Int. J. Agriworld, Vol. 7[2] August 2026
©2020 SVPSS, India
Online ISSN: 2582-7537
Journal's URL:http://www.svpss.in/ijaw
DOI: https://doi.org/10.51470/IJAW.2026.07.02.15
Received 11.07.2026 Revised 31.07.2026 Accepted 03.08.2026
REVIEW ARTICLE **OPEN ACCESS**

Impacts of Heat Waves on Flora and Fauna of Terrestrial Habitats with Special Reference to Their Adaptive Mechanisms

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Abstract

Heat waves adversely affect various elements of population and community dynamics, encompassing physiology, behaviour, relationships, and biogeography across a wide array of taxa. Heat waves have recently become a significant concern due to their effects on plant life, ecosystems, and agricultural practices. They may pose severe threats to food stability, agricultural communities, water availability, and ecological diversity. They induce harmful physiological, developmental, and carbon-regulatory consequences in plants, leading to irregular growth, diminished water supply, or potential death. Recurring heat waves can impose persistent constraints on critical growth phases, while increased intensity affects community and ecosystem composition, particularly vegetation height and carbon exchange.

Keywords: *Heat waves, Heat stress, Flora, Fauna, ROS, Stress tolerance, Adaptation etc*.

Introduction

Heat waves are defined as prolonged intervals of elevated temperatures consistently experienced during the day. They are referred to as instances when the temperature is unusually high and lasts longer than a certain amount of time. Temperature thresholds for categorizing heat waves differ by region and may be determined by the highest or minimum air temperature. In recent decades, extreme heatwaves have increased in frequency and intensity, and are anticipated to substantially affect carbon fluxes at regional levels within global terrestrial ecosystems (Qu, *et al.,* 2024). According to existing mitigation accords, global temperatures are anticipated to increase by 2.7°C relative to pre-industrial levels by the year 2100 (Grant *et al.,* 2025). Heatwaves also endanger wetlands, which are vital ecosystems providing crucial services such as carbon storage, water purification, and habitats for many animals (Miracle *et al.,* 2025). Heat wave conditions can significantly harm flora and fauna, as well as disturb ecological interactions. They can cause significant physiological effects on plants and animals, leading to mortality, sudden demographic and community-level changes, and alterations in ecosystems (Smale and Wernberg, 2013; Teskey *et al.,* 2015; Ainsworth *et al.,* 2016). The stress and damage resulting from such events have been examined across various species, and circumstantial evidence suggests that plants exhibit heightened sensitivity with increased exposure to the pertinent conditions. The prolonged consequences of heatwaves can initiate adaptive mechanisms in both flora and fauna to mitigate physiological stress and acclimatize to altered environments, and result in loss of biodiversity. Any form of biodiversity loss or mismanagement leads to a depletion of resources and ecological imbalances (Das *et al.,* 2022).

Several factors generate heat waves. Metropolitan areas and population are expanding quickly, exerting significant pressure on the Earth's natural balance (Jaman *et al.,* 2020). A significant rise in daytime temperatures can induce stress reactions in plants, resulting in physiological damage, reduced photosynthesis, and ultimately mortality. When elevated temperatures occur alongside high humidity, the impact of heat stress is intensified due to diminished heat loss through evapotranspiration (Lin, *et al.,* 2000; Marai, *et al.,* 2007). Heat stress modifies processes at multiple levels, encompassing the entire body, cellular excitation, and the stretching of molecular bonds in biological macromolecules (Davies *et al.,* 2018; Kan *et al.,* 2023). As most animals in the ecosystem are directly or indirectly dependent on plants, they are also impacted by heat stress. Plant communities serve essential functions within ecosystems, and their diversity is often utilized to evaluate the biological health of a habitat (Dey and Sarkar, 2021). The increase in the frequency, intensity, and duration of heatwaves exacerbates effects on both human and ecological systems. The physiological equilibrium of organisms is essential for assessing functional stability and adaptability during heatwave events, thereby establishing a foundation for comprehending the risks heatwaves pose to biodiversity.

Heat waves, Global Climate Change and Threats to Biodiversity

Heatwaves are becoming seen as a significant climatic occurrence and a source of apprehension, linked to climate change and ecological deterioration. Global warming caused by greenhouse gases in the atmosphere increases the extraction of energy and moisture from the ocean, which is a major cause of extreme weather events and changes in terrestrial ecosystems. As a result of absorbed radiation, surface moisture, and atmospheric pooling layers, enhanced heating is highly dependent on local conditions. In the last twenty years, Marine Heatwaves have also instigated biological, ecological, and socioeconomic transformations over nearly all oceans and seas (Wernberg, 2025). The occurrence of these severe climatic phenomena has raised significant concerns about the survival of flora and the wider implications for biodiversity and ecosystem equilibrium (Evans, *et al.,* 2025). Biodiversity is an abbreviation for biological diversity, referring to the comprehensive range, variety, and variability of living organisms, along with the diversity of their ecosystems (Sarkar and Mazumder, 2016). From antiquity, human endeavours have posed a risk to the equilibrium of the Earth's ecosystem. Throughout evolution, humanity has altered the geographical landscape and surroundings via agriculture, domestication, travel, urbanization, and commerce (Sarkar and Sadhukhan, 2022). As worldwide temperatures escalate, the incidence and intensity of heatwaves are anticipated to intensify (Trancoso, *et al.,* 2020), possibly leading to ecological disintegration in susceptible systems (Urban, 2015).

Another significant indirect consequence of heatwaves is the increased accumulation of ground-level ozone. Ozone is an atmospheric contaminant that can inflict significant harm on vegetation, manifesting visible symptoms on foliage and tissues by disrupting cellular metabolic processes (Leisner and Ainsworth, 2012). This tendency severely endangers infrastructure, as well as the health of animals and humans, agriculture, and ecosystems (Meher, *et al.,* 2025).

Terrestrial organisms experience severe stress when the operative, microclimate, or habitat-determined environmental temperature exceeds the organism's fundamental operating or thermal range. Diverse taxa in distinct biomes encounter heat waves in distinctive ways. Operative heat load does not solely determine thermal performance, and germination, vegetative growth, reproductive success, and fitness can be decoupled from it at elevated temperatures, especially if they remain within other fundamental niche axes. Changes in such performance measures are readily observable and provide a strong basis for distinguishing stress, acclimation, and adaptation. Under extreme, sustained heat-load conditions, species may be pushed beyond their fundamental ecological, range- the point at which performance drops below the minimal viable level, leading to extinction (Miler, *et al.,* 2020). Heat stress events can push organisms and populations beyond their fundamental range by affecting physiological functions, ecological processes, and interactions among species. Heat waves profoundly influence several ecosystems and species globally; however, their visible effects differ significantly across biogeographical areas.

Impacts of Heat Waves on Flora

Although plants perform essential biogeochemical roles, they are progressively exposed to several abiotic stresses. Heatwaves influence vegetation by altering water accessibility. Consequently, water stress adversely impacts vegetative development and reproductive processes (Gehring, 2006). The scarcity of water due to elevated heat waves diminishes the nutritional quality of the foliage. Heat stress in plants affects growth and crop yield by impacting diverse physiological and metabolic processes, culminating in reproductive failure (French, *et al.,* 2019). Vegetation experiencing thermal stress is prone to producing less fruit, reduced moisture content in both fruit and foliage, or markedly smaller fruit than typical. Temperature exerts a crucial impact on biological systems, ranging from cellular structures to entire ecosystems (Portner, 2012). Heat waves elicit many sublethal effects on plants, affecting physiological processes, development, and reproduction, including distinct trait categories and habitats (Niu, *et al.,* 2014; Felton and Smith, 2017). Heat wave events profoundly disrupt plants and ecosystems globally through multiple pathways and mechanisms. Intense heat affects plant functionality through many physiologically detrimental mechanisms, such as membrane destabilization, protein denaturation, increased levels of reactive oxygen species (ROS), the production of heat shock proteins (HSP), and the activation of antioxidant defenses. It may also exert secondary or indirect impacts on ecosystems (Matusick, *et al.,* 2018; Nowicki, *et al.,* 2019). At the cellular scale, elevated temperatures enhance membrane fluidity, cause protein denaturation, and disrupt enzymatic function. Surplus excitation energy and compromised electron transport facilitate the buildup of reactive oxygen species, such as superoxide and hydrogen peroxide. At regulated levels, these molecules serve in signaling, yet their excessive buildup leads to the oxidation of lipids, proteins, and nucleic acids. Heat-sensitive tissues thereafter exhibit electrolyte leakage, chlorosis, necrosis, and hastened senescence.

The impacts of heat waves on vegetation have been predominantly examined with respect to sublethal consequences at the tissue and leaf levels, along with some insights into seedling mortality (Teskey, *et al.,* 2015). Recent research has revealed the effects of heat waves categorized into four levels: sublethal impacts, lethal consequences at the plant level, secondary ecosystem repercussions, and intricate compound events, including heightened frequency of heat waves and their occurrence at unconventional times of the year, alongside interactions with other disturbances (Breshears, *et al.,* 2021). At the level of plants, elevated temperatures influence growth (Niu, *et al.,* 2014), redirect biomass distribution towards the synthesis of secondary metabolites (Werner, *et al.,* 2020), and enhance respiration rates (Crous *et al.,* 2022). Moderate warming can enhance growth by speeding up metabolism, but heatwaves frequently surpass crucial limits, resulting in irreparable tissue harm (Bernacchi *et al.,* 2023). Heat waves exacerbate plant-water dynamics by causing immediate increases in leaf water potential and vapour pressure deficit, which lead to heightened transpiration and stomatal closure, disrupt the soil-plant-atmosphere continuum, initiate hysteretic moisture-loss cycles, and create water-stressed conditions that amplify drought co-stress effects. Increased temperatures diminish stomatal conductance, constraining transpiration and decreasing evaporative cooling, which further elevates leaf and interior gas-phase temperatures (Wang, *et al.,* 2026). Transpiration aids the transfer of water within the soil–plant–atmosphere continuum and has been shown to relate to timber growth over extensive spatial and temporal scales (Silva, *et al.,* 2022). Heat waves elevate the evaporative requirements from foliage and soil. When root water absorption fails to keep pace with transpiration, leaf water potential diminishes, tissues lose turgor, and xylem tension escalates (Bhatla and Kathpalia, 2023). Extended or severe stress may lead to embolism, hindering water movement from roots to foliage. Recurring thermal events may exhaust the stored carbohydrates essential for xylem restoration and root upkeep, resulting in delayed mortality several months following the observable occurrence (Vijayakumar and Beena, 2023; Xalxo, *et al.,* 2024). The combination of heat and drought is hence more detrimental than each stressor individually. Arid soil restricts transpiration and evaporative cooling, and elevated temperatures increase atmospheric moisture requirements. In grasslands, combined drought and heat occurrences have modified the time and duration of the growing season, impacting fodder accessibility and ecosystem efficiency (Tian, *et al.,* 2024). The interaction can preferentially benefit deep-rooted shrubs at the expense of shallow-rooted herbs and grasses, leading to a progressive alteration in community composition. Significantly, elevated temperatures induce recurrent surges in vapour pressure deficit and augmented transpiration rates, without substantial enhancements in soil moisture after ostensibly advantageous precipitation occurrences.

Photosynthesis is one of the initial plant functions influenced by extreme temperatures. Elevated temperatures compromise photosystem II, modify chloroplast membranes, diminish Rubisco activation, and elevate photorespiration. Simultaneously, respiration typically quickens, utilizing a greater share of newly sequestered carbon. This combination diminishes net carbon accumulation before any observable damage manifests. In ecological fields, the outcome may be diminished growth, leaf surface area, storage reserves, and reproductive commitment. In C_3 plants, the increase in respiration rate surpasses the rise in photosynthesis rate, and carbohydrates transported into vacuoles are transformed into osmotic and structural substances (Davies, *et al.,* 2018). Elevated nighttime temperatures may exacerbate recovery by sustaining increased respiration and constraining the duration for repair, glucose replenishment, and restoration of cellular equilibrium (Carter and Fleming, 2025). By controlling their heat exchange with the surrounding air through convection or latent heat loss, plants can withstand low to moderate heat waves and other heat drought episodes longer (Parkhurst and Loucks, 1972). The most significant impact of extreme heat waves on wild flora and vegetation is anticipated in habitats where species and ecosystems lack adaptation to such extremes (Abeli, *et al.,* 2014). During heat waves, thermosensing is the initial process through which plants react to rising temperatures by converting external thermal signals into internal physiological responses or by directly detecting intracellular heat fluctuations and modifying their RNA and protein concentrations (Kan and Lin, 2021). Numerous molecular pathways have been identified to elucidate how plants detect increased temperatures, encompassing phase separation, isomerisation, subcellular translocation, RNA structural alterations, and chromatin remodeling (Kumar and Wigge, 2010; Jung, *et al.,* 2016; Chung et al., 2020). Disturbances in protein equilibrium (*i.e.,* excessive accumulation of cytotoxic proteins and aberrant protein synthesis) may result in cellular injury and potentially cell death (Kan, *et al.,* 2023).

The exposure of plants to extreme temperatures during the initiation of the reproductive phase significantly affects fruit or grain yield in all species (Resentini, *et al.,* 2023). The pollination phase is particularly vulnerable to elevated temperatures. The influence of temperature is amplified under elevated vapour pressure deficits, as pollen viability relies on pollen moisture content, which is significantly affected by vapour pressure deficit (Fonseca and Westgate, 2005). Besides the evident hazards linked to heat waves, like heat-induced illnesses, drought, and wildfires, there is increasing evidence that these extreme weather phenomena may also facilitate the dissemination of dangerous microorganisms (Mora, *et al.,* 2022).

Impact of Heat Waves in Animals

Organisms exhibit particular temperature tolerance thresholds that affect numerous physiological functions based on temperature. In general, acclimatisation to extended heat waves could result in decreased productivity (Sejian, *et al.,* 2010). It also induces alterations in both phenotypic and genotypic characteristics in animals (Rashamol, *et al.,* 2018). When the temperatures generated by heatwaves surpass the limits of heat tolerance, such circumstances may prove fatal, possibly resulting in the demise of animals within a few periods, from mere minutes to many hours (Wang, *et al.,* 2024). The temperature gradient required for passive heat loss either narrows or reverses during heat waves. Ectotherms are known for their ability to closely monitor environmental temperatures and can be pushed beyond critical thermal limits. Endotherms, on the other hand, can maintain body temperature while incurring increasingly high water and energetic costs. When evaporative cooling cannot counteract heat gain, body temperature increases, cellular function declines, and mortality may result. Risk is influenced by a variety of factors, including body size, colour, insulation, posture, activity, and access to water. Small animals can quickly exchange heat and may exploit small refuges; however, they also experience rapid dehydration. Although large mammals have thermal inertia, they may be unable to dissipate accumulated heat, particularly during warm nights. Arboreal species may be subject to significant exposure when canopy temperature increases and the availability of water-rich nutrients decreases. Nestlings, eggs, larvae, pupae, old individuals, and diseased animals are frequently more susceptible than sound adults.

In the immediate term, animals mitigate heatwaves by employing cooling strategies, including panting and finding refuge in cooler, shady locations. In the intermediate term, thermal stress can induce metabolic alterations that modify physiological responses, including diminished hunger to regulate body temperature and compromised fur/coat quality (Bernabucci, *et al.,* 2010). Prolonged exposure to heat stress commonly leads to heat stroke. Heatwaves can interfere with the metabolic processes of animals, impeding their capacity to distribute resources and energy for growth, reproduction, and survival in extreme conditions, which may ultimately result in diminished fitness and other prolonged adverse consequences (Wang, *et al.,* 2024). Disturbances in metabolic balance during heat stress reduce energy available for immune processes, leading to impaired immune system performance (Rollins-Smith, *et al.,* 2023). For ectothermic organisms, thermal conditions can significantly affect their biological functions, such as behaviour, metabolic rates, growth, and reproduction, as their body temperatures are largely reliant on the surrounding temperature (Angiletta, 2009; Adamo and Lovett, 2011; Goessling, *et al.,* 2019). Acute temperature stress can provoke the generation of ROS, subsequently leading to oxidative harm in ectothermic organisms (Zhang, *et al.,* 2019). Antioxidant enzyme systems, including superoxide dismutase (SOD), glutathione peroxidase (GSH-Px), and catalase (CAT), are activated to eliminate ROS and sustain oxidative equilibrium (Zhang, *et al.,* 2019; Baker, *et al.,* 2020). Unregulated elevations of ROS levels result in free radical-driven chain reactions that indiscriminately affect proteins, lipids, polysaccharides, and deoxyribonucleic acid (Belhadj Slimen, *et al.,* 2016). Heat stress significantly influences biological molecules, disrupts cellular functions, modulates metabolic processes, induces oxidative cellular damage, and activates both apoptosis and necrosis pathways (Pandey, *et al.,* 2012). When the equilibrium concentration of ROS is disrupted, mitochondria are the initial cellular organelles to sustain damage. Indeed, it has been demonstrated that the disruption of the stable state of ROS generation leads to the inactivation of the respiratory chain by the oxidation of complexes I, II, IV, and V (Belhadj Slimen, *et al.,* 2016). Song, *et al.,* (2000) documented modifications in mitochondrial architecture due to thermal stress: the mitochondria exhibit swelling, their cristae are disrupted, and they possess diminished matrix density.

Reproductive capability may diminish at temperatures lower than those that induce adult mortality. Elevated temperatures can hinder spermatogenesis, diminish sperm efficacy, modify ovarian activity, and disturb hormonal communication (Pilakouta, *et al.,* 2023). Eggs and embryos frequently possess limited thermal ranges, and temperature-sensitive sex determination in many reptiles introduces another demographic vulnerability. Diminished courtship, parental involvement, and nest supervision exacerbate direct physiological impacts. These sublethal effects can remain undetected until a decrease in recruitment occurs in subsequent seasons. Many researchers have indicated that fertility, especially male fertility, is significantly affected by heat stress (Porcelli, *et al.,* 2017; Sales, *et al.,* 2018; Pilakouta, *et al.,* 2023). Heat waves, although they occur briefly in an animal's lifespan, can significantly diminish reproductive success if they are experienced even once during the pre-reproductive developmental phase (Burggren, *et al.,* 2018). Breedveld, *et al.,* (2023) indicated that a decline in sperm quality or efficacy may have resulted in diminished fertilization success or reduced hatching rates. Throughout the continuum of life, from gestation to senescence, individuals encounter the detrimental impacts of hazardous substances. Throughout gestation, these impacts are mostly linked to thermoregulatory abilities and physiological alterations, resulting in an elevated future risk of chronic ailments for both mothers and their offspring (Chersich, *et al.,* 2020).

Heat tolerance refers to the capacity of animals to sustain the manifestation of their genetic functional potential while reared in elevated temperatures. The physiological foundation of heat tolerance comprises a substantial skin surface area relative to body weight, pigmented skin and eyelids, protected eyes, and a light or white body covering (Belhadj Slimen, *et al.,* 2016). Animals that are resilient to environmental heat must be able to traverse extensive distances, adapt to limited water consumption, endure elevated salt levels (whether in drinking water or forage), and tolerate substandard nutrition (Habeeb, *et al.,* 1997). Organisms with temperature tolerances tailored for severe environments like the intertidal zone or desolate rock pools are predicted to suffer increased mortality as heat waves become more common in the future owing to the cumulative consequences of heat exposure (Siegle, *et al.,* 2018). Animals experiencing heat stress exhibit physiological adaptation, which consists of two elements: 1) Thermal burden resulting from metabolic processes, thermal exchange, radiation, and convective interactions with the surroundings; 2) Thermal dissipation characterized by the release of heat through the evaporation of sweat (Indu and Pareek, 2015). The predominant cellular mechanisms through which organisms modulate their sensitivity to extreme temperatures encompass alterations in protein levels and types, modifications in membrane characteristics, and changes in the small molecules constituting the cytoplasm (Stillman, 2019). The expression of heat shock proteins has been observed to be upregulated in numerous ectotherms, such as turtles, following acute or gradual heat exposure. This protects organisms from the physiological damage caused by high temperatures (Tedeschi, *et al.,* 2015; Dang, *et al.,* 2018; Harada and Burton, 2019).

Conduct frequently serves as the initial barrier. Fauna seeks shelter, inhabit burrows, alter stance, increase panting or gular flutter, reduce locomotion, and adjust activity to twilight or nocturnal hours. These reactions diminish heat absorption but incur opportunity costs: there is less time for foraging, defending territory, attracting mates, and nurturing progeny. Nutritional consumption may diminish specifically when upkeep expenses are heightened. Severe heat can hinder cognitive functions, decision-making abilities, and predator evasion. Cognitive impacts may occur due to brain temperature sensitivity, dehydration, oxidative stress, or energy reallocation. Even in scenarios with restricted mortality, modified behaviours can influence interaction frequencies between predators and prey, aggregate animals near water sources, and elevate disease spread or conflicts between humans and wildlife.

Thermal exposure presents significant dangers to human well-being, increasing the likelihood of illness and death by causing widespread physiological impairment (Romanello, *et al.,* 2023; Bell, *et al.,* 2024). Exposure to heat is a major factor in excess mortality in humans, since global and regional studies reliably connect high temperatures to increased risks of deaths from all causes and specific causes. Epidemiological data indicate that heat exposure is associated with various multisystem health consequences beyond mortality (Grant, *et al.,* 2025).

Future Perspective of Research

Both plants and animals under heat stress mainly rely on physiological response mechanisms to deal with the unfavourable environmental conditions, and the phenotypic markers that arise in this pathway may be helpful indicators of the welfare of flora and fauna in the changing climate. With the realisation that the frequency and severity of heatwaves are anticipated to rise in the future, particularly affecting high latitudes and mountainous regions (Grabherr, *et al.,* 1994; Thuiller, *et al.,* 2005), additional endeavours are necessary to comprehend their effects on vegetation through ongoing field observations and controlled environment simulations (Abeli, *et al.,* 2014). Mountain flora typically possesses adaptations to combat freezing conditions and can mitigate stress in various ways (Sarkar,2015). Thus, excessive heat waves result in phenotypic plasticity in such plants. Empirical studies regarding the impact of heat waves on terrestrial plants and animals are very few, resulting in a considerable knowledge deficit. The current investigation seeks to fill this void by amalgamating existing data and providing concrete instances of heat-wave effects on land-dwelling animals across several biomes. The central theme of the examination is the adaptive strategies utilised by plants and animals to alleviate the impacts of heat waves, along with an evaluation of how these adaptations vary throughout different life stages and environments. The detrimental consequences of heat waves on human beings are extensively recorded, although the repercussions on plant and animal life are still not as thoroughly comprehended. In this context, enhancing awareness and executing preventive strategies are crucial to mitigate the effects of Heat Waves. Collaboration among academics from various fields is essential, alongside robust public policies that tackle both public health and environmental conservation. Advocating for interdisciplinary research and implementing initiatives to address the repercussions of Heat Waves are crucial for safeguarding the health and welfare of communities, particularly in at-risk areas.

Table 1: Major impact of heat waves on different parts of Alants and Animals

Biotic component	Major heat-wave impacts	Key adaptive mechanisms	Important limits or trade-offs	Recent evidence
Leaves and shoots	Reduced photosynthesis; overheating; water loss; ROS injury; senescence	Leaf angle/rolling; cuticle and trichomes; stomatal regulation; HSPs; antioxidants; osmolytes	Cooling requires water; closure protects hydraulics but restricts carbon gain	Liang *et al.,* (2023); Samat *et al.,* (2025)
Roots and whole plants	Root growth inhibition; hydraulic failure; carbon depletion; delayed mortality	Deep rooting; root-to-shoot adjustment; embolism resistance; carbohydrate storage; stress memory	Roots can be more heat-sensitive; repeated events exhaust reserves	Samat *et al.,* (2025); Baum *et al.,* (2026)
Flowers, pollen and seeds	Pollen sterility; failed fertilization; low seed viability; altered dormancy	Phenological escape; reproductive HSPs; selection for stable fertility	Reproductive thresholds may be below lethal thresholds	Samat *et al.,* (2025)
Ectothermic animals	Body temperature tracks microclimate; locomotor failure; dehydration; mortality	Shade and burrow use; activity shifts; thermal acclimation; diapause; movement	Refugia may disappear; movement reduces feeding and reproduction	Briscoe *et al.,* (2023); Burraco *et al.,* (2025)
Birds and mammals	High cooling costs; dehydration; nest failure; reduced abundance; mass mortality	Panting/sweating; peripheral heat loss; nocturnality; migration; selective cooling	Warm nights limit recovery; water dependence; juveniles vulnerable	Kotz *et al.,* (2025); Baum *et al.,* (2026)
Communit	Phenologica	Species	Specialists	Carter

ies and food webs	l mismatch; altered predation, herbivory and pollination; refuge crowding	turnover; behavioral flexibility; landscape connectivity; demographic rescue	and fragmented populations adapt slowly	and Fleming (2025); Heinicke *et al.,* (2026)
Ecosystem processes	Reduced GPP and carbon uptake; fire feedbacks; canopy loss; habitat simplification	Structural diversity; soil moisture retention; refugia; post-event regeneration	Compound drought/fire can exceed recovery capacity	Baum *et al.,* (2026); Heinicke *et al.,* (2026)

Conclusion

Climate change is intensifying the occurrence and intensity of extreme heat events, thus increasing the burden of disease due to heat exposure. Heat waves affect land-based vegetation and wildlife through associated thermal, hydrological, metabolic, and ecological channels. Flora endures declines in photosynthetic activity and growth, disturbances in water transport, oxidative harm, changes in phenological patterns, and failures in reproduction. As immobile entities, plants have employed a wide spectrum of adaptive strategies to cope with and respond to heat stress in their surroundings, including variations in genotype, phenotypic plasticity, and physiological adjustments. Animals face dehydration, elevated body temperature, diminished reproductive and developmental capabilities, behavioural changes, and, during extreme occurrences, death. These direct impacts result in food shortages, phenological discrepancies, changed species interactions, decreased primary productivity, and feedbacks from disturbances. Adaptive mechanisms are active across various levels. Swift reactions mitigate risk; physiological functions maintain water and thermal balance; cellular mechanisms defend and repair tissues; phenological flexibility modifies delicate periods; populations utilise dispersal and genetic variation; and evolution can adjust tolerance through generations. Their success depends on the degree and duration of heat exposure, cooling at night, moisture levels, habitat configuration, and the availability of refugia. Conserving microclimates, aquatic systems, structural diversity, connectivity, and genetic diversity can broaden the parameters for successful natural adaptation, although sustainable biodiversity protection also demands restricting additional climate warming.

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CITATION OF THIS ARTICLE

Biswas, R., Kumar, M., Yadav, R. and Mandal, S. (2026). Impacts of Heat Waves on Flora and Fauna of Terrestrial Habitats with Special Reference to Their Adaptive Mechanisms, *Int. J. Agriworld*, 7 [2]: 15-25.