbances are taken into account, the percentage of plants that grow in forests rises with elevation while the number of plants growing in disturbed areas falls. According to predictions, climate change would cause a decline in cold-adapted evergreen broad-leaved trees, which are primarily found in alpine and subalpine regions. These trees may only survive in alpine sections of North Korea or the Democratic People's Republic of Korea (DPRK).

The impact of climate change on population genetic dynamics has not received much attention in research (Kim et al. 2015a). Determining the ability of plants to adapt to climate change requires a fundamental understanding of population genetic diversity and how it changes in response to climatic conditions. Twelve Sasa borealis populations around the country were subjected to amplified fragment length polymorphism analysis in order to gather data (Kim et al. 2015a). As latitude rose, the genetic diversity of S. borealis populations declined, indicating that the species is negatively impacted by climate change. National research institutes have mostly examined how climate change affects gene expression and secondary metabolite production.

Animals

Numerous studies have calculated population changes (increases or declines) in vertebrates and invertebrates that are related to climate change. Numerous animal species have demonstrated shifts in population abundance or range expansion in response to global warming. According to Lee et al. (2016), climate conditions are a primary driver of changes in arthropod diversity. Elevation was also revealed to be a powerful explanatory factor for diversity variations in research conducted in forest regions. Because Korea is a peninsula, the northern species' rate of decline was far greater than the southern species' rate of increase. One theory is that, over time, Korea's overall species variety and abundance would decline due to global warming.

The distribution ranges of butterfly species prior to (1938–1950) and following (1996–2011) the Korean War were compared by Kwon et al. (2014a). The northern boundary line of southern species shifted both northward and southward of the southern border line of northern species, they discovered. Furthermore, over the past 60 years, the distribution range has shifted by 1.6 km annually. The authors came to the conclusion that both warming and forest increase were responsible for the spread of northern species. Numerous northern butterflies can be found in the alpine and subalpine belt of Mt. Hallasan in high-elevation regions, from Yeongsil (1280 m) to Baengnokdam (1950 m) (Kim et al. 2014).

The open grassland area beneath Baengnokdam is the primary habitat for butterflies, as evidenced by the observation of butterfly species and populations at elevations ranging from 1665 to 1700 meters above sea level. Hipparchia autonoe, Aphantopus hyperantus, Oeneis urda, and Plebejus argus are butterflies that live in alpine regions. By comparing the current situation with previous monitoring of these species, it was confirmed that species' distribution is shifting from alpine regions to higher altitude regions, while species from low mountain regions are starting to be observed in alpine regions.

Apart from rising temperatures, habitat is still another crucial factor to take into account. Low-temperature environments are preferred by bird species like Strix uralensis, Dryocopus martius, and Strix aluco, which are primarily found in the Baekdudaegan Mountain ranges' continuous forest zone, which stretches from Mount Soraksan to Mount Juryman on the Korean peninsula. Planning management measures for endangered species residing in this ecosystem should take into account the change in forest area brought on by global warming (Kim et al. 2018b). Pycnonotus sinensis, Sturnus sericeus, Pitta nympha, Hydrophasianus chirurgus, Rostraltula benghalensis, and Terpsiphone atrocaudata are the six bird species whose distribution ranges were compared between 1997–2005 and 2005–2014 by Park et al. (2018).

However, it is unclear exactly how the temperature change and R. huanrenensis population were related. On the other hand, the breeding success and survival rate of this amphibian species were impacted by the decrease in the mean annual maximum temperature; thus, local microclimate change affected this species (Choi et al. 2018b).There are more and more reports of oriental moth species in Korea. For example, three Gelecthid moths, which were previously thought to be found only in southern China and Taiwan, were discovered in Jeju-do (Kim and Park 2017); a huge Uraniid moth, Lyssa zampa, was collected in Seoquipo, Jeu-do (Jeong et al. 2016).

Additionally, the nation was home to two southern epiplemid moths (Sohn et al. 2019). It is unclear, nevertheless, if these species were unintentionally brought to Korea or if global warming was the cause of their arrival. The southern and western Korean islands have also been home to the following subtropical birds: Laysan albatross (Yang et al. 2018), Camominis merulinus querulous (Kim et al. 2018c), and Culicicapa ceylonensis calochrysea (Park and Oh 2018). It is currently unknown, nevertheless, if climate change is to blame for Korea's recent surge in subtropical birds.

The future direction of biota

Phenology

Prunus yedoensis, Pyrus pyrifolia, and Prunus persica have all had their flowering times predicted to be impacted by climate change (Hur et al. 2014; Hur and Ahn 2015). Under the RCP 4.5 and RCP 8.5 climate change scenarios, P. yedoensis' flowering date is expected to advance by 6.3 and 11.2 days in 2090, respectively. In contrast, P. pyrifolia and P. persica are forecast to flower by 6.1 and 10.7 days and 7.0 and 12.7 days, respectively. Predictive models and an assessment index based on satellite imagery were created in order to examine how climate change is affecting forest vegetation.

The growing season was expected to start earlier under the RCP 4.5 and 8.5 scenarios, according to the link between the total primary productivity of forests and meteorological parameters. Nonetheless, it was anticipated that overall primary production will decline, particularly in alpine and subalpine areas. These findings imply that an ecosystem's responses to climate change seem to vary geographically; as a result, elements like vegetation and climate zone should be taken into account when assessing the effects of climate change .

Diversity and distribution range

Plants

At the local and regional levels, the geographic range of plants and changes in that range due to climate have been studied. According to studies on climate-suitable habitat conditions or individual plant species (Shin et al. 2018; Koo et al. 2015; Koo et al. 2016; Park et al. 2016b; Koo et al. 2017a; Koo et al. 2017b; Koo et al. 2017c; Koo et al. 2018; Park et al. 2019), as well as adjustments to the species composition and diversity of plant communities based on elevational gradients (Kim et al. 2018a; An et al. 2019), studies have forecast range shifts under climate change. To examine the effects of global warming on alpine plants, plant species deemed susceptible to climate change were chosen from the summits of Mount Baekdusan, Mount Soraksan, Mount Juryman, and Mount Hallasan.

The ranges of warm-adapted plants, or those that live in low-lying areas, were primarily predicted to expand and shift to the north (Park et al. 2016a, 2016b; Koo et al. 2017b; Park et al. 2019), while the ranges of cold-adapted plants, or those found in high mountainous areas like alpine and subalpine belts, were primarily predicted to shrink and shift to northern and high-elevation areas (Koo et al. 2015; Koo et al. 2017a). Nonetheless, species-specific projections and management strategies are required, as evidenced by the degree of change in future ranges (Koo et al. 2016).

According to an assessment of the flora on a few islands off the southern coast of Jeollanam-do (Kim et al. 2016a), species that like cool climates, such as Juniperus chinensis var. sargentii and Primula farinosa subsp. modesta, may see a sharp decline in range under the effects of climate change. Furthermore, about 25% of species were located on a single island, and 69% of species lived on fewer than seven islands, highlighting the southern coastal islands' biogeographical significance. Because of their remote location and distinct environment, most islands may be especially sensitive to the effects of fast climate change.

Warm-adapted broad-leaved plant range changes were species-specific (Park et al. 2016a, 2016b). It was expected that with climate change, the presently widely distributed ranges of Machilus thunbergii, Castanopsis cuspidata, Pittosporum tobira, Raphiolepis indica var. umbellate, Eurya emarginata, and Hedera japonica would continue to grow (Park et al. 2016b; Koo et al. 2017b). However, it was expected that species with narrow current ranges—that is, those distributed exclusively in particular locations, like the coast—including Kadsura japonica, Neolitsea sericea, Ilex integra, and Dendropanax morbifera would lose their habitats (Koo et al. 2017c; Koo et al. 2018). Furthermore, the degree of expansion declined when adaptive capacity—such as dispersal capacity—was taken into account (Park et al. 2017; Park et al. 2019).

Animals

Lee et al. (2016) used the RCP 4.5 and RCP 8.5 scenarios to estimate the changes in arthropod diversity and abundance in Korea between 2056 and 2065. They came to the conclusion that when global temperatures rose, diversity and abundance would decline by 13–36% and 5–13%, respectively. No similar pattern was detected across all arthropods when Lee et al. (2015a, 2016) assessed the alterations at higher taxonomic levels like family or order. The Anisopodidae might significantly decline among dipterans as a result of climate change. They live in humid woodlands and are either detritivores or fungi-feeders.

They will disappear in fifty years, even if they are now in the Gangwon province. There is a substantial correlation between climate and anisopodidae numbers, which rise with precipitation and fall with warming. The number of Dolichopodidae, which are little predatory flies that reside in open spaces and whose abundance is closely related to the lowest temperature, would rise by 17.5–54.3%. While Dolichopodidae are currently common in Gyungnam Province, they will move to southern regions in 50 years. Kwon et al. (2014b), Kwon and Lee (2015), and Kwon et al. (2015) calculated changes in the abundance of ants (Kwon and Lee 2015), spiders (Kwon et al. 2014b), and other organisms.

In order to project future distribution in 501 research sites around Korea, the distribution of aquatic insects, including Ephemeroptera, Odonta, Plecoptera, and Trichoptera, was investigated (Li et al. 2013; Li et al. 2014). According to these estimates, the majority of aquatic insects—aside from Odonata—would be going extinct by the 2060s after steadily declining in number by the 2040s. By the 2080s, 20% of species in high mountain streams will have gone extinct, reducing biodiversity (Li et al. 2013). With a 62.1% decline, Plecoptera would be most negatively impacted, followed by Trichoptera (17.8%) and Ephemeroptera (15.2%). Aquatic insects that prefer colder temperatures will relocate to higher latitudes or elevations when temperatures rise. Since they can only fly up to 60 meters, plecopterans will be the most at risk, while dragonflies will proliferate as temperatures rise.

The species were expected to become more similar in the future, according to an analysis of species composition by elevation (Li et al. 2014). The MaxEnt model was used to forecast the distribution of fish species in the Geum River basin in light of climate change (Bae and Jung 2015). The RCP 8.5 scenario was used to forecast the distribution of fish species in 2050 and 2100, and factors including minimum water temperature, precipitation, and water depth significantly influenced these predictions. Furthermore, areas of the watershed with high species abundance migrated north, and by 2100, some fish species were predicted to vanish from the Geum River watershed, indicating that climate change could significantly disrupt this aquatic environment.

Species of great concern (current and future directions)

Endangered species

At Mount Gayasan, climate change-endangered plants were identified and categorized into three groups: lowland, subalpine, and extensive distribution (Kim et al. 2017b). While subalpine species are anticipated to be more vulnerable to climate change because of their tiny population sizes and restricted distribution range, lowland and widespread species are predicted to be comparatively less impacted by global warming or to increase their vertical distribution.

It is commonly anticipated that endangered species with limited geographic ranges will be particularly vulnerable to climate change. Using the RCP 4.5 and 8.5 scenarios, Kim et al. (2018b) investigated how the distribution of endangered species would change as a result of climate change. They discovered that species like Pteromys volans, Strix uralensis, Dryocopus martius, Strix aluco, Gallicrex cinerea, Ixobrychus eurhythmus, and P. nympha would be at risk in the 2070s. In their estimation of the spread of Ursus thibetanus ussuricus, another endangered species, following climate change, Kim et al. (2016b) discovered that precipitation and forest cover had a greater impact on U. thibetanus distribution than temperature. This species' range of distribution may expand tenfold by 2050 and fifteenfold by 2070.

Koo et al. (2019) forecasted the future distribution range of Sibynophis chinensis, an endemic species, and examined its habitat needs. Due to its endemic status in Jejdu-do, this species is currently protected under endangered species regulations and laws, although other species are found throughout Southeast Asia, including China, Hong Kong, and Vietnam. The main factor influencing S. chinensis's spread was precipitation during the monsoon season; its future range may vary according on the region, maybe growing in the eastern portion of the island and decreasing in the western and high mountain regions.

INVASIVE AND PEST SPECIES

Conyza bonariensis, Amaranthus viridis, and Paspalum distichum var. indutum are invasive plant species whose range alterations due to climate change were anticipated to be managed (Cho and Lee 2015; Lee et al. 2015b, 2016). According to Lee et al. (2016), the potential distribution of A. viridis was expected to grow by 110% under RCP 4.5 and 470% under RCP 8.5 by 2090. It was anticipated that P. distichum var. indutum would move to northern regions and spread farther inland (Cho and Lee 2015). According to Lee et al. 2015b, the potential distribution of C. bonariensis was expected to rise by 338% under RCP 4.5 and 769% under RCP 8.5 in the 2100s.

Given the changes in warmth and wetness brought about by climate change, the distributions of disease vectors, such as mosquitoes and mites, may alter on the Korean peninsula. According to Lee et al. (2017), global warming may cause insect disease vectors to migrate northward. For instance, in the 2050s, when the mean winter temperature in Korea is higher than 10 °C, the Asian tiger mosquito, Stegomyia albopicta, which is a vector of Dengue fever and the Zika virus, may be present. Scrub typhus vectors, Leptotrombidium pallidum and Leptotrombidium scutellare, are presently found throughout Korea, with L. pallidum found in the midlands and L. scutellare found in the southern regions, which include Jeju-do Island.

The invasive wasp species Vespa velutina nigrithorax, often known as the Asian hornet, has expanded its range since 2003. After being discovered for the first time in Busan in 2003, it progressively spread to 103 counties in 2014 and 155 counties in 2015. Climate variables like a shorter monsoon season and warmer summer temperatures contributed to this expansion by increasing the number of honeybee colonies and the rate of overwintering (Park and Jung 2016). The Asian hornet's potential nationwide range in the RCP 8.5 scenario might alter the wasp community by altering species interactions among wasp species (Park and Jung 2016).

Invasive wasps like the Asian hornet (Vespa velutina nigrithorax) have expanded their range since 2003. Busan was the initial location in 2003, and it progressively spread to 103 counties in 2014 and 155 counties in 2015. Reduced monsoon season and warmer summer temperatures, which accelerated overwintering and expanded the number of honeybee colonies, were the causes of this dissemination (Park and Jung 2016). If the Asian hornet spreads throughout the entire nation as predicted by RCP 8.5, it would alter wasp interactions and alter the wasp community (Park and Jung 2016).

Since 2010, trees in orchards and along roadsides have been negatively impacted by the brown-winged cicadas Pochazia shantungensis, another invasive pest species. This Chinese species was initially discovered in midwestern Korea, namely in Gongju and Yesan, Chungchungnam-do (Kim et al. 2015b). Climate parameters, such as summer mean temperature and precipitation, were the primary environmental factors influencing this species' range; other considerations included forest cover and plant species. P. shantungensis's range may be limited to the midwestern region, or around 34% of Korea's total area, based on its existing distribution. Nonetheless, there are over 138 species of its host plants, including grass, deciduous, and coniferous types.

It has been demonstrated that raising the temperature can slow the growth of certain insects that are sensitive to high temperatures. By taking into account high-temperature susceptibility above 40 °C, Kim et al. (2016c) examined the reason behind variations in the seasonal occurrence of two moth species, Plutella xylostella and Spodoptera exigua, both of which are significant cabbage pest species. Because P. xylostella's heatshock protein coding genes, including Hsp70, Hsp74, and Hsp83, were translated into proteins involved in the regulation of temperature stress and the synthesis of glycerol (blood sugar), they discovered that P. xylostella was more sensitive to high temperatures than S. exigua. Pest species populations may be impacted by global warming regardless of whether they have physiological defenses against temperature fluctuations.

CONCLUSION

During the current review, we found that populations have been moving, developing, or reproducing earlier than their previous growth or breeding time, and that plants and animals in Korea are responding to climate change by expanding or shifting their ranges toward the north. The food web will become asymmetrical as a result, further increasing the vulnerability of species and ecosystems. According to Settele et al. (2015), between 20 and 30 percent of plant and animal species, particularly those that are climate sensitive and/or adapted to alpine or subalpine ecosystems, are in danger of going extinct by the end of this century. Ecosystem degradation and biodiversity loss are the results of continuing climate change and human disruptions.

Korea is not an anomaly. At the local, regional, national, and international levels, it is important to implement ongoing monitoring of ecosystem change to track phenology, population fluctuation, and pest outbreaks. Appropriate conservation management and practices at the genetic and population levels should also be adhered to.

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