A peer-reviewed open-access journal
NeoBiota
Advancing research on alien species and biological invasions

NeoBiota 108: 305–334 (2026)
DOI: 10.3897/neobiota.108.190976

Research Article

Non-native land planarians (Platyhelminthes, Tricladida, Geoplanidae) in Belgium: A review and risk assessment

Tom Van den Neucker[1,2], Jan Soors[3], Arnaud Jacobs[4], Jane Reniers[4], Soria Delva[3], Nikol Kmentová[1,5], Maarten P.M. Vanhove[1,5], Bram D'hondt[3], Kevin Scheers[3], Louis Bronne[6], Christine Ewers[7], Laura Abraham[8], Quentin Groom[8], David Halfmaerten[3], Sabrina Neyrinck[3], Karin Breugelmans[1], Thierry Backeljau[1,9], Jean-Lou Justine[10], Romain Gastineau[11], Leigh Winsor[12], Tim Adriaens[3]

1 Royal Belgian Institute of Natural Sciences, Vautierstraat 29, 1000 Brussels, Belgium
2 University of Antwerp, Department of Biology, ECOSPHERE Research Group, Universiteitsplein 1C, 2610 Wilrijk, Belgium
3 Research Institute for Nature and Forest (INBO), Havenlaan 88/73, 1000 Brussels, Belgium
4 National Scientific Secretariat on Invasive Alien Species, Royal Belgian Institute of Natural Sciences, Vautierstraat 29, 1000 Brussels, Belgium
5 Hasselt University, Centre for Environmental Sciences, Research Group Zoology: Biodiversity and Toxicology, 3590 Diepenbeek, Belgium
6 Natagora, Impasse des Muses 1, 5000 Namur, Belgium
7 Zoological Museum, Kiel University, Hegewischstraße 3, 24105 Kiel, Germany
8 Meise Botanic Garden, Nieuwelaan 38, 1860 Meise, Belgium
9 University of Antwerp, Department of Biology, Evolutionary Ecology Group, Universiteitsplein 1D, 2610 Wilrijk, Belgium
10 ISYEB, Institut de Systématique, Évolution, Biodiversité (UMR7205 CNRS, EPHE, MNHN, UPMC, Université des Antilles), Muséum National d'Histoire Naturelle, CP 51, 55 rue Buffon, 75231 Paris Cedex 05, France
11 Institute of Marine and Environmental Sciences, University of Szczecin, Szczecin, Poland
12 College of Science and Engineering, James Cook University, Townsville, Qld 4811, Australia

Corresponding author: Tom Van den Neucker (tom.vandenneucker@uantwerpen.be)

OPEN ACCESS

Academic editor: Katelyn Faulkner
Received: 8 March 2026
Accepted: 9 July 2026
Published: 12 August 2026

Citation: Van den Neucker T, Soors J, Jacobs A, Reniers J, Delva S, Kmentová N, Vanhove MPM, D'hondt B, Scheers K, Bronne L, Ewers C, Abraham L, Groom Q, Halfmaerten D, Neyrinck S, Breugelmans K, Backeljau T, Justine J-L, Gastineau R, Winsor L, Adriaens T (2026) Non-native land planarians (Platyhelminthes, Tricladida, Geoplanidae) in Belgium: A review and risk assessment. NeoBiota 108: 305–334. https://doi.org/10.3897/neobiota.108.190976

Abstract

Multiple species of land planarians have become established outside their natural ranges. Some are considered invasive because of their rapid spread and adverse effects on ecosystems. Once established, land planarians are difficult to manage. Therefore, it is crucial to document their presence and spread and assess their risk. This study provides an annotated checklist and distribution maps of all non-native land planarians recorded in Belgium, as well as a climate-matching analysis and a Harmonia+ risk assessment for each species. A climate-matching analysis and a risk assessment were also conducted for two species that do not occur in Belgium but are included in the European Union's list of invasive alien species of Union Concern: *Platydemus manokwari* and *Arthurdendyus triangulatus*. Thus far, nine non-native land planarian species have been recorded in Belgium: *Anisorhynchodemus* cf. *signata*, *Bipalium kewense*, *Caenoplana coerulea*, *C. variegata*, *Diversibipalium multilineatum*, *Dolichoplana striata*, *Marionfyfea adventor*, *Obama nungara*, and *Parakontikia ventrolineata*. Climate-matching percentages were highest for *A. triangulatus*, *M. adventor*, *C. variegata*, and *O. nungara*. *Obama nungara* is the only species that received a very high environmental risk score. *Diversibipalium multilineatum* and *P. manokwari* both received high environmental risk scores. The overall risk score was medium for *O. nungara* and *D. multilineatum* and low for all other species. The information presented in this review may provide a basis for developing suitable detection and monitoring methods and rapid-response strategies for high-risk non-native land planarians.

Key words: Annotated checklist, climate matching, distribution, Harmonia+, invasive species, land planarians

Introduction

Currently, more than 1,000 species of land planarians are known to science (Geoplanidae in GBIF Secretariat 2025), and this number will undoubtedly continue to increase because the most species-rich subtropical and tropical regions are undersampled (Murchie and Justine 2021). Several land planarians have successfully colonized areas outside their native ranges (Winsor et al. 2004; Sluys 2016; Murchie and Justine 2021; Thunnissen et al. 2022). In Europe, at least 30 non-native land planarian species have been found in heated glasshouses of botanical gardens and plant nurseries or in outdoor environments, including urbanized areas, gardens, and agricultural fields (Cannon et al. 1999; Álvarez-Presas et al. 2014; Justine et al. 2022; Mori et al. 2022a; Thunnissen et al. 2022).

The horticultural trade is considered the primary pathway for the introduction of non-native land planarians worldwide. The commercial trade and transport of potted plants allow land planarians to spread easily as contaminants. Other means of introduction and spread may include the movement of topsoil, agricultural produce, and farm goods such as silage bales and farmyard manure (Winsor 1983; Cannon et al. 1999; Álvarez-Presas et al. 2014; Sluys 2016; Murchie and Justine 2021). Several land planarians have become established in humid outdoor environments outside their natural ranges (Winsor et al. 2004; Sluys 2016; Murchie and Justine 2021; Thunnissen et al. 2022). The spread of land planarians and the subsequent colonization of new environments may be facilitated by several reproductive traits, such as hermaphroditism, sperm storage, the production of egg capsules containing multiple offspring, and asexual reproduction by fragmentation (Ducey et al. 2005, 2006). Egg capsules of land planarians usually contain between one and 15 offspring. The number of offspring per capsule may vary among populations of the same species, depending on food availability (Ducey et al. 2005). Asexual fragmentation can be the primary means of reproduction in some species (Connella and Stern 1969; Ducey et al. 2006). The invasive potential of land planarians may also be attributed to the lack of natural predators. Rhabditogen cells (i.e., gland cells that secrete rodlike structures referred to as rhabdites) produce a distasteful mucous secretion that may repel most potential predators (Denny 1989; Winsor et al. 2004; Sluys 2016). Only a handful of natural enemies of land planarians have been reported, including some birds, shrews, carabid and staphylinid beetles, a predatory fungus gnat, a carnivorous snail, and other planarians, but planarians are generally not preferred prey (Hickman 1965; Cannon et al. 1999; Winsor et al. 2004; Lemos et al. 2012; Boll and Leal-Zanchet 2016). Parasites and pathogens of land planarians are almost unknown, although recent research demonstrated the presence of two species of Microsporidia in land planarians in Northern Ireland (Gastineau et al. 2025a).

Some non-native land planarians are considered invasive because of their rapid spread and adverse effects on ecosystems (Winsor et al. 2004; Sluys 2016; Murchie and Justine 2021; Thunnissen et al. 2022). Four land planarians, *Arthurdendyus triangulatus*, *Bipalium kewense*, *Obama nungara*, and *Platydemus manokwari*, are listed as invasive alien species of Union Concern (European Commission, Directorate-General for Environment 2019, 2025). The list of Union Concern lies at the heart of European Regulation (EU) 1143/2014, which is intended to prevent the introduction and spread of invasive species (European Parliament, Council of the European Union 2014). Among other measures, it obliges European Member States to draft action plans to prevent unintentional introductions. The New Zealand flatworm, *A. triangulatus*, was added to the list of Union Concern in 2019 (European Commission, Directorate-General for Environment 2019). It has established populations in the UK, Ireland, and the Faroe Islands, where it was most likely introduced via potted plants and soil (Cannon et al. 1999). Climate-matching models suggest that the species may be capable of surviving in parts of mainland Europe as well, with coastal regions in the Atlantic and Continental biogeographical regions from France to Germany and the southern tips of Norway and Sweden especially at risk of establishment (Boag et al. 1995a, 1995b; Boag and Yeates 2001; Murchie 2017). *Arthurdendyus triangulatus* probably feeds exclusively on earthworms (Cannon et al. 1999), which are considered beneficial soil organisms in their native ranges (Edwards and Arancon 2022; Gérard et al. 2025). The New Guinea flatworm, *P. manokwari*, was added to the list of Union Concern in 2025, along with *B. kewense* and *O. nungara* (European Commission, Directorate-General for Environment 2025), but it had been recognized much earlier as one of the world's worst invasive alien species (Lowe et al. 2000). *Platydemus manokwari* has spread to a variety of (semi)natural habitats and urban areas in many countries outside its natural range, including multiple Atlantic and Pacific islands (Winsor et al. 2004; Justine et al. 2014, 2015, 2021; Hu et al. 2019). The species was deliberately introduced into the Philippines, Japan, and the Maldives to control the giant African snail *Lissachatina fulica* (Bowdich, 1822) (Justine et al. 2014), although the potted plant trade is likely its main introduction pathway (Sugiura 2009). It is a voracious predator of gastropods and other invertebrates and is considered a major threat to endemic partulid snails on several Pacific islands (Hopper and Smith 1992; Ogren 1995; Okochi et al. 2004; Winsor et al. 2004). *Platydemus manokwari* is a host and transmission vector for the rat lungworm *Angiostrongylus cantonensis* (Chen, 1935), which can infect humans and cause meningitis (Asato et al. 2004; Qvarnstrom et al. 2013).

Although most land planarians are likely not harmful, vigilance is required regarding non-native species other than those listed as invasive alien species of Union Concern because all land planarians are predators of a variety of ground- and soil-dwelling invertebrates, including gastropods, earthworms, and arthropods such as isopods and spiders (Winsor et al. 2004; Murchie and Justine 2021; Cardoso et al. 2023). Once established, land planarians are difficult to manage because of their cryptic and soil-dwelling behavior (Murchie 2017; Murchie and Justine 2021). Documenting the presence and spread of (potentially) invasive land planarians is therefore crucial for identifying introduction pathways and sources, assessing the risk of establishment, and evaluating potential adverse effects on native ecosystems. An overview of the non-native land planarians occurring in Belgium, their distribution, and their potential risks was lacking. To address this knowledge gap, the objectives of this study are threefold: (1) to provide a checklist and up-to-date distribution maps of all non-native land planarians recorded in Belgium, (2) to assess the similarity between each species' current climatic distribution and the Belgian climate through a climate-matching analysis, and (3) to assess the risk they pose to Belgium using a Harmonia$^+$ risk assessment.

Methods

Non-native land planarians in Belgium

An annotated checklist and distribution maps of non-native land planarians occurring in Belgium were compiled using data collected by the authors and citizen scientists. These observation data are available via iNaturalist (2025) and Waarnemingen.be/Observations.be (2025) (Vanreusel et al. 2025). The latter has proven to be a valuable tool for monitoring non-native species in Belgium (Swinnen et al. 2018). The Waarnemingen.be/Observations.be dataset includes land planarian observations collected as part of the ongoing FlatwormWatch citizen science project (https://www.iasregulation.be/nl/flatwormwatch). The project, launched on 6 May 2024, encourages citizens to report observations of non-native land planarians on Waarnemingen.be/Observations.be by providing online identification tools. It ensures community engagement through a newsletter and various articles in specialized media. Validation of these observations was carried out by the authors. Information on the worldwide distribution and prey preferences of the non-native land planarians occurring in Belgium was also included in the annotations because this information is valuable for assessing their invasion and impact risks.

Climate matching

Open data from the Global Biodiversity Information Facility (GBIF Occurrence Download 2025) and Köppen–Geiger climate maps (Beck et al. 2023) were used to perform climate matching for the non-native land planarians recorded in Belgium, as well as for *Arthurdendyus triangulatus* and *Platydemus manokwari*. *Arthurdendyus triangulatus* and *P. manokwari* do not occur in Belgium but are included in the list of invasive alien species of Union Concern. Köppen–Geiger climate matching was applied as a first-line screening method. It provides a consistent baseline for assessing the climatic suitability of a new territory for non-native species based on their known distribution across climatic zones. Specifically, a climate-match value was assigned to each Köppen–Geiger climate zone based on the percentage of a species' recorded outdoor occurrences within that zone. These values were then linked to the Köppen–Geiger climate zones defined for Belgium under current and future conditions to obtain a final climate-match score for the country. Currently, Belgium is situated almost entirely within Köppen–Geiger climate zone Cfb (i.e., a temperate climate with warm summers and no dry season), except for a very narrow zone in the eastern part of the country that is classified as Dfb (i.e., a cold climate with warm summers and no dry season). Future climate conditions were derived from projections provided by Beck et al. (2023) for the periods 2041–2070 and 2071–2099 under four shared socioeconomic pathways (SSPs) representing scenarios with low, intermediate, high, and very high emissions. Under scenarios with high and very high emissions, climate zone Cfa (i.e., a temperate climate with hot summers and no dry season) is expected to become relevant. All climate-matching analyses were performed using R v. 4.5.0 (R Core Team 2025), and only species with a minimum of 20 GBIF records were retained for analysis. A detailed overview of the data selection and analyses can be found in the supplementary material (Suppl. material 1).

Harmonia⁺ risk assessment

A Harmonia⁺ risk assessment (D'hondt et al. 2015; Vanderhoeven et al. 2015) was carried out for the non-native land planarians recorded in Belgium, as well as for *Arthurdendyus triangulatus* and *Platydemus manokwari*, using the default settings of the Harmonia⁺ protocol. The assessment considers the arithmetic mean of scores derived from answers provided to different questions within each Harmonia⁺ module (introduction, establishment, spread, and impact) and uses the geometric mean to combine the scores of the introduction, establishment, and spread modules into an invasion risk score (also termed the "exposure score"). Using the default settings of Harmonia⁺, an overall risk score is obtained by multiplying the invasion risk score by the maximum score of the individual impact risk modules (environment, plants, animals, humans, and other) (D'hondt et al. 2015). An environmental risk score is obtained by multiplying the invasion risk score by the environmental impact module score (D'hondt et al. 2025). The assessment was performed by TVdN, JS, AJ, and JR based on a literature review and was discussed until consensus was reached. The assessors used the same literature sources. The consensus-building method was applied to effectively capture the opinions of the assessors and address uncertainty (Vanderhoeven et al. 2017). The assessment was conducted using the online version of the protocol, which is freely available at http://ias.biodiversity.be/harmoniaplus. The Harmonia⁺ risk-scoring system yields a score ranging from 0 to 1. The assessment emphasized the invasion, environmental, and overall risk scores. To facilitate interpretation, the invasion, environmental, and overall risk scores were classified as very low, low, medium, high, and very high (Table 1). Cutoff values for the risk classes were adopted from D'hondt et al. (2025). The cutoff values for all Harmonia⁺ modules (introduction, establishment, spread, environment, plants, animals, humans, and other) used to determine the invasion, environmental, and overall risk scores are provided in the supplementary material (Suppl. material 2).

Results

Non-native land planarians in Belgium

Thus far, nine non-native land planarian species have been recorded in Belgium: *Anisorhynchodemus* cf. *signata*, *Bipalium kewense*, *Caenoplana coerulea*, *Caenoplana variegata*, *Diversibipalium multilineatum*, *Dolichoplana striata*, *Marionfyfea adventor*, *Obama nungara*, and *Parakontikia ventrolineata*. Distribution data for each species are shown in Fig. 1. *Obama nungara* is the most widespread species.

Table 1. Cutoff values for risk scores used for the Harmonia⁺ risk classification of non-native land planarians in Belgium, adopted from D'hondt et al. (2025).

Color code risk	Risk classification	Invasion risk score	Environmental risk score	Overall risk score
	Very low	0	0	0
	Low	]0, 0.397]	]0, 0.172]	]0, 0.294]
	Medium	]0.397, 0.478]	]0.172, 0.237]	]0.294, 0.375]
	High	]0.478, 0.593]	]0.237, 0.315]	]0.375, 0.472]
	Very high	]0.593, 1]	]0.315, 1]	]0.472, 1]

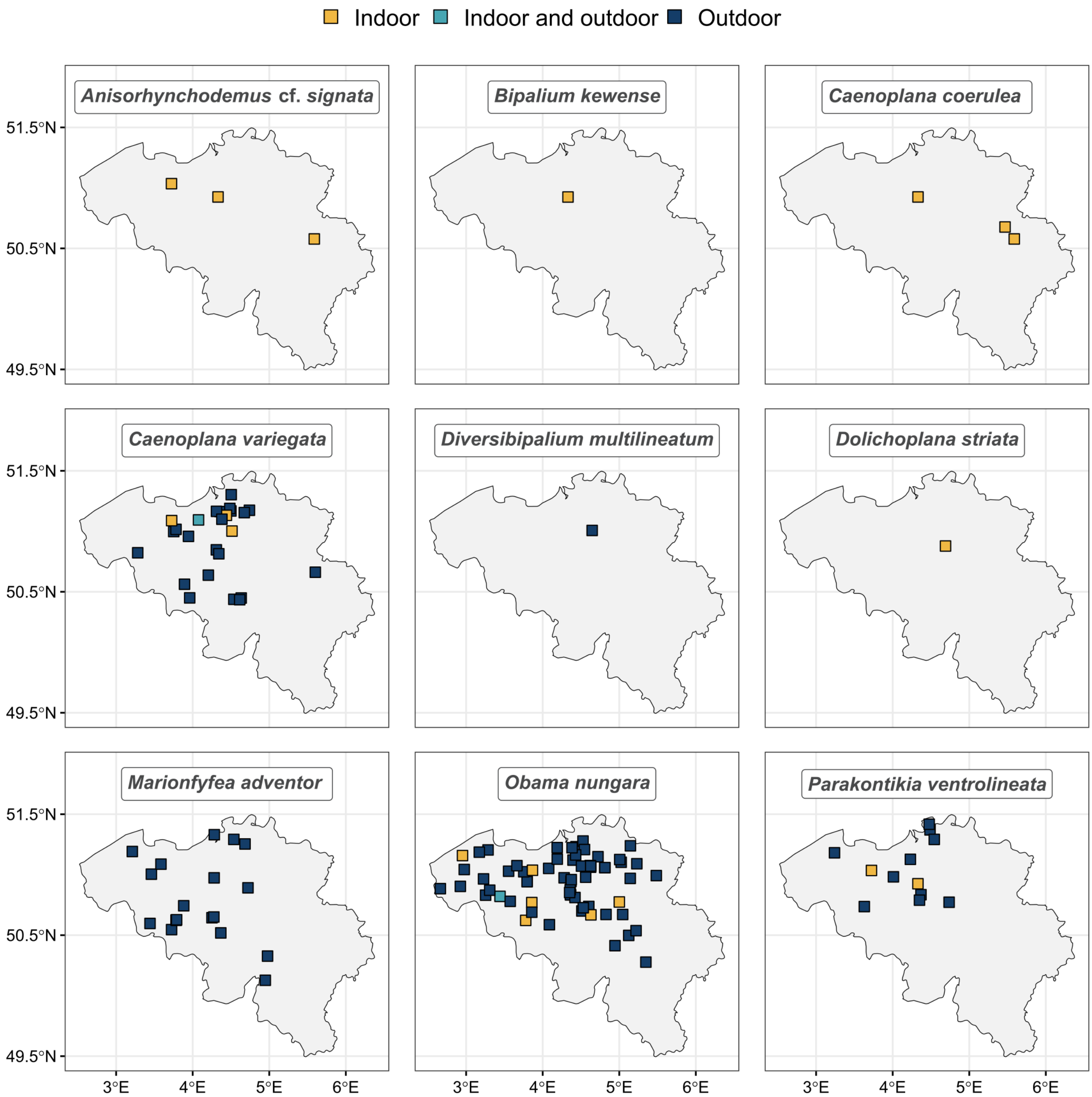

Figure 1. Distribution of the nine non-native land planarian species recorded in Belgium through 31 December 2025.

Anisorhynchodemus cf. *signata* (von Graff, 1899)

Note. Planarians with the external characteristics of *Anisorhynchodemus signata* (von Graff, 1899), except for length, were first found in Belgium on 29 May 2019 in the tropical rainforest glasshouse of Meise Botanic Garden (50°55'31.0"N, 4°19'51.3"E). Subsequently, *A.* cf. *signata* has been observed on multiple occasions in this glasshouse and in the anthropogenic biome glasshouse. On 23 November 2022, *A.* cf. *signata* was found in the Victoria glasshouse of the Ghent University Botanical Garden (51°02'06.2"N, 3°43'22.3"E). On 14 May 2025, a specimen of *A.* cf. *signata* was found in the glasshouse of the University of Liège at Domaine du Sart Tilman in Angleur (50°34'41.2"N, 5°35'16.5"E). In most cases, *A.* cf. *signata* was found on damp, bare soil. *Anisorhynchodemus* cf. *signata* was first reported in Belgium as *Dolichoplana* cf. *signata* (Van den Neucker et al. 2020). This may explain why Thunnissen et al. (2022) grouped this species with *Dolichoplana* sp. in their checklist of non-native planarians in Europe. However, Belgian specimens of *A.* cf. *signata* are much smaller (up to approximately 16 mm in stretched length) than the specimen described by von Graff (1899) (100 mm) and have a single dark dorsal line, whereas *Dolichoplana* sp. from the Netherlands is larger (up to 110 mm) and has five parallel dorsal lines (Thunnissen et al. 2022: fig. 1G). In addition, *Anisorhynchodemus* sp. depicted in Thunnissen et al. (2022: fig. 1A) differs from *A.* cf. *signata* in having a dark, almost black body with two parallel pale dorsal lines. In Belgium, *A.* cf. *signata* appears to be restricted to heated glasshouses. The glasshouses in the botanical gardens of Meise and Ghent maintain tropical regimes with air humidity > 70%.

Distribution. *Anisorhynchodemus signata* was originally described from Indonesia (von Graff 1899). Introduced specimens of *A.* cf. *signata* have been reported from Australia, Israel, Italy, and the USA (Mienis 2022a; Mori et al. 2022a; iNaturalist 2025; Mienis and Vaisman 2025a). A specimen reported from Israel was found in a commercial shipment of mosses from the Netherlands (Mienis and Vaisman 2025a), where the species has thus far not been detected (Thunnissen et al. 2022; de Waart et al. 2025).

Prey preference. The prey preference of *A.* cf. *signata* is largely unknown, but gastropods are part of its diet because it has been observed feeding on *Eopolita protensa jebusitica* (J. R. Roth, 1855) (Mienis 2022a).

Bipalium kewense Moseley, 1878

Note. The earliest Belgian records of *B. kewense* date to December 1906 and are from the Ghent University Botanical Garden (Van De Woestijne 1907). However, the species has not subsequently been reported from Ghent. On 29 May 2019, *B. kewense* was discovered in the anthropogenic biome glasshouse of Meise Botanic Garden (50°55'29.1"N, 4°19'49.2"E) (Van den Neucker et al. 2020). Subsequently, *B. kewense* has been found on several other occasions in both the anthropogenic biome and rainforest glasshouses, on bare ground, among leaf litter, and under wooden planks. In Belgium, the species has thus far been found only in glasshouses with tropical temperatures and high humidity.

Distribution. *Bipalium kewense* was first described from Kew Gardens (UK) (Winsor 1983) but probably originates from Southeast Asia. Currently, the species occurs in at least 78 countries worldwide (de Luna et al. 2022; Boll and de Luna 2025; Gastineau et al. 2025b; iNaturalist 2025), most likely through the transport of potted plants. In tropical and subtropical regions, *B. kewense* can survive in outdoor environments. In Europe, it has been found outdoors in France, Italy, Portugal (including the Azores and Madeira), and Spain (including the Canary Islands), but in temperate regions, it seems to be found most commonly in heated glasshouses. In Austria, Germany, the Netherlands, and Sweden, it has been found exclusively in heated glasshouses, although detailed information about older records is often lacking (Marcus and Marcus 1959; Winsor 1983; Sanchez-García 2014; Sluys 2016; Justine et al. 2018, 2024b; Fourcade et al. 2022; Thunnissen et al. 2022; Glaw et al. 2024; de Waart et al. 2025; Gastineau et al. 2025b; iNaturalist 2025; Bouguerche et al. 2026).

Prey preference. *Bipalium kewense* feeds on earthworms and other invertebrates (Justine et al. 2018; Thunnissen et al. 2022).

Caenoplana coerulea Moseley, 1877

Note. Land planarians belonging to the *Caenoplana coerulea* species complex (Álvarez-Presas et al. 2014; Mori et al. 2023) were recorded for the first time in Belgium on 6 March 2019 in the research glasshouses of Meise Botanic Garden (50°55'30.4"N, 4°19'49.7"E). Thereafter, multiple observations were reported from the anthropogenic biome and Victoria glasshouses in Meise. From 26 May 2021 onward, *Caenoplana coerulea* was also found on three occasions in the glasshouse of the University of Liège at Domaine du Sart Tilman in Angleur, and a single observation was reported from a garden center. The specimen from the garden center was found in a plant pot from Italy, where *C. coerulea* has not yet been detected. The species has been found in and under plant pots, on bare soil, among leaf litter, and under wooden planks. All Belgian records of *C. coerulea* are indoor observations.

Distribution. *Caenoplana coerulea* is native to eastern Australia and has been introduced to Western Australia, Lord Howe Island, Norfolk Island, New Zealand, Canada, the USA, Mexico, Argentina, South Africa, and Israel. In Europe, *C. coerulea* has been introduced to Austria, Denmark, France, Germany, Greece, Italy, the Netherlands, Portugal (including the Azores), Spain (including Menorca and the Canary Islands), and the UK (Negrete et al. 2011; Breugelmans et al. 2012; Sluys 2016; Suárez et al. 2018; Mienis 2022b; Mori et al. 2022a; Thunnissen et al. 2022; de Luna and Boll 2023; de Waart and Thunnissen 2023; Glaw et al. 2024; Justine et al. 2024b; Boll and de Luna 2025; iNaturalist 2025).

Prey preference. *Caenoplana coerulea* feeds on a variety of invertebrates, including earthworms, isopods, diplopods, earwigs, beetles, dipteran larvae, and snails (Negrete et al. 2011; Álvarez-Presas et al. 2014).

Caenoplana variegata (von Graff, 1899)

Note. *Caenoplana variegata* was first observed in Belgium on 22 April 2015 in a private garden in Hamme (51°05'38.5"N, 4°04'34.0"E) (Soors et al. 2017). Multiple observations have been reported from Hamme. Currently, the species is known from 25 localities in Belgium. Most of these are outdoor observations from private gardens, but the species has also been found indoors in private houses, glasshouses, and verandas. The species has been observed under wooden planks, plant pots, and other man-made objects, as well as on stone tiles and damp soil.

Distribution. *Caenoplana variegata* is native to Australia and has been introduced to Austria, Croatia, France, Germany, Gibraltar, Greece, Ireland, Italy, the Netherlands, Spain, Sweden, Switzerland, the UK, Morocco, and Russia (Sluys 2016; Vardinoyannis and Alexandrakis 2019; Mori et al. 2022a; Thunnissen et al. 2022; Glaw et al. 2024; Justine et al. 2024b; iNaturalist 2025; Bouguerche et al. 2026).

Prey preference. *Caenoplana variegata* feeds on a variety of invertebrates, including isopods and spiders (Jones et al. 2020).

Diversibipalium multilineatum (Makino & Shirasawa, 1983)

Note. *Diversibipalium multilineatum* has been observed only once in Belgium, in a private garden in Keerbergen (51°00'26.1"N, 4°38'46.3"E). On 22 September 2024, a single specimen was found under dead wood in tall grass.

Distribution. The species is native to Japan and occurs as an introduced species in Austria, Croatia, France, Germany, Hungary, Italy, the Netherlands, Slovenia, Switzerland, Türkiye, the USA, and South Korea (Mazza et al. 2016; Sluys 2016; Justine et al. 2018, 2024b; Fourcade et al. 2022; Mori et al. 2022a; Thunnissen et al. 2022; Lazányi et al. 2024; iNaturalist 2025; Ritter 2025).

Prey preference. *Diversibipalium multilineatum* feeds on earthworms (Thunnissen et al. 2022).

Dolichoplana striata Moseley, 1877

Note. Thus far, only two Belgian records of *Dolichoplana striata* exist. On 30 November 2019, a single specimen was found on waterlogged silty soil along the edge of an indoor pond in the Orangery of the Hortus Botanicus Lovaniensis (50°52'41.9"N, 4°41'23.8"E), the botanical garden of Leuven (Van den Neucker et al. 2020). Another specimen was found on 27 December 2025 at the same location. The glasshouse in Leuven where the specimens were found has a tropical regime.

Distribution. *Dolichoplana striata* originates from Indonesia and Malaysia and has been introduced to several other Asian countries, including China, India, the Philippines, Sri Lanka, Thailand, and Vietnam. It also occurs as a non-native species on several Caribbean islands, in French Guiana, in most Central American countries from Panama to Mexico, and in the USA, including Hawaii. It has also been introduced to South Africa, Comoros, Mayotte, Réunion Island, Australia, Fiji, French Polynesia, and New Caledonia. In Europe, *D. striata* has been introduced to glasshouses in Bulgaria, Denmark, Germany, Ireland, Italy, Jersey, Slovakia, Spain, and the UK (Pfitzner 1956, 1958; Anderson 1986; Sluys 2016; Brown et al. 2022; Mori et al. 2022b; Thunnissen et al. 2022; de Luna and Boll 2023; Glaw et al. 2024; Justine et al. 2024b; Boll and de Luna 2025; iNaturalist 2025; Simov et al. 2025).

Prey preference. The species feeds on earthworms (Thunnissen et al. 2022).

Marionfyfea adventor Jones & Sluys, 2016

Note. The first Belgian record of *Marionfyfea adventor* occurred on 20 February 2021 in Merendree (51°05'13,9"N, 3°35'08,2"E) (Soors et al. 2022). The species is currently reported from 19 localities. It has been found on limestone, stone tiles, tree bark, and under dead wood, mostly in private gardens (five localities) and woodland areas (nine localities). On one occasion, it was found on driftwood along the Scheldt River (Soors 2024). In Belgium, *M. adventor* has been reported only from outdoor environments.

Distribution. The exact origins of *M. adventor* are unknown (Jones and Sluys 2016), but it is considered an introduced species in Denmark, France, Germany, Ireland, the Netherlands, Spain, and the UK (Thunnissen et al. 2022; Glaw et al. 2024; Justine et al. 2024b; Rojo et al. 2024; iNaturalist 2025).

Prey preference. The prey preference of *M. adventor* was previously unknown. However, Belgian citizen scientists have photographed *M. adventor* feeding on several small gastropods: the snails *Alinda biplicata* (Montagu, 1803) (Fig. 2) and *Vitrina pellucida* (O.F. Müller, 1774), and a slug belonging to the *Arion hortensis* A. Férussac, 1819 species complex (Callens 2022; Bronne 2024; Hindricq 2024; Salmon 2024).

Figure 2. *Marionfyfea adventor* feeding on *Alinda biplicata* (photo: Louis Bronne).

Obama nungara Carbayo, Álvarez-Presas, Jones & Riutort, 2016

Note. *Obama nungara* was first found in Belgium on 15 June 2017 in Elsene (50°50'2.8"N, 4°21'52.0"E) (Soors et al. 2019). It is the most widespread non-native land planarian in Belgium and is currently reported from 63 localities. These localities mainly include private gardens or courtyards (30 localities) and plant nurseries or garden centers (29 localities). The species has mostly been observed outdoors, but indoor observations have also been reported from glasshouses at five localities and private houses at two localities. Citizen scientists photographed *O. nungara* on a variety of hard surfaces, such as stone tiles, bricks, concrete, and wooden planks; on plastic plant pots and trays; and on geotextile and damp soil (iNaturalist 2025; Waarnemingen.be 2025).

Distribution. *Obama nungara* is probably native to Brazil and Argentina (Lago-Barcia et al. 2015, 2019; Negrete et al. 2020) and has been reported outside its native range from Austria, Bulgaria, Croatia, the Czech Republic, France, Finland, Germany, Greece, Guernsey, Hungary, Ireland, Italy, Malta, the Netherlands, Portugal (including the Azores and Madeira), Slovakia, Sweden, Switzerland, Slovenia, Spain, Türkiye, the UK, Réunion Island, and the USA (Carbayo et al. 2016; Lago-Barcia et al. 2019, 2020; Justine et al. 2020, 2022, 2024a, 2024b; Čapka and Čejka 2021; Thunnissen et al. 2022; Mori et al. 2023; Cilia 2024; Glaw et al. 2024; Lazányi et al. 2024; Bouguerche et al. 2025; de Waart et al. 2025; Greilhuber et al. 2025; iNaturalist 2025; Mienis and Vaisman 2025b; Antonova et al. 2026). *Obama nungara* has recently been reported from Israel, where it was detected in a plant shipment originating from the Netherlands (Mienis and Vaisman 2025b).

Prey preference. The species feeds on a variety of invertebrates, including gastropods, earthworms, and other planarians (Boll and Leal-Zanchet 2016; Roy et al. 2022).

Parakontikia ventrolineata (Dendy, 1892)

Note. *Parakontikia ventrolineata* has thus far been reported from 12 localities in Belgium. The first Belgian record dates from 26 February 2017 at the Victoria glasshouse of the Ghent University Botanical Garden. On 30 May 2019, the species was reported from the tropical glasshouse of Meise Botanic Garden (Van den Neucker et al. 2020). *Parakontikia ventrolineata* was subsequently reported repeatedly from both botanical gardens, where it is commonly found under plant pots, on bare soil, and among leaf litter and wood chips. In addition, from 11 May 2019 onward, several outdoor observations of *P. ventrolineata* were recorded, including one from a plant nursery, six from private gardens, and three from woodland areas. Citizen scientists photographed *P. ventrolineata* outdoors on stone, wood, and soil (iNaturalist 2025; Waarnemingen.be 2025).

Distribution. *Parakontikia ventrolineata* is native to Australia and has been introduced to Fiji, Lord Howe Island, New Zealand, France, Germany, Ireland, Italy, the Netherlands, Portugal (including Madeira), Spain, the UK, Réunion Island, South Africa, Brazil, Chile, Colombia, Costa Rica, Ecuador, Mexico, Canada, and the USA, including Hawaii (Sanchez-García 2014; Sluys 2016; Thunnissen et al. 2022; Kappes 2023; Justine et al. 2024b; Mori et al. 2024; iNaturalist 2025).

Prey preference. The species feeds on a variety of invertebrates, including isopods, earthworms, and gastropods (Álvarez-Presas et al. 2014).

Climate matching

Under current climatic conditions in Belgium and future projections for the period 2041–2070, climate-matching percentages (Table 2) were highest for *Arthurdendyus triangulatus*, *Marionfyfea adventor*, *Caenoplana variegata*, and *Obama nungara*. Climate-matching percentages were low for *Platydemus manokwari*, *Dolichoplana striata*, *Bipalium kewense*, and *Diversibipalium multilineatum*. For the period 2041–2070, there were no differences in climate-matching percentages among the different SSPs (Beck et al. 2023). However, using the climate projections for the period 2071–2099, climate-matching percentages under the high-emissions scenario SSP3-7.0 and the very-high-emissions scenario SSP5-8.5 decreased for *A. triangulatus*, *Caenoplana coerulea*, *C. variegata*, *M. adventor*, *O. nungara*, and *Parakontikia ventrolineata*, whereas climate-matching percentages increased for *B. kewense*, *D. multilineatum*, *D. striata*, and *P. manokwari* (Table 2; Suppl. material 1). *Anisorhynchodemus* cf. *signata* was excluded from the climate-matching analyses because there were fewer than 20 records of this species in GBIF (2025).

Harmonia⁺ risk assessment

The invasion, environmental, and overall risk scores are presented in Table 3. Scores, confidence levels, and classifications for each Harmonia⁺ module (introduction, establishment, spread, environment, plants, animals, humans, and other) are provided in the supplementary material (Suppl. material 2). *Obama nungara* is the only non-native land planarian that received a very high environmental risk score, resulting from a very high invasion risk score and a medium environmental impact score. Note that the environmental and overall risk scores are identical for all species (Table 3), although their risk classifications differ (Table 1). The overall risk scores were classified as medium for *D. multilineatum* and *O. nungara* and as low for all other species.

Table 2. Climate-matching percentages for the non-native land planarians recorded in Belgium, as well as for *Arthurdendyus triangulatus* and *Platydemus manokwari*. Percentages are shown for current climatic conditions in Belgium and future climate projections under four SSPs (Beck et al. 2023) (n.d. = no data). Percentages > 50% are highlighted in bold.

Taxon	Current climate	Climate projection 2041–2070				Climate projection 2071–2099			
		SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5	SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Anisorhynchodemus cf. *signata*	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Arthurdendyus triangulatus	**99.9**	**99.9**	**99.9**	**99.9**	**99.9**	**99.9**	**99.9**	**69.7**	10.7
Bipalium kewense	6.8	6.8	6.8	6.8	6.8	6.8	6.8	24.4	**58.7**
Caenoplana coerulea	48.8	48.8	48.8	48.8	48.8	48.8	48.8	44.1	35
Caenoplana variegata	**74.5**	**74.5**	**74.5**	**74.5**	**74.5**	**74.5**	**74.5**	**57.6**	24.5
Diversibipalium multilineatum	12.5	12.5	12.5	12.5	12.5	12.5	12.5	33.8	**75.4**
Dolichoplana striata	1.9	1.9	1.9	1.9	1.9	1.9	1.9	8.6	21.9
Marionfyfea adventor	**95.8**	**95.8**	**95.8**	**95.8**	**95.8**	**95.8**	**95.8**	**66.9**	10.2
Obama nungara	**68.5**	**68.5**	**68.5**	**68.5**	**68.5**	**68.5**	**68.5**	**52.9**	22.5
Parakontikia ventrolineata	**53.7**	**53.7**	**53.7**	**53.7**	**53.7**	**53.7**	**53.7**	39.7	12.4
Platydemus manokwari	0.2	0.2	0.2	0.2	0.2	0.2	0.2	8	23.4

Table 3. Harmonia+ risk assessment scores for the non-native land planarians reported from indoor and outdoor environments in Belgium, as well as for *Arthurdendyus triangulatus* and *Platydemus manokwari*. Risk classifications and color coding are explained in Table 1. Information on their presence in indoor and outdoor environments in Belgium is also provided.

Taxon	Indoor records in Belgium	Outdoor records in Belgium	Invasion risk score	Environmental risk score	Overall risk score
Anisorhynchodemus cf. *signata*	yes	no	0.397	0.099	0.099
Arthurdendyus triangulatus	no	no	0.471	0.235	0.235
Bipalium kewense	yes	no	0.538	0.179	0.179
Caenoplana coerulea	yes	no	0.679	0.226	0.226
Caenoplana variegata	yes	yes	0.747	0.187	0.187
Diversibipalium multilineatum	no	yes	0.617	0.308	0.308
Dolichoplana striata	yes	no	0.397	0.132	0.132
Marionfyfea adventor	no	yes	0.747	0.187	0.187
Obama nungara	yes	yes	0.747	0.373	0.373
Parakontikia ventrolineata	yes	yes	0.593	0.197	0.197
Platydemus manokwari	no	no	0.428	0.250	0.250

Discussion

Thus far, nine non-native land planarians have been observed in Belgium. Five of these, *Caenoplana variegata*, *Diversibipalium multilineatum*, *Marionfyfea adventor*, *Obama nungara*, and *Parakontikia ventrolineata*, were reported from outdoor environments.

Land planarians reported from outdoor environments

Obama nungara is the most widespread species and is the only species that received a very high environmental risk score, resulting from a very high invasion risk score and a medium environmental impact score. Its overall risk was classified as medium. The species is found almost exclusively in gardens, courtyards, garden centers, and plant nurseries (Waarnemingen.be 2025). Therefore, it is highly likely that dispersal through the transport of potted plants and topsoil is its main means of introduction and secondary spread. French and Dutch populations of *O. nungara* may be capable of reaching Belgium without human intervention, as there are outdoor observations of the species near the Belgian border in France (Justine et al. 2024b) and the Netherlands (de Waart et al. 2025; Waarneming.nl 2025). However, man-made and natural obstacles such as roads, canals, and rivers may limit its capacity to spread by natural means. Moreover, movement over longer distances may be possible only under humid conditions because land planarians are sensitive to desiccation (Winsor et al. 2004; Murchie and Justine 2021). Nonetheless, *O. nungara* already appears to be firmly established in Belgium. Predictions from species distribution models suggest that the species tolerates a broad climatic range and that the Belgian climate is suitable for *O. nungara* (Negrete et al. 2020; Fourcade 2021). These findings are consistent with our climate-matching analysis. The private gardens and plant nurseries where *O. nungara* occurs likely provide ample refuges and suitable prey. *Obama nungara* feeds on gastropods and earthworms (Boll and Leal-Zanchet 2016; Noël et al. 2026), including deep-dwelling (endogeic) earthworms (Roy et al. 2022). Earthworms are beneficial soil organisms because they play a major role in soil aeration, drainage, and nutrient recycling (Edwards and Arancon 2022; Gérard et al. 2025). Gastropods may also play an important role in plant decomposition, nutrient recycling, and soil formation (Stephenson 1968; Keller and Snell 2002; Buschmann et al. 2005; Kappes 2006). Predation on earthworms and gastropods may therefore affect soil properties, with cascading effects on the food web. However, a qualitative model by Fourcade et al. (2025) suggests that the soil ecosystem is resilient to invasion by *O. nungara*, although the authors emphasize that several improvements to the model are needed to enhance its predictive accuracy. Nonetheless, *O. nungara* can attain high densities in gardens (cumulative abundances of up to 1,585 individuals per month), and its populations can rebound after dry periods (Noël et al. 2025). Moreover, the opportunistic feeding behavior of *O. nungara*, along with its ability to shrink to survive starvation and produce egg capsules after several weeks in isolation, may add to its invasive potential (Noël et al. 2026).

Diversibipalium multilineatum, another species found outdoors in Belgium, received a high environmental risk score, and its overall risk was classified as medium. Its invasion risk was scored slightly lower than that of *O. nungara* because *D. multilineatum* is not as widespread and has not yet been detected close to the Belgian border in neighboring countries (Justine et al. 2024b; de Waart et al. 2025; Waarneming.nl 2025), making additional introductions into Belgium by natural means less likely. Records from Belgium and the Netherlands (de Waart 2022) are from gardens, suggesting that the horticultural trade is the most likely pathway of introduction. There is some uncertainty as to whether the Belgian climate is suitable for *D. multilineatum*. Our climate-matching analysis showed very low climatic similarity between the current distribution of *D. multilineatum* and both the present climate in Belgium and the projected conditions for 2041–2070. These findings are supported by predictions from species distribution models, which suggest that the current Belgian climate is suboptimal for *D. multilineatum* (Fourcade et al. 2022). Interestingly, most European records of *D. multilineatum* are outdoor observations, and the species appears to be expanding its range northward (de Waart et al. 2025), which contributes to the uncertainty regarding its climatic tolerance. *Diversibipalium multilineatum* received a medium environmental impact score, although it was assigned a low confidence level because little information has been published on its prey preferences and predation rate. According to Thunnissen et al. (2022), *D. multilineatum* feeds on earthworms. Because it is a large species, it may be capable of preying on a wide variety of earthworms.

The three other non-native land planarians that occur outdoors in Belgium, *Caenoplana variegata*, *Marionfyfea adventor*, and *Parakontikia ventrolineata*, were given medium environmental risk scores, resulting from very high invasion risk scores and very low environmental impact scores. The horticultural trade is the most likely introduction pathway for *C. variegata*, *M. adventor*, and *P. ventrolineata* because *C. variegata* was found almost exclusively in private gardens, and a large proportion of the observations of *M. adventor* and *P. ventrolineata* were also from private gardens. *Caenoplana variegata* occurs near the Belgian border in France (Justine et al. 2024b) and the Netherlands (Waarneming.nl 2025), and *M. adventor* has been found at two localities near the Belgian border in the Netherlands (Waarneming.nl 2025). Therefore, additional specimens of *C. variegata* and *M. adventor* may reach Belgium by hitchhiking on equipment and materials stored near and transported across the border or even without human intervention. However, their capacity to spread by natural means was rated as low because of the presence of man-made and natural obstacles and their sensitivity to desiccation (Winsor et al. 2004; Murchie and Justine 2021). Nonetheless, the low score was assigned with a low confidence level because *M. adventor* and *P. ventrolineata* have been found in woodland areas, which may suggest that they can spread naturally, although it cannot be ruled out that they were introduced into such areas through discarded garden waste or forestry equipment. The occurrence of *M. adventor* on driftwood in a tidal marsh of the Scheldt River suggests that the species can spread without human assistance. During a spring tide, a single ebb or flow phase can move an object up to 20 km upstream or downstream in the Scheldt River (Meire et al. 2005). Transport by domestic animals may contribute to the spread of *C. variegata* (Justine and Winsor 2026). *Caenoplana variegata*, *M. adventor*, and *P. ventrolineata* are likely already firmly established in Belgium because these species have been repeatedly observed outdoors and their climate-matching percentages were high. Whereas *C. variegata* is found mostly in private gardens, *M. adventor* and *P. ventrolineata* occur in a variety of outdoor environments. Refuges and suitable prey items are likely abundant in private gardens and (semi)natural environments in Belgium. The environmental impact of *C. variegata* and *M. adventor* was scored as very low, mainly because they do not feed on earthworms and therefore probably do not substantially affect abiotic soil properties, such as soil structure or drainage. *Caenoplana variegata* feeds mostly on isopods (Jones et al. 2020), and photographic evidence provided by citizen scientists suggests that *M. adventor* feeds on small gastropods. Both *C. variegata* and *M. adventor* may therefore adversely affect the biotic properties of the soil because isopods and gastropods play an important role in plant decomposition, nutrient recycling, and soil formation (Stephenson 1968; Keller and Snell 2002; Buschmann et al. 2005; Kappes 2006; Špaldoňová and Frouz 2014; Jia et al. 2015; Yang et al. 2020). In addition, as a predator of small gastropods, *M. adventor* could potentially prey on *Vertigo angustior* Jeffreys, 1830 and *V. moulinsiana* (Dupuy, 1849), which are both listed in Annex II of the Habitats and Species Directive [92/43/EEC]. *Parakontikia ventrolineata* preys on earthworms, although not exclusively (Álvarez-Presas et al. 2014). Because it likely preys only on small prey, its effects on abiotic soil properties may be less severe than those of larger land planarians.

Land planarians only observed in heated glasshouses

Four non-native land planarians, *Anisorhynchodemus* cf. *signata*, *Bipalium kewense*, *Caenoplana coerulea*, and *Dolichoplana striata*, were observed exclusively in heated glasshouses in Belgium. *Bipalium kewense* and *C. coerulea* received medium environmental risk scores. The invasion risk score was high for *B. kewense* and very high for *C. coerulea*. The latter received a slightly higher invasion risk score, partly because there is a single record of *C. coerulea* close to the Belgian border in France (Justine et al. 2024b). Outdoor populations of *B. kewense* have not yet been found close to the Belgian border in neighboring countries (Glaw et al. 2024; Justine et al. 2024b; de Waart et al. 2025; Waarneming.nl 2025). Both species were most likely accidentally introduced via potted plants. There are multiple potential sources of introduction because *B. kewense* and *C. coerulea* occur at multiple locations in Europe, mainly in southern regions (Fourcade et al. 2022; Justine et al. 2024b; de Waart et al. 2025). Potentially suitable habitats for *B. kewense* and *C. coerulea* are present throughout Belgium, but differences in their potential to survive the Belgian climate contributed to the slight difference in their invasion risk scores. According to the climate-matching model of Fourcade et al. (2022), conditions in Belgium are suboptimal for *B. kewense*. In accordance with these predictions, our analysis shows a low match between the species' current climatic distribution and the current Belgian climate. In addition, *B. kewense* has been present for more than a century in glasshouses in Belgium and neighboring countries (Winsor 1983), whereas European outdoor populations appear to be restricted to France, Italy, Portugal, and Spain (de Waart et al. 2025). *Caenoplana coerulea* is native to eastern Australia, but the Belgian climate may be suitable for the species because it occurs at high elevations in the Australian Alps (Camac et al. 2021) and has been recorded outdoors near the Belgian border in France (Justine et al. 2024b). Our climate-matching analysis suggests that *C. coerulea* is likely able to tolerate Belgian climatic conditions, as nearly half of its GBIF occurrences were recorded in climate zones present in Belgium. However, European outdoor records of *C. coerulea* appear to be concentrated mainly in southern regions (Justine et al. 2024b). Secondary spread of *B. kewense* and *C. coerulea* by natural means would probably be limited because of man-made and natural obstacles, but there is some uncertainty regarding the potential spread rate of *C. coerulea*. Garrick et al. (2012) suggested that it has the capacity to persist in and disperse through moderately dry microhabitats. The environmental impact score was very low for *B. kewense* and *C. coerulea*, mainly because neither species feeds exclusively on earthworms (Negrete et al. 2011; Álvarez-Presas et al. 2014; Justine et al. 2018; Thunnissen et al. 2022). Consequently, it is unknown to what extent predation by *B. kewense* and *C. coerulea* may adversely affect earthworm populations or other invertebrates. *Anisorhynchodemus* cf. *signata* and *D. striata* both received very low environmental risk scores because of their respective invasion risk scores and very low environmental impact scores. A medium invasion risk score was assigned to *A.* cf. *signata* because, thus far, it has not been found in any country neighboring Belgium. There is only one other European record of *A.* cf. *signata* from a glasshouse in Italy (Mori et al. 2022a), and there are few records worldwide (Mienis 2022a; iNaturalist 2025; Mienis and Vaisman 2025a), which may indicate that there are few potential sources of introduction. However, its detection in a commercial shipment of mosses (Mienis and Vaisman 2025a) and its presence in at least three botanical garden glasshouses in Belgium suggest that the species can spread via plant exchange and could inadvertently be introduced outside the glasshouses when plants and potting soil are discarded. Detection of *A.* cf. *signata* may be challenging because specimens reported outside its natural range have never exceeded approximately 30 mm in length (Mienis 2022a; iNaturalist 2025). Uncertainty regarding its tolerance of cooler outdoor environments also contributed to the medium invasion risk score. The Belgian records of *A.* cf. *signata* are all from heated glasshouses, but there are also outdoor records from a humid subtropical climate (Köppen–Geiger Cfa) in the USA and from Mediterranean climates in Australia and Israel (Köppen–Geiger Csa) (Beck et al. 2023; Mienis 2022a; iNaturalist 2025). The environmental impact score of *A.* cf. *signata* was very low because the species does not appear to attain a large size in Belgium and therefore likely feeds exclusively on small invertebrates, so its predation probably has a limited effect on ecosystem integrity. Thus far, *A.* cf. *signata* has been observed feeding only on small gastropods (Mienis 2022a). Potentially, *A.* cf. *signata* could prey on the *Vertigo* O.F. Müller, 1773 snail species listed in Annex II of the Habitats and

Species Directive [92/43/EEC]. The Harmonia+ risk assessment resulted in a low invasion risk score for *Dolichoplana striata* for reasons similar to those for *A.* cf. *signata*. The introduction and spread risks of *D. striata* are probably limited because the species has been observed only twice in Belgium, both times in a heated botanical garden glasshouse. The European records of *D. striata* closest to Belgium are from glasshouses in Germany (Pfitzner 1956, 1958; Glaw et al. 2024; Justine et al. 2024b). European observations of *D. striata* remain rare and are limited to glasshouses (Álvarez-Presas et al. 2014; Mori et al. 2022b; Glaw et al. 2024). The establishment risk of *D. striata* is probably low in outdoor environments because, according to Justine et al. (2024b), the species prefers a tropical climate. Accordingly, the potential impact of *D. striata* received a very low score, although it was slightly higher than that of *A.* cf. *signata* because *D. striata* is a larger species and preys on earthworms (Thunnissen et al. 2022; Justine et al. 2024b). However, *D. striata* never reaches high densities in the French overseas territories (Justine et al. 2024b), so its potential impact on earthworm populations is uncertain.

Land planarians of Union Concern not yet observed in Belgium

Arthurdendyus triangulatus and *Platydemus manokwari* do not occur in Belgium, but they were included in the Harmonia+ risk assessment because of their status as highly invasive species and their inclusion in the list of Union Concern (Lowe et al. 2000; European Commission, Directorate-General for Environment 2019, 2025). *Arthurdendyus triangulatus* received a medium environmental risk score, resulting from a medium invasion risk score and a medium environmental impact score. *Platydemus manokwari* received a high environmental risk score, resulting from a medium invasion risk score and a high environmental impact score. The medium invasion risk scores for both species were partly due to the fact that *A. triangulatus* and *P. manokwari* cannot reach Belgium by natural means because there are no populations on the European mainland. Established non-native populations of *A. triangulatus* occur in the UK, Ireland, and the Faroe Islands (Cannon et al. 1999), and *P. manokwari* occurs in Australia, on several Pacific islands, in the French Antilles, and in Florida (Justine et al. 2014, 2015, 2021, 2024b). It is reasonable to assume that *A. triangulatus* and *P. manokwari* can be introduced through horticultural activities. However, the risk of introduction through human activities appears to be low because *A. triangulatus* was discovered in the UK in 1963 (Cannon et al. 1999) and has never been detected on the European mainland, whereas *P. manokwari* has been observed only once in Europe, in 2013 (Justine et al. 2014), and has not been reported since (Justine et al. 2024b). Horticulturists may be vigilant regarding the potential presence of *A. triangulatus* because the species has been included in the UK Wildlife and Countryside Act since 1992, and a Code of Practice for nursery stock producers and traders recommends specific measures to reduce the risk of non-indigenous land planarians being introduced into or spread between plant nurseries or garden centers (Cannon et al. 1999). Awareness of the potential invasiveness of *P. manokwari* may have increased after it was included in an often-cited list containing a selection of the world's worst invasive alien species (Lowe et al. 2000), which is considered a valuable communication tool (Luque et al. 2014). *Arthurdendyus triangulatus* was included in the list of invasive alien species of Union Concern in 2019 (European Commission, Directorate-General for Environment 2019), and *P. manokwari* was added in 2025, along with *B. kewense* and *O. nungara* (European Commission, Directorate-General for Environment 2025). The medium invasion risk scores for *A. triangulatus* and *P. manokwari* also resulted partly from their potential establishment risk. Both our climate-matching analysis and predictions made using CLIMEX (Boag et al. 1995a, 1995b; Boag and Yeates 2001) suggest that the current Belgian climate is highly suitable for *A. triangulatus*. The climate in Belgium is similar to that of Britain and Ireland (Beck et al. 2023), where *A. triangulatus* is firmly established (Cannon et al. 1999). Regarding *P. manokwari*, Belgian climatic conditions are probably suboptimal because the species prefers year-round wet, humid conditions (Justine et al. 2014). Moreover, Sugiura (2009) suggested that a temperature of 10 °C may be the minimum threshold for the establishment of *P. manokwari* and hypothesized that low winter temperatures may have restricted the invasion and establishment of the species in temperate countries. However, according to Justine et al. (2014), *P. manokwari* appears to be an upland species that tolerates a broad climatic range, from alpine to tropical climates. In its native range, temperatures may drop to near freezing during the night (Justine et al. 2014). Therefore, it cannot be ruled out that *P. manokwari* could survive in Belgium, although our climate-matching analysis indicated very low similarity between the species' current climatic distribution and the Belgian climate. The spread of *A. triangulatus* and *P. manokwari* by natural means is probably slow (Muniappan 1987; Winsor 1990; Boag and Neilson 2014). *Platydemus manokwari* appears to be incapable of traveling long distances without human intervention, and its spread depends on the transport of potted plants and soil or on deliberate introduction (Winsor 1990; Justine et al. 2014). *Arthurdendyus triangulatus* received a medium environmental impact score because it probably feeds exclusively on earthworms (Cannon et al. 1999), and a decline in earthworm populations may affect ecosystem integrity (Edwards and Arancon 2022; Gérard et al. 2025). The presence of *A. triangulatus* can reduce earthworm densities and pasture grass biomass (Murchie and Gordon 2013; Murchie and Justine 2021). *Platydemus manokwari* received a high environmental impact score because it is a predator of gastropods and other invertebrates and can subdue large prey. It is therefore considered a threat to native snails (Hopper and Smith 1992; Winsor et al. 2004; Justine et al. 2014). Potentially suitable prey species in Belgium may include the Roman snail *Helix pomatia* Linnaeus, 1758, which is listed in Annex V of the EU Habitats Directive.

Monitoring, risk assessment, and management options

The information about the presence and distribution of non-native land planarians in Belgium, along with the Köppen–Geiger climate-matching analyses and the Harmonia⁺ risk assessments presented in this review, can serve as a baseline for further research and monitoring and allow policymakers to develop preventive and mitigating measures and set management priorities. Forecasting the distributions of land planarians remains challenging. Factors such as microclimates, human-mediated transport, biotic interactions, and propagule pressure may strongly affect invasion success (Álvarez-Presas et al. 2014; Fourcade et al. 2022). Despite these uncertainties, the simple Köppen–Geiger climate-matching analysis applied in our study appears to be consistent with published climate-matching and species distribution models (Boag et al. 1995a, 1995b; Boag and Yeates 2001; Fourcade et al. 2022). Although this analysis provides a coarse assessment of climatic suitability, its simplicity and the similarity of our results to those obtained through species distribution modeling suggest that Köppen–Geiger climate matching can serve as a useful tool for first-line risk screening. Management options for land planarians are limited (Justine et al. 2014; Murchie 2017; Murchie and Justine 2021). There are no known biological control methods (Cannon et al. 1999; Murchie 2017), and no pesticides available for land planarians are free of nontarget effects on earthworms (Murchie 2017). A combination of removal trapping, removal of refuges, hot-water treatment, scorching, and turning the soil may be somewhat suitable as eradication or control measures once an invasive land planarian has been introduced. However, the effectiveness of these measures may depend on the extent of the infestation and the habitat suitability and complexity of the area where the species was introduced. Because a substantial proportion of a land planarian population can remain hidden in the soil (Murchie and Harrison 2004) and populations can spread once established (Boag and Neilson 2014), it is uncertain whether eradication or population-control measures will be effective (Blackshaw et al. 1996; Murchie 2017). Considering that Geoplanidae is a highly diverse and species-rich family and that land planarians are primarily introduced unintentionally through the trade in live plants, a two-tier approach could be applied to prevent new introductions: blacklisting selected high-impact invasive flatworm species to which restrictions, surveillance, early-warning, and rapid-response obligations under the EU IAS Regulation apply, and conducting generic biosecurity inspections of live plants by plant health authorities. Our work contributes by providing a broad-scale risk assessment of non-native land planarians in Belgium, but more work is needed to integrate biodiversity and plant health biosecurity regimes.

The role of citizen science in early detection and continued monitoring

Most land planarian observations were reported by citizen scientists on the Waarnemingen.be/Observations.be data platform (Vanreusel et al. 2025; Waarnemingen.be 2025), which includes observations collected in the context of the ongoing FlatwormWatch citizen science project (https://www.iasregulation.be/nl/flatworm-watch). The target audience includes gardeners, naturalists, terrarium hobbyists, visitors to botanical gardens, and the general public, who are asked to look for land planarians in hiding places in gardens or glasshouses and to check potted plants and suitable locations in natural environments. The project provides identification tools, a guide with search guidance, in-person courses and excursions, and feedback to participants through a newsletter. This citizen science project was established in response to the EU Regulation on invasive alien species. It raises awareness of land planarians, both native and alien, and provides a platform for continued monitoring in the wider environment (i.e., post-introduction). However, because it lacks a formal sampling scheme with a firm statistical basis grounded in detection probabilities and focused on sites with propagule pressure or impact, the scheme is relatively passive and only weakly risk-oriented. Because most records originate from private gardens, botanical gardens, and areas around nurseries, the sampling effort is biased, which could be addressed through greater effort or more targeted surveys. Despite these limitations, several new locations and species have been reported in Belgium since the project began, and the resulting data are reported here. In addition, the project yields fragmented information on potential active introduction pathways (e.g., nurseries and specific plant species) and ecology (e.g., photographs of prey). This illustrates the value of citizen science for early detection as a complement to professional monitoring (González-Moreno et al. 2024).

Continued monitoring is important because the nine species reported here may underestimate the actual number of non-native planarians in Belgium, and additional species may be introduced. More species have been found in the neighboring countries of France and the Netherlands (Justine et al. 2024b; de Waart et al. 2025). In addition, several non-native land planarians that occur in Belgium may still be in the early stages of their invasion and may expand their ranges. Our review may provide a basis for developing suitable detection and monitoring methods, as well as rapid-response strategies for high-risk non-native land planarians.

Acknowledgments

FlatwormWatch is an initiative of the National Scientific Secretariat on Invasive Alien Species, with the Royal Belgian Institute of Natural Sciences, Meise Botanic Garden, the Research Institute for Nature and Forest, and Hasselt University as partners. The authors are grateful to all the citizen scientists who shared their observations on Waarnemingen.be/Observations.be or iNaturalist. The authors thank the editor and three anonymous reviewers for their helpful comments and feedback, which greatly improved the manuscript.

References

Álvarez-Presas M, Mateos E, Tudó Á, Jones H, Riutort M (2014) Diversity of introduced terrestrial flatworms in the Iberian Peninsula: a cautionary tale. PeerJ 2: e430. https://doi.org/10.7717/peerj.430

Anderson R (1986) The land planarians of Ireland (Tricladida: Terricola) a summary of distribution records. Irish Naturalists' Journal 22(4): 141–146.

Antonova V, Borissov S, Popova T, Simov N (2026) They are here – *Obama nungara* – another invasive Geoplanidae species newly recorded in Bulgaria (Platyhelminthes: Tricladida). North-Western Journal of Zoology 22(1): 1–7. https://doi.org/10.61215/nwjz.2026.22.1.01

Asato R, Taira K, Nakamura M, Kudaka J, Itokazu K, Kawanaka M (2004) Changing epidemiology of angiostrongyliasis cantonensis in Okinawa Prefecture, Japan. Japanese Journal of Infectious Diseases 57(4): 184–186. https://doi.org/10.7883/yoken.jjid.2004.184

Beck HE, McVicar TR, Vergopolan N, Berg A, Lutsko NJ, Dufour A, Zeng Z, Jiang X, van Dijk AIJM, Miralles DG (2023) High-resolution (1 km) Köppen-Geiger maps for 1901–2099 based on constrained CMIP6 projections. Scientific Data 10: e724. https://doi.org/10.1038/s41597-023-02549-6

Blackshaw RP, Moore JP, Alston R (1996) Removal trapping to control *Artioposthia triangulata*. Annals of Applied Biology 129(2): 355–360. https://doi.org/10.1111/j.1744-7348.1996.tb05758.x

Boag B, Neilson R (2014) The spread and movement of the New Zealand flatworm (*Arthurdendyus triangulatus*) in Scotland. Proceedings of Crop Protection in Northern Britain 2014: 55–59.

Boag B, Yeates GW (2001) The potential impact of the New Zealand flatworm, a predator of earthworms, in western Europe. Ecological Applications 11: 1276–1286. https://doi.org/10.1890/1051-0761(2001)011[1276:tpiotn]2.0.co;2]2.0.CO;2

Boag B, Evans KA, Neilson R, Yeates GW, Johns PM, Mather JG, Christensen OM (1995a) The potential spread of terrestrial planarians *Artioposthia triangulata* and *Australoplana san-*

guinea var. *alba* to continental Europe. Annals of Applied Biology 127: 385–390. https://doi.org/10.1111/j.1744-7348.1995.tb06682.x

Boag B, Evans KA, Yeates GW, Johns PM, Neilson R (1995b) Assessment of the global potential distribution of the predatory land planarian *Artioposthia triangulata* (Dendy) (Tricladida: Terricola) from ecoclimatic data. New Zealand Journal of Zoology 22(3): 311–318. https://doi.org/10.1080/03014223.1995.9518046

Boll PK, de Luna MD (2025) Diversity of land planarians (Platyhelminthes: Tricladida: Geoplanidae) in Central America: Annotated checklist with new records of native and introduced species from citizen science. Zootaxa 5695(1): 1–70. https://doi.org/10.11646/zootaxa.5695.1.1

Boll PK, Leal-Zanchet AM (2016) Preference for different prey allows the coexistence of several land planarians in areas of the Atlantic Forest. Zoology 119: 162–168. https://doi.org/10.1016/j.zool.2016.04.002

Bouguerche C, Roth J, Boström S, Justine J-L (2025) Lövplattmask *Obama nungara* – en invasiv landplanarie funnen i Sverige. Fauna og flora 120(2): 36–45.

Bouguerche C, Justine J-L, Boström S (2026) Fler arter av invasiva landplanarier funna i Sverige – Fauna og flora 121(2): 8–15.

Breugelmans K, Cardona JQ, Artois T, Jordaens K, Backeljau T (2012) First report of the exotic blue land planarian, *Caenoplana coerulea* (Platyhelminthes, Geoplanidae), on Menorca (Balearic Islands, Spain). ZooKeys 199: 91–105. https://doi.org/10.3897/zookeys.199.3215

Bronne L (2024) Data via Waarnemingen.be. https://waarnemingen.be/observation/318675365/ [Accessed 30 November 2024]

Brown MD, Lindo J, Robinson R (2022) First record of exotic terrestrial flatworms (Tricladida: Geoplanidae) *Bipalium vagum* Jones & Sterrer, 2005 and *Dolichoplana striata* Moseley, 1877 with confirmation of *Platydemus manokwari* de Beauchamp, 1963 in Jamaica. BioInvasions Records 11(2): 373–382. https://doi.org/10.3391/bir.2022.11.2.10

Buschmann H, Keller M, Porret N, Dietz H, Edwards PJ (2005) The effect of slug grazing on vegetation development and plant species diversity in an experimental grassland. Functional Ecology 19: 291–298. https://doi.org/10.1111/j.1365-2435.2005.00960.x

Callens W (2022) Data via Waarnemingen.be. https://waarnemingen.be/observation/247486719/ [Accessed 30 June 2024]

Camac JS, Umbers KDL, Morgan JW, Geange SR, Hanea A, Slatyer RA, McDougall KL, Venn SE, Vesk PA, Hoffmann AA, Nicotra AB (2021) Predicting species and community responses to global change using structured expert judgement: An Australian mountain ecosystems case study. Global Change Biology 27(18): 4420–4434. https://doi.org/10.1111/gcb.15750

Cannon RJC, Baker RHA, Taylor MC, Moore JP (1999) A review of the status of the New Zealand flatworm in the UK. Annals of Applied Biology 135(3): 597–614. https://doi.org/10.1111/j.1744-7348.1999.tb00892.x

Čapka J, Čejka T (2021) First record of *Obama nungara* in Slovakia (Platyhelminthes: Geoplanidae). Biodiversity & Environment 13(2): 41–44.

Carbayo F, Álvarez-Presas M, Jones HD, Riutort M (2016) The true identity of *Obama* (Platyhelminthes: Geoplanidae) flatworm spreading across Europe. Zoological Journal of the Linnean Society 177(1): 5–28. https://doi.org/10.1111/zoj.12358

Cardoso JCF, Carbayo F, Gonzaga MO (2023) Land planarians (Platyhelminthes) also prey on web-building spiders. Neotropical Biology and Conservation 18(3): 157–162. https://doi.org/10.3897/neotropical.18.e103322

Cilia DP (2024) On the occurrence of the invasive terrestrial flatworm *Obama nungara* Carbayo, Álvarez-Presas, Jones & Riutort, 2016 (Platyhelminthes Geoplanidae) in the Maltese Islands. Naturalista Siciliano S. IV 48(1): 35–40.

Connella JV, Stern DH (1969) Land planarians: sexuality and occurrence. Transactions of the American Microscopical Society 88: 309–311. https://doi.org/10.2307/3224508

de Luna M, Boll PK (2023) An annotated checklist of terrestrial flatworms (Platyhelminthes: Tricladida: Geoplanidae) from Mexico, with new records of invasive species from a citizen science platform and a new nomen dubium. Zootaxa 5297: 518–532. https://doi.org/10.11646/zootaxa.5297.4.3

de Luna M, García-Barrios R, Valle P, Boll PK (2022) New records of invasive hammerhead flatworms (Platyhelminthes, Geoplanidae, Bipaliinae) from Mexico using a citizen science platform, with an identification key to the species found in North America. Check List 18(5): 925–935. https://doi.org/10.15560/18.5.925

de Waart S (2022) Eerste vondsten van de meerlijnige hamerhoofdplatworm *Diversibipalium multilineatum* in Nederland (Platyhelminthes: Geoplanidae). Nederlandse Faunistische Mededelingen 59: 37–41.

de Waart S, Thunnissen N (2023) Uitheemse landplatwormen in Nederland. Een aanvullende verkenning. Minyoo Advies, Utrecht.

de Waart S, Vanhove M, Kmentová N, Justine J-L (2025) Going Dutch: Invasion pathways and current European distribution of non-native land flatworm species belonging to Geoplaninae and Bipaliinae with focus on the Netherlands. NeoBiota 99: 285–321. https://doi.org/10.3897/neobiota.99.145703

Denny MW (1989) Invertebrate mucous secretions: Functional alternatives to vertebrate paradigms. In: Chantler E, Ratcliffe NA (Eds) Symposia for Experimental Biology, no. XLIII, Mucus and related topics. The Company of Biologists: 337–366.

D'hondt B, Vanderhoeven S, Roelandt S, Mayer F, Versteirt V, Adriaens T, Ducheyne E, San Martin G, Grégoire JC, Stiers I, Quoilin S, Cigar J, Heughebaert A, Branquart E (2015) Harmonia+ and Pandora+: risk screening tools for potentially invasive plants, animals and their pathogens. Biological Invasions 17: 1869–1883. https://doi.org/10.1007/s10530-015-0843-1

D'hondt B, Vanderhoeven S, Adriaens T, Branquart E (2025) A demarcation of risk categories for invasion risk assessments using the Harmonia+ protocol. Zenodo. https://doi.org/10.5281/zenodo.15006587

Ducey PK, West LJ, Shaw G, De Lisle J (2005) Reproductive ecology and evolution in the invasive terrestrial planarian *Bipalium adventitium* across North America. Pedobiologia 49(4): 367–377. https://doi.org/10.1016/j.pedobi.2005.04.002

Ducey PK, Cerqua J, West LJ, Warner M, Eberle ME (2006) Rare egg capsule production in the invasive terrestrial planarian *Bipalium kewense*. The Southwestern Naturalist 51(2): 252–255. https://doi.org/10.1894/0038-4909(2006)51[252:recpit]2.0.co;2]2.0.CO;2

Edwards CA, Arancon NQ (2022) The role of earthworms in organic matter and nutrient cycles. In: Edwards CA, Arancon NQ (Eds) Biology and Ecology of Earthworms. Springer, New York, 233–274. https://doi.org/10.1007/978-0-387-74943-3_8

European Commission, Directorate-General for Environment (2019) Commission Implementing Regulation (EU) 2019/1262 of 25 July 2019 amending Implementing Regulation (EU) 2016/1141 to update the list of invasive alien species of Union concern. Official Journal of the European Union L 199/1.

European Commission, Directorate-General for Environment (2025) Commission Implementing Regulation (EU) 2025/1422 of 17 July 2025 amending Implementing Regulation (EU) 2016/1141 to update the list of invasive alien species of Union concern. Official Journal of the European Union L series.

European Parliament, Council of the European Union (2014) Regulation (EU) No 1143/2014 of the European Parliament and of the Council of 22 October 2014 on the prevention and management of the introduction and spread of invasive alien species. Official Journal of the European Union L 317/35.

Fourcade Y (2021) Fine-tuning niche models matters in invasion ecology. A lesson from the land planarian *Obama nungara*. Ecological Modelling 457: e109686. https://doi.org/10.1016/j.ecolmodel.2021.109686

Fourcade Y, Winsor L, Justine J-L (2022) Hammerhead worms everywhere? Modelling the invasion of bipaliin flatworms in a changing climate. Diversity and Distributions 28: 844–858. https://doi.org/10.1111/ddi.13489

Fourcade Y, Poirier L, Fauré A, Gaucherel C, Dupont L (2025) A qualitative model suggests that the soil ecosystem is resilient to the invasion by the land flatworm *Obama nungara*. Biological Invasions 27: e96. https://doi.org/10.1007/s10530-025-03557-w

Garrick RC, Rowell DM, Sunnucks P (2012) Phylogeography of saproxylic and forest floor invertebrates from Tallaganda, south-eastern Australia. Insects 3(1): 270–294. https://doi.org/10.3390/insects3010270

Gastineau R, Murchie AK, Winsor L, Justine J-L (2025a) An Irish cocktail of flatworm, earthworm and parasite DNAs: Genomics of invasive land flatworms (Geoplanidae) reveal infestations by two new *Mitosporidium* species (Microsporidia). Parasite 32: 1–67. https://doi.org/10.1051/parasite/2025060

Gastineau R, Ravelomanana A, Ramzy RR, Koken M, Soavolamanoro SE, Otis C, Boyle B, Gey D, Winsor L, Justine J-L (2025b) First confirmed records with molecular data of the invasive terrestrial flatworm *Bipalium kewense* Moseley, 1878 (Tricladida, Geoplanidae) in Madagascar, Egypt, and South Africa. Check List 21(3): 557–564. https://doi.org/10.15560/21.3.557

GBIF (2025) GBIF Home Page. https://www.gbif.org [Accessed 25 November 2025]

GBIF Occurrence Download (2025) GBIF.org. https://doi.org/10.15468/dl.sugpe7 [Accessed 19 July 2025]

Geoplanidae in GBIF Secretariat (2025) GBIF Backbone Taxonomy. Checklist dataset. https://doi.org/10.15468/39omei [Accessed 1 August 2025]

Gérard S, Decaëns T, Butt KR, Briones MJI, Capowiez Y, Cluzeau D, Hoeffner K, Le Bayon R-C, Marchán DF, Marsden C, Muys B, Pelosi C, Pérès G, Phillips HRP, Santini L, Thuiller W, Hedde M (2025) Putting earthworm conservation on the map: Shortfalls and solutions for developing earthworm conservation. Biological Conservation 302: e110911. https://doi.org/10.1016/j.biocon.2024.110911

Glaw F, Mass R, Glaw T, Schreiner J (2024) Non-native terrestrial planarian species in Germany and Austria, with first locality records of *Caenoplana variegata* for both countries (Platyhelminthes, Geoplanidae). Spixiana 47(1): 113–118.

González-Moreno P, Anđelković A, Adriaens T, Botella C, Demetriou J, Bastos R, Bertolino S, López Cañizares C, Essl F, Fiser Z, Glavendekić M, Herremans M, Hulme P, Jani V, Katsada D, Kleitou P, La Porta N, Lapin K, López-Darias M, Pocock M (2024) Citizen science platforms can effectively support early detection of invasive alien species according to species traits. People and Nature 7(1): 278–294. https://doi.org/10.1002/pan3.10767

Greilhuber M, Egger B, Reitmeier W, Haring E (2025) First record of the introduced land planarian *Obama nungara* (Platyhelminthes: Geoplanidae) in Austria. BioInvasions Records 14(4): 819–831. https://doi.org/10.3391/bir.2025.14.4.06

Groom Q, Adriaens T, August T, Capinha C, Cardoso A, Dehnen-Schmutz K, Essl F, Franklin A, Golivets M, Gonçalves J, Hendrickx L, Hodgson D, Høye T, Hulme PE, Kumschick S, Lenzner B, Malta-Pinto E, Martinou A(F)K, Meeus S, Myers T, Noé N, Novoa A, Pocock MJO, Poimala A, Preda C, Pyšek P, Reyserhove L, Rozylowicz L, Sapundzhieva A, Vale C, Vicente J, Yovcheva N, Zolyomi A, Roy H (2025) OneSTOP: OneBiosecurity systems and technology for people, places and pathways. Research Ideas and Outcomes 11: e165316. https://doi.org/10.3897/rio.11.e165316

Hickman VV (1965) On *Planarivora insignis* gen. et sp. n. (Diptera: Mycetophilidae), whose larval stages are parasitic in land planarians. Papers and Proceedings of the Royal Society of Tasmania 99: 1–8. https://doi.org/10.26749/iwzo5701

Hindricq P (2024) Data via Waarnemingen.be. https://waarnemingen.be/observation/318908313/ [Accessed 30 November 2024]

Hopper DR, Smith BD (1992) Status of tree snails (Gastropoda: Partulidae) on Guam, with a resurvey of sites studies by H.E. Crampton in 1920. Pacific Science 46: 77–85.

Hu J, Yang M, Ye ER, Ye Y, Niu Y (2019) First record of the New Guinea flatworm *Platydemus manokwari* (Platyhelminthes, Geoplanidae) as an alien species in Hong Kong Island, China. ZooKeys 873: 1–7. https://doi.org/10.3897/zookeys.873.36458

iNaturalist (2025) iNaturalist. https://www.inaturalist.org [Accessed 31 December 2025]

Jia Y, Lv Y, Kong X, Jia X, Tian K, Du J, Tian X (2015) Insight into the indirect function of isopods in litter decomposition in mixed subtropical forests in China. Applied Soil Ecology 86: 174–181. https://doi.org/10.1016/j.apsoil.2014.10.015

Jones HD, Sluys R (2016) A new terrestrial planarian species of the genus *Marionfyfea* (Platyhelminthes: Tricladida) found in Europe. Journal of Natural History 50(41–42): 2673–2690. https://doi.org/10.1080/00222933.2016.1208907

Jones HD, Mateos E, Riutort M, Álvarez-Presas M (2020) The identity of the invasive yellow-striped terrestrial planarian found recently in Europe: *Caenoplana variegata* (Fletcher & Hamilton, 1888) or *Caenoplana bicolor* (Graff, 1899)? Zootaxa 4731(2): 193–222. https://doi.org/10.11646/zootaxa.4731.2.2

Justine J-L, Winsor L (2026) Cats, dogs, and sticky worms: invasion by land flatworms (Geoplanidae) is facilitated by household pets. PeerJ 14: e20713. https://doi.org/10.7717/peerj.20713

Justine J-L, Winsor L, Gey D, Gros P, Thévenot J (2014) The invasive New Guinea flatworm *Platydemus manokwari* in France, the first record for Europe: Time for action is now. PeerJ 2: e297. https://doi.org/10.7717/peerj.297

Justine J-L, Winsor L, Barrière P, Fanai C, Gey D, Han AWK, La Quay-Velázquez G, Lee BPY, Lefevre J, Meyer J, Philippart D, Robinson DG, Thévenot J, Tsatsia F (2015) The invasive land planarian *Platydemus manokwari* (Platyhelminthes, Geoplanidae): records from six new localities, including the first in the USA. PeerJ 3: e1037. https://doi.org/10.7717/peerj.1037

Justine J-L, Winsor L, Gey D, Gros P, Thévenot J (2018) Giant worms chez moi! Hammerhead flatworms (Platyhelminthes, Geoplanidae, *Bipalium* spp., *Diversibipalium* spp.) in metropolitan France and overseas French territories. PeerJ 6: e4672. https://doi.org/10.7717/peerj.4672

Justine J-L, Winsor L, Gey D, Gros P, Thévenot J (2020) *Obama* chez moi! The invasion of metropolitan France by the land planarian *Obama nungara* (Platyhelminthes, Geoplanidae). PeerJ 8: e8385. https://doi.org/10.7717/peerj.8385

Justine J-L, Gey D, Vasseur J, Thévenot J, Coulis M, Winsor L (2021) Presence of the invasive land flatworm *Platydemus manokwari* (Platyhelminthes, Geoplanidae) in Guadeloupe, Martinique and Saint Martin (French West Indies). Zootaxa 4951(2): 381–390. https://doi.org/10.11646/zootaxa.4951.2.11

Justine J-L, Marie AD, Gastineau R, Fourcade Y, Winsor L (2022) The invasive land flatworm *Obama nungara* in La Réunion, a French island in the Indian Ocean, the first report of the species for Africa. Zootaxa 5154(4): 469–476. https://doi.org/10.11646/zootaxa.5154.4.4

Justine J-L, Gastineau R, Gey D, Robinson DG, Bertone MA, Winsor L (2024a) A new species of alien land flatworm in the Southern United States. PeerJ 12: e17904. https://doi.org/10.7717/peerj.17904

Justine J-L, Gastineau R, Winsor L (2024b) Land flatworms (Tricladida: Geoplanidae) in France and French overseas territories: ten years of research. Zoologia 41: e24004. https://doi.org/10.1590/S1984–4689.v41.e24004

Kappes H (2006) Relations between forest management and slug assemblages (Gastropoda) of deciduous regrowth forests. Forest Ecology and Management 237(1–3): 450–457. https://doi.org/10.1016/j.foreco.2006.09.067

Kappes H (2023) Freilandfund der invasiven Landplanarie *Kontikia ventrolineata* (DENDY, 1892) (Platyhelminthes: Tricladida: Geoplanidae) bei Köln. Mainzer naturwissenschaftliches Archiv 60(1): 191–194.

Keller HW, Snell KL (2002) Feeding activities of slugs on Myxomycetes and macrofungi. Mycologia 94(5): 757–760. https://doi.org/10.1080/15572536.2003.11833169

Lago-Barcia D, Fernández-Álvarez FÁ, Negrete L, Brusa F, Damborenea C, Grande C, Noreña C (2015) Morphology and DNA barcodes reveal the presence of the nonnative land planarian *Obama marmorata* (Platyhelminthes: Geoplanidae) in Europe. Invertebrate Systematics 29(1): 12–22. https://doi.org/10.1071/IS14033

Lago-Barcia D, Fernández-Álvarez FÁ, Brusa F, Rojo I, Damborenea C, Negrete L, Grande C, Noreña C (2019) Reconstructing routes of invasion of *Obama nungara* (Platyhelminthes: Tricladida) in the Iberian Peninsula. Biological Invasions 21(2): 289–302. https://doi.org/10.1007/s10530-018-1834-9

Lago-Barcia D, González-López JR, Fernández-Álvarez FÁ (2020) The invasive land flatworm *Obama nungara* (Platyhelminthes: Geoplanidae) reaches a natural environment in the Oceanic Island of São Miguel (Açores). Zootaxa 4830(1): 197–200. https://doi.org/10.11646/zootaxa.4830.1.9

Lazányi E, Boll PK, Páll-Gergely B, Simon J, Szeder KH, Turóci Á, Katona G (2024) First records of alien land planarians (Platyhelminthes: Geoplanidae) in Hungary. Zootaxa 5403(5): 592–596. https://doi.org/10.11646/zootaxa.5403.5.6

Lemos VS, Canello R, Leal-Zanchet AM (2012) Carnivore mollusks as natural enemies of invasive land flatworms. Annals of Applied Biology 161(2): 127–131. https://doi.org/10.1111/j.1744-7348.2012.00556.x

Lowe S, Browne M, Boudjelas S, De Poorter M (2000) 100 of the World's Worst Invasive Alien Species A selection from the Global Invasive Species Database. Published by The Invasive Species Specialist Group (ISSG) a specialist group of the Species Survival Commission (SSC) of the World Conservation Union (IUCN).

Luque GM, Bellard C, Bertelsmeier C, Bonnaud E, Genovesi P, Simberloff D, Courchamp F (2014) The 100th of the world's worst invasive alien species. Biological Invasions 16: 981–985. https://doi.org/10.1007/s10530-013-0561-5

Marcus E, Marcus E (1959) Turbellaria from Madeira and the Azores. Boletim do Museu Municipal do Funchal XII Art. 30: 15–42.

Mazza G, Menchetti M, Sluys R, Solà E, Riutort M, Tricarico E, Justine J-L, Cavigioli L, Mori E (2016) First report of the land planarian *Diversibipalium multilineatum* (Makino & Shirasawa, 1983) (Platyhelminthes, Tricladida, Continenticola) in Europe. Zootaxa 4067(5): 577–580. https://doi.org/10.11646/zootaxa.4067.5.4

Meire P, Ysebaert T, Van Damme S, Van den Bergh E, Maris T, Struyf E (2005) The Scheldt estuary: A description of a changing ecosystem. Hydrobiologia 540: 1–11. https://doi.org/10.1007/s10750-005-0896-8

Mienis HK (2022a) Terrestrial flatworms in Israel, 9. On the presence of an unidentified species of *Microplana* or *Rhynchodemus*. Natural History and Other Notes 33: 13–15.

Mienis HK (2022b) Terrestrial flatworms in Israel, 10. Additional records concerning *Caenoplana coerulea*, *Rhynchodemus sylvaticus* and an unidentified *Microplana* or *Rhynchodemus* species. Natural History and Other Notes 35: 6–9.

Mienis HK, Vaisman S (2025a) An unknown terrestrial planarian *Microplana* or *Rhynchodemus* encountered in a commercial shipment of Mosses from the Netherlands to Israel. Natural History and Other Notes 46: 13–14.

Mienis HK, Vaisman S (2025b) The exotic, southamerican terrestrial flatworm *Obama nungara* arrived in Israel via the Netherlands. Natural History and Other Notes 45: 3–8.

Mori E, Magoga G, Panella M, Montagna M, Winsor L, Justine J-L, Menchetti M, Schifani E, Melone B, Mazza G (2022a) Discovering the Pandora's box: the invasion of alien flatworms in Italy. Biological Invasions 24: 205–216. https://doi.org/10.1007/s10530-021-02638-w

Mori E, Magoga G, Mazza G (2022b) New records based on citizen-science report alien land planarians in the three remaining Italian regions and Pantelleria Island, and first record of *Dolichoplana striata* (Platyhelminthes Tricladida Contineticola [sic] Geoplanidae) in Italy. Redia: Giornale di Zoologia 105: 91–95. https://doi.org/10.19263/REDIA-105.22.12

Mori E, Touloupakis E, Viviano A, Mazza G (2023) Opening a gate to shade some light: Alien land planarians in the Eastern Mediterranean and Northern Africa. Zootaxa 5319: 295–300. https://doi.org/10.11646/zootaxa.5319.2.12

Mori E, Romiti F, Magliano A, Liberato CDE, Ancillotto L (2024) New alien in town: First record of *Parakontikia ventrolineata* (Platyhelminthes: Geoplanidae) in Italy. Zootaxa 5447(3): 444–448. https://doi.org/10.11646/zootaxa.5447.3.11

Muniappan R (1987) Biological control of the giant African snail, *Achatina fulica* Bowdich, in the Maldives. FAO Plant Protection Bulletin 35: 127–133.

Murchie AK (2017) Annex 10: Risk assessment for *Arthurdendyus triangulatus*. European Commission, Directorate-General for Environment, Study on invasive alien species – Development of risk assessments to tackle priority species and enhance prevention – Final report, Publications Office, 2018.

Murchie AK, Gordon AW (2013) The impact of the 'New Zealand flatworm', *Arthurdendyus triangulatus*, on earthworm populations in the field. Biological Invasions 15: 569–586. https://doi.org/10.1007/s10530-012-0309-7

Murchie AK, Harrison AJ (2004) Mark-recapture of 'New Zealand flatworms' in grassland in Northern Ireland. Proceedings of Crop Protection in Northern Britain 2004: 63–67.

Murchie AK, Justine J-L (2021) The threat posed by invasive alien flatworms to EU agriculture and the potential for phytosanitary measures to prevent importation. Technical Report IUCN, hal-03547527.

Negrete L, Lenguas Francavilla M, Damborenea C, Brusa F (2020) Trying to take over the world: Potential distribution of *Obama nungara* (Platyhelminthes: Geoplanidae), the Neotropical land planarian that has reached Europe. Global Change Biology 26(9): 4907–4918. https://doi.org/10.1111/gcb.15208

Negrete LH, Brusa F, Winsor L (2011) The blue land planarian *Caenoplana coerulea*, an invader in Argentina. Revista Mexicana de Biodiversidad 82: 287–291. https://doi.org/10.22201/ib.20078706e.2011.1.450

Noël S, Fourcade Y, Roy V, Bonnet G, Dupont L (2025) Population dynamics of the exotic flatworm *Obama nungara* in an invaded garden. Ecology and Evolution 15(1): e70827. https://doi.org/10.1002/ece3.70827

Noël S, Fourcade Y, Roy V, Gigon A, Dupont L (2026) Experimental assessment of the predation pressure by the exotic flatworm *Obama nungara* in its introduced range. Current Zoology 72(1): 69–80. https://doi.org/10.1093/cz/zoaf025

Observations.be (2025) Observations.be, Stichting Observation International and local partners. https://www.observations.be [Accessed 31 December 2025]

Ogren RE (1995) Predation behaviour of land planarians. Hydrobiologia 305: 105–111. https://doi.org/10.1007/bf00036370

Okochi I, Sato H, Ohbayashi T (2004) The cause of mollusk decline on the Ogasawara Islands. Biodiversity and Conservation 13: 1465–1475. https://doi.org/10.1023/B:BIOC.0000021334.39072.2d

Pfitzner I (1956) Die Landplanarie *Dolichoplana feildeni* Graff 1899 neu in Deutschland. Zoologischer Anzeiger 156: 226–228.

Pfitzner I (1958) Die Bedingungen der Fortbewegung bei den deutschen Landplanarien. Zoologische Beiträge 3: 235–311.

Qvarnstrom Y, Bishop HS, da Silva AJ (2013) Detection of rat lungworm in intermediate, definitive, and paratenic hosts obtained from environmental sources. Hawai'i Journal of Medicine & Public Health 72(6, Suppl. 2): 63–69.

R Core Team (2025) R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. https://doi.org/10.32614/r.manuals

Ritter E (2025) Die Landplanarie *Diversibipalium multilineatum* in Lochau (Vorarlberg): Neu für Österreich. inatura – Forschung online 129: 2S.

Rojo I, Escudero N, Fernández R, Fernández-Álvarez FÁ (2024) First record of the alien land flatworm *Marionfyfea adventor* (Platyhelminthes: Geoplanidae) in the Iberian Peninsula. Zootaxa 5397: 291–294. https://doi.org/10.11646/zootaxa.5397.2.10

Roy V, Ventura M, Fourcade Y, Justine J-L, Gigon A, Dupont L (2022) Gut content metabarcoding and citizen science reveal the earthworm prey of the exotic terrestrial flatworm, *Obama nungara*. European Journal of Soil Biology 113: e103449. https://doi.org/10.1016/j.ejsobi.2022.103449

Salmon L (2024) Data via Waarnemingen.be. https://waarnemingen.be/observation/314554946/ [Accessed 30 June 2024]

Sanchez-García I (2014) Cuatro planarias terrestres exóticas nuevas para Andalucía. Revista de la Sociedad Gaditana de Historia Natural 8: 15–20.

Simov N, Borissov S, Antonova V (2025) A silent predator *ad portas* – *Dolichoplana striata* Moseley, 1877 (Platyhelminthes: Tricladida: Geoplanidae) recorded for the first time in Bulgaria. Historia naturalis bulgarica 47: 125–130. https://doi.org/10.48027/hnb.47.054

Sluys R (2016) Invasion of the flatworms. American Scientist 104: 288–295. https://doi.org/10.1511/2016.122.288

Soors J (2024) Data via Waarnemingen.be. https://waarnemingen.be/observation/314155785/ [Accessed 30 November 2024]

Soors J, de Waart S, Backeljau T, Breugelmans K, Pletinck R, Sluys R (2017) Invasie van Down Under: exotische platwormen straks heer en meester? Natuurpunt Nieuwsbericht. https://www.natuurpunt.be/nieuws/invasie-van-down-under-exotische-platwormen-straks-heer-en-meester-20170331 [Accessed 3 January 2025]

Soors J, Van den Neucker T, Halfmaerten D, Neyrinck S, de Baere M (2019) On the presence of the invasive planarian *Obama nungara* (Carbayo, Álvarez-Presas, Jones & Riutort, 2016) (Platyhelminthes: Geoplanidae) in an urban area in Belgium. Belgian Journal of Zoology 149(1): 43–47. https://doi.org/10.26496/bjz.2019.29

Soors J, Mees J, Sevrin D, Van den Neucker T (2022) *Marionfyfea adventor* Jones & Sluys (2016) a non-native land planarian new for Belgium (Platyhelminthes: Tricladida: Geoplanidae). Belgian Journal of Zoology 152: 113–116. https://doi.org/10.26496/bjz.2022.102

Špaldoňová A, Frouz J (2014) The role of *Armadillidium vulgare* (Isopoda: Oniscidea) in litter decomposition and soil organic matter stabilization. Applied Soil Ecology 83: 186–192. https://doi.org/10.1016/j.apsoil.2014.04.012

Stephenson JW (1968) A review of the biology and ecology of slugs of agricultural importance. Proceedings of the Malacological Society of London 38(3): 169–178.

Suárez D, Martín S, Naranjo M (2018) First report of the invasive alien species *Caenoplana coerulea* Moseley, 1877 (Platyhelminthes, Tricladida, Geoplanidae) in the subterranean environment of the Canary Islands. Subterranean Biology 26: 67–74. https://doi.org/10.3897/subtbiol.26.25921

Sugiura S (2009) Seasonal fluctuation of invasive flatworm predation pressure on land snails: Implications for the range expansion and impacts of invasive species. Biological Conservation 142(12): 3013–3019. https://doi.org/10.1016/j.biocon.2009.07.032

Swinnen KRR, Vercayie D, Vanreusel W, Barendse R, Boers K, Bogaert J, Dekeukeleire D, Driessens G, Dupriez P, Jooris R, Steeman R, Van Asten K, Van Den Neucker T, Van Dorsselaer P, Van Vooren P, Wysmantel N, Gielen K, Desmet P, Herremans M, all working groups, species validators and recorders (2018) Waarnemingen.be – Non-native plant and animal occurrences in Flanders and the Brussels Capital Region, Belgium. BioInvasions Records 7: 335–342. https://doi.org/10.3391/bir.2018.7.3.17

Thunnissen NW, de Waart SA, Collas FPL, Jongejans E, Hendriks AJ, van der Velde G, Leuven RSEW (2022) Risk screening and management of alien terrestrial planarians in The Netherlands. Management of Biological Invasions 13(1): 81–100. https://doi.org/10.3391/mbi.2022.13.1.05

Van De Woestijne M (1907) La découverte en Belgique de *Placocephalus kewensis*. Annales de la Société Royale Zoologique et Malacologique de Belgique 42: 110–112.

Van den Neucker T, Soors J, Scheers K, Groom Q, Adriaens T (2020) Minstens vijf exotische landplatwormen in Vlaamse plantentuinen. Natuurpunt Nieuwsbericht. https://www.natuurpunt.be/nieuws/minstens-vijf-exotische-landplatwormen-vlaamse-plantentuinen-20200326 [Accessed 3 January 2025]

Vanderhoeven S, Adriaens T, D'hondt B, Van Gossum H, Vandegehuchte M, Verreycken H, Cigar J, Branquart E (2015) A science-based approach to tackle invasive alien species in Belgium – the role of the ISEIA protocol and the Harmonia information system as decision support tools. Management of Biological Invasions 6: 197–208. https://doi.org/10.3391/mbi.2015.6.2.10

Vanderhoeven S, Branquart E, Casaer J, D'hondt B, Hulme PE, Shwartz A, Strubbe D, Turbé A, Verreycken H, Adriaens T (2017) Beyond protocols: Improving the reliability of expert-based risk analysis underpinning invasive species policies. Biological Invasions 19(9): 2507–2517. https://doi.org/10.1007/s10530-017-1434-0

Vanreusel W, Swinnen K, Gielen K, Vercayie D, Driessens G, Veraghtert W, Desmet P, Herremans M (2025) Waarnemingen.be – Non-native animal occurrences in Flanders and the Brussels Capital Region, Belgium. Version 1.117. Natuurpunt. Occurrence dataset. https://doi.org/10.15468/k2aiak [Accessed via GBIF.org 25 November 2025]

Vardinoyannis K, Alexandrakis G (2019) First record of the land planarian *Caenoplana bicolor* (Graff, 1899) (Platyhelminthes, Tricladida, Continenticola) in Greece. BioInvasions Records 8(3): 500–504. https://doi.org/10.3391/bir.2019.8.3.04

von Graff L (1899) Monographie der Turbellarien. II. Tricladida Terricola (Landplanarien) Vol 1: XII+574 pp. Engelmann, Leipzig.

Waarnemingen.be (2025) Waarnemingen.be, Stichting Observation International and local partners. https://www.waarnemingen.be [Accessed 31 December 2025]

Waarneming.nl (2025) Waarneming.nl, Stichting Observation International and local partners. https://www.waarneming.nl [Accessed 25 November 2025]

Winsor L (1983) A revision of the cosmopolitan land planarian *Bipalium kewense* Moseley, 1878 (Turbellaria: Tricladida: Terricola). Zoological Journal of the Linnean Society 79(1): 61–100. https://doi.org/10.1111/j.1096–3642.1983.tb01161.x

Winsor L (1990) Taxonomic studies on free-living flatworms (Turbellaria: Platyhelminthes) of the Australian Zoogeographic Region. Chapter 4: Taxonomy and biology of a molluscivorous terrestrial flatworm *Platydemus manokwari* Beauchamp, 1962. MSc Thesis, James Cook University.

Winsor L, Johns PM, Barker GM (2004) Terrestrial planarians (Platyhelminthes: Tricladida: Terricola) predaceous on terrestrial gastropods. In: Barker GM (Ed.) Natural Enemies of Terrestrial Molluscs. CAB International, London, 227–278. https://doi.org/10.1079/9780851993195.0227

Yang X, Shao M, Li T (2020) Effects of terrestrial isopods on soil nutrients during litter decomposition. Geoderma 376: e114546. https://doi.org/10.1016/j.geoderma.2020.114546

Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

Artificial Intelligence (AI) use

The authors accept full responsibility for the content of the manuscript, including the disclosure of any use of AI.
No AI tools were used in the preparation of this manuscript.

Funding

FlatwormWatch was coordinated by the National Scientific Secretariat on Invasive Alien Species, which is funded under a cooperation agreement between the federal authority, the communities, and the regions, with funds provided by the Belgian competent authorities: the Federal Public Service Health, Food Chain and Environment, Brussels Environment, Agency for Nature and Forests, Research Institute for Nature and Forest, and Walloon Public Service, Department Nature and Forest. Some FlatwormWatch activities are supported by the European Union's Horizon Europe HORIZON-CL6-2024-BIODIV-01 project OneSTOP – OneBiosecurity Systems and Technology for People, Places and Pathways (Grant Agreement No. 101180559) (Groom et al. 2025). Part of this study was carried out at Hasselt University, with the Belgian National Scientific Secretariat on Invasive Alien Species as a technological partner, using infrastructure funded by the European Marine Biological Research Centre (EMBRC) Belgium (Research Foundation – Flanders [FWO-Vlaanderen] project GOH3817N) and with support from the Belgian Federal Science Policy Office (BELSPO; AfroWetMaP project). This work was cofinanced by the Minister of Science under the "Regional Excellence Initiative" Program for 2024–2027 (RID/SP/0045/2024/01).

Author contributions

All authors contributed to the study conception and design, material preparation, data collection, data validation and/or data analyses. The Harmonia+ risk assessments were performed by Tom Van den Neucker, Jan Soors, Arnaud Jacobs and Jane Reniers. Soria Delva performed the climate matching analyses. The first draft of the manuscript was written by Tom Van den Neucker and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Author ORCIDs

T. Van den Neucker https://orcid.org/0000-0003-2736-0711
J. Soors https://orcid.org/0000-0003-3092-6018
A. Jacobs https://orcid.org/0000-0001-5952-2581
J. Reniers https://orcid.org/0009-0000-4176-040X
S. Delva https://orcid.org/0000-0002-7164-6031
N. Kmentová https://orcid.org/0000-0001-6554-9545
M.P.M. Vanhove https://orcid.org/0000-0003-3100-7566
B. D'hondt https://orcid.org/0000-0002-1330-1457
K. Scheers https://orcid.org/0000-0002-4756-4247
L. Bronne https://orcid.org/0000-0002-3396-184X
C. Ewers https://orcid.org/0000-0003-1891-7901
L. Abraham https://orcid.org/0000-0003-4070-2982
Q. Groom https://orcid.org/0000-0002-0596-5376
D. Halfmaerten https://orcid.org/0000-0001-5105-6328
S. Neyrinck https://orcid.org/0000-0002-7379-9269
K. Breugelmans https://orcid.org/0000-0002-1236-7403
T. Backeljau https://orcid.org/0000-0002-9057-9727
J.-L. Justine https://orcid.org/0000-0002-7155-4540
R. Gastineau https://orcid.org/0000-0001-8661-5118
L. Winsor https://orcid.org/0000-0002-6679-470X
T. Adriaens https://orcid.org/0000-0001-7268-4200

Data availability

All of the data that support the findings of this study are available in the main text or Supplementary Information.

Supplementary material 1

Detailed overview of the climate-matching data selection and analyses for the non-native land planarians reported from indoor and outdoor environments in Belgium and for *Arthurdendyus triangulatus* and *Platydemus manokwari*

Authors: Tom Van den Neucker, Jan Soors, Arnaud Jacobs, Jane Reniers, Soria Delva, Nikol Kmentová, Maarten P.M. Vanhove, Bram D'hondt, Kevin Scheers, Louis Bronne, Christine Ewers, Laura Abraham, Quentin Groom, David Halfmaerten, Sabrina Neyrinck, Karin Breugelmans, Thierry Backeljau, Jean-Lou Justine, Romain Gastineau, Leigh Winsor, Tim Adriaens

Data type: pdf

Link: https://doi.org/10.3897/neobiota.108.190976.suppl1

Supplementary material 2

Risk assessment scores and confidence levels for each Harmonia+ module for the non-native land planarians reported from indoor and outdoor environments in Belgium and for *Arthurdendyus triangulatus* and *Platydemus manokwari*

Authors: Tom Van den Neucker, Jan Soors, Arnaud Jacobs, Jane Reniers, Soria Delva, Nikol Kmentová, Maarten P.M. Vanhove, Bram D'hondt, Kevin Scheers, Louis Bronne, Christine Ewers, Laura Abraham, Quentin Groom, David Halfmaerten, Sabrina Neyrinck, Karin Breugelmans, Thierry Backeljau, Jean-Lou Justine, Romain Gastineau, Leigh Winsor, Tim Adriaens

Data type: xlsx

Link: https://doi.org/10.3897/neobiota.108.190976.suppl2