

# IDENTIFICATION AND EVALUATION OF PATHWAYS TO DENMARK FOR THE 26 INVASIVE ALIEN SPECIES OF UNION CONCERN UNDER EU REGULATION 2025/1422

Technical Report from DCE – Danish Centre for Environment and Energy No. 405 2026

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# Data sheet


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Abstract: This report assesses the introduction pathways, modes of entry, impacts and climate sensitivity of the 26 invasive alien species added to the EU Union List by Commission Implementing Regulation (EU) 2025/1422, supporting Danish implementation of EU Regulation 1143/2014. Using the pathway framework of Grousset et al. (2018) and Madsen et al. (2023) and the Danish HARMONIA-based impact methodology, it finds that a few pathways dominate introduction risk: horticultural trade, contaminated biological materials, aquarium trade, aquaculture and ballast water. Escape, contamination and stowaway are the most common modes of entry into natural habitats. The highest impacts are associated with established or establishment-capable species such as *Neogale vison*, the knotweed complex, *Castor canadensis*, *Cherax destructor*, *Faxonius immunis* and *Asterias amurensis*. Climate change mainly affects currently climate-limited species, such as *Vespa mandarinia* and terrestrial flatworms, though the evidence varies in strength. The results confirm earlier Danish pathway priorities and support pathway-based prevention, focused on accidental introductions, early detection and limiting secondary spread.



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# Preface

This report was prepared by DCE – Danish Centre for Environment and Energy, Aarhus University, with contributions from DTU Aqua. It supports Danish implementation of EU Regulation 1143/2014 on invasive alien species, following the addition of 26 species to the list of invasive alien species of Union concern through Commission Implementing Regulation (EU) 2025/1422.

The report extends earlier Danish pathway analyses and uses the same methods, so its results can be compared directly with previous assessments. Together, these assessments now cover every species on the current Union List. The aim is to identify the most important routes by which invasive alien species reach Denmark and enter natural habitats, and to provide a knowledge base for prioritising prevention, early detection and management.

The assessment draws on existing Danish HARMONIA-based species factsheets and on the pathway frameworks developed in previous work. The authors thank Agency for Green Transition and Aquatic Environment and all colleagues and experts who contributed data, assessments and comments during the preparation of the report.

# Sammenfatning

Denne rapport er udarbejdet af DCE – Nationalt Center for Miljø og Energi, Aarhus Universitet, med bidrag fra DTU Aqua, for Styrelsen for Grøn Arealomlægning og Vandmiljø med henblik på at understøtte implementeringen af EU-forordning 1143/2014 om forebyggelse og håndtering af invasive ikke-hjemmehørende arter. Rapporten omfatter de 26 arter, som blev tilføjet EU-listen over invasive ikke-hjemmehørende arter af EU-betydning gennem Kommissionens gennemførelsesforordning (EU) 2025/1422.

Analysen bygger videre på tidligere danske spredningsvejsanalyser og anvender den metodiske ramme udviklet af Grousset et al. (2018) og Madsen et al. (2023), kombineret med den reviderede danske HARMONIA-baserede metode til vurdering af arters påvirkninger (Strandberg et al. 2023). De 26 nye arter på EU-listen, fordelt på terrestriske, ferskvands- og marine arter, blev vurderet ved hjælp af en samlet analyse af introduktionsveje (Pathways of Introduction; POI), spredningsveje efter introduktionen (Modes of Entry; MOE), tilknyttede vektorer og potentielle påvirkninger. Analysen skal ses som en udvidelse af de tidligere danske spredningsvejsanalyser og vurderer de yderligere risici, som de 26 nytilføjede arter bidrager med. Sammen med de tidligere danske spredningsvejsanalyser bidrager vurderingen til et samlet grundlag for alle invasive ikke-hjemmehørende arter, der aktuelt er omfattet af EU-listen.

For hver art blev relevante introduktionsveje, hvorved arten transporteres til Danmark, samt de processer, hvorigennem introducerede individer efterfølgende kan komme ud i naturen, identificeret og analyseret. Introduktionsvejene blev vurderet ved hjælp af en standardiseret Pathway of Introduction-score (POI) baseret på den metodiske tilgang anvendt af Grousset et al. (2018) og Madsen et al. (2023). Påvirkningsvurderingerne bygger primært på eksisterende danske HARMONIA-baserede faktaark og den tilhørende konsensusmetode (Strandberg et al. 2023), mens to arter uden eksisterende danske vurderinger blev vurderet efter samme metode for at sikre sammenlignelighed. Derudover blev der gennemført klimascenarier med henblik på at vurdere, hvordan fremtidige klimaforhold kan påvirke sandsynligheden for etablering og realisering af kendte påvirkninger under danske forhold.

Analysen viser, at et begrænset antal introduktionsveje står for størstedelen af de identificerede introduktionsmuligheder. Gartneri-, planteskole- og akvariehandel, transport af forurenet biologisk materiale, akvakulturaktiviteter og ballastvand fremstod som de vigtigste introduktionsveje blandt de vurderede arter. Disse introduktionsveje beskriver, hvordan arter transporteres til Danmark og bliver tilgængelige for efterfølgende spredning.

Efter introduktion var arterne hyppigst knyttet til spredningsvejene undslip fra fangenskab eller dyrkning (escape), forurening af varer og biologisk materiale (contaminant) samt blind passager (stowaway). Mens introduktionsvejene beskriver, hvordan arter ankommer til Danmark, beskriver spredningsveje efter introduktionen, hvordan introducerede individer efterfølgende spredes til naturlige habitater. På tværs af terrestriske og akvatiske miljøer var et begrænset antal introduktionsveje knyttet til størstedelen af de vurderede arter og udgjorde dermed de væsentligste drivkræfter bag den identificerede invasionsrisiko. Selvom flere af disse introduktionsveje nu er underlagt regulering gennem

EU-forordning 1143/2014, illustrerer de fortsat de mekanismer, der historisk har været ansvarlige for introduktionerne, og som fortsat kan bidrage til utilsigtede introduktioner eller sekundær spredning.

De højeste effekt-scorer blandt de vurderede arter blev fundet for arter, der enten allerede er etablerede i Danmark eller vurderes at kunne etablere sig under danske forhold, hvis de introduceres. Denne gruppe omfatter blandt andet amerikansk mink (*Neogale vison*), pileurt-komplekset (*Reynoutria japonica*, *R. sachalinensis* og *R.* × *bohemica*), amerikansk bæver (*Castor canadensis*), blå australsk krebs (*Cherax destructor*), kalikokrebs (*Faxonius immunis*) og stillehavssøstjerne (*Asterias amurensis*). Flere af de vurderede arter har endnu ikke etableret sig i Danmark, men vurderes at kunne gøre det, hvis introduktion finder sted. Deres høje scorer afspejler derfor både dokumenterede påvirkninger og sandsynligheden for, at disse påvirkninger kan realiseres under danske forhold.

Klimascenarierne viste, at klimaændringer forventes primært at påvirke etableringssandsynligheden og dermed sandsynligheden for, at kendte påvirkninger realiseres under danske forhold. De tydeligste klimaeffekter blev fundet for arter, hvis spredning til Danmark er begrænset af klimatiske forhold, herunder asiatisk kæmpegedehams (*Vespa mandarinia*) og flere terrestriske fladorme. For arter, der allerede vurderes at kunne etablere sig under de nuværende danske forhold, var klimaeffekten generelt begrænset.

Tilgængelig dokumentation indikerer, at fremtidige klimaforhold kan øge etableringssandsynligheden for enkelte arter, men at styrken af denne evidens varierer betydeligt mellem arterne. Mens *Broussonetia papyrifera* understøttes af artsudbredelsesmodeller, bygger vurderingerne for *Brachyponera chinensis* og *Platydemus manokwari* i højere grad på biologisk plausibilitet og ekspertvurderinger, og der er fortsat betydelig usikkerhed om etablering under danske forhold.

De identificerede pathway-mønstre bekræfter i vid udstrækning tidligere danske analyser. De største bidrag fra de 26 nye arter var knyttet til gartneri- og planteskolehandel, transport af forurenet biologisk materiale, akvariehandel og akvakulturrelaterede pathways, mens ingen tidligere lavt prioriteret pathway fremstod som en ny dominerende introduktionsvej.

Samlet peger analysen på, at forebyggelse gennem målrettet håndtering af introduktionsveje fortsat er den mest effektive strategi til at reducere fremtidig invasionsrisiko. For arter, der endnu ikke forekommer i Danmark, er forebyggelse af introduktion særligt vigtig. Da samtlige vurderede arter er omfattet af EU-listen over ikke-hjemmehørende invasive arter af EU-betydning, er handel, besiddelse, opdræt og udsætning allerede reguleret gennem EU-forordning 1143/2014. Fremtidige forvaltningsindsatser bør derfor især fokusere på at forebygge utilsigtede introduktioner, sikre tidlig opdagelse af nye forekomster og begrænse sekundær spredning efter etablering. Resultaterne understøtter derfor fortsat fokus på pathway-baseret forvaltning rettet mod et begrænset antal højt prioriterede introduktionsveje frem for artsvise indsatser alene.

# Summary

This report was prepared by DCE – Danish Centre for Environment and Energy, Aarhus University, with contributions from DTU Aqua, to support Danish implementation of EU Regulation 1143/2014 following the inclusion of 26 additional species on the Union List of invasive alien species of Union concern through Commission Implementing Regulation (EU) 2025/1422.

The assessment builds upon previous Danish pathway analyses and applies the pathway framework developed by Grousset et al. (2018) and Madsen et al. (2023), together with the revised Danish HARMONIA-based impact assessment methodology (Strandberg et al., 2023). The twenty-six newly listed invasive alien species, comprising terrestrial, freshwater and marine taxa, were evaluated through a pathway-based framework integrating analyses of Pathways of Introduction (POI), Modes of Entry (MOE), associated vectors and species impacts. The assessment should be regarded as an extension of previous Danish pathway analyses and evaluates the additional pathway risks associated with the 26 species added through Commission Implementing Regulation (EU) 2025/1422. Together with previous Danish pathway assessments, the analysis provides pathway information covering all invasive alien species currently included on the EU List.

For each species, relevant pathways responsible for transport to Denmark and the mechanisms through which introduced individuals may subsequently enter natural habitats were identified and evaluated using a standardised Pathway of Introduction (POI) scoring system following the approach developed by Grousset et al. (2018) and Madsen et al. (2023). Impact assessments were derived primarily from existing Danish HARMONIA-based species factsheets and the associated consensus methodology (Strandberg et al., 2023), while two species lacking Danish assessments were evaluated using the same framework to ensure comparability. Climate-scenario evaluations were additionally undertaken to assess how future climatic conditions may influence establishment success and the likelihood that documented impacts are realised under Danish conditions.

The analysis demonstrates that a limited number of introduction pathways account for the majority of identified introduction opportunities. Horticultural trade, contaminated biological materials, aquarium trade, aquaculture activities and ballast-water transport emerged as the most important introduction pathways within the assessed species set. These pathways describe how species are transported to Denmark and become available for subsequent introduction into natural habitats.

Following introduction, species were most frequently associated with the Mode of Entry categories escape, contaminant and stowaway. While introduction pathways describe how species arrive in Denmark, Modes of Entry describe the processes through which introduced individuals subsequently enter natural habitats. Across both terrestrial and aquatic environments, a limited number of introduction pathways were associated with most assessed species and therefore represented the principal drivers of the identified invasion risk. Although several of these pathways are now subject to restrictions under EU Regulation 1143/2014, they remain important because they represent the mechanisms historically responsible for introductions and may still contribute to accidental introductions, legacy populations and secondary spread.

The highest impact scores were associated with species that are either already established in Denmark or are considered capable of establishment under Danish environmental conditions if introduced. This group included *Neogale vison*, the knotweed complex (*Reynoutria japonica*, *R. sachalinensis* and *R.* × *bohemica*), *Castor canadensis*, *Cherax destructor*, *Faxonius immunis* and *Asterias amurensis*. Several additional species are not currently present in Denmark but possess impact profiles indicating that substantial impacts could occur if establishment takes place.

Future climate scenarios are expected primarily to influence establishment probability and thereby the likelihood that documented impacts are realised under Danish conditions. The most pronounced climate effects were associated with species currently constrained by climatic conditions, including *Vespa mandarinia* and several terrestrial flatworms. Species already considered capable of establishment under current Danish conditions generally exhibited limited climate-driven changes.

Available evidence suggests that future climatic conditions may reduce climatic constraints for several species, although the strength of evidence varies considerably. While species-distribution models suggest the potential for increased climatic suitability for *Broussonetia papyrifera*, assessments for *Brachyponera chinensis* and *Platydemus manokwari* rely to a greater extent on biological plausibility and expert judgement, and substantial uncertainty remains regarding future establishment under Danish conditions.

The pathway patterns identified for the additional species are broadly consistent with those described in previous Danish pathway analyses and reinforce previously identified pathway priorities. The largest increases in pathway support were associated with horticultural pathways, contaminated biological materials, aquarium trade and aquaculture-related pathways, while no previously low-priority pathway emerged as a new dominant pathway.

Overall, the assessment indicates that pathway-based prevention remains the most effective strategy for reducing future invasion risk. For species not yet present in Denmark, prevention of introduction remains particularly important. Because all assessed species are included on the EU IAS List, intentional trade, keeping, breeding and release are already regulated under EU Regulation 1143/2014. Future management efforts should therefore focus primarily on preventing accidental introductions, ensuring early detection of new incursions and limiting secondary spread following establishment. The results support continued emphasis on pathway-based management directed towards a limited number of high-priority pathways rather than species-specific interventions alone.

# 1 Background

The present study focuses on the species added to the EU IAS List through Commission Implementing Regulation (EU) 2025/1422 and should be regarded as a targeted extension of previous Danish pathway analyses rather than a complete reassessment of Danish invasion pathways. In addition to assessing pathways associated with the newly listed species, the study evaluates how inclusion of these species influences pathway priorities previously identified for Denmark, thereby contributing to pathway information covering all species currently included on the EU List.

The assessment applies the pathway framework developed by Grousset et al. (2018) and updated by Madsen et al. (2023), while relying primarily on the revised Danish HARMONIA-based impact assessments available through the national invasive-species factsheet system (Strandberg et al., 2023).

Unlike previous Danish pathway analyses, which primarily focused on pathway prioritisation at a national scale, the present study combines species-specific pathway assessments, existing Danish HARMONIA-based impact evaluations and climate-scenario analyses for the species added through Regulation (EU) 2025/1422. Particular attention is given to the relationship between pathways of introduction, subsequent entry into natural habitats and the likelihood that documented impacts can be realised under current and future Danish conditions.

It should be noted that all species assessed in the present study are included on the EU List of invasive alien species of Union concern and are therefore subject to the restrictions established under EU Regulation 1143/2014. These restrictions include prohibitions on import, trade, breeding, transport, keeping and intentional release. Consequently, several historically important introduction pathways are expected to be reduced in importance following implementation of the Regulation. The pathway analysis presented here therefore focuses primarily on identifying the pathways historically associated with the assessed species and the mechanisms through which future introductions could occur despite existing regulatory measures. Pathway rankings should thus be interpreted as indicators of pathway relevance and pathway association rather than direct measures of current introduction pressure under the post-listing regulatory regime.

For species already established in Denmark, analysis of modes of entry additionally provides information on mechanisms contributing to continued spread and expansion within the country. For species not currently present in Denmark, the analysis focuses primarily on pathways that could facilitate future introductions and subsequent entry into natural habitats under Danish conditions.

The objectives of the present report were to:

- identify Pathways of Introduction (POI), Modes of Entry (MOE), and vectors relevant to Denmark for the species added through Regulation (EU) 2025/1422;
- identify pathways contributing to secondary spread following establishment;

- evaluate pathway importance using a standardised Pathway of Introduction (POI) scoring system;
- compile and apply existing Danish HARMONIA-based impact assessments and assess species lacking Danish factsheets using the same framework;
- evaluate the influence of future climatic conditions on establishment success and impact realisation;
- identify priority pathways based on pathway frequency, pathway importance and associated impacts;
- evaluate how inclusion of the species added through Regulation (EU) 2025/1422 influences pathway prioritisation previously identified for Denmark;

and

- provide recommendations to support pathway-based prevention and management.

The resulting analysis is intended to support continued Danish implementation of EU Regulation 1143/2014 and to complement previous national pathway assessments by extending pathway evaluation, impact assessment and climate-risk analysis to the species added through Commission Implementing Regulation (EU) 2025/1422. The assessment further examines how inclusion of these species affects existing pathway priorities and thereby provides an updated pathway perspective for the full set of invasive alien species currently included on the EU List.

# 2 Methods

## 2.1 Analytical framework

The assessment of invasive alien species was conducted using a semi-quantitative framework integrating evaluations of introduction pathways and species impacts. This approach follows established concepts in invasion ecology, whereby invasion risk is determined by both the likelihood of introduction and the magnitude of impacts following establishment (CBD, 2014; Hulme et al., 2008). Consistent with the pathway-based assessments of Grousset et al. (2018) and Madsen et al. (2023), pathway frequency and species impacts were assessed separately but subsequently interpreted jointly to characterise invasion risk and identify priority pathways for management.

Two complementary components were considered. First, the probability of introduction (POI) was assessed across a standardised set of pathways. Second, species impacts were evaluated using the Danish HARMONIA-derived assessment framework applied in national invasive-species assessments and pathway analyses (Grousset et al., 2018; Strandberg et al., 2023). This framework builds on the original ISEIA methodology developed by Branquart et al. (2009) and incorporates assessments of environmental, economic and human-health impacts (Branquart et al., 2009; Madsen et al., 2014; Strandberg et al 2023; Madsen et al., 2023). These components were assessed separately but interpreted jointly to characterise invasion risk profiles.

## 2.2 Data sources and assessment context

Assessments were based on a synthesis of available information, including European Union Risk Assessments prepared in support of species listing under Regulation (EU) 1143/2014, the CABI Invasive Species Compendium and peer-reviewed scientific literature. EU Risk Assessments constituted the primary source of information on introduction pathways, vectors, climatic suitability, establishment potential and documented impacts. Risk assessments were obtained from the EPPO Pest Risk Analysis (PRA) database, EASIN and other relevant sources associated with the EU listing process. Supplementary information was obtained from EASIN, EPPO and other relevant technical sources where appropriate (Katsanevakis et al., 2012).

Assessments have been conducted with explicit reference to Danish conditions, including climate suitability, habitat availability and pathway relevance. Consequently, scores reflect impacts considered realistic under Danish environmental conditions rather than the maximum impacts reported elsewhere in the species' introduced range. This approach follows the Danish consensus protocol for invasive-species assessments (Strandberg et al. 2023) and the methodology applied by Madsen et al. (2023).

The baseline assessment reflects current environmental conditions. In addition, a supplementary climate-scenario assessment was conducted to evaluate potential changes in establishment success, spread and impact under projected future climatic conditions. This climate assessment was intended to identify species for which climatic constraints may currently limit the realisation of impacts in Denmark (Madsen et al., 2023). Future climate evaluations were based primarily on the climate-scenario assessments included in the

underlying EU Risk Assessments and associated species factsheets. Where available, these assessments considered future climate projections based on Shared Socioeconomic Pathways (SSPs), including SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5, typically extending to the middle and end of the twenty-first century. Consequently, the climate-scenario assessment should be interpreted as an exploration of potential long-term changes in climatic suitability rather than a prediction of conditions within the ten-year time horizon used in the Danish factsheet assessments.

Future climate scenarios did not alter the intrinsic impact mechanisms of a species. Instead, future scores were adjusted only where climate change was expected to influence establishment probability, habitat suitability, reproduction or spread. Consequently, climate-driven score increases primarily reflect a greater likelihood that documented impacts are realised under Danish conditions rather than an increase in intrinsic impacts. Where climate projections did not indicate a meaningful increase in establishment potential under Danish conditions, future scores remained unchanged. Future scores should therefore be interpreted as scenario-based estimates of impact realisation under projected climate conditions rather than predictions of future species distributions.

Each species was analysed individually using a standardised pathway and impact framework. Results were subsequently synthesised across species and separated into terrestrial and aquatic taxa to facilitate pathway comparison and prioritisation.

## 2.3 Probability of introduction (POI)

The pathway assessment followed the framework adopted by the Convention on Biological Diversity (CBD), Hulme et al. (2008), Grousset et al. (2018) and Madsen et al. (2023). Species were evaluated using a hierarchical pathway structure consisting of Pathways of Introduction (POI), Modes of Entry (MOE) and vectors. POIs describe the mechanisms responsible for introducing a species to Denmark or the European Union, whereas MOEs describe the mechanisms through which species subsequently enter natural habitats following introduction.

Pathways of Introduction (POI) describe the specific activities that transport species to Denmark. Examples include horticultural trade, aquarium trade, aquaculture transfers, ornamental planting, ballast water, shellfish movements, live bait pathways and freight transport. In practice, many species utilise more than one pathway and may be associated with several vectors simultaneously.

Following introduction, species may enter natural habitats through a smaller number of Modes of Entry (MOE). These correspond to the major CBD pathway categories and include release, escape, contaminant, stowaway, corridor and unaided spread (CBD, 2014; Hulme et al., 2008). MOEs therefore describe the mechanisms through which introduced individuals or propagules subsequently enter natural environments.

Finally, vectors were used to describe the physical means through which species are transported. Examples include nursery stock, root balls, contaminated soil, ballast water, shipping containers, live fish consignments, shellfish transfers and ornamental plants.

Species–pathway combinations were evaluated using a semi-quantitative Pathway of Introduction (POI) score ranging from 0 to 4. The POI score reflects the relative importance of a pathway for the introduction of a given species to Denmark and synthesises information from documented introduction events, pathway classifications reported in EU risk assessments, evidence of repeated transport, estimated propagule pressure and pathway relevance under Danish conditions.

Consistent with previous Danish pathway analyses, the POI score evaluates only the likelihood of introduction and does not incorporate establishment probability or impact magnitude, which were assessed separately through the Danish HARMONIA-based impact framework (Grousset et al., 2018; Madsen et al., 2023). A complete overview of the species–pathway matrix and associated POI scores is provided in Appendix D.

**Table 2.1.** Table 1:Criteria for assigning POI scores

| Score | Description |
|---|---|
| 0 | Pathway absent or not relevant for the species |
| 1 | Weak pathway; introduction is theoretically possible but poorly documented or expected only under exceptional circumstances |
| 2 | Occasional pathway; introduction has been documented but is expected to occur infrequently under Danish conditions |
| 3 | Important pathway; the pathway is well documented, active and likely to facilitate repeated introductions under Danish conditions |
| 4 | Primary pathway; strongly associated with the species and responsible for repeated international introductions and/or establishment events |

## 2.4 Impact assessment

Potential impacts were evaluated using the Danish HARMONIA-derived assessment framework applied in national invasive-species assessments and pathway analyses (Grousset et al., 2018; Madsen et al., 2023). The framework is based on the original ISEIA methodology developed by Branquart et al. (2009) and the revised Danish consensus protocol for invasive species assessments (Strandberg et al., 2023). Six criteria were assessed:

- Dispersal potential
- Conservation and nature value of invaded habitats
- Impact on native species
- Impact on ecosystem functions
- Economic impacts
- Human-health impacts

For most species, impact scores were obtained directly from the Danish invasive-species factsheets produced as part of the national HARMONIA-based assessment framework (Strandberg et al., 2023). These factsheets assess species using a four-level ordinal scale ranging from 0 to 3, where 0 indicates no documented impact, 1 indicates low impact, 2 indicates moderate impact, and 3 indicates high impact (Strandberg et al., 2023). Scores reflect impacts expected under Danish conditions rather than the maximum impacts reported elsewhere within the species' introduced range. The Danish assessment framework distinguishes between species that have no documented impacts and species that cannot establish under current and near-future (10 years) Danish conditions. Such cases are indicated in tables by "–" and should not be interpreted as zero impact.

Two species, namely *Cipangopaludina chinensis* and *Mulinia lateralis*, have not yet been covered by Danish factsheets and were therefore assessed using the same Danish HARMONIA-based framework applied in previous national assessments (Strandberg et al. 2023). These assessments were based on EU Risk Assessments, the CABI Invasive Species Compendium, peer-reviewed literature and other relevant technical sources.

Scores across the six criteria were summed to produce a total impact score ranging from 0 to 18. In addition, a biological impact score was calculated as the sum of the native-species impact and ecosystem-impact criteria, consistent with the approach used by Madsen et al. (2023) when evaluating pathway-associated impacts.

All assessments were interpreted within a Danish context. Consequently, climatic suitability, habitat availability and establishment potential were explicitly considered when evaluating the extent to which documented impacts could realistically be realised in Denmark. Future climate scenarios did not alter the intrinsic impact mechanisms of a species. Instead, future scores were adjusted only where climate change was expected to influence establishment probability, habitat suitability, reproduction or spread. Consequently, future score increases primarily reflect a greater likelihood that documented impacts are realised under Danish conditions rather than changes in intrinsic impact potential.

## 2.5 Pathway prioritization

Following Madsen et al. (2023), overall pathway priority was determined using a joint evaluation of: (i) pathway frequency (number of associated species), (ii) pathway importance as reflected by mean POI scores, and (iii) mean species impacts measured by current HARMONIA scores. Pathways combining high introduction probability and high species frequency associated impacts were assigned the highest management priority.

# 3 Synthesis of Terrestrial Pathways

## 3.1 Overview of pathways

The sixteen terrestrial species assessed encompass a broad range of taxonomic groups, including mammals (3), birds (2), insects (2), terrestrial flatworms (3) and vascular plants (6). Despite substantial differences in biology and invasion history, the analyses reveal a strong concentration around a relatively small number of Pathways of Introduction (POI). Most species were associated with pathways linked to horticultural trade, movement of contaminated materials, fur farming and other managed animal holdings, wildlife management and conservation activities, or commercial transport. Only a few species were associated with natural spread or water-mediated dispersal, which are mostly considered secondary spread rather than introduction pathways. This pattern is consistent with previous Danish and European pathway analyses, which have repeatedly identified human-mediated transport as the dominant driver of terrestrial invasions.

An important observation is that many species are associated with more than one Pathway of Introduction (POI). This is particularly evident for *Brachyponera chinensis*, *Obama nungara*, *Delairea odorata* and the knotweed complex (*Reynoutria* spp.), which are linked to both horticultural trade and contaminated biological materials. Consequently, introduction risk is often associated with several pathways simultaneously rather than a single dominant pathway. For species already established in Denmark, subsequent spread following establishment may occur through additional mechanisms that were considered separately from the introduction pathways assessed here.

#### Horticultural Trade and Plant-Associated Pathways

Horticultural trade emerged as the dominant terrestrial introduction pathway. Ten of the sixteen assessed species were directly associated with vectors such as the movement of ornamental plants, nursery stock, root balls, growing media, or associated substrates. This pathway includes a diverse range of taxa, from invasive plants and terrestrial flatworms to invasive ants, demonstrating its broad importance across multiple organism groups. The pathway remains highly active due to the continuous movement of live plants within Europe and through international trade. Several species not yet established in Denmark remain widely available through commercial horticulture or internet-based trade, causing ongoing introduction pressure.

Closely linked to horticultural trade is the movement of contaminated soil, growing media and other habitat materials. Eight species were associated with this pathway and associated vectors, which function both as an introduction pathway and as an important mechanism for secondary spread. For knotweeds, contaminated soil is now one of the principal causes of new infestations. Similarly, terrestrial flatworms may be transported unnoticed within soil and root systems, while the ant, *B. chinensis* may be moved in soil, mulch, timber, leaf litter and nursery stock. Because this pathway facilitates dispersal even after species have established, it represents a major challenge for long-term management.

A related pathway and vectors involve the disposal and movement of garden waste, vegetative material and green waste. Although associated with fewer species than horticultural trade itself, this pathway is particularly important for species capable of regenerating from small propagules. Knotweeds, *D. odorata* and several terrestrial flatworms can establish from discarded fragments or propagules that survive routine vegetation management. In such cases, garden waste may become a more important driver of local spread than deliberate planting.

Combined, horticultural trade, contaminated soil and garden waste form a continuum of interconnected pathways. They account for the majority of terrestrial species assessed and represent the principal pathways by which species are introduced and subsequently spread within Denmark. Consequently, these pathways constitute the highest management priority.

### Vertebrate Introduction Pathways

Several vertebrate species were associated with pathways linked to fur farming, deer parks, hunting estates and wildlife management activities. These activities constitute the principal pathways through which species may be transported and maintained outside their native ranges. For example, *Neogale vison* is primarily associated with fur farming, whereas *Cervus nippon* is associated with deer parks and hunting estates. Outside Denmark, *Castor canadensis* has historically been introduced through wildlife management and conservation programmes.

### Trade in Live Animals and Commercial Transport

The pet and ornamental animal trade was associated primarily with the two bird species *Pycnonotus jocosus* and *Acridotheres cristatellus*. International trade in captive birds has repeatedly been identified as the principal pathway through which these species are transported beyond their native ranges. Although relatively few species in the present assessment are associated with this pathway, the continued movement of captive birds through commercial trade means that introduction pressure persists.

Commercial transport pathways were represented primarily by *B. chinensis* and *Vespa mandarinia*. These insect species may be transported through freight, cargo, timber, shipping containers, and other traded goods. Freight-related pathways illustrate how modern transport networks can facilitate long-distance movement of species across biogeographical regions. Although fewer assessed species were associated with these pathways than with horticultural trade, the large volume of international trade creates repeated opportunities for introduction. Consequently, freight and cargo pathways remain important targets for biosecurity measures and surveillance activities.

### Natural Spread

Natural spread was generally less important than human-mediated pathways. Nevertheless, it contributes to secondary expansion following establishment. The most important examples involve dispersal of knotweed fragments along watercourses and gradual population expansion by species such as *C. nippon* and potentially *C. canadensis*. Under current Danish conditions, however, natural spread primarily facilitates local and regional expansion rather than initial introduction.

**Table 3.1.** Summary of terrestrial pathway importance

| Pathway (POI) | Associated species (n) | Relative priority |
|---|---|---|
| Horticultural trade, nursery stock and ornamental planting | 10 | Very High |
| Contaminated soil, growing media and plant material | 8 | Very High |
| Garden waste and vegetative fragments | 6 | High |
| Fur farming, deer parks and managed animal holdings | 3 | High |
| Wildlife management, hunting and conservation introductions | 2 | Medium |
| Freight, containers and commercial transport | 2 | Medium-High |
| Pet and ornamental animal trade | 2 | Medium |
| Natural spread and water-mediated dispersal | 5 | Low-Medium |

Natural spread and water-mediated dispersal differ from the other pathways in Table 3.1 because they primarily represent mechanisms of secondary spread rather than Pathways of Introduction. While several species are associated with natural spread following establishment, these processes contribute little to the arrival of new species in Denmark and therefore receive lower priority within a pathway-introduction framework (Table 3.1).

## 3.2 Overall Conclusions

The pathway analysis demonstrates that a relatively small number of Pathways of Introduction (POI) account for most terrestrial introduction opportunities. Horticultural trade and the movement of contaminated soil, growing media and plant material clearly dominate the terrestrial pathway landscape and together account for more than half of the assessed species. These pathways remain highly active and therefore continue to generate substantial introduction pressure.

In contrast, pathways associated with animal husbandry, deer parks, wildlife management and other managed populations involve relatively few species but may nevertheless be associated with substantial ecological consequences if introductions occur. Similarly, freight and commercial transport pathways are linked to comparatively few species but provide repeated opportunities for long-distance transport and accidental introduction.

Consistent with the framework applied by Madsen et al. (2014) and Madsen et al. (2023), the highest management priority should therefore be assigned to introduction pathways that combine both high frequency and high associated impacts. Within the assessed species set, horticultural trade, contaminated biological materials and associated plant pathways emerged as the most important targets for preventive management and biosecurity measures.

## 3.3 Modes of Entry

The sixteen terrestrial species assessed were associated with a limited number of Modes of Entry (MOE) as defined by the CBD pathway framework. MOEs describe the mechanisms by which species enter the natural environment following introduction, regardless of whether introduction occurs through deliberate or accidental transport. The dominant MOE categories among the assessed species were escape, contaminant, stowaway, release and unaided spread.

For species that are already established in Denmark, MOEs primarily describe mechanisms responsible for continued spread and expansion within the country. For species not yet present in Denmark, MOEs describe the mechanisms through which introduced individuals or propagules would be expected to enter natural habitats following introduction as it occurs in the species' invasive range.

### Escape

Escape was the most frequently represented MOE category and included species associated with cultivation, ornamental planting, captive animal holdings and managed populations. Examples include *N. vison*, *C. nippon*, *P. jocosus* and *A. cristatellus*. For several plant species, escape from cultivation represents the principal mechanism by which introduced individuals enter the wider environment.

### Contaminant

Contaminant MOEs were associated primarily with species transported unintentionally within soil, growing media, plant material or other biological substrates. This category included terrestrial flatworms, *B. chinensis* and the knotweed complex. For established species such as the knotweeds, contaminant pathways are especially important because they facilitate secondary spread through movement of infested soil and plant fragments.

### Stowaway

Stowaway MOEs were represented mainly by species capable of accidental transport through freight, cargo and international trade networks. *V. mandarinia* and *B. chinensis* were the principal representatives of this category. In these cases, transport pathways describe mechanisms by which species may reach Denmark, whereas the subsequent Mode of Entry reflects how individuals enter natural habitats following arrival.

### Release

Release MOEs were comparatively uncommon within the assessed species set and were associated primarily with vertebrate species. Historical examples include wildlife management, hunting-related introductions, conservation translocations and deliberate release of captive animals (*N. vison*). For species already established in Denmark, unaided spread contributes to local and regional expansion of populations. For species not yet present in Denmark, unaided spread was only considered where natural dispersal from populations in neighbouring countries could contribute to arrival in Denmark.

### Unaided Spread

For the species assessed here, unaided spread was relevant primarily after establishment and was associated with local and regional expansion of existing populations. The category therefore had limited relevance to the introduction process itself.

**Table 3.2.** Potential Modes of Entry (MOE) for terrestrial species. For species not currently present in Denmark, MOE categories describe expected mechanisms through which introduced individuals would enter natural habitats following introduction.

| Mode of Entry | Representative species |
|---|---|
| Escape | *Reynoutria* spp., *Delairea odorata*, *Neogale vison*, *Cervus nippon*, *Pycnonotus jocosus*, *Acridotheres cristatellus*, *Acacia mearnsii*, *Broussonetia papyrifera* |
| Release | *Castor canadensis*, historical introductions of *Cervus nippon* and *Neogale vison* |
| Contaminant | *Brachyponera chinensis*, knotweeds, *Obama nungara*, *Platydemus manokwari*, *Bipalium kewense* |
| Stowaway | *Vespa mandarinia*, *Brachyponera chinensis* |
| Unaided spread | *Reynoutria* spp., *Cervus nippon*, *Castor canadensis, Neogale vison, Acacia mearnsii, Broussonetia papyfera, Delairea odorata* |

## 3.4 Impact Profile and Climate-Mediated Risk Realisation

The impact assessment revealed substantial variation among the sixteen terrestrial species, with current HARMONIA scores ranging from low values for species whose impacts are constrained by Danish climatic conditions to high values for species already capable of establishing and spreading under present environmental conditions. Consistent with the Danish HARMONIA framework, scores reflect impacts considered realistic under Danish conditions rather than the maximum impacts reported elsewhere in the introduced range.

Across the assessed species, impacts on native biodiversity emerged as the dominant concern. Invasive plants were primarily associated with competitive exclusion of native vegetation, habitat homogenisation and alteration of ecosystem processes, whereas invasive animals more frequently affected native biodiversity through predation, competition, hybridisation and ecosystem engineering. Economic impacts generally represented a secondary concern, while human-health impacts only contributed substantially to overall scores for a small number of species, particularly the insects *V. mandarinia* and *B. chinensis*.

The highest current scores were associated with *N. vison*, *R. japonica*, *Reynoutria* × *bohemica*, *C. canadensis*, *V. mandarinia* and *C. nippon*. These species are already capable of establishing under Danish conditions and possess well-documented impact mechanisms. Their risk profiles therefore reflect current rather than potential future concerns. Since completion of the Danish HARMONIA factsheet assessment, a new genetic study of Danish sika deer populations has reported no evidence of ongoing F1 hybridisation between *C. nippon* and *Cervus elaphus* in the sampled populations (Tommerup et al., 2026). However, the study has not yet undergone peer review. To ensure consistency and comparability across all assessed species, the present analysis follows the existing Danish HARMONIA-based factsheet assessments and associated consensus framework.

A second group of species is associated with documented impact mechanisms but exhibits lower or no current scores because establishment or persistence remains uncertain or unlikely under present climatic conditions. This group includes *B. chinensis*, *O. nungara*, *B. papyrifera*, *P. jocosus* and *A. cristatellus*. These species possess active introduction pathways and documented impacts elsewhere, but climatic conditions currently limit the probability that such impacts are fully realised in Denmark.

Finally, a small number of species were not assessed under current Danish conditions because available factsheets considered establishment unlikely within a timescale of < 10 years. This group includes *B. kewense* and *P. manokwari*. Their future scores therefore represent potential impacts if climatic barriers are reduced rather than quantified increases from current conditions.

Future climate scenarios should not be interpreted as changing the intrinsic impact mechanisms of species. Instead, climate change primarily influences establishment success, reproduction and spread, thereby increasing the likelihood that known impacts are realised. The largest projected increases were associated with *Broussonetia papyrifera*, *B. chinensis*, *O. nungara* and *V. mandarinia*, whereas species already capable of establishment under current Danish conditions generally exhibited little or no change in overall score.

**Table 3.3.** Current and future HARMONIA scores for terrestrial species assessed under Danish conditions. Future scores reflect climate-mediated changes in establishment probability and impact realisation rather than changes in intrinsic species impacts.

| Species | Current HARMONIA | Future HARMONIA | Principal driver of change |
|---|---|---|---|
| Neogale vison | 13 | 13 | Already suitable |
| Cervus nippon | 11 | 11 | Already suitable |
| Castor canadensis | 11 | 11 | Already suitable |
| Vespa mandarinia | 13 | 14 | Increased establishment probability |
| Pycnonotus jocosus | 3 | 5 | Reduced climatic limitation |
| Acridotheres cristatellus | 3 | 5 | Reduced climatic limitation |
| Brachyponera chinensis | 3 | 11 | Increased overwinter survival |
| Bipalium kewense | – | 5 | Reduced climatic limitation |
| Obama nungara | 4 | 8 | Improved establishment |
| Platydemus manokwari | – | 7 | Reduced climatic limitation |
| Reynoutria japonica | 12 | 12 | Already suitable |
| Reynoutria sachalinensis | 10 | 10 | Already suitable |
| Reynoutria × bohemica | 11 | 11 | Already suitable |
| Acacia mearnsii | 7 | 8 | Improved establishment |
| Broussonetia papyrifera | 7 | 11 | Improved climatic suitability |
| Delairea odorata | 8 | 8 | Already suitable |

# 4 Synthesis of Aquatic Pathways

## 4.1 Overview of pathways

The ten aquatic species assessed encompass freshwater fishes, crayfish, gastropods, marine invertebrates and aquatic plants. Despite substantial differences in taxonomy and ecology, introductions were strongly concentrated around a limited number of pathways. In contrast to the terrestrial assessment, where horticultural trade and contaminated soil dominated, aquatic invasions were primarily associated with aquarium trade, ornamental pond pathways, aquaculture transfers and maritime transport. This pattern is consistent with previous European and Danish pathway analyses, which have repeatedly identified human-assisted movement of aquatic organisms and associated materials as the principal drivers of aquatic invasions.

An important observation is that many species are associated with multiple introduction pathways and vectors. For example, *Cherax destructor*, *Misgurnus anguillicaudatus* and *Cipangopaludina chinensis* may be transported through aquarium, ornamental pond or aquaculture-related pathways, whereas *Nanozostera japonica* is associated primarily with aquaculture and shellfish transfers. Following introduction and establishment, many aquatic species are additionally capable of local and regional expansion through natural dispersal mechanisms, including movement through connected water bodies, coastal currents or vegetative spread. Consequently, effective management must address both the pathways responsible for introduction and the mechanisms that facilitate spread after establishment.

### Aquarium and Ornamental Aquatic Trade

Aquarium and ornamental aquatic trade emerged as the dominant aquatic introduction pathway. Six of the ten assessed aquatic species are strongly associated with this pathway, including *C. helmsii*, *C. destructor*, *Marisa cornuarietis*, *C. chinensis*, *M. anguillicaudatus* and *Misgurnus bipartitus*. Most introductions outside the native range have been linked to intentional importation followed by release or escape from captivity.

The pathway remains highly active and continues to introduce propagules to Europe through commercial trade and internet sales. Consequently, aquarium and ornamental trade represent the highest-priority aquatic introduction pathway under Danish conditions.

### Aquaculture and Shellfish Transfers

Aquaculture-related pathways formed the second major group of aquatic pathways. These pathways involve movement of shellfish, aquatic plants, sediments, and associated biological material between production facilities.

*N. japonica* represents the clearest example of an aquaculture-associated introduction pathway and has repeatedly been linked to shellfish movements in other regions. Similar mechanisms may facilitate transport of propagules and associated organisms over considerable distances. Because these pathways directly connect ecologically valuable coastal habitats, they represent an important management concern.

### Ballast Water and Shipping Pathways

Maritime transport pathways were represented primarily by *Asterias amurensis* and *Mulinia lateralis*. Both species are associated with ballast water and shipping-related transport and illustrate the continuing importance of international maritime traffic as a mechanism for marine introductions.

Although relatively few species utilise these pathways, introductions may result in substantial ecological consequences. Consequently, ballast water management, shipping biosecurity and port surveillance remain important components of aquatic invasion prevention.

### Live Fish, Bait and Stocking Pathways

Live bait, fish stocking and associated freshwater pathways were linked primarily to *Faxonius immunis* and the two *Misgurnus* species. These pathways remain important because they combine repeated opportunities for introduction with species capable of causing substantial ecological impacts following establishment.

As in the terrestrial assessment, prevention is likely to be considerably more effective than post-establishment control because eradication becomes increasingly difficult in connected freshwater systems.

### Secondary Spread: Natural and Water-Mediated Dispersal

Unlike the preceding Pathways of Introduction (POI), natural spread and water-mediated dispersal primarily contribute to secondary spread following establishment rather than to the initial introduction of species into Denmark. The mechanism was nevertheless included in the pathway overview because it was associated with a relatively large number of assessed species and may strongly influence subsequent expansion and management requirements (Table 4.1).

Natural spread and water-mediated dispersal were associated with several aquatic species, including *C. helmsii*, *C. destructor*, *M. anguillicaudatus*, *M. bipartitus*, *N. japonica* and *C. chinensis*. Following introduction and establishment, many aquatic organisms can expand through river networks, connected water bodies, coastal currents or vegetative dispersal. Consequently, natural spread contributes substantially to the expansion of established populations.

Although of limited relevance to primary introduction, natural and water-mediated dispersal remain important from a long-term management perspective because they may facilitate regional expansion after establishment. For species such as *C. helmsii* and *N. japonica*, local dispersal may ultimately become more important for distribution within Denmark than the original introduction pathway.

**Table 4.1.** Summary of aquatic pathway importance

| Pathway | Associated species (n) | Relative priority |
|---|---|---|
| Aquarium, ornamental aquatic species and pond trade | 6 | Very High |
| Aquaculture and shellfish transfer pathways | 3 | High |
| Ballast water and maritime shipping | 2 | High |
| Live fish, bait and stocking pathways | 3 | High |
| Natural spread and water-mediated dispersal | 6 | Medium |

## 4.2 Modes of Entry (MOE)

Following introduction, aquatic species may enter natural habitats through a limited number of Mode of Entry (MOE) categories. Among the assessed species, the dominant MOE categories were escape, contaminant, stowaway, release and unaided spread.

For species not currently present in Denmark, MOEs describe the mechanisms through which introduced individuals or propagules are expected to enter natural habitats following introduction. For species already established following introduction, MOEs additionally describe mechanisms contributing to secondary spread and expansion.

Escape modes of entry were primarily associated with aquarium species, ornamental pond species, and aquaculture-associated taxa. Contaminant pathways were linked mainly to shellfish and aquaculture transfers, while stowaway MOE's were associated with ballast water and maritime transport. Release MOE's were represented primarily by bait use and stocking activities. Unaided spread and water-mediated dispersal were relevant mainly for species already established following introduction and therefore describe secondary expansion rather than primary introduction (Table 4.2).

**Table 4.2.** Distribution of aquatic species among CBD Mode of Entry categories.

| Mode of Entry | Representative species |
|---|---|
| Escape | *Cherax destructor*, *Misgurnus anguillicaudatus*, *Misgurnus bipartitus*, *Cipangopaludina chinensis*, *Marisa cornuarietis*, *Crassula helmsii* |
| Release | *Faxonius immunis* |
| Contaminant | *Nanozostera japonica* |
| Stowaway | *Asterias amurensis*, *Mulinia lateralis* |
| Unaided spread | Secondary spread of established populations and larval dispersal pathways |

## 4.3 Impact Profile and Climate-Mediated Risk Realisation

The impact assessment revealed substantial variation among the ten aquatic species, with current HARMONIA scores ranging from species considered climatically unsuitable under present conditions to species associated with high ecological impacts and broad establishment potential. As in the terrestrial assessment, scores reflect impacts considered realistic under Danish conditions rather than maximum impacts reported elsewhere.

The highest current scores were associated with *C. destructor*, *A. amurensis*, *F. immunis*, *C. helmsii* and *M. anguillicaudatus*. These species combine active introduction pathways, suitable habitat availability, and documented impacts on native biodiversity or ecosystem functioning.

Intermediate scores were associated with *N. japonica*, *C. chinensis* and *M. lateralis*. These species possess active pathways and suitable habitat but are currently associated with more moderate ecological consequences.

*M. cornuarietis* represents the most strongly climate-constrained aquatic species assessed. Although substantial impacts have been documented elsewhere, establishment under Danish conditions is currently considered unlikely, and the species was therefore not assigned a current impact score. The future score represents a hypothetical impact scenario should climatic limitations be reduced.

In contrast to several terrestrial species, many aquatic taxa already appear capable of establishing under current Danish conditions. Consequently, climate change is expected to influence spread, abundance and impact realisation more than establishment itself. The most pronounced future increases occur for *N. japonica* and, to a lesser extent, *C. destructor*. By comparison, species such as *F. immunis*, *C. helmsii*, *M.anguillicaudatus*, *M. bipartitus* and *C. chinensis* already occupy suitable climatic space and therefore exhibit only limited climate-driven changes (Table 4.3).

As in the terrestrial assessment, future HARMONIA scores primarily reflect increased likelihood of impact realisation rather than changes in intrinsic impact potential.

**Table 4.3.** Current and future HARMONIA scores for aquatic species

| Species | Current HARMONIA | Future HARMONIA | Principal driver of change |
|---|---|---|---|
| Asterias amurensis | 12 | 12 | Improved establishment and spread |
| Faxonius immunis | 12 | 12 | Increased spread and habitat suitability |
| Cherax destructor | 13 | 13 | Reduced climatic limitation |
| Crassula helmsii | 8 | 8 | Suitable under current conditions |
| Misgurnus anguillicaudatus | 5 | 6 | Improved establishment probability |
| Misgurnus bipartitus | 4 | 4 | Suitable under current conditions |
| Nanozostera japonica | 8 | 11 | Improved establishment and spread |
| Cipangopaludina chinensis | 8 | 8 | Limited climatic effect |
| Mulinia lateralis | 8 | 8 | Increased reproductive success |
| Marisa cornuarietis | - | 1 | Slightly improved climatic suitability |

# 5 Comparison of Terrestrial and Aquatic Introduction Pathways

The terrestrial and aquatic assessments reveal both important differences and notable similarities in invasion pathways. Terrestrial introductions are dominated by horticultural trade, contaminated soil and garden waste, whereas aquatic introductions are primarily associated with aquarium trade, aquaculture transfers and maritime transport. Despite these differences, both environments are characterised by a relatively small number of highly active human-mediated pathways that account for the majority of introduction opportunities.

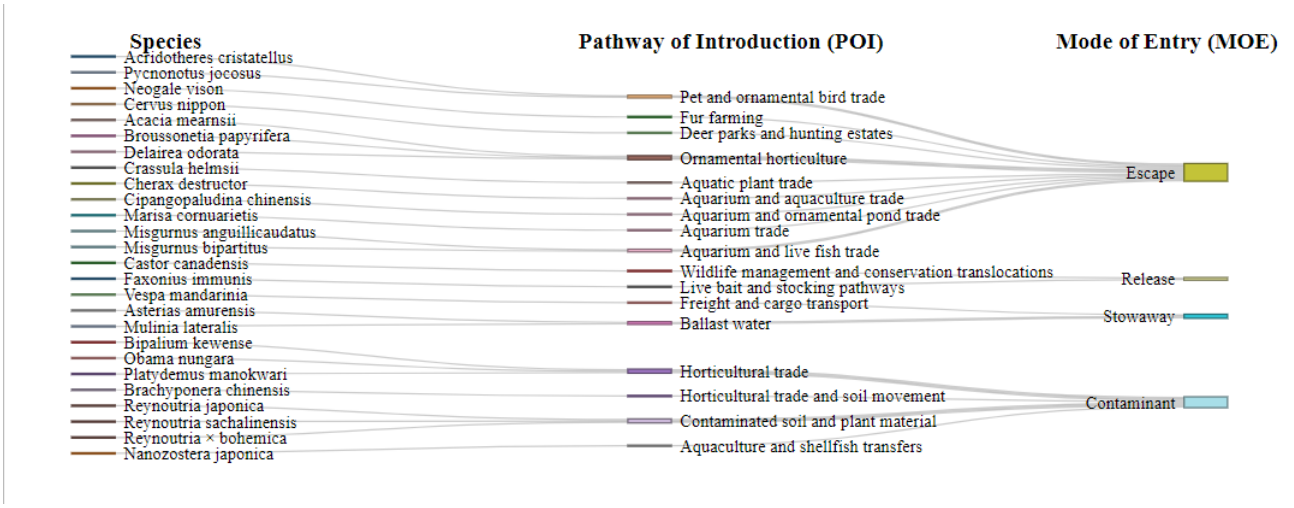



**Figure 5.1.** Relationship between assessed species, primary Pathways of Introduction (POI) and Mode of Entry (MOE) categories under Danish conditions. The figure illustrates how multiple species converge on a limited number of introduction pathways, highlighting key targets for pathway-based prevention and management.

The Sankey diagram illustrates how a relatively small number of Pathways of Introduction (POI) account for most identified introduction opportunities. Horticultural trade contaminated biological materials, aquarium trade, aquaculture transfers and ballast-water transport emerged as the most important introduction pathways across the assessed species set. Escape presented as the most dominating MOE (Figure 5.1). Secondary spread following establishment was considered separately and is particularly relevant for species already established in Denmark, such as the knotweed complex and *N. vison*.

## 5.1 Overall Prioritisation of Pathways of Introduction (POI)

Following Madsen et al. (2014, 2023), Pathways of Introduction (POI) were prioritised according to:

- the number of assessed species associated with each pathway,
- the relative importance of the pathway for introduction to Denmark (POI score),
- the magnitude of current and future impacts associated with pathway-linked species.

Modes of Entry (MOE) were used descriptively to characterise how species are expected to enter natural habitats following introduction but were not prioritised separately.

**Table 5.1.** Updated prioritisation of Pathways of Introduction following inclusion of the 26 species listed in Regulation (EU) 2025/1422, based on pathway frequency, mean POI scores, associated impacts and future relevance. Pathway rankings reflect the assessed species set and should not be interpreted as a complete reassessment of Danish invasion pathways. Natural spread and water-mediated dispersal are presented separately because they primarily contribute to post-establishment spread and range expansion rather than to the initial introduction of species into Denmark.

| Pathway (POI) | Species (n) | Mean POI | Impact level | Climate relevance | Priority | Suggested management |
|---|---|---|---|---|---|---|
| Horticultural trade, nursery stock and ornamental planting | 10 | 4.0 | High | High | Very High | Nursery certification, inspection of imported plants, restrictions on high-risk species, awareness among gardeners and landscapers |
| Contaminated biological material | 8 | 3.2 | High | High | Very High | Regulation of soil movement, hygiene protocols, inspection of growing media, handling of contaminated materials |
| Aquarium and ornamental aquatic trade | 8 | 3.9 | Moderate–High | High | Very High | Ban on releases, public awareness, internet-trade surveillance, pet amnesty programmes |
| Garden waste and vegetative fragments | 6 | 2.8 | High | Moderate | High | Improved disposal systems, guidance to landowners, restrictions on movement of invasive plant material |
| Aquaculture and shellfish transfers | 6 | 3.0 | Moderate–High | Moderate–High | High | Biosecurity protocols, screening of transfers, equipment disinfection |
| Live fish, bait and stocking pathways | 5 | 3.4 | High | Moderate | High | Restrictions on live bait use, monitoring of stocking activities, awareness campaigns |
| Fur farming, deer parks and managed animal holdings | 3 | 3.7 | High | Moderate | High | Containment standards, inspection of facilities, monitoring of wild populations |
| Ballast water and maritime shipping | 3 | 3.2 | High | Low–Moderate | High | Ballast water treatment, compliance monitoring, port surveillance |
| Freight, containers and commercial transport | 2 | 2.5 | Moderate–High | Increasing | Medium–High | Border inspections, container hygiene, surveillance at entry points |
| Wildlife management, hunting and conservation introductions | 2–3 | 1.8 | Very High | Low | Medium | Continued regulation and prevention of deliberate releases |
| Pet and ornamental animal trade | 2 | 3.0 | Moderate | Moderate | Medium | Monitoring of trade, awareness campaigns, enforcement of ownership restrictions |
| Natural spread and water-mediated dispersal* | Multiple | 1.6 | Moderate | Moderate–High | Low–Medium | Early detection, containment, local eradication, habitat-specific management |

The combined analysis demonstrates that only a limited number of Pathways of Introduction (POI) account for many identified introduction opportunities across both terrestrial and aquatic environments. Horticultural trade, contaminated biological materials, aquarium trade and aquaculture-related pathways emerged as the most important introduction pathways because they combine high pathway frequency, high mean POI scores and association with species capable of causing substantial ecological impacts. By contrast, pathways such as ballast-water transport, freight-related transport and wildlife management introductions involve relatively few species but remain important because they are associated with species capable of generating substantial impacts if introduced and established (Table 5.1). Consistent with Madsen et al. (2023), pathway prioritisation should therefore consider pathway frequency, pathway importance and the impacts associated with

pathway-linked species. Mean POI scores were calculated from all species–pathway associations included in Appendix D.

The present analysis extends previous Danish pathway assessments by incorporating the 26 species added through Regulation (EU) 2025/1422. Together with the assessments of Grousset et al. (2018) and Madsen et al. (2023), the analysis provides pathway information covering all 114 species currently included on the EU List. Pathway rankings should therefore be interpreted as pathway patterns emerging from the additional species assessed here and evaluated within the broader context of Danish pathway assessments.

## 5.2 Management Implications and Priority Actions

The results demonstrate that prevention remains the most cost-effective strategy for reducing future invasion risk. Although the dominant pathways differ between terrestrial and aquatic environments, both systems are characterised by a relatively small number of introduction pathways associated with most potential introductions. Because all assessed species are included on the EU IAS List, several historically important pathways are already subject to regulatory restrictions. Consequently, management efforts should focus on pathway-based interventions that remain relevant for accidental introductions, legacy populations and secondary spread following establishment.

Preventative management is expected to be particularly cost-effective for pathways associated with large numbers of species and repeated introduction opportunities, notably horticultural trade, contaminated biological materials, aquarium trade and aquaculture-related pathways. Measures targeting these pathways can reduce introduction risk for multiple species simultaneously, whereas interventions implemented after establishment, or those directed at individual species rather than pathways, generally require repeated species-specific control efforts and are often applied only after impacts have already occurred. The recommendations below should therefore be interpreted as priority actions for reducing invasion risk through targeted pathway management and biosecurity measures.

Because all assessed species are included on the EU IAS List, several historically important introduction pathways are already subject to regulation under EU Regulation 1143/2014. Consequently, the recommendations below should be interpreted as addressing pathways that remain relevant for accidental introductions or contribute to secondary spread following establishment. For species already established in Denmark, management priorities increasingly focus on limiting further spread rather than preventing primary introduction. Preventive pathway management is generally more cost-effective than post-establishment control, particularly for aquatic introductions and species with high dispersal capacity.

The relative importance of a pathway reflects its association with the assessed species and documented introduction history rather than the current level of regulatory control. Consequently, some highly ranked pathways may now be subject to substantial management measures, while others remain active or primarily contribute to secondary spread following establishment.

# 6 Highest priority terrestrial pathways

Among the assessed species, the highest-priority terrestrial Pathways of Introduction (POI) were horticultural trade and contaminated biological materials, both of which were associated with large numbers of species, high mean POI scores, and substantial pathway-linked impacts. Garden waste and vegetative fragments were also associated with numerous species but primarily contribute to secondary spread following establishment rather than to primary introduction.

Management should therefore focus on:

- strengthened biosecurity within horticultural supply chains
- certification and inspection of nursery stock
- regulation of soil movement from infested areas
- improved disposal of garden waste and invasive plant material
- public awareness campaigns targeting gardeners, landscapers and contractors.

Highest priority freshwater pathways

Freshwater introductions within the assessed species set were associated primarily with aquarium trade, aquaculture-related pathways and live fish, bait and stocking activities. Although several of these pathways are now regulated for EU-listed species, they remain relevant because accidental introductions, legacy populations and movement of non-listed but potentially contaminated organisms may continue to facilitate introductions.

Management should therefore focus on:

- preventing release of aquarium species;
- regulating internet sales and trade in high-risk aquatic organisms;
- strengthening biosecurity within aquaculture operations;
- restrictions on live bait and stocking activities;
- implementation of eDNA-based surveillance and early detection programmes.

Highest priority marine pathways

Ballast water remains the primary introduction pathway associated with the assessed marine species, although introduction pressure has been reduced through implementation of the International Ballast Water Management Convention. Consequently, surveillance and monitoring remain important despite existing regulation.

Recommended management actions include:

- maintaining international ballast-water standards;
- surveillance around ports and shipping hubs;
- biosecurity screening of shellfish transfers;

- monitoring of high-risk coastal ecosystems, particularly the Wadden Sea, Limfjorden and major estuaries.

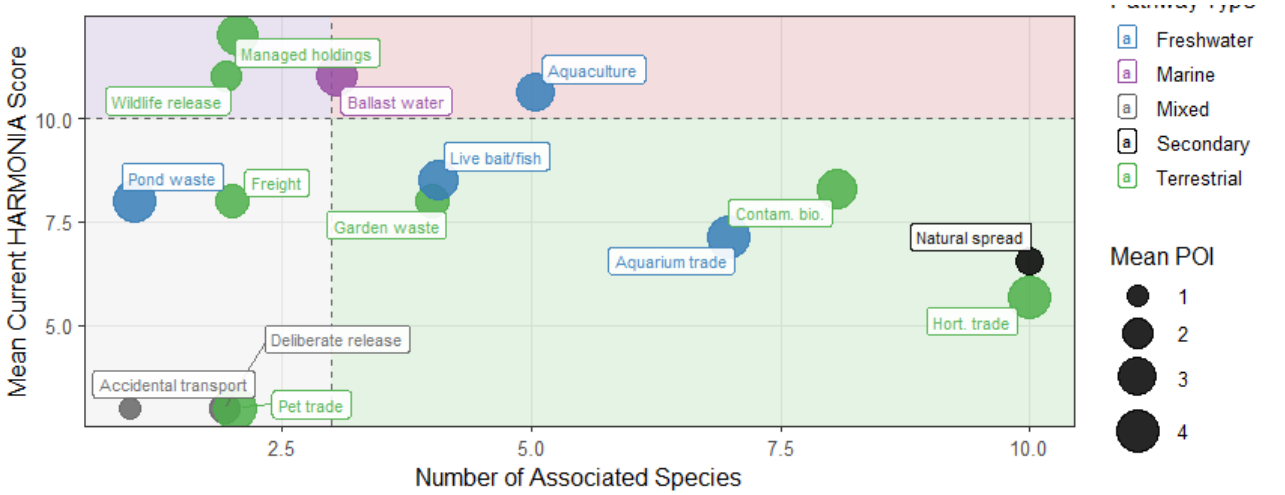



**Figure 6.1.** Pathway prioritisation matrix showing the relationship between pathway frequency (number of associated species), mean current HARMONIA score and mean Pathway of Introduction (POI) score for the assessed pathways. Bubble size represents the mean POI score calculated from all species–pathway associations included in Appendix D. Background shading indicates relative management priority, with red denoting pathways characterised by both high impact and high pathway frequency, purple denoting high-impact pathways of lower frequency, green denoting high-frequency pathways of comparatively lower impact, and grey denoting pathways of relatively low overall priority. Pathways positioned towards the upper-right quadrant represent the highest priorities for pathway-based management and prevention. Abbreviated pathway labels are defined as follows: Hort. trade = Horticultural trade, nursery stock and ornamental planting. Contam. bio. = Contaminated biological material. Garden waste = Garden waste and vegetative fragments. Pond waste = Pond waste and discarded vegetation. Managed holdings = Fur farming, deer parks and managed animal holdings. Wildlife release = Wildlife management, hunting and conservation introductions. Freight = Freight, containers and commercial transport. Pet trade = Pet and ornamental animal trade. Aquarium trade = Aquarium and ornamental aquatic trade. Aquaculture = Aquaculture and shellfish transfers. Live bait/fish = Live fish, bait and stocking pathways. Ballast water = Ballast water and maritime shipping. Natural spread = Natural spread and water-mediated dispersal (secondary spread following establishment). Natural spread and water-mediated dispersal are shown separately because they primarily represent mechanisms of secondary spread following establishment rather than primary introduction pathways.

Based on the assessed species, the pathway-prioritisation analysis demonstrates that only a limited number of pathways combine both high frequency and high impact. However, pathway rankings should be interpreted as patterns emerging from the assessed species set rather than a comprehensive national pathway inventory.

Horticultural trade contaminated biological materials, aquarium trade, and aquaculture-related pathways occupy the highest-priority region of the figure because they combine high pathway frequency with substantial associated impacts. In contrast, ballast-water transport and wildlife-management-related pathways are associated with relatively few species but remain important because of their potential consequences following successful introduction. This pattern supports the conclusion that management efforts should focus on a small number of dominant pathways rather than individual species alone (Figure 6.1).

# 7 Comparison with Previous Danish Pathway Assessments

The pathway patterns identified in the present assessment are broadly consistent with those reported by Grousset et al. (2018) and Madsen et al. (2023). The present assessment should therefore be viewed as a targeted extension of earlier Danish pathway analyses rather than a reassessment of Danish invasion pathways.

Inclusion of the 26 species added through Commission Implementing Regulation (EU) 2025/1422 does not fundamentally alter previously identified pathway priorities. Instead, the additional species strengthen the evidence supporting several pathways already recognised as particularly important for Denmark. In particular, the additional species reinforce the importance of horticultural pathways, contaminated biological materials, aquarium trade, aquaculture-related pathways and ballast-water transport. Transport pathways associated with freight, containers and traded goods also gain greater prominence due to their association with several newly listed species. Together, the previous and present assessments provide pathway information covering all invasive alien species currently included on the EU List.

The pathway analysis conducted by Madsen et al. (2023) covered the species included on the EU List at that time. The present assessment evaluates the 26 species subsequently added through Regulation (EU) 2025/1422 and examines their contribution to the overall Danish pathway assessment. To facilitate direct comparison with previous Danish pathway analyses, pathway frequencies were harmonised using the pathway categories applied by Madsen et al. (2023). Table 7.1 therefore provides an updated overview of pathway frequencies across all species currently included on the EU List.

**Table 7.1.** Updated pathway frequencies following inclusion of the 26 species listed under Regulation (EU) 2025/1422. Species may be associated with multiple pathways. Values from Madsen et al. (2023) represent pathway frequencies for the previously assessed EU-listed species, while additional frequencies represent contributions from the 26 species assessed in the present study.

| Pathway of Introduction | Species in Madsen et al. (2023) | Additional species | Updated total | Effect |
|---|---|---|---|---|
| Horticulture | 35 | 10 | 45 | Strongly reinforced |
| Aquaria | 30 | 8 | 38 | Strongly reinforced |
| Transport | 29 | 2 | 31 | Increased importance |
| Natural spread, secondary introduction and range expansion | 25 | 6 | 31 | Reinforced |
| Other (primarily contaminated soil and biological materials) | 20 | 8 | 28 | Strongly reinforced |
| Aquaculture | 8 | 6 | 14 | Reinforced |
| Agriculture | 8 | 0-1 | 8-9 | Little change |
| Ballast water and sediments | 8 | 3 | 11 | Reinforced |
| Forestry | 5 | 1 | 6 | Largely unchanged |
| Angling / sport | 5 | 5 | 10 | Reinforced |
| Landscaping | 1 | 0 | 1 | Unchanged |
| Medicinal use | 1 | 0 | 1 | Unchanged |

The updated pathway frequencies indicate that inclusion of the 26 additional species reinforces rather than changes the overall pathway structure

previously identified for Denmark. Horticulture, aquaria, transport, secondary introduction and other contaminant pathways continue to account for the largest numbers of associated species. The largest increases were observed for horticulture, aquaria, contaminated soil and biological materials (included under "Other"), and aquaculture-related pathways. Freight- and container-associated transport pathways also receive additional support through species such as *Vespa mandarinia* and *Brachyponera chinensis*. No pathway previously considered of lower importance emerged as a new dominant pathway following inclusion of the additional species. Consequently, the pathway priorities identified by Madsen et al. (2023) remain robust and continue to provide an appropriate basis for Danish pathway management and action plans.

# 8 Climate-adaptation priorities

Climate sensitivity differed substantially among pathways because associated species varied in their climatic limitations. The strongest climate-related increases in risk were associated with horticultural pathways linked to *B. papyrifera*, terrestrial flatworms and *B. chinensis*, and freight-associated pathways linked to *V. mandarinia*. For these species, climate change may reduce current establishment barriers, although considerable uncertainty remains.

By contrast, pathways associated with species already established or capable of establishment under Danish conditions, including the knotweed complex, *C. helmsii*, *F. immunis*, *Misgurnus* spp., *N. vison*, *C. nippon* and *C. canadensis*, are unlikely to change substantially in importance under future climates.

These patterns should be interpreted as pathway-specific indications of future risk rather than predictions of future species distributions.

## 8.1 Implications for monitoring and biosecurity

From a management perspective, the results suggest that climate-adaptation measures should focus particularly on pathways combining both high propagule pressure and high climatic sensitivity. Aquarium trade, aquaculture transfers, horticultural trade and freight-associated pathways may therefore warrant enhanced surveillance and horizon-scanning efforts. Monitoring programmes should prioritise species currently constrained by climate but associated with active pathways, including *V. mandarinia*, *B. chinensis*, *C. destructor*, *N. japonica*, *B. papyrifera, P. jocosus*, *A. cristatellus*, and several terrestrial flatworm species. Early intervention targeting these pathways is likely to provide greater long-term benefits than measures implemented after climate-driven establishment barriers have been reduced.

# 9 Overall Assessment

The analysis indicates that a relatively small number of Pathways of Introduction (POI) account for the majority of invasion opportunities identified within the assessed species set. For terrestrial species, horticultural trade, contaminated biological materials and pathways associated with managed animal holdings emerged as the most important introduction routes, consistent with previous Danish pathway assessments. Inclusion of freshwater and marine species additionally highlighted the importance of aquarium trade, aquaculture and shellfish-transfer pathways, live fish and bait pathways, and ballast-water transport, demonstrating that aquatic invasions are associated with a partly different set of introduction mechanisms than terrestrial invasions.

Although the relative importance of several pathways is likely to have been reduced by implementation of EU Regulation 1143/2014, the results indicate that a limited number of historically important and currently relevant introduction pathways remain associated with the majority of assessed species. These pathways therefore represent key targets for pathway-based prevention, surveillance and biosecurity measures.

Although the dominant introduction pathways differ between terrestrial and aquatic environments, a common pattern emerges across all taxa: a relatively small number of historically important and currently relevant Pathways of Introduction (POI) are associated with most identified introduction opportunities. Furthermore, pathways associated with the highest numbers of species were frequently also associated with some of the highest current and future HARMONIA scores, emphasising the importance of pathway-based prevention and biosecurity measures.

Overall, the assessment suggests that future invasion risk will be driven primarily by the continued operation of already active introduction pathways combined with increased establishment success of some pathway-associated species under future climatic conditions. Climate change is therefore likely to increase the effectiveness of existing introduction pathways rather than create fundamentally new invasion routes, reinforcing the value of preventive pathway management, early detection and targeted biosecurity measures under both current and future environmental conditions.

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Robertsonian translocations in Danish sika deer (*Cervus nippon*). Markers for absent F1-hybridization with red deer (*C. elaphus*) and implications for selection, speciation and infertility

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# Appendix A. Overview of Assessed Species

Table A1. Species, pathways and impact scores

Overview of the 26 invasive alien species assessed in the present study, including taxonomic group, primary mode of entry (MOE), principal pathway of introduction (POI) and current HARMONIA scores.

| Species | MOE | Primary POI | POI | Current HARMONIA |
|---|---|---|---|---|
| Acridotheres cristatellus | Escape | Pet and ornamental bird trade | 4 | 3 |
| Pycnonotus jocosus | Escape | Pet and ornamental bird trade | 4 | 3 |
| Neogale vison | Escape | Fur farm escape | 4 | 13 |
| Cervus nippon | Escape | Deer park escape | 4 | 11 |
| Castor canadensis | Release | Deliberate wildlife release | 4 | 11 |
| Vespa mandarinia | Stowaway | Freight and cargo transport | 3 | 13 |
| Bipalium kewense | Contaminant | Horticultural trade | 4 | - |
| Obama nungara | Contaminant | Horticultural trade | 4 | 4 |
| Platydemus manokwari | Contaminant | Horticultural trade | 4 | - |
| Brachyponera chinensis | Contaminant | Horticultural trade / soil movement | 4 | 3 |
| Reynoutria japonica | Contaminant | Contaminated soil and plant material | 4 | 12 |
| Reynoutria sachalinensis | Contaminant | Contaminated soil and plant material | 4 | 10 |
| Reynoutria × bohemica | Contaminant | Contaminated soil and plant material | 4 | 11 |
| Acacia mearnsii | Escape | Ornamental horticulture | 4 | 7 |
| Broussonetia papyrifera | Escape | Ornamental horticulture | 4 | 7 |
| Delairea odorata | Escape | Ornamental horticulture | 4 | 8 |
| Crassula helmsii | Escape | Aquatic plant trade | 4 | 8 |
| Asterias amurensis | Stowaway | Ballast water | 4 | 12 |
| Cherax destructor | Escape | Aquaculture / aquarium trade | 4 | 13 |
| Cipangopaludina chinensis | Escape | Aquarium and pond trade | 4 | 8 |
| Marisa cornuarietis | Escape | Aquarium trade | 4 | - |
| Misgurnus anguillicaudatus | Escape | Aquarium and live fish trade | 4 | 5 |
| Faxonius immunis | Release | Live bait release | 4 | 12 |
| Misgurnus bipartitus | Escape | Aquarium and live fish trade | 4 | 4 |
| Mulinia lateralis | Stowaway | Ballast water | 4 | 8 |
| Nanozostera japonica | Contaminant | Aquaculture contamination | 4 | 8 |

Note: Only the primary pathway of introduction is shown in this table. A complete overview of all pathway associations and corresponding POI scores is provided in Appendix D.

# Appendix B. Current HARMONIA Assessment

Table B1. Current HARMONIA criterion scores

Criterion-level HARMONIA scores under current Danish conditions. Scores reflect species impacts considered realistically achievable under present climatic and environmental conditions. A dash (–) indicates that a current assessment was not undertaken because establishment under current Danish conditions was considered unlikely.

| Species | Disp. | Habitat | Native spp. | Ecosystem | Economic | Health | Biological | Total |
|---|---|---|---|---|---|---|---|---|
| Acridotheres cristatellus | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 3 |
| Pycnonotus jocosus | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 3 |
| Neogale vison | 3 | 3 | 3 | 1 | 2 | 1 | 4 | 13 |
| Cervus nippon | 3 | 2 | 3 | 1 | 1 | 1 | 4 | 11 |
| Castor canadensis | 2 | 3 | 2 | 2 | 1 | 1 | 4 | 11 |
| Vespa mandarinia | 3 | 3 | 1 | 1 | 2 | 3 | 2 | 13 |
| Bipalium kewense | 0 | - | - | - | - | - | 0 | 0 |
| Obama nungara | 3 | - | - | - | - | 1 | 0 | 4 |
| Platydemus manokwari | - | - | - | - | - | 0 | | 0 |
| Brachyponera chinensis | 1 | - | - | - | - | 2 | 0 | 3 |
| Reynoutria japonica | 2 | 2 | 3 | 3 | 2 | 0 | 6 | 12 |
| Reynoutria sachalinensis | 2 | 2 | 3 | 2 | 1 | 0 | 5 | 10 |
| Reynoutria × bohemica | 2 | 2 | 3 | 2 | 2 | 0 | 5 | 11 |
| Acacia mearnsii | 1 | 2 | 2 | 2 | 0 | 0 | 4 | 7 |
| Broussonetia papyrifera | 2 | 2 | 1 | 1 | 0 | 1 | 2 | 7 |
| Delairea odorata | 2 | 2 | 1 | 1 | 1 | 1 | 2 | 8 |
| Crassula helmsii | 2 | 2 | 2 | 1 | 1 | 0 | 3 | 8 |
| Asterias amurensis | 2 | 2 | 3 | 3 | 2 | 0 | 6 | 12 |
| Cherax destructor | 2 | 3 | 3 | 3 | 2 | 0 | 6 | 13 |
| Cipangopaludina chinensis | 2 | 3 | 2 | 1 | 0 | 0 | 3 | 8 |
| Marisa cornuarietis | - | - | - | - | - | - | 0 | 0 |
| Misgurnus anguillicaudatus | 2 | 2 | 1 | 0 | 0 | 0 | 1 | 5 |
| Faxonius immunis | 3 | 2 | 3 | 3 | 1 | 0 | 6 | 12 |
| Misgurnus bipartitus | 1 | 2 | 1 | 0 | 0 | 0 | 1 | 4 |
| Mulinia lateralis | 3 | 3 | 1 | 1 | 0 | 0 | 2 | 8 |
| Nanozostera japonica | 1 | 2 | 2 | 2 | 1 | 0 | 4 | 8 |

# Appendix C. Future HARMONIA Assessment

Table C1. Current and future scores

Projected future HARMONIA scores under future climate scenarios. Future scores reflect potential impacts if climatic barriers to establishment, survival and spread are reduced. Species' current HARMONIA scores not assessed due to unsuitable current conditions are indicated by a dash (–).

| Species | Current | Future | Change | Climate driver | Climate confidence |
|---|---|---|---|---|---|
| Acridotheres cristatellus | 3 | 5 | +2 | Reduced climatic limitation | Moderate |
| Pycnonotus jocosus | 3 | 5 | +2 | Reduced climatic limitation | Moderate |
| Neogale vison | 13 | 13 | 0 | Already suitable | High |
| Cervus nippon | 11 | 11 | 0 | Already suitable | High |
| Castor canadensis | 11 | 11 | 0 | Already suitable | High |
| Vespa mandarinia | 13 | 14 | +1 | Increased establishment probability | Moderate |
| Bipalium kewense | – | 5 | n.a. | Reduced climatic limitation | Low |
| Obama nungara | 4 | 8 | +4 | Improved establishment | Moderate |
| Platydemus manokwari | – | 7 | n.a. | Reduced climatic limitation | Low |
| Brachyponera chinensis | 3 | 11 | +8 | Increased overwinter survival | Moderate |
| Reynoutria japonica | 12 | 12 | 0 | Already suitable | High |
| Reynoutria sachalinensis | 10 | 10 | 0 | Already suitable | High |
| Reynoutria × bohemica | 11 | 11 | 0 | Already suitable | High |
| Acacia mearnsii | 7 | 8 | +1 | Improved establishment | Low-Moderate |
| Broussonetia papyrifera | 7 | 11 | +4 | Improved climatic suitability | High |
| Delairea odorata | 8 | 8 | 0 | Already suitable | High |
| Crassula helmsii | 8 | 8 | 0 | Already suitable | High |
| Asterias amurensis | 12 | 12 | 0 | Already suitable | High |
| Cherax destructor | 13 | 13 | 0 | Limited climatic limitation | Moderate |
| Cipangopaludina chinensis | 8 | 8 | 0 | Limited climatic effect | Moderate |
| Marisa cornuarietis | – | 1 | n.a. | Marginal suitability increase | Low |
| Misgurnus anguillicaudatus | 5 | 6 | +1 | Improved establishment | Moderate |
| Faxonius immunis | 12 | 12 | 0 | Increased spread | Moderate |
| Misgurnus bipartitus | 4 | 4 | 0 | Already suitable | Moderate |
| Mulinia lateralis | 8 | 8 | 0 | Increased reproduction only | Low-Moderate |
| Nanozostera japonica | 8 | 11 | +3 | Improved establishment | Moderate |

# Appendix D. Species–Pathway Matrix

The table below compiles all Pathways of Introduction (POI) identified during the species assessments. The matrix was used to support pathway ranking and prioritisation. Pathways are scored on the 0–4 POI scale following Grousset et al. (2018) and Madsen et al. (2023).

| Species | POI | POI score |
|---|---|---|
| Acridotheres cristatellus | Pet and ornamental animal trade | 4 |
| Acridothertes cristatellus | Deliberate release | 2 |
| Acridothertes cristatellus | Accidental transport | 1 |
| Acacia mearnsii | Horticultural trade, nursery stock and ornamental planting | 4 |
| Acacia mearnsii | Garden waste and vegetative fragments | 2 |
| Acacia mearnsii | Natural spread and water-mediated dispersal | 2 |
| Asterias amurensis | Ballast water and maritime shipping | 4 |
| Asterias amurensis | Aquaculture and shellfish transfers | 2 |
| Bipalium kewense | Horticultural trade, nursery stock and ornamental planting | 4 |
| Bipalium kewense | Natural spread and water-mediated dispersal | 1 |
| Brachyponera chinensis | Horticultural trade, nursery stock and ornamental planting | 4 |
| Brachyponera chinensis | Freight, containers and commercial transport | 2 |
| Broussonetia papyrifera | Horticultural trade, nursery stock and ornamental planting | 4 |
| Broussonetia papyrifera | Garden waste and vegetative fragments | 3 |
| Broussonetia papyrifera | Natural spread and water-mediated dispersal | 1 |
| Castor canadensis | Wildlife management, hunting and conservation introductions | 2 |
| Castor canadensis | Natural spread and water-mediated dispersal | 1 |
| Cervus nippon | Fur farming, deer parks and managed animal holdings | 3 |
| Cervus nippon | Wildlife management, hunting and conservation introductions | 2 |
| Cervus nippon | Natural spread and water-mediated dispersal | 2 |
| Cherax destructor | Aquarium and ornamental aquatic trade | 4 |
| Cherax destructor | Aquaculture and shellfish transfers | 4 |
| Cherax destructor | Live fish, bait and stocking pathways | 3 |
| Cipangopaludina chinensis | Aquarium and ornamental aquatic trade | 4 |
| Cipangopaludina chinensis | Contaminated biological material | 3 |
| Cipangopaludina chinensis | Natural spread and water-mediated dispersal | 2 |
| Crassula helmsii | Aquarium and ornamental aquatic trade | 4 |
| Crassula helmsii | Garden waste and vegetative fragments | 4 |
| Crassula helmsii | Contaminated biological material | 3 |
| Crassula helmsii | Natural spread and water-mediated dispersal | 3 |
| Delairea odorata | Horticultural trade, nursery stock and ornamental planting | 4 |
| Delairea odorata | Garden waste and vegetative fragments | 3 |
| Delairea odorata | Contaminated biological material | 2 |

| Species | POI | POI score |
|---|---|---|
| Faxonius immunis | Live fish, bait and stocking pathways | 4 |
| Faxonius immunis | Aquarium and ornamental aquatic trade | 3 |
| Faxonius immunis | Aquaculture and shellfish transfers | 3 |
| Marisa cornuarietis | Aquarium and ornamental aquatic trade | 4 |
| Misgurnus anguillicauda-tus | Aquarium and ornamental aquatic trade | 4 |
| Misgurnus anguillicauda-tus | Live fish, bait and stocking pathways | 3 |
| Misgurnus bipartitus | Aquarium and ornamental aquatic trade | 4 |
| Misgurnus bipartitus | Live fish, bait and stocking pathways | 3 |
| Mulinia lateralis | Ballast water and maritime shipping | 4 |
| Mulinia lateralis | Aquaculture and shellfish transfers | 2 |
| Nanozostera japonica | Aquaculture and shellfish transfers | 4 |
| Nanozostera japonica | Contaminated biological material | 3 |
| Neogale vison | Fur farming, deer parks and managed animal holdings | 4 |
| Obama nungara | Horticultural trade, nursery stock and ornamental planting | 4 |
| Obama nungara | Contaminated biological material | 3 |
| Obama nungara | Natural spread and water-mediated dispersal | 1 |
| Platydemus manokwari | Horticultural trade, nursery stock and ornamental planting | 4 |
| Pycnonotus jocosus | Pet and ornamental animal trade | 4 |
| Pycnonotus jocosus | Deliberate release | 2 |
| Pycnonotus jocosus | Natural spread and water-mediated dispersal | 1 |
| Reynoutria japonica | Horticultural trade, nursery stock and ornamental planting | 4 |
| Reynoutria japonica | Contaminated biological material | 4 |
| Reynoutria sachalinensis | Horticultural trade, nursery stock and ornamental planting | 4 |
| Reynoutria sachalinensis | Contaminated biological material | 4 |
| Reynoutria sachalinensis | Garden waste and vegetative fragments | 2 |
| Reynoutria × bohemica | Horticultural trade, nursery stock and ornamental planting | 4 |
| Reynoutria × bohemica | Contaminated biological material | 4 |
| Reynoutria × bohemica | Natural spread and water-mediated dispersal | 3 |
| Vespa mandarinia | Freight, containers and commercial transport | 3 |
| Vespa mandarinia | Ballast water and maritime shipping | 3 |

# IDENTIFICATION AND EVALUATION OF PATHWAYS TO DENMARK FOR THE 26 INVASIVE ALIEN SPECIES OF UNION CONCERN UNDER EU REGULATION 2025/1422

This report assesses the introduction pathways, modes of entry, impacts and climate sensitivity of the 26 invasive alien species added to the EU Union List by Commission Implementing Regulation (EU) 2025/1422, supporting Danish implementation of EU Regulation 1143/2014. Using the pathway framework of Grousset et al. (2018) and Madsen et al. (2023) and the Danish HARMONIA-based impact methodology, it finds that a few pathways dominate introduction risk: horticultural trade, contaminated biological materials, aquarium trade, aquaculture and ballast water. Escape, contamination and stowaway are the most common modes of entry into natural habitats. The highest impacts are associated with established or establishment-capable species such as Neogale vison, the knotweed complex, Castor canadensis, Cherax destructor, Faxonius immunis and Asterias amurensis. Climate change mainly affects currently climate-limited species, such as Vespa mandarinia and terrestrial flatworms, though the evidence varies in strength. The results confirm earlier Danish pathway priorities and support pathway-based prevention, focused on accidental introductions, early detection and limiting secondary spread.

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