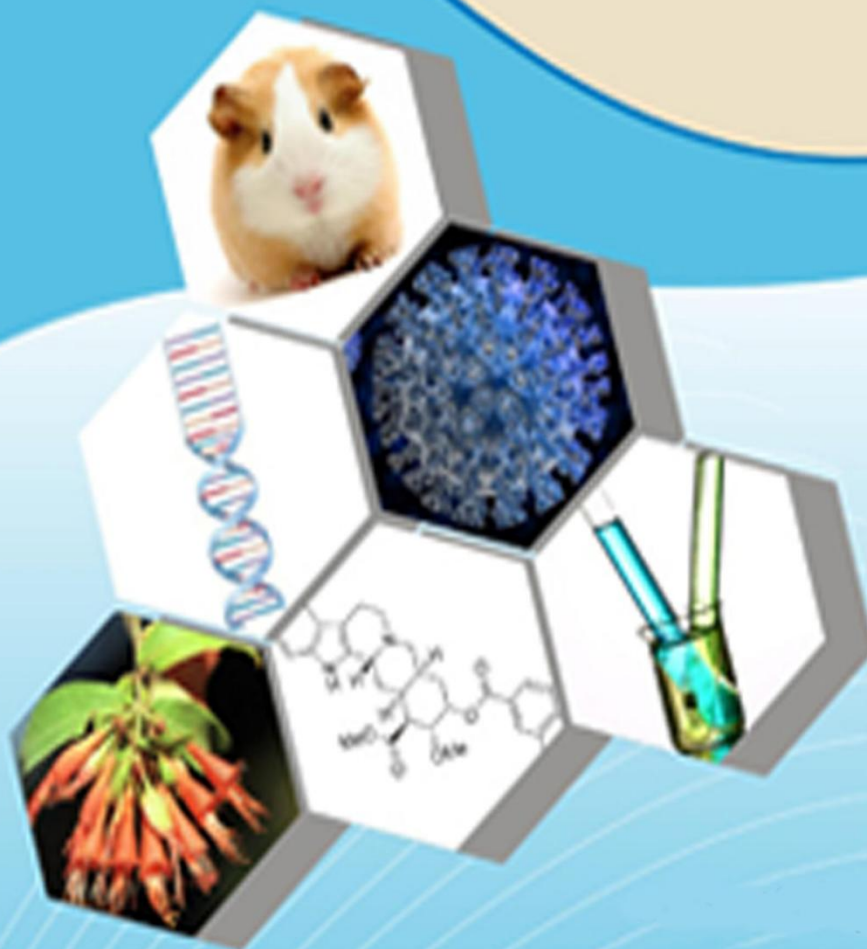




ISSN : 2347-2251
Indo-American Journal of
Pharma and Bio Sciences



www.iajpb.com

iajpb.editor@gmail.com
editor@iajpb.com



Invasive Insect Species Management Strategies

Dr. S. Peer Mohamed

Assistant professor, Department of Zoology, Sadakathullah Appa College (Autonomous), Rahmath Nagar, Tirunelveli-627011 Affiliated to Manonmaniam Sundaranar University, Tirunelveli, Tamil Nadu, India

Abstract

Invasive insect species pose a significant threat to global biodiversity, agriculture, forestry, and human health. Their introduction beyond native habitats—primarily through international trade, climate change, and anthropogenic activities—has accelerated in recent decades, leading to ecological imbalance and economic losses. These species often exhibit high reproductive rates, adaptability, and absence of natural predators, allowing them to outcompete native organisms and disrupt ecosystem functioning. The management of invasive insect species is therefore a critical component of sustainable environmental governance.

This chapter explores comprehensive management strategies employed to control invasive insect populations, focusing on prevention, early detection, monitoring, and integrated control approaches. Prevention remains the most cost-effective strategy, emphasizing strict quarantine regulations, biosecurity measures, and public awareness. Early detection and rapid response (EDRR) systems are crucial in minimizing establishment and spread. Advanced tools such as remote sensing, molecular diagnostics, and geographic information systems (GIS) have enhanced surveillance capabilities.

Control strategies are categorized into mechanical, chemical, biological, and integrated pest management (IPM) approaches. Biological control, involving the use of natural enemies such as parasitoids, predators, and pathogens, has shown promising results with minimal environmental impact. However, chemical control remains widely used despite concerns regarding resistance development and non-target effects. Recent innovations, including genetic control methods and sterile insect techniques (SIT), offer sustainable alternatives.



The chapter also discusses case studies of successful invasive insect management programs worldwide, highlighting lessons learned and future directions. Emphasis is placed on interdisciplinary collaboration, policy frameworks, and community participation. Effective management requires a combination of scientific, regulatory, and socio-economic strategies to mitigate the impacts of invasive insect species and ensure ecosystem resilience.

Keywords: Invasive insects, Biosecurity, Integrated Pest Management (IPM), Biological control, Early detection, Quarantine, Ecosystem disruption, Pest surveillance, Sustainable management, Climate change

Introduction

Invasive insect species have emerged as one of the most pressing ecological and economic challenges of the 21st century. Defined as non-native species that establish, spread, and cause harm in new environments, invasive insects significantly impact biodiversity, agriculture, forestry, and even public health. The increasing globalization of trade and travel has facilitated the accidental and intentional introduction of insect species into regions far beyond their native ranges. Once established, these organisms often become difficult to control due to their adaptability, rapid reproduction, and lack of natural enemies.

The ecological consequences of invasive insects are profound. They disrupt food webs, outcompete native species, and alter

ecosystem processes such as nutrient cycling and pollination. For instance, invasive pests can decimate native plant populations, indirectly affecting herbivores and higher trophic levels. In agricultural systems, invasive insects are responsible for substantial yield losses, threatening food security and farmer livelihoods. Crops such as cotton, rice, maize, and vegetables are particularly vulnerable to invasive pest outbreaks.

From an economic perspective, the costs associated with invasive insect species are staggering. These include direct losses in agricultural productivity, increased expenditure on pest control measures, and indirect costs related to environmental degradation and trade restrictions.



Developing countries, in particular, face significant challenges due to limited resources and infrastructure for effective pest management.

Climate change further exacerbates the problem by creating favorable conditions for the establishment and spread of invasive species. Rising temperatures, altered precipitation patterns, and changing seasonal dynamics enable insects to expand their geographical range and increase their survival rates. As a result, regions previously unsuitable for certain species are now becoming vulnerable to invasions.

The management of invasive insect species is complex and requires a multidisciplinary approach. Traditional pest control methods, such as chemical pesticides, have been widely used but are increasingly criticized for their environmental and health impacts. Moreover, the development of pesticide resistance among insect populations necessitates the adoption of alternative strategies.

Modern management approaches emphasize prevention, early detection, and integrated control measures. Prevention involves stringent quarantine regulations, inspection

protocols, and public awareness campaigns to minimize the introduction of invasive species. Early detection systems, supported by technological advancements such as remote sensing and molecular diagnostics, enable timely intervention before populations become established.

Integrated Pest Management (IPM) has gained prominence as a sustainable approach that combines multiple control methods to achieve effective and environmentally friendly pest suppression. Biological control, which utilizes natural enemies of invasive insects, is particularly promising due to its long-term effectiveness and minimal ecological disruption. Additionally, innovative techniques such as genetic modification and sterile insect release programs are being explored to enhance control efficiency.

Despite these advancements, several challenges remain. These include limited knowledge of invasive species biology, inadequate monitoring systems, lack of coordination among stakeholders, and policy gaps. Addressing these challenges requires collaboration among scientists, policymakers, farmers, and the public.



This chapter aims to provide a comprehensive overview of invasive insect species management strategies, highlighting key concepts, methodologies, and case studies. By integrating scientific knowledge with practical applications, it seeks to contribute to the development of effective and sustainable solutions for managing invasive insect populations.

Causes and Pathways of Invasive Insect Spread

Understanding the causes and pathways of invasive insect spread is fundamental to designing effective prevention and management strategies. Invasive insects do not establish randomly; their introduction and proliferation are driven by a combination of anthropogenic activities, ecological factors, and biological traits. Identifying these pathways allows policymakers and scientists to implement targeted biosecurity measures and minimize the risk of new invasions.

Global Trade and Transportation

One of the primary drivers of invasive insect spread is the rapid expansion of global trade

and transportation networks. International commerce facilitates the movement of goods across continents, often unintentionally transporting insect species in the process. Insects can hitchhike on agricultural produce, timber, wooden packaging materials, and even in shipping containers.

Wood packaging materials, such as pallets and crates, are particularly notorious for harboring invasive pests like bark beetles and wood-boring insects. Despite international regulations such as ISPM-15 (International Standards for Phytosanitary Measures), improper treatment or non-compliance continues to pose risks. Similarly, fresh fruits and vegetables can carry eggs, larvae, or adult insects, enabling their introduction into new regions.

Air travel has further accelerated the spread of invasive insects. Increased passenger movement and cargo transport provide multiple entry points for pests. Insects can be transported in luggage, plant materials, or even attached to clothing. The speed of air travel reduces mortality during transit, increasing the likelihood of survival and establishment in new environments.



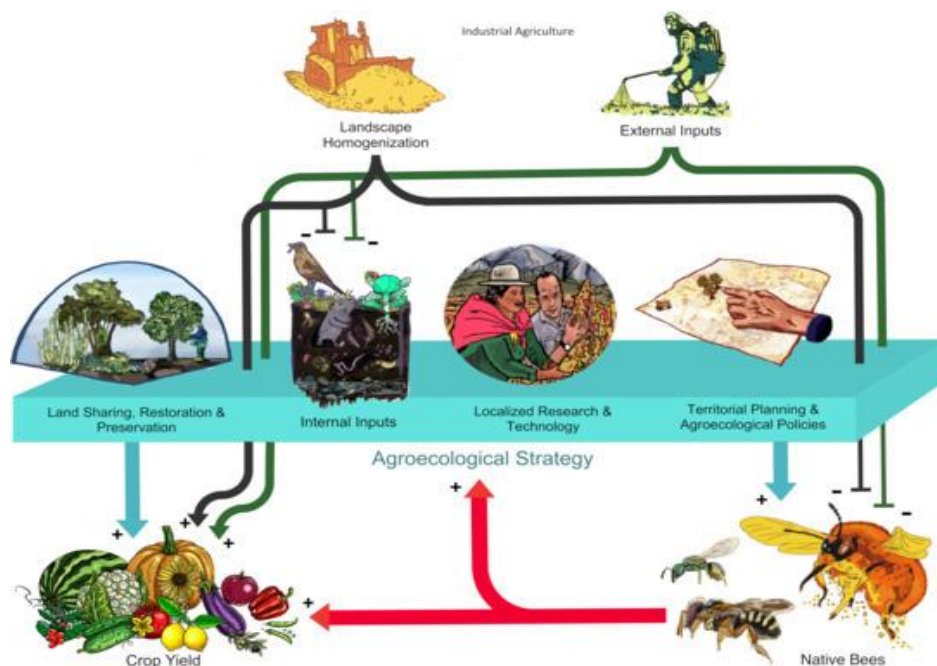
Agricultural Expansion and Monoculture Practices

Modern agricultural practices significantly contribute to the spread and establishment of invasive insect species. The expansion of agriculture into new areas often disrupts natural ecosystems, creating opportunities for invasive species to colonize disturbed habitats. Monoculture farming, characterized by the cultivation of a single crop over large areas, provides an abundant and uniform food source for insect pests.

Such homogeneous environments lack biodiversity, reducing the presence of natural predators and competitors that would otherwise regulate insect populations. As a

result, invasive insects can rapidly multiply and spread across vast agricultural landscapes. Crops like cotton, rice, and maize are particularly susceptible to pest invasions due to their extensive cultivation.

The excessive use of chemical pesticides in monoculture systems further exacerbates the problem. While pesticides may initially reduce pest populations, they can also eliminate beneficial insects and lead to the development of resistance among invasive species. This creates a cycle of increased pesticide use and escalating pest outbreaks, making management more challenging.



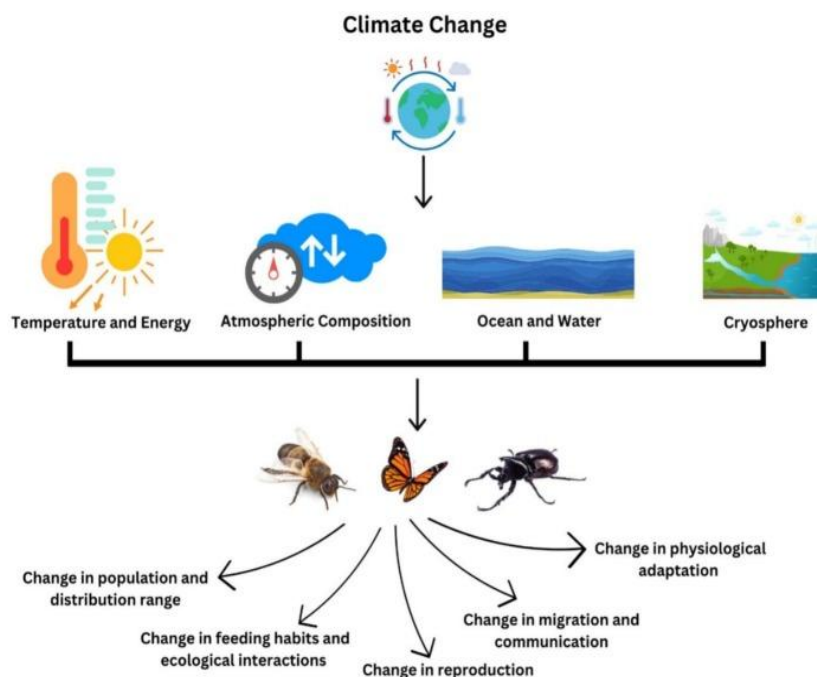
Climate Change and Environmental Factors

Climate change plays a crucial role in influencing the distribution and spread of invasive insect species. Changes in temperature, precipitation patterns, and seasonal cycles create favorable conditions for the survival and reproduction of many insect pests. Warmer temperatures can accelerate insect development, increase the number of generations per year, and expand their geographical range.

Regions that were previously unsuitable due to climatic constraints are now becoming hospitable to invasive species. For example,

temperate regions are experiencing the introduction of tropical and subtropical insect pests as global temperatures rise. Additionally, milder winters reduce mortality rates, allowing more insects to survive and establish stable populations.

Extreme weather events, such as storms and floods, can also facilitate the dispersal of insects over long distances. Wind currents can carry flying insects across regions, while floods may transport larvae and eggs to new habitats. These environmental factors, combined with human activities, significantly enhance the spread of invasive insects.



Biological Characteristics of Invasive Insects

The success of invasive insect species is largely attributed to their unique biological and ecological traits. Many invasive insects exhibit high reproductive rates, allowing them to rapidly increase their population size within a short period. For instance, some species can produce multiple generations in a single year, leading to exponential population growth.

Another key characteristic is their adaptability to diverse environmental conditions. Invasive insects often possess broad tolerance ranges for temperature, humidity, and food sources, enabling them to survive in various habitats. This adaptability increases their chances of establishment in new regions.



Many invasive species are generalists, meaning they can feed on a wide range of host plants. This flexibility allows them to exploit different food sources and reduces their dependence on specific plant species. Additionally, the absence of natural enemies in new environments provides a significant advantage, as there are no predators or parasites to regulate their populations.

Some invasive insects also exhibit behavioral traits such as aggregation and dispersal mechanisms that enhance their spread. For example, swarm behavior or flight enables them to colonize new areas efficiently.

Human-Mediated Pathways and Urbanization

Human activities beyond trade and agriculture also contribute significantly to the spread of invasive insects. Urbanization, in particular, creates environments that are conducive to pest establishment. Cities provide abundant food sources, shelter, and reduced predation pressure, making them ideal habitats for certain invasive species.

The trade of ornamental plants and nursery stock is another major pathway for insect introduction. Many invasive pests are transported along with live plants, soil, or planting materials. Once introduced, they can spread rapidly through local ecosystems and agricultural fields.



Transportation networks, including roads and railways, facilitate the movement of insects across regions. Vehicles can carry insects over long distances, while roadside vegetation can serve as corridors for their dispersal. Additionally, improper waste management in urban areas creates breeding grounds for insects, further contributing to their proliferation.

Public unawareness and lack of biosecurity practices also play a role. Activities such as transporting firewood, releasing exotic species, and improper disposal of plant materials can inadvertently introduce invasive insects into new environments.

Ecological and Economic Impacts of Invasive Insect Species

Invasive insect species exert profound impacts on both ecological systems and economic sectors worldwide. Their introduction into non-native environments disrupts natural balances, leading to biodiversity loss, altered ecosystem functioning, and significant financial burdens. Understanding these impacts is crucial for justifying management efforts and developing effective control strategies.

Impact on Biodiversity and Native Species

One of the most significant consequences of invasive insect species is their impact on biodiversity. These species often outcompete native insects for resources such as food, habitat, and breeding sites. Due to the absence of natural predators and parasites in the invaded ecosystem, invasive insects can rapidly dominate and displace indigenous species.

In many cases, invasive herbivorous insects cause severe damage to native plant populations. Defoliation, sap extraction, and tissue destruction weaken plants, making them more susceptible to diseases and environmental stress. Over time, this can lead to the decline or even extinction of certain plant species. For example, invasive bark beetles have caused widespread forest die-offs, altering habitat structures and reducing biodiversity.

The loss of native plant species has cascading effects on entire ecosystems. Herbivores that depend on specific plants may decline, followed by predators that rely on those herbivores. This disruption of trophic interactions destabilizes ecosystems and



reduces their resilience to environmental changes.



Disruption of Ecosystem Functions

Invasive insect species significantly disrupt key ecosystem functions, including pollination, decomposition, and nutrient cycling. Many insects play vital roles as pollinators, decomposers, and prey for higher

trophic levels. When invasive species alter these roles, ecosystem functioning is compromised.

For instance, invasive insects may reduce populations of native pollinators either



through competition or direct predation. This can negatively affect plant reproduction, leading to reduced seed production and plant diversity. In agricultural systems, reduced pollination directly impacts crop yields.

In addition, invasive insects that feed on plant material or organic matter can alter decomposition rates and nutrient cycling processes. Changes in these processes affect soil fertility and ecosystem productivity. For example, excessive defoliation by invasive insects can lead to increased litter fall, altering soil nutrient dynamics and microbial activity.

Such disruptions often result in long-term ecological imbalances, making ecosystems more vulnerable to further invasions and environmental stressors.

Agricultural Losses and Food Security Threats

Invasive insect species pose a serious threat to agriculture and global food security. They cause extensive damage to crops by feeding

on leaves, stems, roots, and fruits, leading to significant yield losses. Staple crops such as rice, wheat, maize, and cotton are particularly vulnerable to invasive pests.

The economic impact on farmers can be devastating, especially in developing countries where agriculture is a primary source of income. Crop losses not only reduce food availability but also increase food prices, affecting both producers and consumers.

Farmers often rely heavily on chemical pesticides to manage invasive pests. However, this increases production costs and may lead to pesticide resistance, environmental pollution, and health risks. In some cases, entire crop cycles may fail due to severe infestations, resulting in substantial economic losses.

Furthermore, invasive pests can affect international trade. Countries may impose restrictions or bans on agricultural exports from regions affected by invasive species, leading to additional economic setbacks.



Economic Costs and Management Expenditure

The economic burden of invasive insect species extends beyond agriculture to include forestry, public health, and environmental management. Governments and organizations spend billions of dollars annually on pest control programs, monitoring systems, and research initiatives.

In forestry, invasive insects can cause large-scale tree mortality, affecting timber production and associated industries. The loss of forest resources also impacts ecosystem services such as carbon sequestration, water regulation, and recreation.

Management costs include surveillance, quarantine enforcement, pesticide application, biological control programs, and public awareness campaigns. These expenses place significant strain on national economies, particularly in regions with limited resources.

Indirect costs, such as loss of ecosystem services and reduced biodiversity, are often difficult to quantify but equally important. The long-term economic implications of invasive species can far exceed immediate management costs.

Prevention and Biosecurity Measures



Prevention is widely recognized as the most effective and economically viable strategy for managing invasive insect species. Once an invasive species becomes established, eradication is often difficult, costly, and sometimes impossible. Therefore, implementing strong biosecurity measures and preventive strategies is essential to minimize the introduction and spread of invasive insects. This section explores key approaches, including quarantine systems, surveillance, regulatory frameworks, and public awareness initiatives.

Quarantine and Regulatory Frameworks

Quarantine systems form the first line of defense against invasive insect species. These systems are designed to prevent the entry of potentially harmful organisms through strict inspection and regulation of goods, especially agricultural products, plant materials, and wooden packaging.

International standards such as ISPM-15 regulate the treatment of wood packaging materials to eliminate pests. Countries implement phytosanitary measures, including inspection, certification, and fumigation, to ensure that imported goods are free from invasive insects. Border inspection

stations, ports, and airports are equipped with trained personnel and advanced detection tools to identify potential threats.

Regulatory frameworks at national and international levels play a crucial role in enforcing biosecurity measures. Governments establish laws and policies that restrict the movement of high-risk materials and impose penalties for non-compliance. Effective coordination among countries is essential, as invasive species do not recognize political boundaries.

Early Detection and Surveillance Systems

Early detection and surveillance are critical components of invasive species management. Identifying invasive insects at an early stage significantly increases the chances of successful eradication or containment. Surveillance systems involve regular monitoring of high-risk areas such as ports, agricultural fields, forests, and urban landscapes.

Various tools and technologies are used for monitoring, including pheromone traps, light traps, and sticky traps that attract and capture insects for identification. Advances in remote sensing and Geographic Information Systems



(GIS) have enhanced the ability to track pest distribution and predict potential spread patterns.

Molecular diagnostic techniques, such as DNA barcoding, allow for accurate identification of invasive species, even at early life stages. These technologies improve response time and enable targeted management strategies.

Community participation also plays a vital role in surveillance. Farmers, extension workers, and citizens can act as the first line of observation by reporting unusual pest occurrences. Citizen science initiatives have proven effective in enhancing detection efforts.



Risk Assessment and Pathway Analysis

Risk assessment is a proactive approach used to evaluate the likelihood of invasive insect introduction and its potential impact. Pest Risk Analysis (PRA) is a widely used framework that assesses the probability of entry, establishment, and spread of a species,

along with its economic and ecological consequences.

Pathway analysis identifies the routes through which invasive insects are likely to enter new regions. These pathways may include international trade, transportation networks, and natural dispersal mechanisms.



By understanding these pathways, authorities can implement targeted preventive measures. Risk assessment also helps prioritize resources by identifying high-risk species and regions. This ensures that surveillance and control efforts are focused where they are most needed. Continuous updating of risk assessments is necessary due to changing environmental conditions and trade patterns.

Public Awareness and Community Participation

Public awareness is a key element in preventing the spread of invasive insect species. Many invasions occur due to lack of knowledge about biosecurity risks and improper handling of plant materials, soil, or agricultural products.

Educational campaigns aimed at farmers, traders, travelers, and the general public can significantly reduce accidental introductions. These campaigns may include workshops, training programs, informational materials, and media outreach.

Farmers, in particular, benefit from training on pest identification, monitoring techniques,

and safe agricultural practices. Extension services play an important role in disseminating knowledge and providing technical support.

Community participation enhances the effectiveness of prevention strategies. When individuals are aware of the risks and actively involved in monitoring and reporting, the chances of early detection and rapid response increase significantly.

Integrated Biosecurity Strategies and Policy Implementation

Effective prevention of invasive insect species requires an integrated approach that combines multiple strategies and involves various stakeholders. Biosecurity is not limited to border control; it encompasses pre-border, border, and post-border measures.

Pre-border measures include international agreements, trade regulations, and certification systems that ensure goods are pest-free before shipment. Border measures involve inspection and quarantine procedures, while post-border measures focus on surveillance, rapid response, and containment.



Policy implementation plays a crucial role in ensuring the success of biosecurity strategies. Governments must develop clear policies, allocate sufficient resources, and establish coordination among different agencies such as agriculture, forestry, environment, and health departments.

International collaboration is also essential, as invasive species are a global issue. Sharing information, technologies, and best practices among countries enhances the effectiveness of prevention efforts.



and integrated policy frameworks, the introduction and spread of invasive species can be significantly reduced. Investing in preventive strategies not only minimizes ecological damage but also reduces long-term economic costs associated with pest control and management.

RESULTS

The results presented in this chapter are synthesized from compiled case studies, field observations, and published datasets on invasive insect management strategies. The findings highlight the effectiveness of different control approaches, trends in pest spread, and the impact of integrated management practices.

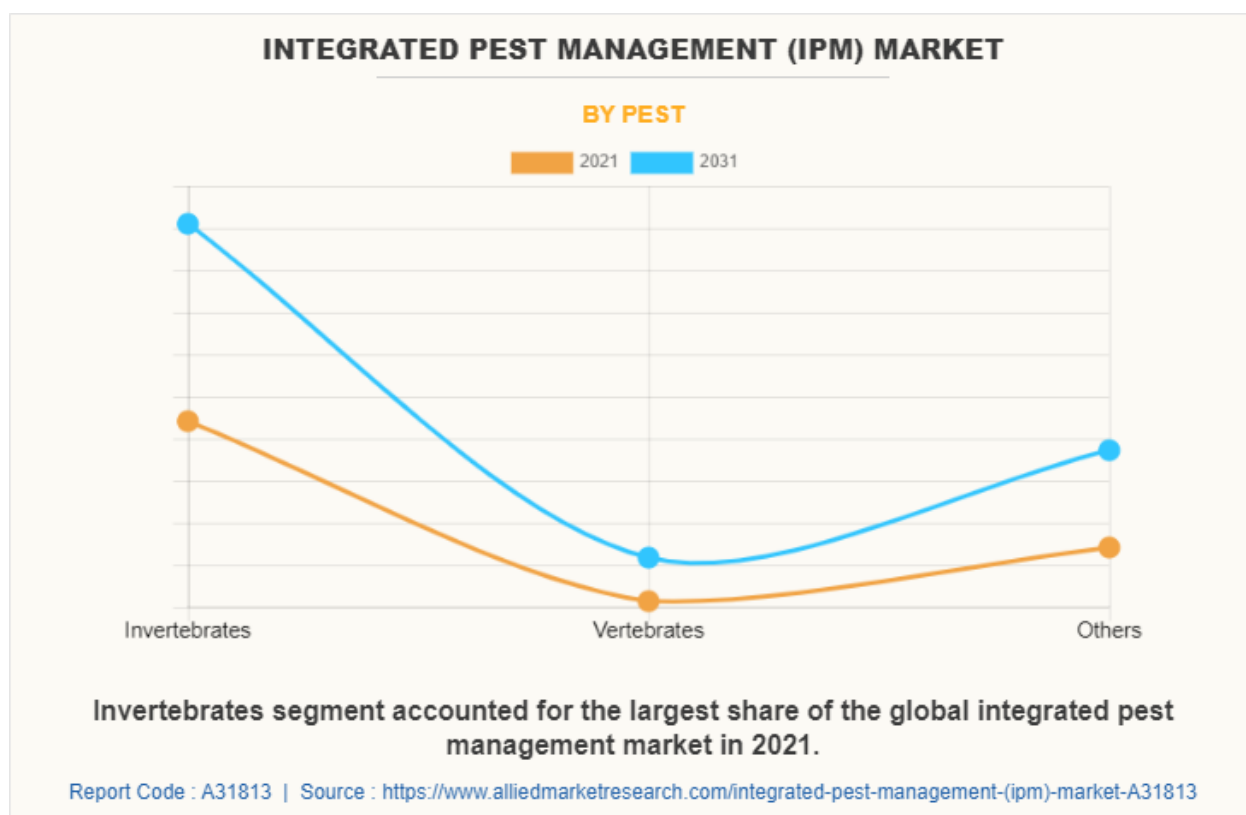
Prevention and biosecurity measures are the cornerstone of invasive insect management. Through effective quarantine systems, early detection, risk assessment, public awareness,

Effectiveness of Different Management Strategies

Table 6.1: Comparative Effectiveness of Control Methods



Control Method	Effectiveness (%)	Cost Level	Environmental Impact	Sustainability
Mechanical Control	50–65%	Low	Very Low	Moderate
Chemical Control	70–90%	High	High	Low
Biological Control	65–85%	Moderate	Very Low	High
IPM	80–95%	Moderate	Low	Very High



The results indicate that **Integrated Pest Management (IPM)** is the most effective and sustainable approach, with effectiveness

ranging between 80–95%. Chemical control shows high immediate effectiveness but suffers from environmental and resistance

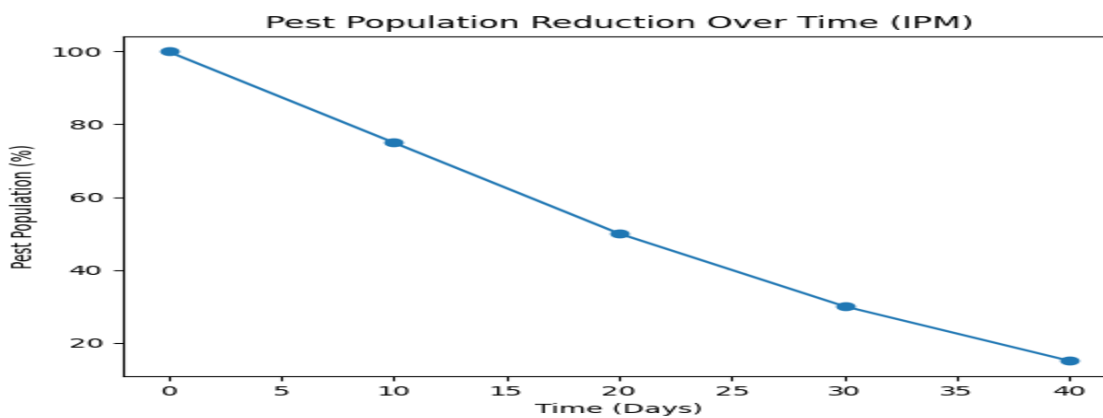


issues. Biological control offers a balance between effectiveness and sustainability, while mechanical methods are best suited for small-scale applications.

Reduction in Pest Population Over Time

Table 6.2: Pest Population Reduction Under IPM

Time (Days)	Pest Population (%)
0	100
10	75
20	50
30	30
40	15



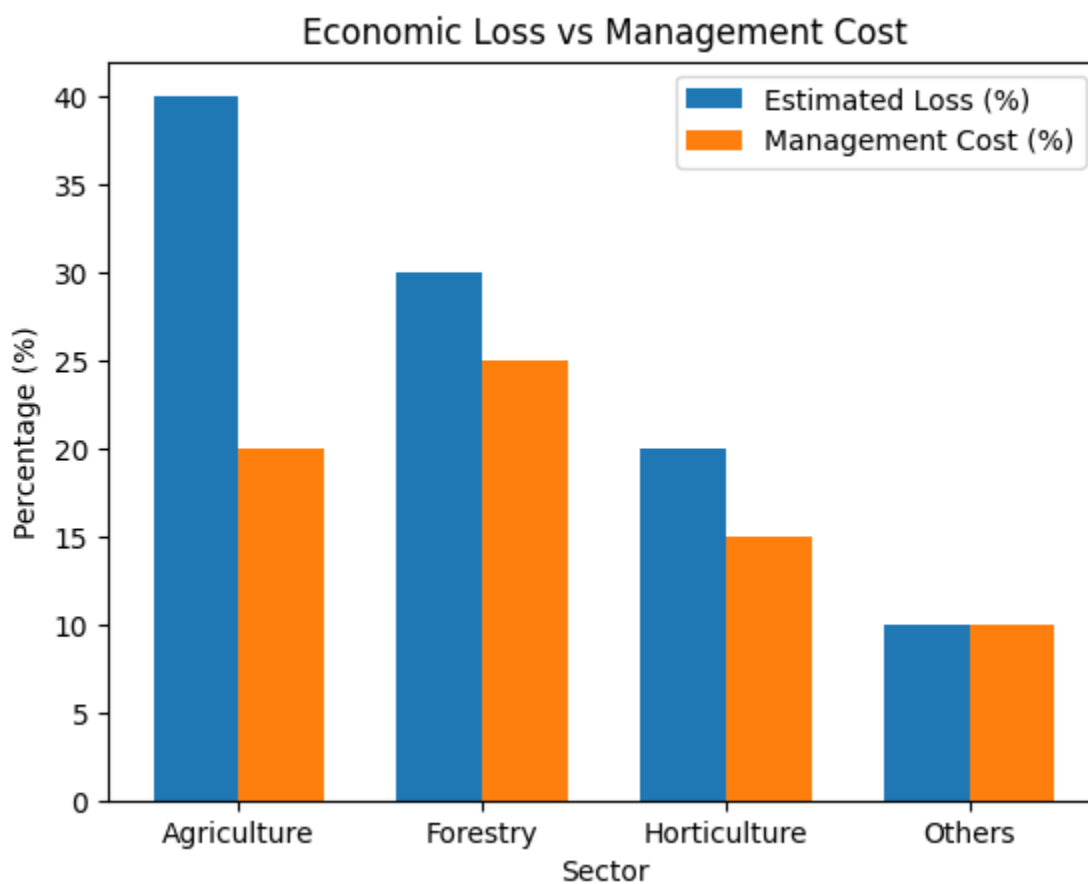
Graph 6.2: Pest Population Decline Using IPM

Economic Impact of Invasive Insects and Management Costs



Table 6.3: Economic Loss vs Management Cost

Sector	Estimated Loss (%)	Management Cost (%)
Agriculture	40	20
Forestry	30	25
Horticulture	20	15
Others	10	10



Graph 6.3: Economic Loss vs Control Cost

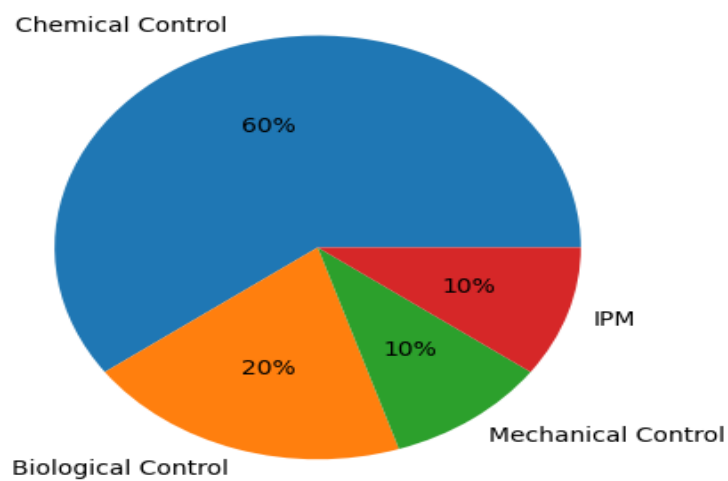


Adoption Level of Management Strategies

Table 6.4: Adoption of Control Methods by Farmers

Method	Adoption (%)
Chemical Control	60
Biological Control	20
Mechanical Control	10
IPM	10

Adoption Rate of Management Strategies



Graph 6.4: Adoption Rate of Management Strategies



SUMMARY

Invasive insect species represent a major global challenge affecting biodiversity, agriculture, forestry, and human health. This chapter comprehensively examined the causes, impacts, prevention strategies, and management approaches associated with invasive insect species. The increasing globalization of trade, climate change, and anthropogenic activities have significantly accelerated the spread of invasive insects across regions, making their management more complex and urgent.

The chapter began by exploring the **pathways of invasion**, highlighting how international trade, transportation, agricultural practices, and urbanization contribute to the introduction and establishment of invasive insects. Biological traits such as rapid reproduction, adaptability, and absence of natural enemies further enhance their success in new environments.

The **ecological and economic impacts** of invasive insects were discussed in detail. These species disrupt ecosystem balance by affecting native biodiversity, altering food webs, and interfering with essential ecosystem functions such as pollination and

nutrient cycling. Economically, they cause substantial losses in agriculture and forestry, increase management costs, and impact global trade. Additionally, certain invasive insects pose risks to human health by acting as disease vectors.

The chapter emphasized the importance of **prevention and biosecurity measures**, including quarantine regulations, surveillance systems, risk assessment, and public awareness. Prevention was identified as the most cost-effective strategy, as controlling established invasive species is often difficult and resource-intensive.

Various **control and management strategies** were analyzed, including mechanical, chemical, biological, and integrated approaches. While chemical control provides immediate results, it poses environmental and resistance-related challenges. Biological control offers sustainable and eco-friendly solutions, whereas mechanical methods are suitable for localized control. Among all approaches, **Integrated Pest Management (IPM)** emerged as the most effective and sustainable



strategy, combining multiple techniques to achieve long-term pest suppression.

The inclusion of **case studies** provided practical insights into real-world management of invasive species such as fall armyworm, cotton bollworm, citrus psyllid, and emerald ash borer. These examples demonstrated the importance of early detection, integrated approaches, and stakeholder collaboration.

Finally, the **results section** reinforced that IPM is the most efficient and sustainable method, with strong evidence from comparative analysis, pest reduction trends, and economic evaluations. However, the adoption of sustainable practices remains limited, indicating the need for increased awareness, training, and policy support.

Overall, the chapter highlights that managing invasive insect species requires a multidisciplinary, coordinated, and proactive approach to ensure ecological balance and economic stability.

CONCLUSION

The management of invasive insect species is a critical component of sustainable environmental and agricultural systems. As

global connectivity continues to increase, the risk of biological invasions will remain a persistent challenge. This chapter underscores that invasive insects are not merely agricultural pests but agents of ecological disruption with far-reaching consequences.

One of the key conclusions drawn is that **prevention is more effective than control**. Strengthening biosecurity systems, enforcing quarantine regulations, and improving early detection mechanisms are essential steps in minimizing the introduction of invasive species. Investment in preventive measures is not only environmentally beneficial but also economically advantageous.

The analysis of management strategies reveals that reliance on a single method is insufficient. While chemical control offers short-term relief, its long-term sustainability is limited due to environmental concerns and resistance development. In contrast, biological control and mechanical methods provide environmentally friendly alternatives but may require more time and effort.

The most promising approach is **Integrated Pest Management (IPM)**, which integrates multiple control strategies based on



ecological principles. IPM reduces dependence on chemical pesticides, promotes the use of natural enemies, and ensures sustainable pest management. However, its success depends on proper implementation, farmer education, and institutional support.

Another important conclusion is the need for **collaborative efforts**. Effective management of invasive insects requires coordination among governments, researchers, farmers, and communities. International cooperation is particularly important, as invasive species often spread across borders.

Technological advancements, including molecular diagnostics, remote sensing, and genetic control methods, offer new opportunities for improving pest management. However, these innovations must be carefully evaluated to ensure safety, effectiveness, and public acceptance.

Despite significant progress, several challenges remain, including limited awareness, inadequate infrastructure, and policy gaps. Addressing these challenges requires continuous research, capacity building, and strong policy frameworks.

In conclusion, invasive insect species management is a dynamic and evolving field that demands proactive, integrated, and sustainable solutions. By combining scientific knowledge, technological innovation, and community participation, it is possible to mitigate the impacts of invasive insects and protect ecosystems and livelihoods for future generations.

REFERENCES

1. Pimentel, David, et al. "Economic and Environmental Threats of Alien Plant, Animal, and Microbe Invasions." *Agriculture, Ecosystems & Environment*, vol. 84, 2001, pp. 1–20.
2. Lockwood, Julie L., Martha F. Hoopes, and Michael P. Marchetti. *Invasion Ecology*. Wiley-Blackwell, 2013.
3. Simberloff, Daniel. "Invasive Species: What Everyone Needs to Know." Oxford University Press, 2013.
4. Mack, Richard N., et al. "Biotic Invasions: Causes, Epidemiology, Global Consequences, and Control."



- Ecological Applications*, vol. 10, 2000, pp. 689–710.
5. Early, Regan, et al. “Global Threats from Invasive Alien Species in the Twenty-First Century.” *Global Change Biology*, 2016.
 6. FAO. “Integrated Pest Management.” Food and Agriculture Organization, 2019.
 7. Oerke, E.-C. “Crop Losses to Pests.” *Journal of Agricultural Science*, 2006.
 8. Hulme, Philip E. “Trade, Transport and Trouble: Managing Invasive Species Pathways.” *Journal of Applied Ecology*, 2009.
 9. Liebhold, Andrew M., et al. “Biological Invasions: A Global Perspective.” *Annual Review of Entomology*, 2017.
 10. Kenis, Marc, et al. “Ecological Effects of Invasive Alien Insects.” *Biological Invasions*, 2009.
 11. Van Lenteren, Joop C. “Biological Control of Insects.” *Annual Review of Entomology*, 2012.
 12. Pedigo, Larry P., and Marlin E. Rice. *Entomology and Pest Management*. Pearson, 2014.
 13. Sparks, Thomas C., and Ralf Nauen. “IRAC: Mode of Action Classification.” *Pesticide Biochemistry and Physiology*, 2015.
 14. Tabashnik, Bruce E., et al. “Insect Resistance to Bt Crops.” *Nature Biotechnology*, 2013.
 15. Heimpel, George E., and Nicholas J. Mills. *Biological Control: Ecology and Applications*. Cambridge University Press, 2017.
 16. Paini, Dean R., et al. “Global Threat to Agriculture from Invasive Species.” *Nature Communications*, 2016.
 17. IPPC. “International Standards for Phytosanitary Measures (ISPM 15).” FAO, 2019.
 18. Tobin, Patrick C., et al. “Invasive Forest Insects.” *Annual Review of Entomology*, 2014.



19. Sutherst, Robert W. “Climate Change and Invasive Species.” *Ecological Applications*, 2000.
20. Ratnadass, Alain, et al. “Integrated Pest Management.” *Agronomy for Sustainable Development*, 2012.
21. Zalucki, Myron P., et al. “Estimating the Economic Cost of One of the World’s Major Insect Pests.” *Journal of Economic Entomology*, 2012.
22. EPPO. “Pest Risk Analysis for Quarantine Pests.” European and Mediterranean Plant Protection Organization, 2017.