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Review

Possible Threats of the Presence of Non-Native Invasive Land Snail Species in Türkiye

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Abstract

Land snails, including some economically important species, are commonly found in forests and mountainous regions of Türkiye. Türkiye's large geomorphological region and four surrounding seas, which offer a variety of malacofauna, help Türkiye achieve an endemism grade of over 65%. Despite extensive research over the past few decades, we still lack a sufficient understanding of the species identification of land snails in Türkiye, particularly in areas like forested mountain regions, and it is assumed that there are more than 1000 taxa in total. This review emphasizes the existence of invasive non-native snail species in Türkiye, such as *Arion ater* (Linnaeus, 1758) and Arion vulgaris Moquin-Tandon, 1855, which have a negative impact on agricultural and horticultural output. In addition to these species, *Theba pisana*, *Cornu aspersum*, *Xeropicta derbentina*, *Xeropicta krynickii, Cernuella virgata* and *Eobania vermiculata* are also found in Türkiye as non-native land snail species. Moreover, it also places a strong emphasis on the necessity of managing invasive species to reduce their detrimental effects on natural ecosystems by giving examples from the world and covers the predictions about the possible threats that the presence of non-native invasive land snail species in Türkiye may pose in the future.

Keywords: *Arion ater*, *Arion vulgaris*, Crop loss, Ecosystems, Environmental problem, Malacofauna

Introduction

Compared to many countries, Türkiye's area is very vast (approximately 1650 km from east to west and about 570 km from south to north) and contains numerous biotopes from extremely damp subtropical to nearly wilderness-like conditions [1]. In addition, Türkiye is surrounded by four seas: the Black Sea, the Mediterranean Sea, the Aegean Sea, and the Sea of Marmara. Thus, Türkiye has a seaboard longer than 8.300 km. These seas differ in terms of parameters such as their biological content, temperature, salinity, and climatic conditions [2]. The fact that Türkiye has such a wide geomorphological area and the overlap of many important biogeographic structures in its region has caused it to have an endemism degree of over 65% [1]. In addition, 44% of the alpine land snail fauna is endemic to Türkiye [3]. It has been reported that 220 species of 74 genus of terrestrial snails detected in Türkiye are endemic to Anatolia [1]. However, land snails, which are endemic to Türkiye, mostly belong to the *Monacha* (Stylommatophora: Hygromiidae) Fitzinger, 1833, *Albinaria* (Stylommatophora: Clausiliidae) Vest, 1867, and *Oxychilus* (Stylommatophora: Oxychilidae) Fitzinger, 1833 genera (20, 13 and 12 species, respectively). For example, *Meijeriella canaliculata* (Stylommatophora: Enidae) Bank, 1985, *Metafruticicola dedegoelensis* (Stylommatophora: Hygromiidae) Hausdorf, Gümüş & Yıldırım, 2004 [4], *Bulgarica denticulata* (Stylommatophora: Clausiliidae) (Olivier, 1801), *Assyriella guttata* (Stylommatophora: Helicidae) (Olivier, 1804) [5] and *Monacha samsunensis* (L. Pfeiffer, 1868) [6] are endemic species of Türkiye. On the other hand, *Helix lucorum* (Stylommatophora: Helicidae) Linnaeus, 1758 is also considered to be a semi-endemic species for the country because it is also found outside the country [7,8].

The first land snails were recorded in Türkiye in 1801. After this record, Türkiye's land snails continued to be researched and a significant number of articles were published, especially in the last fifty years, including approximately one-third of the number of taxa considered valid today [1]. However, it is thought that our knowledge about the species identification of land snails in Türkiye is still insufficient despite many investigations carried out in recent decades. Snail species in some areas, such as most forested mountain areas, are nearly fully unknown. Therefore, although it is assumed that many species have not yet been registered, the total count of species inhabiting Türkiye is estimated to presumably exceed 1000 taxa [1]. On the other hand, although the species belonging to the Achatinidae family are not native species to Türkiye, the term land snail in the Special Hygiene Rules for Animal Foods Regulation of the Ministry of Agriculture and Forestry refers to the terrestrial gastropods of *Helix pomatia* Linnaeus, 1758, *Helix aspersa* Müller, 1774, *Helix lucorum* species and the species belonging to the Achatinidae (Stylommatophora) Swainson, 1840 family [9]. In addition to the presence of plenty of native land snail species of Türkiye, the presence of non-native land snail species has also been reported in the country. For this reason, this paper aims to highlight the record of Non-Native Invasive Land Snail species and possible threats to their existence in Türkiye.

Presence of Non-Native Land Snail Species in Türkiye

Since some synanthropic terrestrial mollusk species hide under various wooden, plastic, and ceramic items, they can spread to new environments because of these items being moved to another place [10]. The Western European snail species *Arion ater* s. l. (Stylommatophora: Arionidae) (Linneaus, 1758) and *A. vulgaris* Moquin-Tandon, 1855, which have recently been reported to exist in Isparta and the Asian and European sides of the Bosphorus in Türkiye [10] are among the most important invasive and harmful mollusk species in terms of their adverse effects on agricultural areas and horticultural production [11].

Biogeographic considerations and a phylogenetic analysis on *Theba pisana* (Stylommatophora: Helicidae) (O. F. Müller, 1774) indicate Morocco as place of origin [12]. This species is found in many regions of Türkiye [13]. *Cornu aspersum* (Stylommatophora: Helicidae) (O. F. Müller, 1774) (the Mediterranean mollusc) is one of the most broadly distributed terrestrial snails on a global scale, North Africa is known as the homeland of this species. Despite it is commonly seen in very humid locations (Istanbul, Antalya, Izmir, Bodrum, etc.), it is not very abundant in regions far from the coastal locations (such as Burdur, Isparta). Furthermore, it is reported in cultivated lands far from the sea in Anatolia [13].

Another land snail, *Xeropicta derbentina* (Stylommatophora: Geomitridae) (Krynicki, 1836), is endemic to the Northern Black Sea steppes, and *X. derbentina* also originally lived in the Eastern Mediterranean, the Caucasus, and Anatolia [14].

Xeropicta krynickii (Krynicki, 1833) is usually recorded in the Eastern Mediterranean. Its main distribution extends between the Black Sea and the Caspian Sea, from Bulgaria and Romania to Iran and Azerbaijan [15]. It is mostly recorded from the Black Sea Region in Türkiye [16].

Cernuella virgata (Stylommatophora: Geomitridae) (Da Costa, 1778) is indigenous to western Europe and Mediterranean. However, this species has also spread rarely in Türkiye. It has been recorded in İstanbul and Marmara Region [17].

Eobania vermiculata (Stylommatophora: Helicidae) (Müller, 1774), is one of the most important examples of the helicid terrestrial snails, achieved a worldwide spread through anthropogenic affairs. It is of Circum-Mediterranean distribution, typical for the coastal areas of Greece, Libya, Spain, Croatia, France, Algeria, Italy, Montenegro, Albania, Tunisia and Morocco. In addition to these countries, it was also recorded in Türkiye [13].

Adverse Effects of Invasive Snail Species on the Environment

An introduced species is a vegetable, animal, or another organism that is not native to a specific region, and which tends to spread to a degree believed to cause damage to the environment, human economy, or human health [18]. Invasive species can be introduced to a new environment through a variety of means, such as accidental or intentional releases by humans, natural dispersal, or through the actions of other animals. Therefore, it is very important to monitor and manage invasive species to minimize their negative effects on native ecosystems [19]. Snails are also among the species introduced in the world in recent years due to their economic importance [20].

Snails have a wide range of feeding habits depending on the species. Some are herbivorous and feed on plants, while others are carnivorous and feed on other invertebrates or even small vertebrates. Some species are scavengers, feeding on decaying organic matter [21]. Snails are hermaphrodites, meaning they possess both male and female reproductive organs [22,23]. They typically reproduce through internal fertilization (self-fertilization) and lay eggs in a variety of habitats such as on the ground, in freshwater, or in marine environments. The eggs hatch

into small, fragile-bodied snails [24,25]. They are important decomposers, breaking down dead plant and animal material and recycling nutrients back into the ecosystem. They are also a food source for numerous animals, including birds, fish, and mammals [26]. Therefore, snails play an important role in many ecosystems [11,27].

Although snails have significant roles in many habitats, some species of snails can be invasive and cause significant ecological and economic damage. For example, the Giant African snail, which is native to Africa, has been introduced in many countries and is considered a pest due to its feeding habits that can damage crops, fruits, and vegetables [28]. Invasive snail species can have a variety of negative impacts on the environment. They can outcompete native snails for resources and habitat, leading to declines in native snail populations. They can also disrupt ecosystem functions and processes, such as decomposition and nutrient cycling. Invasive snails can also cause significant economic damage. For example, some invasive snail species are agricultural pests, feeding on crops, fruits, and vegetables. This can lead to significant crop losses and reduced agricultural productivity [29]. In addition, some invasive snails can act as vectors for disease, spreading diseases that can affect humans and animals. For example, some species of snails can carry bacteria and the parasitic worm responsible for angiostrongyliasis [30] and schistosomiasis, which can cause serious health problems in humans that can be transmitted if handled with bare hands or eaten [31]. In conclusion, invasive snail species can cause significant ecological and economic damage by outcompeting native snails for resources and habitat, disrupting ecosystem functions and processes, and causing damage to crop and infrastructure. Therefore, they can significantly negatively affect the environment, economy, and human health. Thus, it's crucial to monitor and manage invasive snail species to minimize their negative effects on native ecosystems and human activities.

Ecological Impacts of Invasive Snails

Invasive snails can have significant negative ecological impacts, including competition with native species for resources, predation on native species [32,33], disruption of ecosystem processes, the spread of diseases, loss of biodiversity [34-39] and economic impacts [40]. Examples of invasive snail species include the Giant African Snail [41]. Chinese Mystery Snail, European Brown Garden Snail [42] and Golden Apple Snail [43]. These invasive species can have an impact on the population dynamics and distribution of native snails, including alteration of community structure, changes in distribution, and genetic effects [31], which can lead to declines in biodiversity [24].

The Giant African Snail *(Achatina fulica* [Stylommatophora: Achatinidae] [Bowdich, 1822]): This invasive species is native to East Africa and has been introduced to many other parts of the world. It competes with native snails for food and habitat and can also prey on smaller native snails [28,44].

The Chinese Mystery Snail *(Cipangopaludina chinensis* [Architaenioglossa: Viviparidae] [J. E. Gray, 1833]): This invasive species is native to Asia and has been introduced to many parts of North America. It competes with native snails for nutrients and habitat and can also outcompete native snails for space in the substrate (e.g. mud, sand) [25,45,46].

The European Brown Garden Snail *(Helix aspersa):* Scattered throughout Western Europe, Great Britain, and the Mediterranean and Black Sea borders. It was brought to the Atlantic Islands, New Zealand, Australia, South Africa, Mexico, Chile, Argentina, and Australia [25,47,48].

Effects on Population Dynamics and Distribution of Native Snails

Invasive snails can have a significant impact on the population dynamics and distribution of native snails. These impacts can include [30,31]:

Competition for resources: Invasive snails can outcompete native snails for food and habitat, leading to declines in native snail populations [49].

Predation: Some invasive snails, such as the Giant African Snail, can prey on native snails, which can lead to declines in native snail populations [50].

Displacement: Invasive snails can outcompete native snails for space in the substrate (e.g., mud, sand), which can lead to the displacement of native snails from their preferred habitats [51].

Alteration of community structure: Invasive snails can alter the structure of native snail communities by reducing the abundance and diversity of native species [52].

Changes in distribution: Invasive snails can spread to new areas and displace native snails from their natural range, leading to changes in the distribution of native species [53].

Genetic effects: Invasive snails can hybridize with native snails and change the genetic makeup of native snail populations. These impacts can have cascading effects on the ecosystem and can cause declines in biodiversity [54].

Nutrient cycling: Invasive snails can alter nutrient cycling in an ecosystem by consuming large amounts of plant material, which can lead to changes in nutrient availability for other organisms [38].

Decomposition: Invasive snails can alter decomposition processes by consuming large amounts of dead plant material and other organic matter, which can affect the rate and efficiency of decomposition in an ecosystem [55].

Soil formation: Invasive snails can alter soil formation by consuming large amounts of vegetation, which can change the composition of soil and affect the growth of other plants [38].

Disruption of the food web: Invasive snails can disrupt the food web by preying on native snails and other invertebrates, which can lead to declines in native species and altered trophic interactions [40].

Altering ecosystem services: Invasive snails can change ecosystem services such as pollination, seed dispersal, and pest control by reducing the abundance and diversity of native species [51].

Examples of How Invasive Snails Alter Community Structure and Ecosystem Function

In Hawaii, the invasive Giant African Snail *(Achatina fulica)* is known to prey on native snails, which can lead to declines in native snail populations and altered community structure. This can also have ripple effects on other species that rely on native snails as a food source or as part of the ecosystem, leading to declines in biodiversity [42].

Effects on biodiversity and ecosystem services: Invasive snails can lead to a decline in native snail populations and ripple effects on other species that rely on native snails as a food source, resulting in declines in biodiversity. Invasive snails can also alter the structure of native snail communities and ecosystem function through changes in community structure, nutrient cycling [56], decomposition, soil formation, disruption of the food web and altering ecosystem services. These changes can have negative impacts on biodiversity, agriculture, and human health through the spread of diseases. Invasive snails can have negative effects on biodiversity and ecosystem services. These impacts can include:

Loss of native species: Invasive snails can outcompete native snails for resources and prey on native snails, which can lead to declines in native snail populations and loss of biodiversity. This can also have ripple effects on other species that rely on native snails as a food source or as part of the ecosystem [57].

Alteration of community structure: Invasive snails can alter the structure of native snail communities by reducing the abundance and diversity of native species, which can affect the functioning of the ecosystem and lead to declines in biodiversity [58].

Changes in ecosystem services: Invasive snails can change ecosystem services such as pollination, seed dispersal, and pest control by reducing the abundance and diversity of native species. Invasive snails can also change nutrient cycling and decomposition processes, which can affect the functioning of the ecosystem [51].

Economic impacts: Invasive snails can cause damage to crops and gardens, resulting in economic losses for farmers and gardeners [59].

Human health impacts: Some invasive snails can serve as vectors for diseases that can affect humans (i.e., angiostrongyliasis [30] and schistosomiasis [31]).

Overall, invasive snails can have a range of negative impacts on biodiversity and ecosystem services, which can have ripple effects on human well-being and the economy.

Economic Impacts of Invasive Snails

Invasive snails can have a range of economic impacts, which include:

Crop damage: Invasive snails can cause damage to crop by consuming large amounts of plant material, which can result in reduced crop yields and economic losses for farmers [60,61].

Garden damage: Invasive snails can cause damage to gardens by consuming large amounts of plant material, which can result in reduced yields and economic losses for gardeners [56].

Control costs: Invasive snails can be difficult to control, and the costs of control measures can be significant. These costs can include the costs of labor, materials, and equipment for control measures such as snail baiting and manual removal.

Damage to infrastructure: Invasive snails can cause damage to infrastructure such as buildings, roads, and sidewalks by consuming mortar and other building materials [51].

Damage to the tourism industry: Invasive snails can cause damage to natural resources and native ecosystems, which can negatively influence the tourism industry [38].

Reduced exports: Invasive snails can lead to reduced exports of agricultural products and other goods due to quarantine measures and other restrictions [50,61].

Damage to Crop and Agricultural Lands

Invasive snails can cause damage to crops and agricultural lands in several ways:

Crop consumption: Invasive snails can consume large amounts of plant material, which can result in reduced crop yields and economic losses for farmers. This can be particularly damaging to crops such as fruits and vegetables, where even a small amount of damage can greatly reduce the value of the crop [50].

Soil damage: Invasive snails can cause damage to soil by consuming large amounts of vegetation and other organic

matter, which can change the composition of soil and affect the growth of other plants. This can lead to reduced crop yields and decreased productivity of agricultural lands [61].

Spread of diseases: Some invasive snails can serve as vectors for diseases that can affect crops, which can lead to reduced crop yields and economic losses for farmers [50].

Damage to irrigation systems: Invasive snails can cause damage to irrigation systems by consuming the plastic and other materials used in these systems, which can lead to reduced water delivery to crops and decreased crop yields [62].

Damage to farm equipment: Invasive snails can cause damage to farm equipment by consuming the rubber and other materials used in this equipment, which can lead to increased maintenance and repair costs for farmers [44].

Economic Costs of Crop Damage

The economic costs of crop damage caused by invasive snails can be significant. These costs can include:

Reduced crop yields: Invasive snails can consume large amounts of plant material, which can result in reduced crop yields and economic losses for farmers. The cost of this loss can depend on the type of crop, the extent of damage, and the market price of the crop [50].

Increased costs of control and management: Farmers may need to spend additional money on control measures such as snail baiting, manual removal, and other pest management techniques to reduce the damage caused by invasive snails [45].

Damage to irrigation systems: Invasive snails can cause damage to irrigation systems, which can lead to reduced water delivery to crops and decreased crop yields. This can result in additional costs for farmers to repair or replace damaged irrigation systems [46].

Loss of exports: Invasive snails can lead to reduced exports of agricultural products and other goods due to quarantine measures and other restrictions, resulting in economic losses for farmers [38].

Loss of reputation and market value: Damage caused by invasive snails can reduce the quality and market value of crops, which can lead to a loss of reputation and reduced market value for farmers [62].

Reduced productivity: Invasive snails can cause damage to soil and other agricultural lands, which can lead to decreased productivity and reduced crop yields over time [48].

The economic costs of crop damage caused by invasive snails can vary depending on the type of crop, the extent of damage, and the location of the farm. But overall, it can be quite substantial for farmers and the economy [38,46,50,62,63].

Damage to Infrastructure and Buildings

Invasive snails can cause damage to infrastructure and buildings by consuming various materials.

Damage to buildings: Invasive snails can consume mortar and other building materials, which can cause damage to buildings and lead to increased maintenance and repair costs [49].

Damage to roads and sidewalks: Invasive snails can consume asphalt and other materials used in road construction, which can cause damage to roads and sidewalks and lead to increased maintenance and repair costs [44].

Damage to electrical infrastructure: Invasive snails can consume the insulation on electrical wires, which can cause damage to electrical infrastructure and lead to increased maintenance and repair costs [44].

Damage to communication infrastructure: Invasive snails can consume the insulation on telephone and internet cables, which can cause damage to communication infrastructure and lead to increased maintenance and repair costs [44].

Damage to water supply systems: Invasive snails can consume the materials used in water supply systems, which can cause damage to the systems and lead to decreased water delivery and increased maintenance and repair costs [50].

Costs of Control and Management

The costs of control and management efforts for invasive snails can be significant and can include:

Labor costs: Control and management efforts for invasive snails can be labor-intensive, and the costs of labor can be significant. This can include the costs of hiring staff, contractors, or volunteers to carry out control measures [50,64].

Materials and equipment costs: Control and management efforts for invasive snails can require the use of materials and equipment, such as snail bait, pesticides, traps, and protective gear. These costs can vary depending on the type of control measure used [45].

Monitoring and research costs: Control and management efforts for invasive snails often require monitoring and research to assess the effectiveness of control measures and identify new populations. These costs can include the costs of field surveys, laboratory analyses, and data management [51].

Education and outreach costs: Control and management efforts for invasive snails often require education and outreach to inform the public about the risks of invasive

snails and how to prevent the spread. These costs can include the costs of developing educational materials, organizing workshops and presentations, and communicating with stakeholders [51].

Legal costs: Control and management efforts for invasive snails can involve legal measures such as permits, regulations, and enforcement. These costs can include the costs of obtaining permits and compliance with regulations and the costs associated with enforcement actions [45].

Continual costs: Invasive species management is an ongoing effort, and the costs associated with it can be ongoing as well. The population of invasive snails can rebound if the management efforts are not continued [50].

Examples of Control and Management Efforts for Invasive Snails

Physical control: Physical control methods include the manual removal of snails, trapping, and fencing. This method can be effective but can be labor-intensive and costly [52].

Chemical control: Chemical control methods include the use of snail baits, pesticides, and molluscicides. These methods can be effective in reducing snail populations but can also have negative impacts on non-target species and the environment [53].

Biological control: Biological control methods include the release of natural predators or pathogens that target invasive snails. This method can be effective but can also have negative impacts on non-target species and the environment [54].

Cultural control: Cultural control methods include techniques to make the environment less favorable to invasive snails, such as altering the pH of the soil, reducing moisture, and planting repellent plants [38].

Quarantine and regulations: Quarantine and regulations can be used to prevent the introduction and spread of invasive snails by restricting the movement of potentially infested materials and enforcing regulations on the import and export of invasive snails [38].

Public education and outreach: Public education and outreach can help prevent the spread of invasive snails by raising awareness about the risks of invasive snails and how to prevent their spread [51,64].

Invasive snails can have significant economic impacts, including crop and garden damage [28], control costs, damage to infrastructure, harm to the tourism industry and reduced exports. They can cause damage to crop and agricultural lands by consuming large amounts of plant material [38] damaging soil, spreading diseases to crops, and damaging irrigation systems and farm equipment [56]. These impacts can lead to reduced crop yields and decreased productivity of agricultural lands, resulting in economic losses for farmers. The economic costs of crop damage can include reduced crop yields [28], increased costs of control and management, damage to irrigation systems, and loss of exports due to quarantine measures and other restrictions. Invasive snails can also cause damage to infrastructure such as buildings, roads, and sidewalks by consuming mortar and other building materials.

Success and Challenges of Control and Management

Successes and challenges of control and management efforts for invasive snails can vary depending on the invasive species and the ecosystem.

Successes

Physical control: Physical control methods, such as the manual removal of snails and trapping, can be effective in reducing the population of invasive snails in small areas or localized infestations [40].

Chemical control: Chemical control methods, such as the use of snail baits and pesticides, can be effective in reducing the population of invasive snails in large areas [53].

Biological control: Biological control methods, such as the release of natural predators or pathogens that target invasive snails, can be effective in reducing the population of invasive snails over time [54].

Cultural control: Cultural control methods, such as altering the pH of the soil and reducing moisture, can make the environment less favorable to invasive snails and can be effective in preventing the establishment of invasive snails [38].

Quarantine and regulations: Quarantine and regulations can be effective in preventing the introduction and spread of invasive snails by restricting the movement of potentially infested materials and enforcing regulations on the import and export of invasive snails [42].

Challenges

Difficulty in detecting and monitoring invasive snails: Invasive snails can be difficult to detect and monitor, especially in the early stages of an invasion, which can make it difficult to control and manage their populations [51].

Difficulty in controlling and managing large and established populations: Once invasive snails have established large populations, it can be difficult to control and manage their populations effectively [51].

Difficulty in controlling and managing in large and remote areas: Control and management efforts can be difficult and costly in large and remote areas, where access and resources may be limited [51].

Limited knowledge of invasive snails' biology and behavior: Although invasive snails can seriously harm the environment and the economy, managing them successfully can be difficult due to our limited understanding of their biology and behavior.

Control and management efforts for invasive snails can be successful using methods such as physical, and chemical [28], biological control, and quarantine and regulations [38]. These methods can be effective in reducing the population of invasive snails in small areas or localized infestations, large areas, and over time. However, there are also challenges in controlling and managing invasive snails such as difficulty in detecting and monitoring them [57], difficulty in controlling and managing large and established populations, difficulty in controlling and managing in large and remote areas and limited knowledge of their biology and behavior. These challenges can make it difficult to effectively control and manage invasive snail populations.

Importance of Preventing and Managing Invasive Snail Species

Preventing and managing invasive snail species is important for a variety of reasons, including:

Protecting native species and biodiversity: Invasive snails can outcompete, prey on, and alter the habitats of native species, leading to reduced population sizes and distribution of native species and potentially even extinction. Preventing and managing invasive snail species can help protect native species and biodiversity [58,65,66].

Maintaining ecosystem function: Invasive snails can change the composition and dynamics of ecosystems by consuming large amounts of plant material and other organic matter, which can affect the growth of other plants and the functioning of ecosystems. Preventing and managing invasive snails can help maintain the balance and functioning of natural ecosystems [59,67].

Protecting agricultural lands and crops: Invasive snails can cause damage to crop and agricultural lands by consuming large amounts of plant material, causing damage to soil and irrigation systems, and spreading diseases to crops, which can lead to reduced crop yields and decreased productivity of agricultural lands. Preventing and managing invasive snails can help protect agricultural lands and crops [38,58].

Protecting infrastructure and buildings: Invasive snails can cause damage to infrastructure and buildings by consuming various materials, which can lead to increased maintenance and repair costs. Preventing and managing invasive snails can help protect infrastructure and buildings [42].

Saving costs: Control and management efforts for invasive snails can be significant and costly, including labor costs, materials, and equipment costs, monitoring and research costs, education and outreach costs, and legal costs. Preventing the introduction and spread of invasive snails is more cost-effective than trying to manage established populations [59].

Improving the quality of life: Invasive species can have a negative impact on human activities such as agriculture, recreation, and infrastructure. Preventing and managing invasive snail species can improve the quality of life for people who live and work in areas affected by invasive snails [59,66,68].

Future Directions for Research and Management of Invasive Snail Species

Future directions for research and management of invasive snail species can include:

Improving early detection and rapid response methods: Developing more efficient and cost-effective methods for detecting and responding to new invasive snail populations quickly can help prevent the establishment and spread of invasive snails [60,65,66].

Conducting more research on the impacts of invasive snails: More research is needed to understand the full range of impacts that invasive snails have on native species, ecosystems, and human activities, such as agriculture and infrastructure [54].

Developing and testing new control and management methods: New control and management methods, such as biological control methods that use natural predators or pathogens to target invasive snails, may be developed and tested to improve the effectiveness and sustainability of control and management efforts [54].

Incorporating citizen science and public engagement: Involving the public in monitoring, reporting and controlling invasive snails through citizen science programs and outreach can increase the speed and effectiveness of management efforts [61].

Enhancing international cooperation: Invasive snails can be spread through international trade and travel; therefore, international cooperation is needed to develop

and implement effective prevention and management measures [61].

Evaluating the long-term effectiveness of management actions: Long-term monitoring and evaluation of management actions are necessary to assess the effectiveness of management efforts over time and to identify any potential unintended consequences.

Improving risk assessment: A more robust risk assessment process for identifying invasive snails that are likely to establish in new regions and cause harm, will help to prioritize management efforts and resources.

In summary, invasive snail species can have a wide range of negative impacts on the environment, including on native species, ecosystems, and human activities such as agriculture and infrastructure. Preventing and managing invasive snail species is important to protect native species and biodiversity, maintain ecosystem function, protect agricultural lands and crops, protect infrastructure and buildings, and save costs. Future directions for research and management of invasive snail species can include improving early detection and rapid response methods and conducting more research on the impacts of invasive snails [62]. Also, developing more effective control and management strategies, such as biological control and habitat management, can help reduce the negative impacts of invasive snails [64].

Conclusion and Recommendations

Adverse Effects of Invasive Snail Species on the Environment

Invasive snail species can have a wide range of adverse effects on the environment. These include competition with native snails, which can lead to reduced population sizes and distribution of native species, predation on native species, alteration of community structure and ecosystem function, damage to crops and agricultural lands, damage to infrastructure and buildings, and costs of control and management efforts. On the other hand, invasive snails can consume large amounts of plant material and other organic matter, which can affect the growth of other plants and the functioning of ecosystems. Furthermore, they can cause damage to crop and agricultural lands by consuming large amounts of plant material, causing damage to soil and irrigation systems, and spreading diseases to crops, which can lead to reduced crop yields and decreased productivity of agricultural lands, and they can cause damage to infrastructure and buildings by consuming various materials, which can lead to increased maintenance and repair costs. Control and management efforts for invasive snails can be significant and can include labor costs, materials, and equipment costs, monitoring and research costs, education and outreach costs, and legal costs. Overall, invasive snails can have a wide range of negative impacts on the environment, including on native species, ecosystems, and human activities such as agriculture and infrastructure.

Possible Threats of the Presence of Non-native Invasive Land Snail Species in Türkiye

Land snails are accepted in the aquatic products group in Türkiye. Importation of foreign live fishery products to Türkiye is stated in the Fisheries Regulation, "For the fisheries to be imported, it is obligatory to submit a Health Certificate and a Certificate of Origin, issued by the official institutions of the seller country, stating that they are free from infectious diseases and are found to be healthy. In the importation of broodstocks, these documents must also be approved by the Consulates" [69]. In addition, concerning "non-native species", in Article 13 of the "Regulation on the Protection of Wetlands" of the Ministry of Forestry and Water Affairs [70] it is stated that "non-native species cannot be stocked in areas protected by the Ramsar Convention and wetlands of national importance, for whatever purpose, without scientific research and without the approval of the Ministry" and "Removal of non-native species from the area, which have been stocked in the past and which have been found to have a serious negative impact on the wetland ecosystem as a result of scientific research, and if this is not possible, control of their populations is provided by the relevant Administrations under the coordination of the Ministry". However, despite these laws, the existence of non-native invasive land snail species has been reported in Türkiye.

Many non-native and invasive creatures can reach new geographic regions by many means of transport [66]. One of the most important ways of transporting these creatures to other environments is the worldwide ornamental animal trade, which increases its impact with the speed of global trade [22,25,72,73]. The exotic pet trade has increased rapidly in recent years, especially as interest in live animals kept for hobby purposes has increased, and there has been a simultaneous increase in the number of invasive species dispersed in this way [73]. The easy and fast access provided by the trade of pets over the internet has also accelerated this increase. One of the most striking examples of this situation is the sale of members of the African Giant Snail (Achatinidae family), which are known for their invasive and intermediate host properties for some zoonotic parasites [74], offered for sale in web shops in Türkiye. It is expected that these family members, whose invasive characteristics, and damage in the new habitats they enter, are imported to Türkiye, together with all freshwater snails, are indirectly possible according to the regulations [75] and will disperse within the country through various trade channels in the coming years. However, it is predicted that this distribution will create undesirable negativities soon

in terms of both ecological and health risks. For example, the negative impact of *A. vulgaris* on agriculture products has been reported in Düzköy, Trabzon city. It has been stated that *A. vulgaris* is particularly damaging to crops such as potatoes, beans, and cabbage. Therefore, residents, who have been trying to fight the snail species that have been affecting the district for about 4 years, are asking for help from the authorities.

Preventing the introduction and distribution of invasive snail species in Türkiye is essential to protect the country's biodiversity and ecosystems. Invasive snails can cause a wide range of negative impacts on the environment, including competition with native snails, which can lead to reduced population sizes and distribution of native species, predation on native species, alteration of community structure and ecosystem function, damage to crops and agricultural lands, damage to infrastructure and buildings, and costs of control and management efforts in Türkiye. It is therefore important for the Government and public to be aware of the potential risks and report any sightings to the authorities, and for the agricultural industry and travelers to be cautious and not to transfer and release any invasive snails into the wild. The presence of any non-native snail species in any location should be reported. Cooperation of the government, researchers, industry, and the public is vital to prevent the transfer, introduction, and spread of invasive snail species in Türkiye.

In Türkiye, the public, administrations, and especially entrepreneurs who want to import foreign species need to be conscious of the protection of natural genes and resources and the potential dangers and negative effects of foreign species stocking. In addition, it is of great importance to enact more effective import-controlling laws and to implement existing laws. If this is not successful, the quality of Türkiye's resources and the structure of our natural genetic resources will have deteriorated because of the introduction of foreign species into Türkiye's natural environment to gain economic income. Therefore, the importation and sale of invasive non-native snail species must be banned by the government for any purpose. For example, in many countries, including giant African snails, invasive snail species are prohibited from importing, bringing in by any means, and purchasing online, as exotic snails are likely to escape and spread, causing environmental problems. Moreover, more research should be done on the biology, ecology, artificial production, feeding, and rearing of economically important native snail species of Türkiye.

Highlight Keypoints

- The presence of non-native invasive snail species in Türkiye could lead to a decline in the country's unique biodiversity. These invaders might outcompete or prey upon native snails found exclusively in Turkish ecosystems, potentially disrupting the delicate balance of species in various regions across Türkiye.
- Given Türkiye's diverse agricultural practices and varied environmental landscapes, invasive snail species could cause disruptions in these systems. These invaders might negatively affect the intricate harmony within Turkish agricultural practices and environmental ecosystems, potentially leading to economic losses and environmental imbalances in different parts of the country.
- Invasive snails pose a threat to native snails by competing for resources, leading to reduced populations and altered distributions of native species. This disruption can shift the balance in ecosystems, impacting their structure and function.
- Invasive species cause significant harm to agriculture by consuming large quantities of plant material. This not only damages crop directly but also affects soil quality, irrigation systems, and spreads diseases among crops, ultimately decreasing yields and productivity.
- Invasive snails can wreak havoc on infrastructure and buildings by consuming various materials, resulting in increased maintenance and repair costs. Their activities pose threats to the integrity of structures and the need for continuous repairs.
- Managing invasive snail populations comes with considerable expenses, including labour, materials, equipment, monitoring, research, education, and legal costs. Controlling their spread and mitigating their impact demands substantial financial and resource investments.

Declarations

Conflict of Interest: The authors declare that they have no conflict of interest.

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